SCIENCE FOR EVERYONE

IGOR AKIMUSHKIN

ETHOLOGY: ANIMALS DO WHAT AND WHY

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Science
for Everyone

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ETHOLOGY

What Animals Do and Why

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In Lieu of an Introduction

From the beginning of time, human beings have been interested in animal behaviour. Many ancient scholars and philosophers—the great Aristotle among them—were concerned with this field of knowledge. A multitude of schools have advanced various theories and hypotheses to interpret the actions of animals under different conditions. These schools (mechanistic, atomistic, behaviouristic, gestalt, etc.) fall under two large groups: mechanistic and anthropomorphic.

Rémy Chauvin compared these two approaches as follows:

"Mechanists, following Descartes, believed that an animal is merely a machine and hence (as, for instance, was claimed by Malebranche) one may torture a dog without taking heed of its yelps—these yelps are no more than the squeak of an ill-lubricated mechanism. It is obvious that this philosopher had never taken a good look at a dog. By contrast, proponents of anthropomorphism viewed an animal as a creature that is nearly equal to a human being in that it has the faculties for loving, suffering and reasoning. This extreme view leads one to think that the latter zoophil had also never seen a dog".

And one must see in order to understand the secrets of animal behaviour—see and observe. In particular, the animal must be observed in its usual surroundings. The smallest details of its behaviour must be observed and recorded. And it is best to rely on objective recording methods: filming, tape recording and taking notes. The notes should include the name of the experimenter, the date and the time (beginning and end of the experiment).

Even in numerous animal colonies, one should be able to individually identify the animals involved in the experiment. For this purpose animals are often marked: they may be shorn, stained with special dyes, or the tips of their ears may be tagged. They are also assigned a name or a number.

Field observations are most important, but in addition, animals are studied in the laboratory. Mazes, screens, experimental models to simulate animal behaviour, and other devices are designed. Another method used is the rearing of young in isolation to guard them from the impact of one or another environmental factor. Many other methods are used in these types of investigation.

This brings us to the science of animal behaviour, which is called ethology and whose methods have just been mentioned.

Ethology is derived from two Greek words: "ethos", meaning character, or custom; and "logos", meaning study. This term is believed to have been coined by the distinguished French zoologist Geoffroy de Saint Hilaire in 1859. According to other evidence, the term ethology was first used in

1762 in the *Proceedings of the French Academy of Sciences.* Still other sources contend that the term was introduced in 1909 by Dollo. It is not our purpose to delve into the history of the term.

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Movement: The Basic Form of Behaviour

Tropisms

The most obvious distinction between animals and plants is common knowledge: plants cannot move, while animals can. And yet, it was plant movement (the turning of flowers towards the sun) that led to the origin of the science studying the elementary movements of animals, i.e. tropisms.

In 1693 the Englishman John Ray (who incidentally was the first to prove that the whale is not a fish) attempted to substantiate scientifically what was known already by primeval man—that plants grow and orient their flowers towards the source of light. The parts of a plant facing the sun grow at a slow rate, while the shaded parts grow quickly. As a result, the stem bends in the direction of the sun. Physics verifies this; however, the true nature of light orientation in plants was revealed by the botanist de Candolle 150 years later.

Ray believed that heat causes the stem to bend, but de Candolle proved that it is not heat but light which makes the stem orient towards the sun. De Candolle named this phenomenon heliotropism, which marked the beginning of extensive investigations on tropisms.

In addition to heliotropism, there are many other tropisms, and most of them are attributes of the animal kingdom. Tropisms are defined as positive or negative, depending on whether the animal is moving towards the source of stimulation (positive) or away from it (negative). The major types of tropisms are:

hydrotropism, the plant roots bend in the direction of more moist soil layers;

geotropism, the plant stem grows upward, against the direction of the force of gravity;

phototropism, many plants and animals move in the direction of the light source;

stereotropism, animals run and move so that their vibrissae or other tactile organs come in contact with solid objects;

rheotropism, the animal strives to maintain its position against the wind or water current;

chemotropism, movement in response to chemical agents;

thermotropism, striving to remain located in a definite temperature range, etc.

Now let us take a close look at some of the tropisms.

Let us put freshwater hydras into an aquarium, and place the aquarium on a windowsill. Soon it will be evident that all the hydras have started moving towards the source of light and have arranged themselves on the aquarium glass facing the window.

Let us turn the opposite side of the aquarium towards the window. The hydras will immediately perform a micromigration similar to the previous one: they will attach themselves to the side of the aquarium that is better illuminated. This means that hydras exhibit positive phototropism.

Bed bugs display negative phototropism: they hide in dark places in the daytime and set off in search of food at night.

Another bloodsucker—the malaria mosquito Anopheles—exhibits complex phototropism. It responds differently to extremely opposite factors—dark and light. It demonstrates strong negative phototropism under intense illumination and positive phototropism when the light is dim. Hence, one need not be afraid of malaria mosquitoes in the daytime, but things are different at dusk when the malaria mosquitoes become particularly active. At night they are attracted by lamplight, and therefore one must close the windows and screen or cover them with gauze.

A clear example of geotropism is found in the fruit fly *Drosophila*. If placed in a vertical glass tube that is stoppered on both ends, a *Drosophila* will make for the upper end of the tube. Turn the tube upside down, and the fly will again move upward. In this way, the *Drosophila* can be driven from end to end for hours.

Stereotropism (or thigmotropism) is found in rats, mice, and other rodents living in the darkness of caves. The long and sensitive "whiskers" (vibrissae) on their snouts are tactile organs. When rats and mice run about in the dark, they keep close to the wall so that their vibrissae touch it. These rodents also rely on the vibrissae for gauging the width of cracks to see if they can crawl through.

Jan Dembowski described rheotropism in animals in the following passage:

"Trout living in streams with rapid currents are never at rest. They toil day and night in order not to be swept away by the current. When it is windy, birds and insects mostly fly upwind although they might as well fly in any direction."

A spectacular example of thermotropism is provided by infusoria.

If they are placed in a horizontal tube that is heated at one end to approximately 40 °C, and at the other, to 15 °C, they immediately concentrate in a temperature zone equal to 26-27 °C.

Woodlice demonstrate interesting behaviour. These animals, related to crustaceans, dwell on land—under stones, rotting tree trunks, and in other humid places. Should a woodlouse find itself where it is dry, it shortly dies.

Let us place woodlice in a vessel with dry air. This will immediately set them in random motion: they will crawl about in all directions. In a vessel with humid air, woodlice will initially also move about at random. However, they will quickly calm down and then at some point suddenly come to a complete standstill where, for no obvious reason, their travel ends.

Now let us fill one end of the vessel with dry air, and the opposite, with humid air. How will the woodlice respond? They remain motionless at the humid end, while at the dry end they crawl about anxiously without moving directly to the humid place, as animals with specific tropisms would do. Soon, however, random movement results in the majority of woodlice concentrating at the wet end of the tube.

It follows from the experiment that woodlice do not demonstrate any specific tropism; rather, they crawl about at random and find by chance a humid place, where they come to a stop.

The ones that fail, in the course of their haphazard migrations, to find the humid microclimate they require quickly die.

Based on a number of similar experiments some scientists infer that tropisms are directional movements in contrast to random migrations.

But animals may not display tropisms at all stages of life. An example is the larvae of marine animals, whose crowded colonies cover coastal cliffs and sandbars. Among them are various types of worms, barnacles, oysters and other bivalves.

Their tiny larvae swim freely in the seas and are subjected to the rigours of the environment—its storms, surfs, tides, waves and currents. They appear to survive these tests quite easily, but how do they find a suitable habitat when they metamorphose into adult animals?

At the beginning of life, the larvae exhibit positive phototropism. They keep near the sea surface, which is better illuminated. Then, prior to metamorphosis, their phototropism reverses its sign, and the larvae descend to the murky bottom in search of shade. Here a larva finds an environment suitable for its other tropisms (a specific chemical composition of the water and soil structure). It attaches itself to some vacant spot and soon metamorphoses into a barnacle, mollusc, or worm that loses its mobility for life.

Sun Compass

Tropisms (or taxes) as a means of orientation in space in search of a favourable environment are not unique. Animals have other senses performing still more complex functions. Many animals are endowed with a "sun compass". Birds travelling to far-away southern lands, and ants and bees, in search of rich sources of food and on their way to the nest, take their bearings from the sun. These creatures have already received a lot of attention, and everyone is probably familiar with them to some degree. Therefore, we shall not discuss the sun compasses of birds, ants and bees in order to focus on those in other animals, with which the reader may be less familiar.

The snail Elisia, abundant in the subterranean algae of the Mediterranean, behaves very strangely in an aquarium. It is motionless in semi-darkness, but should a ray of light shine on it, the snail is aroused and sets off on its way. And it does not crawl about at random, but at a strictly definite angle to the source of light. Should the direction of the light shift, the snail immediately changes its route to crawl to the light source at the same angle. This angle ranges from 45° to 135°. Perhaps, the Elisia's eyes are so structured that they only perceive the rays incident on it within this range.

The North American white-footed mouse* is not much of a traveller: normally it doesn't wander more than fifty metres away from its burrow. But if taken far away from

* Although called a white-footed mouse (this animal indeed looks very much like a mouse) it is actually a hamster. Of true mice, only the house mouse, which was imported, is found in America.

their burrows, this small rodent, a regular stay-at-home, will travel long distances (in relation to its size) to return home. When taken away and released a mile (1.6 km), from their burrows, they were soon retrieved at their homes. One mouse even covered two miles on its way back. But of the mice taken four miles away, none returned.

The most interesting point of this experiment is that the animals that successfully completed their 1.5-2-mile cross-country race were quite young—only two months old. They had just started leaving their burrows and, of course, had only poor knowledge of the neighborhood. And still they managed to return from afar!

Experiments with voles have revealed that in ten to fifteen minutes they can cover a distance of three hundred metres. This implies that they can travel at a rate of 1200 metres per hour, which means that the voles follow a straight route, without getting lost or wasting time looking for landmarks; they make for home as soon as they are released. They must follow a very straight route and cover fairly long distances through strange forests and fields. It is believed that voles, too, rely on the sun for orientation.

Another unusual phenomenon is the migration of green or edible turtles, dwelling off the coasts of Brazil, over two thousand kilometres to the Central Atlantic, namely, to Ascension Island, to breed. Presumably, they determine their direction by the sun. This ability has been demonstrated in newborn turtles. They are not guided from the nest on the seashore towards the sea by the scent of oceanic water or by the coastal slope as was previously believed. Most likely, they establish their position by the intensity of the illumination of the ocean surface, which is by far greater, both at night and during the day, than that of land.

Experiments with crayfish, crabs, spiders, locusts and other animals support the theory of sun navigation. Almost any animal, when tested, sooner or later reveals a marked ability to orient by the sun.

Learning and Insight

Releasers

Releasers are signals that elicit instinctive reactions in animals. There are a great number of releasers. Let us consider some of them.

A classic subject of laboratory studies is the stickleback. When the breeding season begins, the male stickleback puts on his colourful attire. The most important thing about his nuptial colours is his bright red belly. The fish also reveals a new behaviour: he selects an area at the bottom of his habitat—his personal territory—from which to attack any male conspecific passerby (occasionally that of another species). Scientists looked into what acts as a releaser evoking aggression in this case: the shape of the intruder or, perhaps, the red patch. Experiments revealed that the male is excited by any oblong object that is coloured red on the bottom. This object may not even be a detailed copy of a fish as long as the bottom is red. During the breeding season this red colour in the stickleback functions as a releaser.

In June nymphalid butterflies emerge in our parts. Brown in colour, with two eye-shaped patterns on the front wing, they flutter among the flowers to sip the nectar.

But when a male becomes satiated, he settles down on some hillock and waits. He is waiting for a female to court her. He may wait for a long time until at last he loses his patience and, blind in his heat, he sets off in pursuit of birds flying by and even falling leaves. He may even dash after his own shadow!

At this moment it is easy to attract the butterfly with a paper model of a female. The darker the model, the greater is the male's fervour in pursuing it. When male butterflies were presented models of varying size, large models were found to be definitely preferable, and the most desirable model was four times as large as a live female. Clearly, the dark colour and size are releasers for a nymphalid male, but why it is specifically these traits function as such is not understood.

Herring gull nestlings solicit food as soon as they are born. For several hours they stare at the world with their yellow eyes, apparently heedless of anything around them in their search for a red spot. For them this spot is now the focus of the entire universe. It plays an important role in the signal code of the herring gull: it is a nestling releaser.

An adult herring gull has a yellow beak, but at the tip of the lower beak one can see a bright red spot that looks like a ripe berry. To a newly hatched nestling, this "berry" represents the outside world: it is an intermediary between the nest and the environment. The nestling's response to the red spot is instinctual; the spot is saying: "As soon as you are out of the shell, look for the red spot! It will bring you food and water, it will warm and protect you. Look for it, run after it."

The nestling keeps searching. It pokes its little beak into its parent's beak with the red spot at the tip. This behaviour is also a releaser for the parent. A normal bird cannot disobey this order—it immediately opens its mouth to feed its young.

Experiments have revealed that it is the red spot that the nestling is after. Beak models with white or blue spots elicited no response, and a yellow beak with no spot at all produced the least impression. By contrast, a solid red beak was very attractive. Apparently, the nestlings took it for the spot itself, the large size being of no consequence.

To focus the attention of the nestling from the plain red spot to its functional meaning, the adult bird holds regurgitated food in its beak so that the tasty morsel is close to the spot. The nestling pokes at the spot and gets the food. It swallows the food. How tasty it is!

During the first days of their life, featherless and blind songbird nestlings cannot identify their parents by any visible trait. Hence, for their yet undeveloped brain, a slight shake of the nest is a signal to gape for food. It means that the mother has flown in! One can see this for oneself by pushing the nest slightly. The blind nestlings will raise their heads, and as if on order, open their yellow bills. (The yellow bill of the nestlings is also a releaser: it urges the parents to bring food to their young.)

When nestlings open their eyes, they do not merely raise their heads; they turn them towards their parents. A model that is no more than three millimetres long and is moving also evokes this response. If two sticks are brought near the nestlings from different sides, the nestlings gape towards the nearer and higher stick.

A plain disk attracts the nestlings' attention to a lesser extent than one having notches or projections. The latter are releasers (as the red spots on the beak of a herring gull).

Waxbills, relatives of the sparrows, are found in Africa, South Asia and Australia. The nestlings of these birds do not have a plain yellow bill: on the contrary, it is coloured as brightly as the body of these birds. There are yellow, white or light-blue ridges, occasionally edged with a black ring in the corners of the mouth, and black dots and stripes are found on the palate, tongue and corners of the beak. When this colourful mouth opens, the parents are eager to put more and more food in it. It is conspicuous in the semi-darkness of the nest, and the multi-coloured ridges, at least in some waxbill species, gleam in the darkness, reflecting light! The nest of waxbills is a well-made, closed basket with a narrow entrance. It is partially dark inside, even on a bright day.

Imprinting

A newborn gosling considers the first object that appears over it to be its mother. In nature this is normally a female goose. For an incubated gosling this is usually a person, or occasionally, a box, in case the person has not turned up in time.

If one bends over a gosling and calls it, the gosling responds with a typical bow and greeting with its neck stretched forward. In this way the gosling declares that it considers you to be its mother. From this time onward, nothing can change the gosling's attitude, even if it is taken to a female goose. It will simply not recognize the goose as its mother: according to the gosling, the bird in front of it is a stranger.

This occasionally unfortunate instinct of "fixing" a parental image onto the first object to be seen, i.e. imprinting, has also been noted in mammals. In Africa, newborn rhinoceros, antelopes, zebras or buffalos have been sighted chasing a horseback rider or an automobile that they had seen before their mother (their mother may have abandoned them escaping from a predator). And there is no driving away these trustful babies!

The gosling, too, will follow a person day and night (at a certain distance and angle) and pleasantly and softly peep. This call can be roughly translated as, "I am here, and where are you?".

And it expects the answer that becomes a mother goose, that is, "I am here, don't worry".

Unless it hears this response, the gosling will peep a call of helplessness and solitude. And it will peep like this until it is found by its mother or it dies. In fact, the gosling can get food on its own, but it cannot live long without maternal warmth and protection. Hence, impelled by this instinct, it peeps with all its strength.

If the gosling is answered appropriately it will feel reassured and will come running to greet you.

Such a call of helplessness saves many baby animals from solitude and sure death. For example, a young dolphin that has lost its mother will call it in a whining ultrasonic voice. And it will swim in a circle, two metres in diameter, until the mother dolphin finds it.

The eggs of a pair of young fish (cichlids) that had spawned for the first time in their life were replaced by the eggs of another species. When the fry hatched, the fish tended them as if they were their own children. They became so used to their young that they regarded as enemies all fry dissimilar to them, whether conspecific or not. Later, the fish that had been deceived by the researchers deposited eggs again, but this time the eggs were not removed. When the fry hatched, the parents devoured them. This indicates that the fish had become conditioned to the foreign fry, which led to quite a different stereotype of what their offspring should look like, that is, a different imprinting.

Fry recognize their parents only by visual traits. This has been proved using wax models of varying shape and colour. The movement pattern of the model has also been found to be of significance, such as whether it is smooth or jerky, slow or rapid, straight or zigzaggy. Every species has a pattern of its own, and the response of young fish to this pattern is innate. Some gather near a fast-moving model, while others are attracted to a slow-moving one. If the model is immobile, the fry first surround it and then set off to search for a new foster parent.

Fry are also attracted to models that have the colour pattern of the parents. By contrast the size of the model appears to be of no consequence.

The scientists who investigated this bizarre adaptation made an interesting discovery: the fry were found not to "know" what the absolute size of their parents is, i.e. they did not know whether they were as large as an elephant or as small as a flea. It is only the angle from which fry see their parents that matters. The size of this angle is part of the instinctive knowledge of young fish, similar to, for example, the ability to catch and swallow cyclops, or to assemble at the sight of the parents in an alarm posture.

Fry are used to observing their parents from a certain angle. Thus, if the model of the mother was very large, the fry gathered together and swam after it at a considerable distance: this made the guide appear smaller to them. If the model was small, the fry followed it closely, retaining the same angle of vision. As the fry grow in size, this behaviour-determining angle increases.

Interestingly, this "point of view" with respect to the parents is an innate trait not only in cichlids, but also in other animals, for example geese.

The famous ethologist Konrad Lorenz has described how goslings followed him everywhere, as if he were their mother, but they kept at a much farther distance from him than that kept at when following the mother goose. They invariably retained a distance that allowed the man to be seen from the same angle as a goose would be seen when leading her goslings along a river bank. Since a man is taller than a goose, this distance was naturally longer.

When Lorenz was swimming in a river with his head above water, the goslings swam after him quite closely, retaining the same angle of vision. And when he lowered his head into the water, the goslings approached still closer. When only the top of Lorenz's head was visible, they were ready to clamber onto his head.

The same is true of baby cichlids. When the model was very small, they besieged it, short of getting on the model's back. They strove to swim after the "artificial mother", so that she could be seen from a definite angle: the fry have an innate drive to retain this angle.

The gosling that day and night demands reassurance of your presence is a very difficult baby. But the duckling is, for a human foster parent, a regular "enfant terrible", because it has a more complex "classifier" of parents. First, by its standards, the mother must waddle (it is mainly the legs that must move). Second, she should respond as a duck does.

As soon as a person opens the door of an incubator, the ducklings will dash away in panic, but they will also flee from a duck dummy. In order to attract the ducklings, one must get down on all fours and run about in this very clumsy position (and one is surely out of the habit to move like this!). One must also quack "qwegg-ge-gegeg", the duck call. If one is too lazy to walk on all fours while quacking, the ducklings won't follow and instead will inform everyone of their solitude. Their innate notion of their mother's size suggests that it should be smaller than that of a person. "Hence, one must quack travelling on all fours", claims Zdeněk Veselovský. He continues: "I myself have had the experience of leading a duckling family in the garden of the Biological Faculty, which was in the neighborhood of the Psychiatric Clinic in the Katěrinki. Only the sturdy fence protected me from this renowned institution, since a man quacking on his fours is none other than a madman to any other person in the street."

Chicks have a pronounced imprinting instinct. To observe this, one should remove the eggs from under a hen prior to hatching and put them in an incubator. The human foster parent should be nearby when the chicks are hatching. This way, he or she will be the first living object to be seen and will be followed.

Professor M.N. Noskov explains:

"When released to their conspecifics, which were kept with a hen, the chicks left them to follow the human that reared them."

The German ethologist Manfred Bürger related an interesting case of imprinting that occurred in the Berlin Zoo. He described how once during the night, a female gnu gave birth. While she was in labour she was lying at the door of her stall. Under the door was a depression into which the newborn calf fell. As it rose to its feet, the calf found itself on the other side of the door. The mother looked for it in the stall, but it was in the corridor.

The hungry baby started to search for its mother, but instead it saw the bar used for latching the door. Thus, the calf became imprinted on the bar, accepting it as its parent.

In the morning, the zoo workers saw the calf in front of the door of the enclosure where its mother was kept. The door was opened and the calf was let in. But the calf and the mother gnu were not interested in each other. The mother rejected her baby, and the calf took a piece of wood to be its mother. As a result, the zoo workers had to care for the calf as for an orphan who had lost its mother.

It is important to mention that imprinting only occurs during the first days or weeks after birth. In elks, for example, this period lasts up to three days of age; in the wild boar, between two and three weeks; in hens and ducks, between 13 and 16 hours; and in a human infant, from six weeks to six months.

Play: A Peculiar Form of Cognition

Sally Carrighar describes:

"Play is considered by Thorpe to be closely related to exploration. Dr. Thorpe emphasizes that play has several functions. On the lowest level play helps to develop "a young animal's motor habits". But he says: "Play is much more: play is performed for its own sake", and in describing the play of birds, he writes that "they make it difficult to avoid the conclusion that there is some fun in the performance."

Some animals even have playgrounds. The zoologist Schloeth spent two thousand hours on horseback following a herd of feral cows in Camargue in the south of France. He observed how as soon a cow crosses the boundary of the playground, where the grass is trampled down and there is enough space for exercise, it starts playing "...as if some mechanism is triggered. The cows will butt, chase each other and turn somersaults, rolling on their backs... Calves gallop around, yelping with joy; they hold their tails high and rotate in an attempt to catch them as playfully as kittens".

Normally it is young animals that indulge in play, but often semi-adult and adult cows cannot help joining in a gallop. Calves often play a "mother and child game", where one calf pretends to suck. The other does not protest and pretends to nurse its playmate.

Gibbons have favourite "play" trees in which they jump and swing for hours as if on a horizontal bar. Young monkeys play all day long with a brief break for lunch. "Occasionally", writes Chauvin, "as happens with children, someone loses his self-control and hurts his playmate to elicit a yelp of pain. Then, also as in humans, an adult male will turn up to separate the fighters and slap them a bit.

"A still more striking example is found in baboons. They appear to come to their leader to start a quarrel and demonstrate a fight in front of him, and the former brings in his verdict."

As an infant monkey grows it is accepted by a certain group of young conspecifics. There it finds playmates and makes friends with monkeys of the same age. These bonds of friendship are retained for years. Usually from that time onward the friends never separate: they always migrating together even if they acquire families of their own.

Carl Ackley, who visited Africa many times to make hundreds of the "world's-best" dummies (from elephants to kingfishers) for American museums, watched elephants playing ... football. They had rolled up a big ball of silt and were kicking it.

Playing ball is a favourite pastime for apes, pigs and otters. If a ball is unavailable, they play with chips or pieces of roots. Shrews will roll and throw up dry leaves and feathers. Sea otters play in the water with a ball of algae, and seals play with stones. Dolphins play with sea turtles as if with a ball.

Otters, which are very nice and intelligent animals, are among the playful animals in the Soviet Union. They play cat-and-mouse with fish when they are not hungry and just want to have fun. An otter will release a fish, as a cat lets go of a mouse, allowing the fish to swim away. Then the otter dashes after its prey, grasps it and lets it go again.

The favourite game of otters is sliding downslope. A clayey slope is best for this. The otters clear the bank of branches and snags near the water in order not to get hurt. Then they polish the slide. They clamber up the slope and slide down. The first attempt is not a walkover. The clay is still dry and is not yet ready for sliding. But the second time is easier. The otters climb down with difficulty to leave a wet trail on the slope. Another attempt makes the slide wetter. And then one can slide down as if the slope were covered with oil. The wet bellies and tails have made a magnificent slippery track.

And now the real fun starts! The otter clambers up slope, stretches its head, draws in its front legs, and down it coasts into the water. As soon as one otter plunges into the water, another takes a slide downslope. At the same time a third one is getting out of the water and hurrying not to miss its turn. This is real fun indeed! And in winter, otters make ice slides. They even teach their young to coast down.

Chamois are fond of sliding down snowbanks. They do this in file, bending their legs. Then they run upslope again for another slide.

Snow leopards roll downslope on their back to turn about at the end of the slope and plunge into the snow on all fours.

In her book *The Arctic Wild*, Lois Crisler relates that once she watched polar foxes playing. The foxes climbed up the ridge of a cliff still covered with ice. One of them took a slide, crouching in a cat-like fashion, and looked defiantly at the other fox that was on top of the slope. The latter dashed down, bumped into the other one, and they both rolled down head over heels. Then one of the foxes rushed back up with the obviously clear intention to take another slide.

Sea lions and polar bears frolic, coasting down wet cliffs right into the sea. Guenons slide down clean branches as schoolchildren do down banisters, and are fond of swinging on vines as if on a swing.

Even the seemingly unsociable and prickly porcupine will take a slide. Gerald Durrell, a marvellous author and tireless collector of rare animals, found a slope polished by porcupines in a cave in Africa. "The porcupines scrambled up to the top of the slope, slid down, walked round, climbed up again and slid down once more. They must have been indulging in this game for a number of generations as the cockface was worn almost as glass."

Hedgehogs are also fond of playing. During the first days of their life the mother does not leave her young for a minute; she nurses them constantly. The little hedgehogs are still blind and deaf, but they already know ... how to play: they box each other. Their prickly skin reaches over their forehead and is very mobile. The baby hedgehogs quickly stretch this skin forward and hit the opponent, like a boxer, with this prickly hood. Such a hit is enough to knock out a weak baby hedgehog. The mother hedgehog does not prevent her young from boxing: this is good exercise, which will make them stronger.

Young voles box ecstatically as if they were in a ring.

"Once", relates Durrell, "one of the chameleons had died, and I took the corpse to the monkeys, they formed a respectful circle round me and examined the chameleon with interest. After screwing up his courage the eldest drill touched it quickly, then drew back his hand and wiped it hastily on the ground. I could not persuade the guenons to come anywhere near it, but the drills eventually became very brave and started to play with the corpse, even chasing the screaming guenons with it and threatening them. I had to put a stop to this as the drills were quite bad-mannered enough, and guenons were protesting bitterly and seemed genuinely terrified."

The games of cats, dogs, squirrels, bears, foxes, horses, cows, deer and many other animals are known to everybody.

"If a bison is given a good toy", advises Zdeněk Veselovský, Director of the Prague Zoo, "you can save a lot of fence repair". A bison that was given a log for a toy played with it for hours by tossing it up with his horns; he stopped butting fences.

And in a nearby cage, a chimpanzee amused itself with a rag and a sock, which it had been given. It would put them on its head, feet or hands, and "behaved like a regular woman of fashion".

It is good that such rags may for a long time distract apes from the nasty jokes that they are apt to amuse visitors with. When their toys were taken away "the chimps would sit innocently at the railing and find no better diversion than to fling sawdust or something still worse at the spectators. After every hit they would break into a merry dance".

Leopards also pretend to be fast asleep, stretching out right next to the railing. And, of course, they will stick a paw between the bars, to wait for a spectator to try to wake up the "kitty" with the stroke of an umbrella or a hat. These are snatched away in a flash. "After strenuous attempts", writes Veselovský, "we managed to return to the owner only remnants of his property".

A young and very nice walrus in the Moscow Zoo would play with stones and a ball for hours. And at night, he would pile up all his toys in a corner and fall asleep near them like a child.

It is absolutely necessary for zoo animals to play. This is not merely because they have nothing to do in captivity. It has been proved that when a creature is deprived of freedom, space, strength and agility, its organism fails to function normally. Normal processes in the endocrine glands and in the brain are disturbed, and the animal often dies from the least stress, that is, from some kind of worry or fright. Even such a trifle as being transferred into another cage may kill an animal: its psyche collapses and the animal dies of shock.

Play relieves stress. It is also good exercise.

The German poet Schiller claimed: "One only plays if he is Human in the full sense of the word, and he is only Human when he is playing". Much the same applies to animals. A depressed, or depraved animal never plays. And when an animal plays and frolics, the hardships are easier to bear. Play amuses it, makes it hardy, and develops the agility and skills needed for defense and in hunting.

In addition to playing with conspecifics of the same age or in the same herd, members of different species may play together as, for example, happens in zoos. Occasionally wild animals of different species (for example, ostriches, zebras, and antelopes) play during their encounters at watering places, in the forest, or in pastures. A deer was once seen playing with a fox, squirrels with rabbits, and a hare with a blackbird. A white rabbit and a carrion crow were so fond of playing together that they became inseparable.

Ritualistic mating dances occur not only in birds but also in mammals.

Indian elephants are rumoured to get together in the heart of the jungle for their mysterious ritualistic dances.

Adult chamois males also dance in front of their young male conspecifics and females. They prance around, bending their necks in a sham threat, and rear up to perform many of the steps of their dance in this posture. The sassaby antelope circles in a merry-go-round fashion around a tree or a clump of trees. Others stand aside to look on. After some time the roles are reversed: the spectators in their turn step in to dance. Impala antelopes perform dances while circling around females. Bleating, their heads and tails raised, they run around the females that stand in the centre with lowered heads.

But the most impressive dances are those of chimpanzees. A group of chimps at a research station in Tenerife became famous for their dances, which were almost human in their manner. When these apes were brought to Europe they still danced for some time and Dr. Krumbiegel, the famous wildlife specialist, observed these dances. The males would form a circle and clapping, fairly rhythmically, would stamp their feet, as if they were ramming the ground. They would lower one foot many times to touch the other lightly. Their females would circle clumsily, but rather coquettishly.

According to Krumbiegel, gorillas dance in a similar manner. But more often they amuse themselves with a "chest-beating" rite. George Schaller, who lived for 20 months among wild gorillas in an African jungle and encountered them face to face 314 times, noted that their dance has several different steps, which are performed either separately or in various combinations.

Young gorillas, between three and four months of age, attempt to learn this ritual in parts. But the privilege of performance belongs to the mature males with silver backs. The dance starts with a series of hoots when a male encounters another male or a person. Then the male plucks a leaf from a nearby tree and clasps it in his mouth. Next the animal grabs a whole branch and throws it in the air in a frenzy.

The climax of the "dance" (or threat ritual) occurs when the gorilla pounds his chest with alternating fists. His chest booms as if it were a big drum and one leg may be kicking into the air. The frenzy, even if only feigned, of the huge, black, shaggy giant seems boundless. Then the gorilla runs aside, slapping the vegetation and tearing off branches. And finally, he beats the ground with both palms.

This sequence is believed to be a threat display, but the impressive scenes of "chest beating" can also be seen in the jungle when there are no enemies around.

Perhaps they are merely a rehearsal? Or they may be an amusement? Further study of gorillas will answer this question, but so far this is only guesswork.

Young birds and nestlings were previously thought to differ from cubs and kittens in that they do not engage in play. Special theories have even been advanced on this score. But now we know otherwise, although for a long time no one payed any attention to bird play.

Now science knows of various young birds that play just like young mammals. Among them are sparrows, chaffinches, crows, doves, pheasants, ducks, buzzards, eagles, alders, touracos, hornbills, and hummingbirds.

When playing, parrots roll on the ground or roll stones or balls. Pelicans also play with stones or branches, which they often steal from neighbors. And young sexually immature cormorants like to build nests. This, too, is play.

The famous ethologist Dr. Niko Tinbergen watched how, after a successful hunt in the fields and a subsequent hearty meal, young kestrels flew to where their nests were and played with pine cones on the sand dunes for hours until hunger drove them back to the fields for hunting.

Two weeks before he had learned to fly, a young falcon was seen engaged in an imaginary air fighting game with his father. He would hop, flapping his wings desperately, swoop down, and counter the feigned attacks of the adult male. Neither inflicted heavy blows. This was both play and learning the ABC's of aerobatics.

Adult birds are even more fond of playing than young birds. They play cat-and-mouse with their prey, or tag with one another. They also play with branches, sticks, leaves, and stones. In order to play, magpies will even "commit crimes", stealing whatever shiny "toys" they like.

Even cold-blooded fish play! They carry small branches in their mouths, and drop them only to pick them up again. Sticklebacks are particularly playful when building nests. And archerfish are fond of jokes in the spirit of old film comedies: they will squirt water on a bystander just for fun.

Gnathonemus petersi is an interesting dweller of aquaria. This fish has habits very unusual for its class. It is fond of playing with a small ball just like young mammals, which indicates that it has a well-developed brain.

A tree with a storm-splintered trunk is a godsend for a bear, and particularly for a female bear looking after her cubs. A frolicking bear will grab the splintered end, bend it down, and let it go. The end will hit against the split trunk causing the trunk to vibrate with a rumble. And the huge shaggy music-lover will keep at it again and again, manipulating the splinter. Then he'll stop to listen to the drumming sound reverberating through the canyons and mountains.

Young gorillas play games similar to those of children: tag, sliding (down tree trunks), king of the castle, pulling a playmate off a small hill or a bush, forming a train by placing their hands on a neighbor's shoulders, and running in single file.

Badgers also play the king-of-the-castle game. After sunset they come out of their burrows, and, frequently, before foraging for food, they go to some moss-covered stump or fallen tree. The most agile badger climbs up this throne while the others try to pull him down. They may continue this game for over an hour before setting off to hunt.

Even some invertebrates, such as the octopus, are fond of playing and have enough sense of humour to understand a joke.

Imitation

Imitation is highly diversified in birds. Usually songs are imitated, but this is not all.

The famous ethologist Konrad Lorenz described how a bullfinch learned to sing from a canary. And there is no bird like a canary for mimicking strange songs.

In one study canaries were assigned the best avian teachers: a nightingale, a blackcap, a lark, a linnet, and a human who played the flute and other musical instrument. Special small organs for teaching canaries music were invented. As a result, the songs of some of the canary breeds became strikingly different: they were muffled, soft, low-toned and highly diversified, with the best male canaries displaying up to 32 different rounds or parts.

Professor Noskov explains how animals imitate their parents:

"Many naturalists have demonstrated that elks, goitred gazelle, wild boars, young wolves and foxes, and other animals imitate their mother's behaviour as early as during the initial stages of postnatal ontogenesis: they mimick her when in a pasture, at a watering place, or in encounters with another animal or human being. The young usually eat what their mother eats and imitate her behaviour in unfavourable situations. It has been demonstrated experimentally that wild animals captured during the first days of life and thus devoid of family experience, may, in the course of domestication, eat some detrimental forage and die."

Thus, it is obvious that imitation is quite widespread in the animal kingdom.

Another point of ethological interest that brings us to the next, more complex chapter is an event that occurred in England. Titmice there learned to pierce the foil stoppers of bottles of cream that were delivered to houses by milkmen. They would then drink the cream. Soon this "crime" became common beyond the Channel, in the north of France, spreading at a fast rate from north to south.

This is definitely a case of imitation. One titmouse learned the skill and others copied his thieving habits. But how did the first one learn the skill? Some scientists suggest that the titmouse learned by trial and error. Others claim that it was insight.

Insight

Insight is not such a new term in animal psychology. The term insight (which can be defined as "understanding" in human psychology or "illumination" and even "eureka") was coined by W. Köhler in 1921. But even today the phenomenon is not yet understood and different schools offer conflicting definitions. The public at large may not at all be aware of the mysterious capability that higher animals have of finding the correct solution to situations where neither instinct, experience, trial and error, nor imitation can be relied upon.

Insight is like a sign of intelligence in animal behaviour—a thread connecting instinct to intelligence. Insight proves that instinct and intelligence are not some specific faculties endowed by God, but only different stages in the development of the mind.

Rémy Chauvin writes: "We believe that Thorpe's definition of insight as a sudden realization of a new adaptive response with no preliminary trials and errors is the best one. Insight has often been regarded as a manifestation of the faculty of conceptualization. Immediately the question arose about what the difference between insight and the trial-and-error method is."

True enough, some aspects of animal behaviour treated as insight "occasionally pass through an inconspicuous stage of trial and error". It is particularly difficult to distinguish between the former (insight) and the latter (trial-and-error method) when animals manipulate tools.

There are quite a number of such "skilled" animals. Even a brief list of them would take a lot of space, but still several of them should be mentioned.

The bearded vulture, a bird of prey, can lift a tortoise high up in the air and drop it against stones in order to crack the carapace open to obtain the meat. Crows and gulls also drop molluscs from a height to crush their shells. The song thrush (as well as other birds) break snail shells with stones. The capuchin monkey cracks nuts with a stone in its hand.

Chimpanzees do the same. In addition, using sticks, they can get hold of bananas or other delicacies hanging high up under the ceiling. They also fish termites out of their nest or honey from a hollow with a pre-cleaned twig. Chimps use sticks as weapons against leopards, and they make drinking bowls out of leaves.

The sea otter cracks the shells of molluscs or sea urchins with a stone that it lifts from the bottom of the sea, using the stone as an anvil.

The octopus builds "houses" of stones using a large flat stone as a roof. If it sets off on a short expedition, the octopus may take along the "roof". When danger threatens, the octopus brings the "roof" forward to face the direction of danger. Then, he backs away covering his retreat with the stone shield. Presumably (it remains to be proved) the octopus also uses stones to get molluscs.

The elephant uses stones like a scraper. Picking up a stone (or a stick) with its trunk, the elephant scratches its back or removes land leaches. It also uses a stick to get forage from beyond the cage bars or to defend itself against dogs. It will break off a big branch and fan itself to keep off flies and mosquitoes, and then may put the green fan into its mouth.

Gerbils (small rodents) store food for winter not only in their burrows but also on the ground surface. They stock well-dried hay in small stacks. To keep the stacks from being blown away by the steppe wind, gerbils prop them up: they bring twigs and small sticks in their mouths to the site and drive them into the ground around the edge of the stacks.

Mastophora spiders live in the tropics of South America, South Africa and Australia. They hunt at night with sticky balls on a web that the spider holds with its legs. When an insect flies up within range, the spider throws the ball at the web at the insect and the careless pilot sticks to the web immediately.

One South African spider hunts nocturnal butterflies with a net. It weaves the net with sticky threads that it produces and holds it with its legs. The spider hunts at night, lying in ambush. When a careless moth approaches, it extends its long legs to cover its prey with the net that is the size of a postage stamp.

South Africa is also the home of ecophil ants. As they build their nests, ecophils glue leaves together with cobweb threads. The larvae secrete a sticky substance in abundant amounts and the ants clasp the larvae in their mouths as if they were tubes of glue. Crawling from leaf to leaf, the ants connect the leaf edges with a cobweb frame.

The sand wasps ammophils feed their larvae with paralyzed caterpillars: they sting the caterpillar's nerve centres. The caterpillar is not killed: it is only immobilized and therefore does not spoil for a long time, being, so to say, preserved. The prey is stored in holes that have been dug in sand. There on caterpillars ammophil lay eggs that soon hatch. The wasp then rakes the sand over the hole, whereupon it clasps a small stone in its mandibles to seal the nest up so that even the most experienced predator cannot see the entrance.

Ammophils are found both in Europe and in America. Strangely, the American species have more facility with their "tools". European ammophils apparently do not always seal their nests with stones. By contrast, all members of the species of digger wasps ram the earth at the entrance to their nests with stones.

An adult ant lion is an inconspicuous and colourless insect that looks somewhat like a dragonfly. But its larva has many talents. This larva, which looks like a big mite with sabre-like mandibles, digs trap holes for its prey (arthropods and ants) and hides at the bottom. If a bustling ant runs up close to the trap or falls into it, it tries frantically to get away. With its big head, the predatory larva shoots a spray of sand at the ant. The ant lion almost never misses and knocks the ant down. The ant drops to the bottom of the hole directly into the sabre jaws of the deadly enemy.

The Australian black-breasted buzzard kills its prey in a dive-bomber fashion. It drops stones on the eggs of emu ostriches and other large birds. The Egyptian vulture also uses stones to crack ostrich eggs.

Australian plowerbirds use twigs to build small shelters that are "plastered" inside with a special paste that they prepare themselves. The bird strews the entrance with various bright objects: stones, flowers, bones, feathers, berries, shells, dead cicadas, mushrooms, pieces of snake skins, and a lot of other bizarre objects. One such collection even included a toothbrush, knives, forks, children's toys, ribbons, the cups and even the coffee pot of a coffee service, buckles, diamonds (genuine!) and an artificial eye. These shelters are not nests but structures built to attract a female. This is the place where females are courted.

The tailorbird lives in India. Its closest relative, also a tailorbird, dwells in Mediterranean countries. These birds build their nests by sewing leaf edges together with a needle and a thread. Their thin bills serve as a needle, and they weave threads from vegetable down.

The Galapagos Islands are the home of the woodpecker finch, a bird that looks like a sparrow. When it finds beetle larvae under bark and in wood, the finch breaks off a cactus spine and, holding it in its bill, inserts it into the larval burrows. The bird manipulates the spine vigorously to pierce the "worm" or drive it out of the maze of wood and bark galleries. In its desperate flight, the silly fat larva leaves its apartment. The finch then sticks the spine into the bark or holds it with its claws to grasp the larva in its bill. When spines are unavailable, the woodpecker finch breaks off a small branch and removes the twigs so that it can be used as a tool for extricating larvae.

Experiments have revealed that this bird's drive to clasp "twig-like" objects in the bill and fish "worms" from holes in the tree is innate, but the working skills are acquired through practice. The example that conspecifics present is also an important factor (imitation). It can be said that the theory of obtaining larvae is a birthright of nature called instinct, but the practical skills are obtained through experience.

Crabs of the genus Libia carry a small actinia in one or both claws. The tentacles of this "sea flower" can inflict a nestier sting than nettle. When a predator tries to devour the crab, the crab pushes the actinia into its mouth. The actinia burns like fire and the predator takes off.

And now the question arises whether the ability of animals to use tools can be considered to be the result of insight learning. Or are the skills the result of instinct?

Or perhaps they are learned by trial and error.

Presumably, the criterion here is whether the ability to use tools is shared by all conspecifics or is only found in some individuals. Let us return to the example of vultures cracking ostrich eggs with stones in order to discuss it at greater length.

A steppe fire once drove ostriches off their nests. The eggs remained unprotected. White-backed vultures flew in and tried unsuccessfully to crack the eggs open with their beaks. Soon two other fresh-egg lovers, i.e. Egyptian vultures, arrived. These got down to business skillfully. They flew away and then returned bringing stones of up to 300 grams in weight. First they put the stones down, examined the eggs, and tried the shells for strength with their beaks in a business-like manner. Then they clasped the stones in their beaks, stretched upright and with their heads raised high, dropped the stones on the eggs. The eggs did not break at the first attempt, but apparently the vultures did not expect immediate success. They bombarded the eggs again and again. It took them between four and twelve such attempts to break the eggshell. The vultures started to eat.

Has the ability to handle stones been found in all Egyptian vulture habitats in Africa? So far, the answer is no. Presumably, this behaviour of bombardier vultures can be interpreted as insight. Once, the idea to bombard the eggs with stones occurred to one Egyptian vulture. Then, conspecifics living in the neighborhood mimicked it with success.

The great potential of imitation is well illustrated by the example of the Japanese macaque. M. Kawai reported the following: "In the autumn of 1953, a one-and-a-half-year-old female macaque, named Imo, found a sweet potato in the sand. She dipped the potato in water—it must have happened by chance—and washed off the sand". Thus, the little Imo initiated the unusual tradition for which the Koshima Islands are now known.

One month later Imo's friend saw her handling a sweet potato and aped Imo's cultivated manner. After four months, Imo's mother acquired this habit. Gradually, her sisters and friends adopted the method discovered by Imo, and after four years as many as 15 apes were washing sweet potatoes. Some adult females between five and seven years learned this habit from the young conspecifics, but none of the males did. This was not because they were less smart: they simply ranked differently from Imo's group and hence communicated little with the smart Imo, her family, and her friends.

Gradually, mothers adopted the habit of washing sweet potatoes from their children and, in their turn, taught their children that were younger than Imo. In 1962 as many as 42 of the 59 monkeys of the population to which Imo belonged washed their potatoes before a meal.

Then Imo made a further useful discovery. Researchers scattered wheat grains on the sand. First, the monkeys picked out the grains with difficulty. Imo, however, acted differently: she took a handful of grain, containing sand and dipped it into the water. The sand sank, while the light grain surfaced. The only thing left for Imo to do was to collect the grains from the water surface and eat them. Soon all the close relatives of the ingenious Imo learned this skill.

Another interesting story about monkeys concerns the capuchin monkey P-Y who was famous for her fondness of drawing, the high quality of her pictures, her ability to use tools, and her ability to solve mechanical problems that were beyond the scope of most chimpanzees. She was called a genius-monkey.

When researchers would approach P-Y with a set of objects she woud joyfully rush towards them. She would start her work with a happy air. If she was offered a difficult puzzle she would work at it in deep concentration for hours, oblivious of every thing, even of her meals and of her much-loved bananas.

P-Y first started drawing with a nail

on the floor of the laboratory. This was not mere scratching: P-Y produced abstract patterns. When she considered the drawings complete she would move over to draw in another part of the laboratory. Later she was offered coloured chalks. The pattern of her pictures changed: she would colour the middle bright red and arrange green, blue and yellow planes around it. "This drawing had a full-value form, unprecedented for an anthropoid".

But P-Y's other abilities are of interest to us here. Frequently, when she solved many of the problems assigned to her, she would perform actions that almost indicated insight, according to some specialists, and true insight, according to others.

Once P-Y was chained to a metal bar in the laboratory, and a banana was placed beyond her reach. Instead of a stick, with which it would be easy to get hold of the banana, P-Y was offered a rat tied to a string.

What do you think P-Y did? She had never faced a situation like this before, she had no previous experience. Nor had she ever seen anyone getting hold of a banana by the method she applied, and hence this was not imitation.

P-Y's method was a very clever one, and not every human would have thought it up. P-Y threw the rat at the banana, holding the other end of the string in her hand. After a few attempts the rat grabbed the banana and P-Y at once pulled the rat with the banana back towards herself.

Now returning to the ammophil, since not all members of this species use a stone to press the sand down over the nest, it may well be that this is a case of insight.

The following are quite obvious examples of insight. There is a hungry dog in a room. A bone is suspended under the ceiling at a height well beyond the dog's jump. Then a fairly large and heavy box is brought in. Now what does the dog do?

Several times the dog tries unsuccessfully to get hold of the bone by jumping from the floor. Then suddenly, as if it has been struck by an idea, it starts pushing the box over to the place where the bone is hanging. It climbs onto the box, jumps from it, and reaches the bone! Note that the dog had never done this before (no previous experience), nor had it seen other dogs do this (no imitation).

In order to get food from beyond the cage some birds (for example titmice or jays) can pull it up by strings stretched through the bars that have food tied to the other end. Success depends on the animal's individual ability. Still, almost all of them learn fairly soon by trial and error to pull up the food. While this is a difficult problem for some birds, others solve it immediately. From the very outset they pick up the string in their beak and claws to get the food. In accomplishing this the birds are believed to be guided by insight. The fact that this "revelation" occurs more often in young, inexperienced birds than in old, experienced ones also supports this conclusion.

Rémy Chauvin explains: "The ability of some animals to overcome obstacles without preliminary trials and errors can also be regarded as a case of insight."

Sally Carrighar writes: "... it has been acknowleged—without being taken into account—that man's great advances have come through a different quality: his perception, his insight."

The Experiments of Professor L.V. Krushinsky

Insight-like types of behaviour are also called extrapolation reflexes. Professor L.V. Krushinsky, the top specialist in this field in the Soviet Union, has performed many experiments in order to demonstrate extrapolation reflexes. Let us consider some of them.

Professor Krushinsky writes: "In selecting subjects for extrapolation reflex research we regarded it expedient to use as models animals with relatively simple forms of higher nervous activity, since there were grounds for believing that such animals should exhibit the reflexes under investigation (if any) in the simplest form."

Hence, rabbits and birds (doves, ducks, hens, corvids, such as crows, magpies, and rooks, and some birds of prey) were used as experimental animals.

The procedure was as follows: The first one-and-a-half-metre section of a long feeding trough, which moves along some rails at a constant rate of 8-10 cm per second, was left open so that the animals could follow the trough to eat the food. The trough could also be suddenly shut out of view by the roof of a corridor.

What was the goal of the researchers? They wanted to know if the animal would look for the food only where it disappeared from view or would run ahead along the corridor to where the trough would appear again.

In the former case the experiment would demonstrate that the animal fussing about at the site where the trough disappeared had no extrapolation reflexes. In the latter, the presence of these reflexes would be obvious. What were the results?

The doves followed the exposed trough, pecking at the food, but as soon as the trough disappeared from view they gave up looking for the food to walk in the opposite direction. The ducks did the same. But the hens acted somewhat differently. They would not leave immediately as soon as the food disappeared, but would keep on searching for it for some time where the trough was no longer visible. They showed no inclination, however, to walk over to the other end of the corridor where the trough would emerge.

The behaviour of the corvids was totally different. For example, a crow named Varya searched for the food for a long time, not only where it disappeared, but farther down the corridor where the trough appeared.

The record of Varya's behaviour is as follows: "The crow runs after the trough containing a fixed piece of meat and pecks at it. As soon as the trough disappears from view in the corridor, the bird runs down the corridor, travelling 240 cm, then starts to return to the beginning of its route but does not reach the beginning of the corridor before it proceeds in the direction of the food movement. After 47 seconds, the bird discontinues its search and walks away."

This task was made easier for the corvids by a slit in the middle of the corridor so that the birds could catch a glimpse of the food passing by. The birds immediately improved their performance. As soon as they saw the food in the slit they would run down the corridor to wait for the trough to emerge. And when the trough did reappear, they ate the food.

The behaviour of the rabbits was fairly similar to that of the hens. This indicates that they are by far intellectually inferior to crows and magpies.

Dominance Hierarchy and Territoriality

Animal Rank Order

Japanese biologists have studied the macaques that were still living in some areas on their islands. Their methods were similar to those of other ethologists. They came to know all the monkeys by sight, assigned them numbers, and monitored the behaviour of each of them. The researchers took turns watching the monkeys, tape-recording and entering in a diary whatever they saw and heard. This observation continued day and night, hour by hour, for eight years.

The scientists discovered that the monkeys have a rank order.

One macaque population lived on a mountain cut off on the three sides from the world by the sea, and, on the fourth, by the mountains. The monkeys would sit and walk about the mountain in a rigid pattern according to rank. The highest-ranking males and females were invariably in the centre. Only babies were also allowed to play there.

Sixteen adult males lived on the mountain, and only six of them, the biggest and most robust, were allowed to walk about in the center. Entrance was not permitted to any other monkeys. The rest had their own rank order and lingered on the periphery, at varying distances from the privileged centre.

A general pattern was observed: the perimeter closest to the leaders in the centre was occupied by lower-ranking females, and the more distant perimeter was the domain of young and weaker males. Only the youngest monkeys were allowed to trespass the boundaries of any rank and they frequently took advantage of this opportunity.

In the evening the monkeys went to their sleeping places. They would be led by a patrol of young males, followed by the leaders and highest-ranking females with their young. As soon as they left their central residence on the hill, it was entered without fear by the subordinate males who would take away the lower-ranking females. The young monkeys would be last, usually lingering to frolic at the throne of the leaders accompanied by young adult males.

In the morning, the animals would return to the mountain and arrange themselves in rigid concentric patterns according to the spheres of influence.

The most interesting point about this hierarchy is not the presence of dominants and subordinates, but that the rank order operates rigidly and universally, from top to bottom. Literally every member of the colony is assigned a status, which can be given a number or designated with a letter of the alphabet—from the first to the last—and this is the general practice of scientists.

This discovery was made recently, and initially was a source of debate. When it was examined more closely, it was unexpectedly found that hierarchy and rank order (and this is exactly the term that fits this phenomenon) exists in almost all animals, be they monkeys, hens, wolves, crickets, deer, mice, cows, bumble-bees, cod, or others. Every pack, school, herd, or smaller unit has animals ranked by number, both males and females. Occasionally, even the young are included in the dominance hierarchy, as, for example, in hens.

Chickens have a "general" chick who pecks at everybody, and no one dares to peck at him. This was revealed by estimating the number of pecks occurring right and left in the poultry yard. They also have a "colonel" and a "lieutenant colonel", and so on down to a "private". The "private" is the most unlucky, because it is he who is harassed and pecked at, and he must endure everything like a stoic. Young cocks sort out their ranks by approximately the seventh week after hatching, and young hens by the ninth week. As chicks grow up, their ranks may be reshuffled, because they gain both strength and experience at varying rates; however, the dominance hierarchy remains.

Hen Number One struts like a queen, holding her head up high. She steps straight with dignity. The other hens show their subordination. Whenever she wishes to peck them, they crouch and lower their wings meekly. Their submission is obvious. But if Hen Number One is transferred to another yard she may become number two, number five or even more inferior. And the previously proud hen will turn humble. One hen that found herself in five different groups was ranked numbers one, five, one, five and six. And another hen that was number two in her own yard, became numbers six, two, four, and seven in four consecutive yards.

A hen needs to spend only one hour per day in every group, and she will be remembered there and will be able to maintain her initial status, specific for each group, without fighting. Rémy Chauvin, one of the best specialists in animal hierarchy, believes that the explanation for this is yet unknown.

When a dominant mouse runs around, the other mice make way for him. He has priority in eating the available feed. He bites all the other mice around him, and they let him. They even stand on their hind legs and humbly expose their bellies—the most vulnerable spot. And once a dominant mouse gives in to another, the strongest mouse is promoted to "general" (although for some time he keeps far away from the burrow of the demoted "general").

As in chicks, the lowest-ranking mouse is the worst off. He is bitten, by all the other mice, occasionally to death. If he is not killed, he has a difficult time all the same: he may die of hunger—this outcast has to eat stealthily, after all the other mice have become satiated.

Cows that are driven out to graze in the morning also have dominants and subordinates. If cows lick each other's shoulders, they are close in rank: in this case they normally differ by three levels. Cows that are distant in terms of rank completely ignore each other.

Deer also have a dominance hierarchy. Apparently, a hierarchy exists in all animals that live in groups. And not only in groups.

Rank order has even been discovered in grasshopper warblers. If two warblers encounter each other, they fight: with their antennae locked together, the insects begin a pushing contest. If one of them ranks lower he will not fight back too vigorously, but will instead make for home, where he has command of the situation. An encounter of grasshopper warblers that are close in rank for example, numbers one and two, entails a fierce combat.

The bigger and stronger a warbler, the higher his status. Researchers conducted various experiments with these insects. For example, they coated the eyes of a dominant warbler with lacquer so that he could not see. His antennae were also cut off and a piece of cardboard was fixed on his breast to prevent his conspecifics from recognizing him. All the same, the other warblers recognized and yielded to him. Once, however, the dominant warbler's antennae broke off accidentally at the very base. Apparently no grasshopper warbler "general" lacks antennae completely: the warblers no longer feared their antennaless leader. Another grasshopper warbler became the dominant one in that locality.

A somewhat similar situation was discovered in deer. Their antlers are not only combat weapons: they also function as rank insignia. G. Bruins and H. Hediger found that there were three major ranks in the deer of the Basel Zoo. They designated them by the initial letters of the Greek alphabet: alpha, beta and gamma. The alpha deer dominated all others, but when his antlers were cut off, he abandoned all his privileges in favour of the beta male.

A simple experiment was performed on fallow deer in another zoo. The dominant fallow deer buck had died. A dummy of his head bearing his magnificent antlers was brought into the enclosure, whereupon the lowest ranking deer immediately dashed aside and pressed against the opposite side of the enclosure. It took some time before the deer was able to calm down and approach the dummy.

The fangs of the hamadryas baboon are like those of a leopard. The bigger and larger the fangs, the higher is the male's rank. Fang display is a claim to superiority, which is usually met without combat.

When the ethologist Heinemann showed an old male baboon with worn off teeth a life-size picture of a baboon mouth with huge fangs, the baboon took refuge in the distant corner of the cage. He seemed to be saying, "Spare me. With such fangs, you dominate by law."

In gorillas, the highest rank is held by the silverbacked males. This is not genuine gray hair, but it is a sign of age that appears in ten-year-old gorilla males. Females rank second, particularly the ones that have children, and, generally, the smaller the infant, the higher is the rank of the female. Adolescent males rank third and at the bottom of the hierarchy are young gorillas of either sex that no longer live with their mothers, but have not yet reached adolescence.

The American ethologist George Schaller, who lived side by side with wild gorillas in an African jungle for over twenty months, once watched an episode that clearly illustrated the dominance hierarchy in gorilla families. It was raining and a juvenile took a position under the dry canopy of a tree near its trunk. As soon as a female approached, he rapidly stood up to vacate his seat and found himself under rain again. After the female settled down in a dry place, a silverbacked male arrived and sat down nearby. Then he lazily, not roughly but insistently pushed the female out into the rain to claim the dry place for himself.

Such subordination is also found in hedgehogs. Strangely, their hierarchy is not based on the dominance of the strong over the weak: other factors are involved. Professor Konrad Herter, author of an excellent book on hedgehogs, believes that pronounced individuality and mental gifts play a major role here.

An example is provided by four hedgehogs that were kept in a cage. A young female, who was by far not the strongest or biggest, ordered about, pricked, and bit the three others with impunity. The subdominant hedgehog was the other female, who, in her turn, treated the two male hedgehogs as roughly as she pleased. The biggest, and apparently the strongest, male ranked the lowest in this hierarchy. The other male, the smallest in size, chased and bit him without fear, but was fearful of the two females.

The Malabar danio, a beautiful striped fish, rigidly observes the rights of the strong whether in a tiny stretch of water contained in a glass or plastic container, or at home, in a slow stream in Sri Lanka or off the western coast of India. Their small school of up to a dozen of fish are subordinated to a leader. This little tyrant forces his weakest conspecifics to keep at the boundaries of the territory established by the school in a very bizarre submissive posture.

Professors V.D. Lebedev and V.D. Spanovskaya describe this phenomenon as follows:

"The strongest fish swims almost horizontally at an angle of two degrees in relation to the water surface; the second strongest, at 20°; the one that ranks third, at 32°; the fourth, at 38°; the fifth and the sixth, between 41° and 43°."

Presumably, the weakest and lowest ranking fish do not like this tiresome position and are fearful of the perils menacing them at the boundary. They would be happy to get as close to the centre as possible, but they do not dare. Should some forgetful or defiant fish change the ritualistic posture or stalk in front of Danio Number One, he is in for it. The dominant will deal him a nasty blow with the head or give him a sound lashing with his scathing tail fins.

The striped chieftain himself swims about in a normal, horizontal, position and hence is the first to see food fall on the water surface. He is quick to grab it and takes advantage of his rank. The "uplookers" of his retinue also have the time to snatch a mouthful: after all, they do not look down entirely.

But once the tyrant is captured, or, at least, placed behind a glass, all the aquarium dwellers assume the normal horizontal position.

This hierarchy is fairly simple, but quite intricate ones occur. For example, an animal ranked as number five may not be afraid of number three and gives him a tough time, but he keeps clear of numbers one, two and four. Numbers six, seven and on (and number four, strange as it appears!) are subordinate to numbers one, two, and three. It appears that number three has won the contest with numbers four, six, seven and on, but lost to number five, which, in its turn, lost to number four. This is why number five has no fear of number three.

Yet more complicated hierarchies have been discovered, which shall not be dealt with here in detail. For example, there are collective rank orders, where several males hold ground against a stronger male, or where a bottom or next-to-the-bottom ranking female and her young acquire the number one status as soon as the leader makes her the first, the second, or the third favourite wife. Another example is when the young of females ranked number one assume their haughty manners and mimic the belligerent postures of the leaders, with whom they live side by side, closer than any other conspecifics of the same age: without fighting, as if by right of succession, they inherit a high rank that they are not entitled to.

Intraspecific and interspecific hierarchies exist. For example, in a mixed flock of titmice, all great titmice rank higher than blue titmice, while blue titmice are superior to the black-capped chickadees. There are also relative vs. absolute, temporary vs. constant, linear vs. interrupted, "despotic" vs. "democratic" and others, rank orders, etc. Although they will not be discussed in detail, it is important to be aware that the fact that animals have rank order has been firmly established.

What is the purpose of rank orders? Actually they are of great significance. Nature sees a constant struggle for existence: the sick die, while the healthy survive. This is how evolution refines the world.

In order to avoid unnecessary bloodshed and fighting, dominance hierarchies have evolved among animals. After a single skirmish, everybody knows where they stand: the strongest establishes his superiority without further clashes. Within certain limits, discipline and peace reign in the mouse and hen kingdoms.

If the strong leader should fall ill, grow weak or too old, his position is taken over by the subdominant animal, and he is reduced to the number two position. He remains in full command of his subordinates and his experience is still put to use. But he doesn't take the number one position for nothing. Isn't this arrangement reasonable?

Submissive Postures and Ritualistic Fighting

With their strength and rank order established, animals avoid misunderstandings or fighting by settling their conflicts through peaceful displays. Once the leader assumes the threat posture, subordinates immediately appease him by submissive displays. These are species-specific. For example, the stickleback assumes a head-down position when it threatens, and a head-up position when exhibiting a submissive pose. The carp closes its fins when it submits. When a wolf does not want to fight, it crouches with its tail between its legs and its throat exposed to the stronger rival: this guarantees that it will not be harmed. This is a law of nature, which even a wolf does not dare to violate.

As we know mice give in by rearing and exposing their bellies—the most vulnerable spot to bites: the bites are normally not inflicted. In a submissive posture, jackdaws and crows turn the backs of their heads to the higher ranking rival. Seagulls crouch, fluttering their wings to imitate young birds. Occasionally they gape like nestlings soliciting food.

A baboon leader communicates his first warning with his gaze. He stares at his misbehaving subordinates. His stare has a kind of power that even scuffling apes sense despite the tumult and they give up the row. To make this gaze more conspicuous, nature has furnished it with attributes that can be seen from afar. Some baboon males have conspicuously white eyelids: they are adorned with bright white spots.

When geladas are angry, they turn their eyelids inside out. The message is frightening and so obvious that the offender will hasten to show his loyalty by presenting his bare buttocks to the infuriated leader (baboons also have other submissive postures). This is cheeky behaviour, one might say. And zoo visitors, not infrequently, regard it as a ribald gesture. As a result, a young baboon that exhibited this most respectful attitude to dominant animals often has watermelon rinds or stones flung at him. Zdeněk Veselovský, Director of the Prague Zoo writes, "Infuriated visitors accuse us of teaching our apes malefaction, amoralism and other sins. And all of this is only because we have well-mannered baboons".

The case with dogs is similar. The owner fancies that the dog tries to lick his or her face out of great affection. But the dog is actually showing his respect to his superiors. When two dogs meet, one dog salutes his subordinate with a highly raised head, and the subordinate displays his submission by crouching and showing his nose up to the dominant's snout. Every dog believes that his master is a dominant dog (just as people humanize animals). And since the "canonized" creature is actually very tall, the dog has to jump to reach the man's head in order to salute him.

Human greetings—handshakes and hugs—appear to be older than the most ancient people.

At the same time that Schaller was there, the British researcher Jane Van Lawick-Gudoll "visited" with chimpanzees in Africa in order to investigate their life. She relates the most incredible observations. For example, when two chimpanzees greet each other after a separation their behaviour often amazingly resembles that shown by two humans in the same situation. When the dominant Mike approached, the other chimpanzees would hurry towards him to show respect by bowing or holding out their hand. Mike would either touch them nonchalantly or simply sit staring.

Jane and Hugo Van Lawicks first saw a greeting "kiss" when the adolescent Figan returned to his mother after a day's absence. He approached Flo with his habitual self-assurance and merely brushed the side of her face with his lips. It was very much like the nonchalant kiss mothers receive from their grown sons.

The most affectionate greeting is hugging. The two scientists once witnessed this performed by the males David and Goliath.

Goliath was sitting when David appeared. Fatigued, he was dragging himself along the trail. When they caught sight of each other, the friends approached each other running, stood for a while face to face, shifting from one foot to the other, and hugged while uttering soft cries of pleasure. This was a beautiful sight!

Thus, animals salute each other in various ways. This behaviour does not always express the same thing that human greetings do, but the prehistorical roots of this behaviour are closely connected, in humans and in anthropoids. In fact, the animal salute includes both a greeting, a sign of good intentions and a submissive posture. It serves an important function: conflicts that may have resulted in combat are resolved peacefully. There is no need for fighting.

If two animals are fighting this indicates that they are close in rank, that they have not yet determined which one is the stronger, or that they are reshuffling their rank order. But in this case, too, they fight in a "humane" fashion, without unnecessarily crippling each other.

Many people erroneously think that animals fight "like beasts" and the strong brutally maim the weak. Scientists have only recently focussed attention on the "wars" in nature to reject this false concept.

For example, to defend itself from a leopard or a lion, a giraffe relies on its kick. This kick is strong enough to crack the skull like a clay pot. For this reason, a giraffe will never kick another giraffe. In their quarrels they only butt or lash each other with their long necks. Their necks are elastic, they absorb the blows like a rubber baton and are unwieldy. While the animal is swinging it the impulse is lost. Generally, neck fighting is impressive, particularly, in movies, but not dangerous.

What is really dangerous is when a giraffe takes someone to be an enemy and kicks them. Zdeněk Veselovský explains that when a giraffe considers a zoo janitor whom it does not like to be a conspecific, it butts him, but if the janitor is taken to be an enemy, it kicks him. Understandably, both kinds of treatment are pretty rough, but the latter is by far nastier.

The nilgai antelope are "noble" duellists: they butt standing on their knees, and never inflict deadly wounds. Fighting rams take a running start to strike at each other's horns. They can afford this distraction without detriment to themselves, because their necks and frontal bones are sturdy and well suited for this exercise.

But the brows of male goats are not good for ramming and these beasts do not butt each other in the front. When ibexes fight they rise up on their hind legs to kick at the opponent's horns from above. A male goat and a ram should not be kept in the same enclosure. Goats are arrogant and tend to overestimate their strength, while rams have an "armoured" skull. If, in a contest, a ram should charge and butt a goat head on he may kill his opponent by breaking his neck or frontal bone.

Quarrels, particularly over territorial claims, may, as is known, lead to serious conflicts such as duels, fights or wars. The latter two options, however, are out of the question for poisonous snakes. Their duels have to be performed according to set rules that exclude lethal bites.

The ritualistic contests of rattlesnakes are called dances. They are fairly brief and there are two participants, two males. The snakes stand upright in front of each other with their heads extending to half a meter off the ground as if they were measuring height. The "under-sized" male yields and crawls away.

But some snakes, for example, the Texan rattlesnakes, engage in a very long and complicated ritualistic fight.

The contestants approach each other and crawl together, repeating the same motions as if each snake were a mirror image of its counterpart. During the first act, which lasts for about five minutes, neither opponent charges. The struggle is still ahead.

After an interval the opponents get together again and raise the upper third or more of their length. Sometimes their lithe necks intertwine; sometimes they draw apart, crawl alongside each other, swaying slowly, and then separate only to guardedly draw together again. When tired, the reptiles rest lying on top of each other.

Mexicans are fond of watching snake combat dances. They will spend hours outside small enclosures where the best performers are exhibited. Fresh rivals are repeatedly released into these enclosures.

The finale of this "choreographic" contest is always the same. The snakes weave the upper parts of their bodies together; a brief contest of strength follows and one of the wrestlers falls on the sand flashing its white belly. The winner presses his opponent down for some time and then leaves with his head proudly raised. Then he crawls along the sides of the enclosure as if circling to announce victory. The loser humbly retreats to a corner: in the wild, he would have crawled farther off.

When two salticid spiders meet, for example, on the plank of a fence, they stage quite a performance: furiously raise their "arms" (that is, their front legs) and open their mouths widely. Then, threatening deadly reprisals, they begin to advance. The spiders advance step by step, and then confront each other head on. Their sixteen bulging eyes (eight in each) gleam in fury. They approach each other with their frontal parts just like rams. Their venomous hooks press against each other increasingly tighter. And then they peacefully draw apart.

Do not expect a fight. This is merely a pantomime: a bloodless contest of males. It symbolizes a fight that will never occur. Otherwise, long ago, on the first days of spring, the spiders would have exterminated one another and their kind would have become extinct.

The Difference Between Territory and Distribution Range

A distribution range is that portion of the world where the members of a given species can be found. For example, the squirrels that are found in the Soviet Union range across Europe and northern Asia. But not all parts of the range provide habitat for the squirrel. One does not find squirrels in the tundra, in the steppe, or in deserts, which account for a substantial portion of the squirrel distribution range, as can be seen on a special map. Squirrels dwell only in forests, while sousliks, by contrast, are found in the steppes. Hippos and otters live near lakes and rivers, avoiding forests, which are devoid of water. The sites and landscapes, which animals populate and to which they have become adapted, are called a biochore.

In forests, too, not all animals are randomly scattered. Squirrels prefer trees; hares and foxes travel on the ground. The capercailzie and willow grouse are not found in oak groves: they need dense taiga forests. By contrast, the common partridge avoids the taiga, dwelling in coppices on the edges of steppes and fields. This is their so-called biotope.

During the entire winter, partridges stay together, migrating in flocks, but in the spring they pair off, and each pair stakes out a small area in the previously common biotope. This is their territory and it is staunchly defended against other partridges.

The division of the habitat into territories guarantees every species more uniform utilization of the biotope, that is, of all the livable sites. The innate struggle of animals for their own piece of land, water area, or tree serves a very wise function. The situation never arises where one habitat is overpopulated, while another is underpopulated.

Over the millions of years of evolution the world has been divided an innumerable number of times (and is still being divided now) into millions of millions of individual territories.

There are large, small, and tiny territories. Their size is a function for the particular animal, its size and its feeding behaviour. Most importantly, a territory should be able to support the mammalian, avian, or fish family or population. It is most important that the territory occupied by herbivores, for example, contains an amount of grass sufficient to sustain them, for, say, a month. And when all the grass has been eaten up, there should be enough time for it to grow back before the migrating herd returns. If the habitat is fertile, the territory may be smaller, compared with areas where food is scarce. Hence, the more food the habitat has, the smaller the territories and the denser the animal population.

In their own territories, animals are more "confident" that their mates will remain faithful. Some even do not allow them to cross the territory's boundaries, and should this occur, the mates are immediately driven back.

One's "property" is also easier to protect from thieves within defended boundaries. Theft is not only a human trait. Bowerbirds steal various knick-knacks from their neighbours. Penguins steal stones from strange nests, and do this so zealously that an unprotected nest literally dwindles before one's eyes. According to Rémy Chauvin, stealing pelicans look so scared that one can see from a distance what they are engaged in.

The territories of insects, spiders, fishes, frogs, and lizards are small: they may occupy several square metres or even centimetres, as, for example, aquarium fishes. Zoologists measured some territories and discovered that tropical lizards occupy no more than between 30 or 40 square metres; Texan frogs, 400 square metres; swans, one square kilometre; roe deer, roughly five; and deer, between one and two-and-a-half thousand acres (i.e. ten times as large). The hunting territories of lions and tigers are about twenty square kilometres in size.

The territory is not necessarily the area where the nest or den is located. Ducks may travel over a kilometre away from the nests to forage. Thus, they have two domains: a small one near the nest, and a large one where they feed.

A troop of baboons of approximately 80 apes occupies a territory of about 15 square kilometres, but only part of this area is settled by the apes. Some sites may never be visited; others are always frequented. There are trees where they spend the night, "dining rooms" where they feed, playgrounds, and watering sites.

If water is scarce, several troops may gather where it is still available and drink together. There is no quarrelling or fighting. It is of no consequence in whose territory the water is located: the water holes appear to be communal. After the apes quench their thirst, the troops separate, and the members invariably remain in their respective troops.

The territory of not only baboons, but presumably of all animals are divided into small plots for different activities. There are sleeping, grooming, drinking, and eating sites, and also an area where the den or some other shelter (and often more than one) is located. The boundaries are clearly marked. Many animals even have lavatories—one or several—which are at definite sites.

All these apartments, or, to be more exact, dining rooms, bedrooms, nurseries, bathrooms, toilets and other units are connected by trodden trails, paths, or less conspicuous passages. They wind over a given territory but stop abruptly at the borders with foreign territories.

Animals normally do not roam randomly

about their territory; rather they follow only those trails that are connected with the sites of feeding, rest, bathing, and other daily activities. These trails may be conspicuous (as the ones of elephants, hippos or rhinos), or may be hardly visible. Territory inhabitants normally turn up on their trails and where they regularly forage, sleep or bathe at the same regular hours. According to ethologists they live in a "spatial-temporal" system.

Let us consider, for example, the daily schedule of the Indian rhinoceros, which hardly changes throughout its entire life. Professor Wolfgang Ulrich, Director of the Dresden Zoo, recorded the following schedule in Assam:

6.30. The rhino wakes up in the "bedroom" in the thick elephant grass, whose stalks rise up to form a vault. After he wakes up, the rhino walks slowly along the trail beaten down in the jungle and closed from above to look like a tunnel. He makes for a swampy meadow, his "dining room".

9.30. He has finished his meal. It has grown hot. The rhino walks to his daily rest site, to a mud pool, along the trail that he will use all his life. There he wallows in the mud. The dried mud protects the rhino from annoying bloodsucking insects.

12.00. The rhino drags himself towards his "bedroom", again along the long-trodden trail. There, in the shade of the elephant grass, which is five metres tall, he takes his siesta.

15.00. The rhino shuffles towards his "dining room" on the lawn where he grazes until midnight. After this he heads for his "bedroom", where he spends the rest of the night.

And this goes on day after day. True, deviations from this "spatial-temporal system" do occur. For example, if it is a particularly hot day, the rhino does not visit his "bedroom", but instead remains in the mud pool to sleep there dipping in the water. If it is a cool and rainy day, he is in no hurry to leave his "bedroom" in the morning.

African black rhinoceroses have certain sites, where at set hours they rub against termite nests or tree trunks. The Indian rhino has no such habit.

The "spatial-temporal" pattern of gorilla behaviour is as follows:

After sunrise at 6 a.m., gorillas wake up and eat grass and the foliage of various trees for a couple of hours.

Breakfast is over between 9 and 10 a.m. and it is time for the afternoon rest and sleep. The apes lie down in relaxed positions, on their backs, bellies, or sides; others sit leaning their backs against a tree. Some doze or sleep; others groom their children or lazily chew leaves.

At 3 p.m. the dominant male gets up and everybody is off to forage. They walk slowly through the forest. Then they eat, doze, sunbathe, and eat again. Gorillas travel between one hundred metres and five kilometres a day, depending on their mood, or on how the terrain satisfies their appetites.

At dusk (in the tropics, immediately after sunset, normally at 6 p.m., or if the sky is cloudy, at 5 p.m.) all the members of the troop congregate around their leader and he starts bending the branches of a bush to one site, trampling them. It appears as if an order has been given that no one dares to disobey. This order is to build nests for the night. And the gorillas sleep for 12 or 13 hours until sunrise.

"Power drives power with force", this classical principle of power is predominant in nature. Only humans, who above all value ethics and equal rights, can conquer brute force with moral strength. These concepts are beyond animals, since they are not formed through a formal mechanism of instincts but through the creativity of intelligence, which human beings alone have been able to develop.

But whatever the reason, a stronger animal has a tougher time in driving a weak one from his home than in defending himself from one of equal strength at his own place. This has been proved experimentally.

When a mouse finds itself in a new place, it hesitantly starts to explore the surroundings. First the periphery is investigated—the wall and secluded corners—then it becomes brave enough to walk over to the middle. As it finds proper living quarters, it gains selfconfidence. If two newcomer mice meet, they draw away immediately. But if they later encounter each other again, one of them may pounce on the other without fear.

The mouse that has already had enough time to explore the territory is more aggressive. As explained by Rémy Chauvin, "... irrespective of its status in the hierarchy, any animal is the unquestionable host in its own home. No one will harass it here, even a dominant. The latter will be chased off by warning calls and a sham attack staged at the entrance. The opponent will only persist if the defender has settled down in somebody else's territory."

A newcomer cricket, upon finding a vacant hollow, will also first closely inspect the surroundings in order to make sure that it has not trespassed on somebody else's property. When it is satisfied that the place is vacant, it establishes itself as owner and begins patrolling the surroundings vigillantly in its spare time or just in passing as it sets off to gather food or on some other business. Looking around, it stretches on his legs and twitches its alert antennae: these feelers are the organs of olfaction, touch, and presumably, of other senses. On its own property the cricket may even attack higher ranking crickets that treat it roughly on neutral territory. At home the cricket chirps longer and louder.

Fishes that build nests or protect their eggs leave their schools shortly before depositing eggs. Careless idlers turn into anxious owners. "Real estate" is acquired by the males, at the bottom (sticklebacks, cichlids) or at the surface (macropods).

The first to come obtains the largest area—occasionally even an entire aquarium. But other fish arrive, and after strenuous battles seize at first perhaps only a centimetre of the bottom ground, and then, as opportunity offers itself, furtively expand their property.

Sticklebacks and cichlids defend a small area at the bottom without caring much for other space. But macropods, which build "castles in the air" of foam for their eggs, compete for every millimetre of the surface.

Frogs are also aware of what belongs to them. Some of them croak not only to attract females, but like birds they utter their calls to stake out a particular territory. The Texan frogs Syrrhophus keep a distance of at least two or three metres from each other; hence, a plot of 20 metres is populated by no more than eight or nine frogs. The American investigator James marked all the frogs that he was able to catch beyond the borders of eight such plots. Then he captured the frogs that lived within these plots. In a month's time he removed 87 frogs from an area of 32 thousand square metres.

As the area was vacated it became populated by frogs from the periphery and soon almost half the frog population in the area under investigation were newcomers; 54 percent were old-timers. Some had travelled as far as 100 metres, although normally frogs do not migrate over such long distances.

When James marked 25 frogs and released them into a densely populated area, none of them were able to settle down. Whether they were strong or weak, they were driven away by the legal hosts. The expelled frogs were found 150 metres away from the place of release.

An interesting point about the experiment is that as soon as an area was vacated it was taken over by frogs from the periphery. But these were not homeless frogs: each had held a territory of its own, which was no worse or smaller that the newly occupied one. "Why then did they leave behind their own property to seize somebody else's?", asks Chauvin. His answer is "It is a mystery".

There is however a partial explanation. As was already mentioned, all living creatures are endowed by nature with an irresistible urge to spread, to expand their range as biologists put it. It is not avarice that drove the frogs to vacant lands, but the age-old subconscious instinct, which one led life to populate all corners of the earth. And this law of nature is inexorable.

Niko Tinbergen, one of the founders of ethology, observed sled dogs in Greenland. He noticed that every pack has, as do wolves, a group territory of its own. Its boundaries are rigidly defended. All members of the pack join in fighting other dogs off if they trespass. Even the weakest and, hence, lowest-ranking, dog that commonly crawls in front of other members of the pack changes entirely when the territory has to be defended from an enemy attack: it pounces on strange dogs in a fury.

Immature dogs do not yet know the boundaries and roam around wherever their fancy leads them. But beginning at nine months of age, if they should trespass other territories, they become subject to a fair dressing down from the other pack's adult dogs. From that time on, adolescent dogs join adults in defence of the territory.

Niko Tinbergen writes:

"If neighbouring packs met at the boundary between their two territories, where the issues were even, neither group attacked

The males, and more particularly the leaders, growled at each other. The state of tension in these strongly aroused, yet inhibited, champions also showed itself in acts which, in their similarity to human behaviour, were a source of endless amusement to us: they took it out of their own pack, and the unfortunate dog of low rank who happened to come too near was growled at, or even severely mauled".

In its own element, the marine worm nereis, which is a favourite food of fish, hides in the crevices of cliffs. It also searches for a quiet shelter in an aquarium, and if no cover is available, the worms roll themselves into a ball.

If glass tubes are placed at the aquarium bottom, the worms soon find them and crawl inside. If there are not enough tubes, a homeless nereis will explore the tubes that are already taken and attempt to enter one. The further developments may take three different courses as follows: either the pretender may leave while the going is good; it may break into another worm's house and they will live together in piece, or finally, by penetrating the tube from behind, that is, from the side opposite the host's head, the intruder will bite and gnaw the host to pull it out of its place.

Usually, the last leads to an immediate fight. The opponents confront each other head on and begin biting each other. The fight lasts three to five minutes, whereupon the looser retreats. Some species of nereis rarely have clashes with conspecifics outside of their dwelling places. Others engage in clear-cut territory fights that are fairly frequent.

In worms, because of their primitive nervous system, such behaviour (territorial imperative) is atypical. But it is typical in arthropods, for example, in crabs and dragonflies.

The shallow littoral waters of tropical seas is the home of the fiddler crab of the genus Uca. The males of this crab have been endowed with a huge left claw that is larger than the crab's body. The right claw is disproportionately small. It seems to be a needless appendage, but it serves a useful purpose: it picks up food.

At low tide, the crabs leave their nests to stage a regular performance. They wave their huge claw rhythmically, warning all other male crabs against approaching the nest and the small stretch around it. Neglect of his warning and trespassing results in a fight. Crabs fence with their tremendous claws and, as in sword fights, the clanking of blades is heard far and wide. But this duel lasts for only a few seconds, and the fighters do not inflict serious wounds.

L. Crane observed two fiddler crabs placed in an aquarium. Their daily routine was as follows: early in the morning they got up, left their nests, groomed themselves, and ate. As if on command, they would then make for the boundary between their territories and begin dueling. This would end in the weaker crab hiding in his nest, and the victor continuing his breakfast that was interrupted by the battle.

And this continued from day to day. It seemed that the fight of these crabs was a sort of sport or game. Only occasionally did the victor crab show by his behaviour that it was no game. He trespassed on the territory of the enemy, which he normally did not do, drove the opponent from the nest, and destroyed the nest by burying it in sand.

N. Morre filled a bomb crater with water to produce a small pool near which he released five males of the same dragonfly species. After several days he brought five more male dragonflies. But the previously released dragonflies had got so used to the new place, that they claimed it to be their lawful territory. They attacked the newcomers and chased them off. During the subsequent days, the number of dragonflies remained a constant five.

Defence of the territory was observed by M. Jacobs in two American dragonfly species. The dragonflies even displayed threat postures. When a male dragonfly encountered another male in his territory he would lift his brightly coloured abdomen. This was a warning signal. By contrast, when a male met a female, he lowered his abdomen.

According to C. Barnett the robin redbreast is remarkable in that it does not leave its territory even in autumn and early winter. Also unusual is the fact that both sexes have the same coloration: one can recognize an adult robin by its red breast. Still another distinctive feature is that female robins also sing.

When a male robin redbreast settles down in a new unfamiliar locality, he sings very softly and shyly, and not up in a branch, but down on the ground. Unless he hears some song in response he is reassured that the place is vacant. Then he begins to sing more and more loudly and, finally, flies up to alight on the branch of some tree or bush where he starts singing at the top of his voice. This indicates that he has found his territory and does not intend to leave it.

If another male trespasses, the host's song sounds still louder. If the song is of no use and the intruder persists, the host assumes a threat posture, displaying a red spot on his neck. He will fly over the very head of his opponent and settle down to confront him with his conspicuous red breast. The male stretches up on his legs and lifts his head up, pointing his beak to the sky. The red spot on his breast is not covered by anything and is clearly visible to the opponent.

If this does not work and the newcomer does not become frightened, it occurs, though rarely, that the host dashes at the impostor. The birds peck and claw each other until their feathers are flying.

The ethologist David Lack bought a robin redbreast dummy and put it in a cage where live robin readbreasts were kept. The cage inhabitants immediately assumed threat postures, but the dummy naturally showed no response. The indignant birds then attacked the cheeky intruder. Even after one vigorous male tore off the head of the dummy the robin readbreasts continued exhibiting threat displays.

Why do Birds Sing?

According to the previous view held largely by poets, birds sing in order to amuse the bored mate that is brooding. But in 1920 this opinion lost ground to another extreme view. The book *Territory in Bird Life* by Henry Howard appeared in which the author claimed that birdsongs are no more than a warning to other conspecific males that the territory is taken. From that time onward, the concept that song only serves the function of territorial defence gained currency.

But later, a large body of information

was accumulated that lead scientists to almost unanimously believe that Howard's interpretation of birdsong is by far too limited. It was discovered that song is also a sexual releaser. It is an important feature of the mating ritual: without it mating is impossible. The song of nightingales has an additional meaning.

Nightingale males sing both in winter and during migrations when they have no territory. Some nightingale females sing. The females of other birds, for example, wrens also sing. They sing not at the top of their voices, but softly, as if they are addressing their song to their own nestlings.

Male birds that have not yet found a mate sing louder and longer compared with those conspecifics that have already got a mate. An unmated male pied flycatcher sings 3600 songs a day, that is, three times as many as his "married" conspecifics. Thus, the song here not only announces that the territory is occupied, but also attracts females.

It seems that female pied flycatchers prefer good singers, while female wrens and weaver finches prefer males that build better nests.

Sally Carrighar writes: "It is nightingale's song of which Thorpe writes when he says: "elaboration of patterns seems to have gone to quite excessive length unless indeed we suppose that the listening bird has something approaching aethetic appreciation and is more stimulated by a nightingale song of high elaboration. Most remarkable of all bird songs, it seems to me, are the duets between mates... . The greatest refinement of duetting is the antiphonal song in which one mate sings a few notes to be taken up by the other, the two alternating so perfectly that unless both birds are in view it is impossible to know that more than one is singing. These antiphonal performances are produced by individuals in more than twenty families of birds according to Thorpe who has heard some of them and testifies to the almost unbelievable accuracy of their timing."

Antiphonal singing has been noted not only in mates but also in birds of different species that are capable of imitation. One bullfinch was taught to sing the British anthem. A canary that lived in the same room was also quick to learn the tune. First the canary and the bullfinch sang separately, interrupting each other, and no duet came of it. But then, on their own, without being taught by humans, they learned antiphonal singing. The bullfinch was the first to start singing, and after the first few notes it would become silent. Without any pause, the canary would take up and complete the tune.

Thus, we have found that a birdsong serves many functions. One such function is defence of the nesting territory.

Boundary Posts of Territories

Although there are no visible indications whose domain you are entering, territories still have boundary marks. What they are made of varies: they are often vocal. It has been found that birds do not sing for the sake of lovers, although the latter may like this singing. The message of the song is direct: "Where you hear my voice is my territory".

But very much depends on the area suitable for the building of the nest. If this territory is small, and there are many birds around, when the males sing they are often not only within earshot of each other but also visible to each other. But then their territories are smaller than that prescribed by nature.

Orangutans and howler monkeys have even evolved special devices to amplify their yelps one-hundred-fold. Orangutans inflate their throat sacs like the bag in a bagpipe, and howler monkeys use their special vocal cord resonators. The bellowing of bulls and deer, and the roaring of lions in their territories are also warning to rivals.

Mammals are well-endowed with various odorous glands, which serve useful purposes. Among other functions the glands attract mates and stake out property.

According to Zdeněk Veselovský, territories are heavy with the specific odours of the host mammals. The smell of weasels, polecats or foxes is so pungent that they are even perceived by man. And the scent marks are constantly renewed. After they wake up, wash themselves and have breakfast, the hosts patrol their territories to reapply their scent where necessary.

Dogs, foxes and wolves, which, as is known, leave notes of their presence by raising a hind leg against a fence, a pole, a tree, or a shrub, save literally every drop of urine to scent all the boundary marks.

Monkeys do not raise a leg, but moisten their palms with urine and wipe them on branches. Veselovský writes, "I kept an Indo-Malayan loris in a cage. After every cleaning of the cage this creature used the above liquid with increased zeal."

Bears, too, after rolling in their urine, rub themselves against a tree. European bisons will debark a tree, roll in their urine and then rub themselves against the trunk.

Badgers, hyenas, sables, weasels and many other animals rub themselves against shrubs. When patrolling their domains skunks will now and then spray their combat liquid on the grass.

In addition to scent marks, territory can be staked out visually. Bears, for example, do not confine themselves to scent marks. They strip bark from trees leaving white trunks that signal that the area is taken.

Many birds of prey circle for a long time over fields and forests. And a kestrel that has found a place for a nest swoops down on it.

Some frogs and fishes have special signalling displays to keep the neighbours away. But if the neighbours disregard these boundary signals and approach the stranger's property too closely, they are warned again. The pantomimes staged by some animals in front of a conspecific opponent at the home range boundaries are called "boundary postures". They are often very amusing.

A stickleback threatens a rival that has dared to swim into his territorial waters by performing a dance on his head. If this display does not scare the intruder, the host bites at the bottom of the water body. Herring gulls pull up tufts of grass. Bulls dig into the ground with their horns and hoofs.

During such conflicts cocks peck imaginary grains in front of each other. The same is true of titmice. Starlings and cranes display plumage preening right in front of the enemy. And avocets and oyster catchers pretend that they are very sleepy—one would think that they are bored to death by the very sight of this tedious intruder claiming his share of the land. They put their heads under their wings and crouch, imitating their sleeping pose.

These are certainly instinctive actions, which do not actually convey contempt, but by some queer coincidence are reminiscent of contemptive behaviour.

The males of some animals do not fight at all: they never wound each other. Instead of dueling over territory or a female, these animals perform some peculiar "ritualistic" motions, reminiscent at times of the patterns of some intricate dance. Some British biologists call this sort of fight a bluff. Bluffing males do not fight but kind of bully each other.

Great titmice, for example, hop in front of each other, stretching their necks and swaying slightly from side to side: they display the beautiful black and white spots on their cheeks.

A robin redbreast vaunts his red breast by sticking it out, craning his neck, and also swaying.

Doves puff, ruffle their feathers and stick out their breasts. The one with the most imposing air is the winner.

The fights of snow-buntings are an amusing sight. They alternately pounce and take flight. Like a swinging pendulum, the fighting males rush from side to side, chasing each other. After running some distance, the fugitive suddenly turns round to chase the pursuer back over a nearly equal distance; then he retreats again.

"I have never seen them fight", says one student of Manchurian cranes. "A threat posture is always enough to warn off the opponent." This posture is fairly expressive: the head and beak are stretched forward, and the neck is arched upward or backward. The big long-legged bird hisses and with his "foil" races towards his opponent, lifting his long legs in a funny fashion. The offender loses his nerve and turns tail.

Haplochromis and some other related fishes, for example, Cichlosoma meeki, threaten their rivals by widely opening their gill covers. The opponents face each other nose to nose, puff up, trying to look bigger and more frightening as the self-conceited frog in the famous fable. And the gold-rimmed large black spots on their gill covers sparkle iridescently. The duels of these fish are a magnificent sight.

And male bitterlings butt. In the spring they grow horny warts on their heads and use them in a pushing contest trying to chase the rival further from their favorite shell.

Many fishes use dull weapons, "hitting" each other with spurts of water. Two males will circle around, lashing their tails against the water in their attempt to hit the opponent with a higher wave.

Nose-monkeys, orangutans and howler monkeys try to scare one another with loud howls: the one that howls longer and is able to tolerate the opponent's howl for a longer time wins the battle.

The lemur tree-shrews* greet any unwelcome conspecific with shrill squeals or peeps. If the vocal attack does not scare the intruder, the host will grab and hold onto his tail so firmly, that the escaping animal will end up dragging the rival about for a long time. Occasionally, duelling tree-shrew box like kangaroos: they rear up and strike each other with their front limbs. And they do not forget about squealing. Should the host not win the boxing match, or even lead by several points, he will fall on his back and squeal so shrilly and irritatingly, that the deafened intruder makes off.

Two zoologists demonstrated that squeals are a very effective weapon. They tape-recorded the battle cries of tree-shrews and played them back through an amplifier. The shrews' response was quite a sight! They were literally panic-stricken, and some even fell into convulsions.

If their vocal cords are not powerful enough, some clever apes resort to objects that rumble. An example of this type of behaviour is the response of a chimp called Mike to harrassment by high ranking chimpanzees.

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* Some zoologists attribute tree-shrews to lemurs, others to insectivores; the mystery of the origin of these interesting creatures has not yet been resolved.

Jane van Lawick-Goodall lived for several years in the jungles of Africa among wild chimpanzees whom she befriended. She relates that before her departure from the reserve on the shore of Tanganyika Mike was very nervous and would be startled by any sound or movement. When Jane returned to the reserve she found Mike quite changed. All the chimpanzees were afraid of him. The reason for this change was simple. Mike had learned to make a formidable rumble with the empty paraffin cans that had been left in the camp. "Eventually Mike was able to keep three cans ahead of him at once for sixty yards as he ran flat out across the camp. No wonder that males previously his superiors rushed out of Mike's way". Chimpanzees do not like loud noises other than their own yelps. Thus, Mike was able to bully his conspecifics in this way.

The beisa antelope has very sharp horns like real foils, but actually they are not used like weapons. The horns clank as beisas butt, yet the animals fence without stabbing as in a theatrical performance. Once a hornless beisa buck began to fight with a horned male. The armed conspecific fenced with his rival as if he also had weapons. He parried and struck the imaginary foils at some distance from the hornless buck's head.

It has long been noted that the deadlier the weapon, the more conventional and harmless is the duel itself: it becomes a seemingly belligerent ritual. In poisonous species, where even a small fight is of deadly danger to both parties, it is replaced by a peculiar symbolic dance with contest of strength as the finale. The contests of Texan rattlesnakes over hunting territory are an example of this.

Mating Ceremonies

Some Invertebrates

Fritillaries are easy to recognize: they have beautiful silvery mother-of-pearl-like iridescent spots on the lower part of their hind wings. In the Soviet Union, in July and August these butterflies can be found flying around forest edges, meadows and wherever there is much light and warmth.

Researchers once made a fritillary model out of paper with wings that could beat very fast. The model was painted various colours: the green, light blue and yellow colours attracted male fritillaries, but to a much lesser extent than the yellow-orange colour of the wings, particularly if the wings were moving at a very rapid rate.

When a male and a female meet, they immediately perform a "zigzag dance", they fly quickly changing directions. Then the female lands. The male alights not far from her, and then walks towards her solemnly and salutes her with a characteristic quiver of his wings. Next he strokes her hind wings with his antennae and middle legs. Now the match is made, and the female accepts her mate.

In June nymphalid butterflies appear in the Soviet Union. They are brown in colour and have two eye spots on each front wing. They flutter around flowers and sip the nectar.

But when the male has become satiated and decides to amuse himself, he settles down on some small mound and waits patiently. He waits for a female of his species in order to court her. If he must wait for a long time, his patience may fail and in his excitement he may set off in pursuit of beetles that are flying by, flies, small birds, and even falling leaves. Sometimes he may even chase his own shadow!

However, if he is in luck, he may encounter a female of his species. The male then sets off in pursuit and the female usually immediately lands. This is the cue that he has long awaited. If the living or nonliving object that the butterfly has chased after does not land, the male does not pursue it. The object's behaviour is untypical of nymphalid females: they alight immediately.

The male lands near the female. He folds his wings and approaches her. If the female is sexually immature, she lets him know this with a flutter of her wings, and he again sets off in search of a mate. If she is motionless, he begins his elegant courting.

First, he flutters his wings in front of the female. Then he slightly raises his wings to show the beautiful white black-rimmed spots. He opens and closes his wings rhythmically, his antennae quivering. This lasts from several seconds to one minute.

Then (and this is the most gallant posture) the nymphalid male raises his fore wings, opens them wide, and bows deeply. Next, still bowing, he folds his wings back, tenderly pressing the antennae of the female between them. This is a butterfly kiss! And it is not only a posture: on the male's wings, exactly where he is pressing the female's antennae, are scent glands—a sign of his masculine maturity. He opens his wings again, turns around and starts a fast dance: he circles around the female with the air of a very successful suitor. Nymphalids dance in late July.

Almost all salticid spiders are "well-trained" dancers. In the spring they occasionally dance for up to half an hour. These spiders have very long and thick front legs. They raise their legs up high (one at a time or both together), and spread them apart, stretch them forward, flap them as if they were wings, or sway them in time. They execute the most intricate stunts in front of the mate. One would think that the spider is doing calisthenics, but at a closer look one can discern a real dance.

The dance of the small spider Attulus (it is only 3.5 millimeters long) is reminiscent of classical ballet. Propped up by his three pairs of legs (spiders are endowed with long legs indeed) he extends his two front legs to the sky and, sweeping them gracefully, skips sideways to the right. Then he freezes for a second, skips to the left, swaying his "arms" coquettishly.

For lack of space the diverse wedding dances of various spider families will not be discussed.

But the courting behaviour of the Pisaura mirabilis spider is so unusual that a short description follows.

In May these spiders scurry about in fresh green vegetation in search of a female. As soon as they come across her tracks or the signal thread that the female drags behind her, they set off with new energy to hunt for flies. When the spider catches a fly, it immediately starts entwining it in its cobweb until a white ball is formed.

He carefully holds the fly in his mouth and quickly and ceremoniously carries it in its silken packet to the female. When he sees her, he freezes in a bizarre, grotesque position, and then, very courteously, presents his gift. He stands in front of the female spider like an enigmatic and incomprehensible sculpture at an art exhibit. The male rests on the bottom of his vertically extended abdomen and on his six legs. His fourth pair of legs are raised over the fly packet that he is holding in his mouth.

The female spider, who must be stunned by this unusual sight, slowly moves towards him as if she cannot believe her eyes. She then accepts the wedding gift, tears up the packet and starts sucking on the fly. Should the spider turn up without a gift, he is in for it: the female will eat him up. But spiders can also cheat. Some bridegrooms pack up the remains of a fly carcass for their date.

Even a scorpion in love is courteous to his lady. He courts her tenderly, and takes her to a dance. The male and female scorpion first take a position, crossing their claws. Then they extend their claws towards each other and clasp them just like a man and woman holding hands to dance a polka.

And here the scorpion dance begins. Its absurdity matches the fantastic appearance of the dancers: two steps forward, two steps back, a jerk to the left, a jerk to the right, marking time and awkward turns that a tank would execute more gracefully. This grotesque dance may last a few minutes.

Even cockroaches have a wedding ritual. The behaviour of the genus Naupheta was very well studied by the ethologist L. Roth.

These cockroaches live in warm, damp and dark places. Hence they rely on their sence of touch and olfaction rather than on their vision. A sexually mature Naupheta male is very active: he races around in search of a female, feeling every cockroach he meets with his antennae. When he finds a female, he freezes in front of her in a strange posture (often for up to a full minute). He rises up slightly on his front legs, lifts his wings, and lowers his abdomen down to the ground.

Sticklebacks and Cichlids

The stickleback is an inconspicuous fish, but in the spring it is transformed like Cinderella. The males change their colours. Their bellies redden like tomatoes, their brown backs turn green, and their light blue eyes shine like aquamarines. What smart suitors! And how active they are. One after another they leave the school, each looking for a nest site on the bottom and chasing off vigorously as many fishes as he possibly can. But this seldom comes to fighting. Usually, the host warns the newcomer that the territory is occupied by performing an intricate dance. One could say that he dances on his head: he takes a vertical position with his tail up and twitches angrily with his whole body. He seems to be ready to pierce the bottom with his head. With his mouth open, the newcomer watches the bizarre performance for a minute, and then becoming aware that he is not facing mere buffoonery but a most serious warning, turns tail.

If the intruder does not retreat after the first steps of the dance, the host takes more drastic measures. While dancing with his tail up he begins biting the sand frantically. This behaviour seems to communicate to the rival: "Look what you are in for unless you get out".

If the aggressor is not scared by this display either, the dancer turns to him broadside, spreading his two large abdominal spines. This is the most serious threat. A stickleback resorts to it in despair when cornered by a perch or a pike.

When nobody is in his way, a stickleback is busy building his nest. First he digs out a "trench" for the house. He scoops the sand up in his mouth, carries it 15 centimetres away and disposes of it. Then he returns for another haul. Little by little a small depression appears at the bottom. Then the male brings blades of grass and fragments of algae in his mouth and stacks them in the depression. More building materials are brought and pressed down on top. The mucus produced by the kidneys of the stickleback glues the grass blades into a compact globe. The fish crawls through the centre of the globe to form a tunnel. Now the nest is ready: it is a hollow globe with two openings at the opposite ends.

And now its time to find a female.

When a small school of sticklebacks swim by, the male dashes after them. He dances the dance of love called the zigzag dance in front of one fish. He jerks from side to side while swimming in front of the female. Normally she responds to the courting and bends down towards the male who is dancing at a level that is somewhat lower than that of her head. Then the male hurries to the nest (with the female following) to show her the entrance by a characteristic movement: he lies down on his side pointing his head towards the entrance.

The male may even dance in front of a fish of another species, for example, a young tench, which, in a hurry, he has mistaken for a stickleback female. If the tench follows him, this automatically triggers in the misled fish a chain of futile reflexes. The male swims up to the nest and stretches himself out in front to invite the casual passer-by to enter his home and deposit eggs.

A male stickleback will also perform a zigzag dance in front of a rough model of a female tied to a thin cord, provided the dummy female has a swollen belly.

A female carrying eggs also responds to a rough model of a male (provided that the model has a red belly) and follows it if the model is moved in a manner imitating the zigzag dance. If the female is lured by the model down to the bottom of the aquarium and then, the coloured plywood model is placed flat to mimic the male, the female will peck at the sand in search of the entrance to the nonexistent nest. She believes more in the sham male than in what she sees with her own eyes.

Certainly, the word "believe" is used only metaphorically. The female does not actually reflect. Rather she submits to innate feelings: she reacts to the releasers evolved in sticklebacks over many millions of years of selection in the form of characteristic mating behaviour. Together with her mate they are responsible for the continuation of their kind (although these responsibilities are not too cumbersome in stickleback females). Occasionally, the female stickleback may mistake a fake male fish for her adored one. But humans, too, sometimes err.

The mating ceremonies of cichlids, such as Tilapia and Haplochromis, begin by staking out a plot at the bottom. There the male lies flat, beats his tail against the water and spins on the spot to dig a small depression in the sand. Then he sets off in search of a female.

As soon as he finds her, the male performs his dance. A Tilapia male slowly swims sideways in front of the female, bending his head at 30° to 60° angle. If the female stops, he waits for her. And then again, in the same strange posture with his head down, he swims sideways towards his hollow leading his mate.

A Haplochromis invites his bride in a different fashion. He also freezes in front of her but in another bizarre position: the posterior half of his body is parallel to the sea bottom and the anterior half is curved upward at 30-40°

Mating Games of Birds

In the spring male redstarts return to their territories earlier than the females. They find a suitable hollow or some other cosy recess where a nest can be built, and they defend their find against other claimants. In order to attract the attention of a female, a redstart will, from time to time, hang out a notice: "Have a marvellous one-room flat. Wife wanted!" This notice is his yellow tail spread like a fan and stuck out of the nest. The brides are quick to see the point, and will not keep him waiting long.

A male kestrel also announces that he wants a wife. He makes a ceremonial swooping flight down to some old crow nest of his choice. When he finds a wife, they both repair the nest a little, bring in some fresh litter, and produce their offspring.

Wild ducks get married early, far before the onset of spring. They mate in the autumn on their wintering grounds. Communities of ducks aggregate there and after the bethrothal games, the ducks pair off.

First comes the introduction: they swim towards each other and drink water. It appears as if they are bowing to each other saying, "How do you do? Glad to meet you."

In the peaceful life of duck communities discord is bred by young ducks that urge young drakes to join them, calling invitingly to any strange drake passing by. If a stranger alights near her, the capricious lady tries to set her admirer against the newcomer. She points to the fellow with her bill and quacks.

For the drakes this is an extra pretext to show their nuptial colours to advantage. When he challenges his rival to a duel the drake swims around the duck with his head drawn in and his bill down. He ruffles his feathers and spins his tail. Then, suddenly, he sends up a spray of water with a swish and stands upright. The rival rises into the same position. Further developments follow a set pattern. The rivals arrange themselves side by side, tuck their heads under a wing, and threaten each other with the wing's white patch. Then follows the stage of rattling their bills against a feather shaft. The drake curls up into a compact ball. Next the "dishevelled head" stage commences. He ruffles his head feathers to such an extent that his head looks like a disk. The ritualistic duel ends in "pumping". While facing each other the drakes seem to be pumping water: they thrust their necks rhythmically up and down, nearly touching the water surface.

Normally there are no fights. When the display of strength and handsomeness is over, the rivals separate peacefully. During the "beauty contest" the young ducks have had a chance to take a good look at the plumage and prowess of many drakes in order to choose the one to their liking. And from that time onward they become faithful wives, sometimes for life.

As was already mentioned, ducks are engaged in their nuptial games as early as in the autumn and winter somewhere in Africa. They fly there from various countries of Europe and Asia. And in the spring the drakes migrate after the ducks to where the ducks were born. It sometimes occurs that a drake from England travels to Finland or to the Ukraine. But once he finds himself in the home country of his wife, he gives rein to his wishes: he chases away any duck that he encounters.

The pursuit of strange ducks is interpreted by biologists as the springtime unruliness of males. This behaviour is explained as resulting from the animosity that they feel toward any strange duck, and their desire to chase it off the nest site. This ensures the regular distribution of nesting pairs over an area so that the future ducklings will not suffer from scarcity of food in crowded conditions.

After he has chased the strange duck away, the drake returns to his mate at once. She recognizes him from a distance and utters a call.

Many observations have revealed that animal mates, particularly birds, know each other and their children by voice and "by face" As in humans, the head, beak, nose, snout, ears and eyes of animals of different species have different proportions. And these traits, often imperceptible to the human eye, both males and females distinguish their mates from thousands of their kind of the same coloration.

Seagulls and terns do not mistake their mates for a stranger from as far as twenty metres away, even if he is silent. And if he utters a call, they can recognize him earlier. Ducks fly after their mates as soon as they see him in flight. They also readily identify their ducklings, and if a strange duckling is placed in the nest it will be chased off.

Emperor penguins, returning with prey, easily find their own nestling among an aggregation of hundreds of young penguins that are as alike as peas in a pod. And often, the young animal identifies its parent and hurries towards him, although his father does not seem to differ at all from the other adult penguins.

The German ornithologist Oskar Heinroth once watched, in the Berlin Zoo, a swan pounce on his own mate to chase her off along with a bunch of other swans. She had bent her head for a moment and he had taken her for a strange swan. When, in surprise, the female raised her head, the swan recognized her immediately and was "ashamed". Occasionally geese attack their beloved wives when the latter thrust their heads under the water in search of food.

Male and female geese form stable pairs, and not infrequently, these most clever birds are faithful to each other for life. Even if the female goose dies, her mate will remain a widower for a long time, or even for life.

Geese mate in the autumn. A goose family is very close. Goslings, even if they are already grown up, do not leave their parents. They travel together through the tundra and steppes, and migrate to warm lands. There they do not separate either.

It is not easy for a young goose to abduct his bride from her strict parents. Leaving his own family, he has to join a strange one, and his future father-in-law first chases and beats him up. This is why he begins courting from a distance. First he spies a young female in a family. Then, minding her ferocious father, he swims around for a long time in proud postures. He shows off his valor, attacking various inhabitants of the pond. He chases them off to defend his as of yet inaccessible fiance, although the enemies from whom he protects her are of no danger either to her or to anyone else.

After every such "victory" he swims up proudly to his ladylove, uttering triumphant calls. But if the father chases him, the "hero" leaves hurriedly. Sometimes it happens that the goose's feelings are not reciprocated for a long time. But once his ladylove responds with her charming honk cto a goose ear, of course) to his triumphant call, he becomes betrothed. The female goose leaves her family and from now on the young couple are always together.

The males of many migratory birds return to their territories in the Soviet Union from the warmer climates a week to two earlier than the females. First they make for the site where they had built their nests and brooded. The familiar site is defended from all intruders. Here the male mates with the female that is the most eager to respond to his call. This may be an old mate, or it may be a new one if the bird concerned is not a goose, a swan, or a nightingale, where the union between the male and female is for life.

When a male heron finds his old nest and mends it, or chooses a site for a new one, he settles down on the nest, and utters cacophonic calls. But his gruff voice is like a canticle to the female heron, and she flies to the male. The bride alights on a branch near the nest, but the bridegroom first roughly beats her up and chases her off. Once he chases her off he calls her again. His call attracts her like a magnet, but he beats and chases her off again and again. This continues for a long time. This type of matchmaking is certainly unusual. Finally, birds get used to each other. The male no longer drives the female away. The later she comes to the nest, the more welcome she is. If the female turns up only after a week or two, the male does not beat her but instead lets her into the nest. After a long time, the instinct to reproduce entirely suppresses the innate drive to chase off all those who approach the nest.

The same is true of storks. When a male flies in and chooses a nest (it is usually the old nest), he settles down to patiently wait for a female. As soon as he sees her he salutes her by "applauding" with his beak. If the female responds, she becomes his wife.

Veselovský writes:

"It is generally thought that the stork on a nest is a female, since in humans the female cares for the young. But in this case it is a male: the female only broods at night" He further explains that the main factor in the mating of storks is not faithfulness, but "... merely the fact that the first female that responds to his salute is accepted by the male as his wife. If he waits for his former mate, who on her long way from Africa might have died, he may not nest at all. Sometimes it occurs that the original female returns to the nest, and if a new female is already on the nest, they put up a fight, which the male watches impassively. The one who wins stays to brood."

It was formerly believed that the mates of storks and swallows are faithful for life. Bending, however, has revealed that this is not so. Who is faithful? It is now known that these are ducks, geese, swans, nightingales, and crows.

At the sight of crows mating, one would never think that one is watching a scene of peaceful courtship. Both the male and the female are very hostile. It is hard to judge which of them is a male and which is a female, because they walk, spread their wings halfway, and threaten each other in a similar manner. They face each other with ruffled head feathers and beaks ready for a fight. They go on like this for a day or two. But then, one of the crows (the female) gradually begins to yield.

She no longer attacks so fiercely, and, finally, she exposes her most vulnerable spot—the back of her head—a single blow against which would kill her. But the male does not strike. Instead, he tenderly runs his beak through the feathers of his obstinate mate. The union has been accomplished.

Everyone knows about the dances or mating games of birds. Usually, it is the males which dance. They dance either alone or in congregations at specific sites: in forest clearings, marshes or steppes, or in preselected bushes or trees. Some dance in the air, such as common snipes, woodcocks, tree pipits, and willow grouse.

One may also recall the capercailzie, buff, the little bustard or dove.

During their mating ceremony, birds often try to display the most glamorous features of their plumage by doing some unusual movements, and they normally accompany their dances with calls, muttering, or trilling. Occasionally, they fight and chase each other, but as was already mentioned, these are ritualistic duels rather than serious battles. The females, whom these games are designed to attract, are commonly present as inconspicuous, but highly desirable, spectators. Occasionally, they express their attitude to their admirers by some apparently unimportant movements like pecking actual or imaginary grains and berries. And this pecking encourages the dancers like applause.

Occasionally, the female takes a more active part in the mating ceremony. The mate of the North-American red-winged black-bird, perched on a branch next to the male, repeats all the movements of the male as he is engaged in the pre-mating ceremony.

Sparrows dance around their mates, fanning out their tails and wings. Wagtails, titmice and snow buntings do the same. Even eagle owls dance! In the spring, at dusk and throughout the night before sunrise, the male eagle owl walks in small steps around the female. All birds ruffle their feathers during their mating ceremonies, but the eagle owl, in contrast, presses them tightly against his body. That is why he seems so thin and long-legged. While strolling about he calls, puffing out his throat, and hoots frightfully like a wood goblin.

During his mating ceremony, the golden pheasant struts around the female with an air of importance, looking at her from above his magnificent collar like a coquette with a fan. He even winks at her with his amber eye for greater effect. The Himalayan monal pheasant first dances sideways to the female, then he begins spinning on one spot to show the blaze of his metal-coloured plumage.

The argus pheasant courts his mate in a very picturesque manner. First he ceremoniously approaches her in a spiral pattern. Then he suddenly opens his huge wings like an ornamental umbrella, revealing his iridescent eye-spots that look like stars in the sky. It is because of these eye-spots that he was called Argus after the mythological Greek hero who had one hundred eyes.

These picturesque scenes occur in the morning in the jungles of Sumatra and Indochina in glades overgrown with ferns. These glades are inherited by some of his sons when the old argus dies.

The most unusual mating postures and movements are displayed by the magnificent relatives of our crows—the birds of paradise that live in New Guinea and the nearby islands. When he alights on the branch of a tall tree, the great bird of paradise starts the performance by uttering a loud and raucous call. Then lowering his head he crouches lower and lower and sways from left to right. He begins shaking more intensely, spreads his wings and quivers. Streaming down his sides are the iridescent blazing cascades of his hair-like feathers. All of a sudden the bird bends down, lowers his wings to the ground, and then abruptly raises the orange hair-like feathers on his sides like a flag. He freezes in this position for a minute or two and then, without hurrying, he lowers his " flag"

Other birds of paradise declare their love in a yet more extravagant manner: after quivering they suddenly cling to a bough upside down, the waves of their overwhelmingly beautiful iridescent plumage spreading overhead. They hang stoically in this unnatural position, so that the adored one is overcome with delight. Her feelings can be readily understood, since the mating ceremony of birds of paradise, particularly if about a dozen birds are assembled is indeed a very beautiful sight.

The peacock performs his mating ceremony sure of his irresistible attractiveness. He does not chase brides as a cock chases hens. Rather, he waits for their approach and respectful attention. His harem is fairly small: there are between two and five crowned peahens. The performance that they are favoured with is indeed magnificently regal. The fan-like tail with its one hundred eye-spots attracts them irresistibly, as the victorious flag of a regiment attracts old veterans.

The peahens appear to come to the performance casually, obeying the mewing call of the male. They peck quite indifferently at some imaginary objects on the ground. The peacock remains imperturbable. He poses magnificently, displaying his regal tail. Then when he has decided that the tribute to feminine coquetry is appreciated he abruptly turns his inexpressive back on a lady.

The peahen seems to come to her senses and she runs in front of the peacock to again behold the multi-coloured sight with one hundred eye-spots. But the peacock shakes his feathers noisily and mercilessly deprives her of the attractive sight: in short, he turns his back again.

The iridescent eye-spots on the tail seem to have bewitched the peahen, and she runs over in front of her mate again. But a new 180° turn prevents her from seeing the male's front. This is repeated many times until the peahen bends her legs to lie down in front of the male. He then calls out a victorious "mew" and the wedding ceremony is completed.

Early in the morning, before sunrise, when it is still cold (it is yet April) and hoar-frost and mist envelope the ground, some huge white flowers seem to blossom in the monotonous grey steppe. When the mist clears at sunrise, one can hardly tell what kind of white forms there are in the meadow. These are some kind of creatures walking on bird legs. One can see that they are made of white feathers, but one can hardly distinguish the front from the hind quarters.

These are mating great bustards!

The great bustard is greyish red and brown in colour. The undertail, some feather tails and the abdomen are white. How then can it be transformed into a white enigmatic figure in a few seconds? The male bustard flings his tail over his back and the white feathers of his undertail cover him like a cupola. The wings curve in such an extraordinary way that their snow-white feathers, which are like white rosettes, camouflage the bird's dark sides, and the blackish brown feathers of the wings are turned out to expose their white undersides. The throat air sac swells out to the size of a football. His head is thrown back and is drowned in the luxurious plumage. This is the mating ceremony of a male great bustard.

Grebes are waterfowl. The great crested grebe is the largest of these birds. In the spring grebes are engaged in wedding games. The males and females are similarly coloured, wearing bright collars, crests and other decorations. The mating ceremony of the great crested grebes occurs in an open stretch of water. The male and female swim towards each other. The feathers of the collar are spread and the birds shake their heads and come to face each other bill-to-bill. They rise from the water upright: zoologists call this position "the penguin posture". Facing each other they often clasp bunches of wet algae in their bills, as if they were offering each other wedding gifts. On a quiet day their calls, "kua", "krua", and "korr", can be heard up to a kilometre away.

Common terns exchange real wedding gifts: the male offers the female a fish and the mate accepts this gift. This is a kind of formal wedding act. The male wades in shallow water carrying a fish in his bill. This is his token of a marriage proposal. Male terns and the females that have already mated do not pay any attention to this. Only a female that has not yet found a mate will approach like a nestling and gape for food. In this way she agrees to marry. Then the terns play tag in the air with one of the birds clasping the fish in its bill.

Adélie penguins, which nest in the Antarctic and the nearby islands, have very simple wedding gifts—pebbles! Both males and females wear the same nuptial colours, but there is a simple method for distinguishing between males and females. The bachelors collect pebbles and pile them at the feet of their prospective wives. If the gift is accepted, the male is not mistaken: in front of him is the one whom he sought. The piles of pebbles are now a claim to a nest. Subsequently they serve as building material for the nest itself. The birds pile them up around the hole like a rampart and guard them from neighbours that may steal the construction parts. Inexperienced males build their nests from several big stones. They are very inconvenient for brooding.

Various types of birds present wedding gifts such as pebbles, algae, twigs, and berries. When a male curlew relieves the female on the nest, he ceremoniously, with a deep bow, offers her a stone held in his bill. If the female accepts the gift, she immediately vacates the nest. If not, the male continues to bow until his mate accepts his gift.

Gannets and great crested grebes present algae to their mates. Herons and waxbills offer each other twigs or branches; corncrakes present caterpillars; waxwings and toucans, berries.

The mating ceremony of albatrosses is full of variety. The male walks around his mate with his neck stretched and sways in time to the steps. He nods with his head. This is the beginning of the mating ceremony. Next, the birds face each other and seem to fence with their beaks. Then they raise their beaks high up, gape and click. These movements are repeated in various combinations and other ritualistic behaviour is added, such as sham preening, mutual bowing with beaks pressed against the breast or to the ground (symbolically pointing to the nest), uttering calls, whistling with their heads up, and "dancing" around the nest with widespread wings.

The wedding ceremonies of some birds

include elements of behaviour that are nearly identical to those of humans, for example, kisses. Male and female doves press their bill wax plates against each other tenderly. The rook grips his mate's beak in his mouth and does not let go for a long time. Some birds, such as great crested grebes, murres, black guillemots, and herons, touch each other with their cheeks, necks, breasts, or beaks.

Rémy Chauvin describes the behaviour of other birds as follows:

"The male puffin tenderly rubs his beak against the beak of his mate. They press against each other with their breasts, quickly bow their heads, and, finally, perform a deep bow in front of each other."

The lyrebird, a most extraordinary bird, is found in eastern Australia. Its mating ceremony was clearly described by Gerald Durrell.

"The lyrebird is not particularly spectacular to look at, resembling a rather drab hen pheasant. Its beauty lie in its tail, which consists of two long delicately curved feathers which curve out and round so they resemble an ancient lyre. To add to the illusion, the area between these two immense lyreshaped feathers is criss-crossed with a delicate tracing of fine white feathers that resemble the strings of the lyre. At the beginning of the mating season, the cock birds choose areas in the forest which they convert into dance halls. The area is cleared with the aid of the bird's strong feet and the leaf mould mostly piled up in the centre of the clearing as a sort of stage. When this is ready the cock bird can commence its display, and it is probably one of the most spectacular in the world. With the aid of his tail and his voice he endeavours to seduce every female lyrebird within hearing and even if they could resist his tail it is doubtful that they could remain unmoved by his song. He is the most accomplished mimic and incorporates into his repertoire the songs of other birds, and indeed any other sound which takes his fancy. The result is not the cacophony you might expect but a breathtakingly beautiful performance."

The song of the lyrebird incorporates locomotive hoots, automobile honks, bell chimes, dog barks, horse neighs, the laughter of a kookaburra, and various crashing and rumbling sounds but "these old and unmelodious sounds were incorporated into the basic song so cunningly that they enhanced it rather than spoilt it."

Woodpeckers hammering against dry wood or a bough serenade their mates. These drumming trills are a prerequisite and charming accompaniment to the spring sounds and songs that fill the forest. Every woodpecker has his own rhythm, and the tree vibrates under his pecks in a specific frequency range. Variations in the intervals between the pecks and also in the length of the trill and other aspects of the orchestration of this music communicate the "musician's" intentions to the mate or rival. Experts in woodpecker hammering can unerringly determine whether the cock is tapping in his own territory or laying claim to a strange home range, and whether he is calling his mate, or they are already mated and the cock is inviting his mate to fly after him to show her the place selected for the nest.

The black woodpecker has the longest trill: it lasts for two or three seconds. It includes up to 40 taps in quick succession, which are not difficult to count by slowly playing a recording. He taps at the lowest frequency: 1 to 1.5 kHz. The great spotted woodpecker has a brief trill consisting of 12 to 16 taps within 0.6 second, which sounds at a higher frequency of about 4 kHz. The tap "song" of the lesser spotted woodpecker is within the same frequency range, but is longer, including 30 taps. The same is true of the grey woodpecker, but his trill is somewhat more in the bass range.

When the female responds to this peculiar call the cock is not too friendly. His courting is very belligerent and his mating behaviour includes many threat postures. What follows causes one to think that the mates can hardly stand each other. As soon as one flies in, the mate takes wing. After they have raised their nestlings, they quickly separate. Each partner lives on its own territory from which grown-up children are driven away.

Mammals

The mating ritual of mammals is much less complicated and picturesque than that of birds and even some fishes. One can readily see this by watching domestic animals.

Strange as it might seem, the mating ceremony of marine animals is more expressive than that of terrestrial mammals. Dolphins and whales provide an example. The male bottlenose dolphin courts the female for several days running: he leaps out of the water playfully, and frolics, curving in spectacular poses. Occasionally, the male and female embrace each other with their fins, touch each other with their snouts, and sniff each other. The male gives out a short and shrill bark if the female swims towards another male, whom he chases off while clicking his teeth rather loudly.

The baleen humpback whale is only superficially awkward. He is actually deft and agile, and not infrequently, he leaps out of the water with his belly facing upward. In this way he executes regular loops and then plunges his forty-ton mass back into the ocean with a tremendous splash, his salto completed under water.

The male humpbacks execute these stunts very assidulously as they court their females. Then follows a ritual involving closer contact courting. The male swims after his mate and both spout water in the sky like fountains. He catches up with her, and they both lie down on their sides, belly-to-belly, to flap each other with their fins so resoundingly that these playful flaps are said to be heard within miles. Then they turn onto the other side to assume a very bizarre face-to-face upright posture with their heads down and tails up stuck out of the water. So far all this is play. It is completed by a genuine embrace in a vertical position with their heads above the water.

Many other whales mate in a similar vertical embrace. But not dolphins, who do it fleetingly, in passing, and as we already know, after a long preliminary courtship.

The family life of young wolves also begins with a ritualistic courtship. The mates choose each other when they are still young, awkward, and funny, just like boys and girls.

Then follows a year of mutual courtship. The wolves are said to have "facial orientation": they communicate various information, for example, readiness to mate, by looking at each other. And mating does not occur until this information is received.

Prior to mating, the pairs smile, perform acrobatic jumps and various tricks designed for the adored one. Incidentally, in wolves "stronger" sex does not differ much from the "fairer" sex in its manner of courting.

Hippopotami have a very strange wedding ceremony. Their tails play the main role. It is flattened like an aircraft propeller and can rotate rapidly. The hippo rotates its tail in order to mince and spray his feces around. They are excellent fertilizer for the local vegetation and in the water they promote the growth of plankton, an important fish food.

The hippo seems to be aware of how spectacular this display is and he performs it only on the most ceremonious occasions. When he encounters a charming female hippo he greets her with a mighty spray. The beautiful stranger does not take offence, and if she is glad to see him, she greets him in the same fashion. In contrast, when two opponents are facing each other, fecal spraying is an element of threatening behaviour, a challenge.

No matter how small it is, the tail of the hare also plays an important role in mating games. The female hare alternately raises and lowers her tail, as if she were saluting the buck. The undertail glands emit a fragrance that is irresistible to males. And this odour is propagated by fan-like motions of the tail.

Rabbits and hares court their females in a fairly similar manner. During the rut a single female hare is pursued by several bucks. They try to push each other away; they hop, kick with the hind limbs and box with the forelimbs. During the mating season one can hear the special calls of mating hares. The most successful hare fluffs out his tail (Russian hunters call it a "flower") and plays tag with the female hare. They often get so excited by the chase that they may not notice a stalking fox.

The rabbit courts in much the same way, and his "flower" also acts as an attractant. But most important is his special ritualistic "stepping" on straightened legs like stilts. The hare also walks in front of his mate in this manner: perhaps he wants to look taller!

It should be emphasized once again that the most important factor in the sexual behaviour of mammals is not the glitter of their plumage or their special postures as in birds, but rather the odours secreted by the special glands of males and females. Of course, this does not mean that olfactory releasers are less effective in other animals. In insects, at any rate, they are of still greater importance.

Odours in the Animal World

Insects

The sense of smell plays an important role in animals. They are well guided by scent. One cannot even imagine how comprehensive the information that animals receive from their nose about their surroundings is.

Insects have an excellent sense of smell (olfaction). Many nocturnal butterflies locate their females by scent from as far as a mile away. These butterflies have scent glands in small pockets on their abdomens. The opening of this pocket attracts males throughout the neighbourhood. The female attracts the males not by her calls or the glamour of her colours, but by scent alone. It is not without reason that it is said in the East: "He who has musk in his pocket should not shout about it".

In one experiment, a single giant female silk moth kept indoors attracted 125 males in one night. When the researchers closed the window the males tried to penetrate through the flue.

The female does not release her smell constantly. Sometimes she opens the pocket;

sometimes she closes it. Some even turn their pockets inside out, which is very attractive to males.

Professor Ya.D. Kirshenblat explains, "Presumably, the discontinuous evaporation prevents the adaptation of male olfactory organs to this particular odorous substance."

Since the olfactory organs of insects are situated in their antennae, researchers have used special tools to detect the enhanced biological currents of the antennae of males affected by the female odour. If the antennae are cut off, the male no longer responds to the scents of the female.

Male butterflies are not interested in the appearance of their mate. They are only attracted by her scent. In one experiment a scent gland was removed from a female butterfly and placed near her. The gland proved to be a strong attractant for the males: they totally disregarded the butterfly and, instead, swarmed avidly around the scent.

After many years of work biochemists succeeded in isolating from the gland of a female silkworm the substance responsible for the scent that is so attractive to conspecific males. The gland secretes very little odorous fluid: about half a million silkworms had to be dissected in order to obtain 12 milligrams of pure extract. This substance was called bombycol. It attracts males at a concentration as low as 10^{-19} g per cc.

The American biologists E. Wilson and W. Bossert determined the shape and size of the odorous cloud that envelopes the female and attracts her male conspecifics. It is ellipsoidal in shape, and with a moderate wind, is about several kilometres long! Its transverse axis, parallel to the ground, exceeds two hundred metres.

Jean Fabre, the famous French naturalist, was struck by the distances travelled by males in response to the cues of their mates. He could hardly believe that the males are attracted by scent alone, since as Fabre put it, "... one might as well expect to tint a lake with a drop of carmine".

According to Wilson, Fabre's conclusion was erroneous, but the analogy, exact. The sense of smell in a male silkworm is so keen that it does perceive a "drop" of air in the "lake" of the atmosphere.

Various species of butterflies not only emit different scents but limit the distances from which a male is able to perceive the odour of the female. For example, for the black ashes moth this distance is 300 metres; for the ailanthus silkworm, 2.4 km; for the gypsy moth, 3.8 km; and for the giant silkmoth, as long as 8 kilometres.

Professor Ya.D. Kirshenblat described one experiment:

"Marked male day-flying moths were released through the window of a moving train at various distances from a guaze-covered cage with a conspecific female. At 4.1 km away from the point of release this female was joined by 40 per cent of the males; and from 11 kilometres by 26 per cent."

In many other animals odours play as important a role as that in butterflies. For example, during the nuptial flight that is performed once in her life, the queen bee attracts drones with the scent secreted by her mandibular glands. In bumblebees the attractants are also secreted by the mandibular glands.

By contrast, termites have their scent glands in the last segments of their abdomen like butterflies. The odours of the winged females that have found new nests attract the males when they take wing. After a short flight the termite female lands followed by the males. No sooner are her wings broken off when a lot of admirers crawl after her or around her. The winner is usually the one who is best at finding directions. Other, even very heavy, scents do not distract him.

If the tip of a female's abdomen is cut off and fixed to a stick, the male will leave the female and run after the stick. One can draw the stick across the abdomen of a female several times and in this case, too, the scent gland will attract the male.

The female scent exerts a similar effect on male beetles: the odorous substance of a single female is sufficient to attract as many as 11 thousand males. The same is true of cockroaches. A male cockroach responds to a minute quantity (only 30 molecules!) of the female's pheromone.

In one experiment, ten thousand cockroach females were maintained for nine months in a closed vessel through which air was blown. The air was collected in a special reservoir from which, by the end of the experiment, 12.2 milligrams of the attractant substance were recovered.

The function of odours in animal behaviour and development does not confine itself only to attracting males. Animal scents have a very broad range of action. In many insects, scents play a role in literally all the stages of their lives. These odours, or to be more exact, odorous compounds that produce these scents, have a common name: pheromones.

It is known that endocrine glands secrete hormones in the organism. Hormones are regulator substances that control physiological processes. Investigations have revealed that in many animals an external, or exocrine, system of glands operates that produces exohormones, or pheromones.

In ants, for example, pheromones are like the symbols in a chemical dictionary. Humans speak by exchanging sounds, while ants communicate by exchanging scents. Different odours produced by their exocrine glands impel worker ants to assemble when in danger, run for prey, tend the queen, feed the larvae, and move the cocoons.

After death ants continue to communicate for some time: their bodies secrete pheromones and their conspecifics groom the corpses as if they were alive. After a day or two, however, the body begins to decompose, and the worker ants become aware of the scent of death. It is not until then that they carry the dead away from the nest as far as possible.

These funeral processions are elicited by only a few specific decomposition products of the ant corpses: mostly fatty acids and their esters. When investigators stained live ants with these substances, other members of the nest would not let them in. The poor fellows were seized and dragged over to the cemetery, that is, to the refuse pile, where dead ants are dumped.

Wilson relates that the "live corpses", of course, hurried back home, where they were buried again. And it was not until the odour of death completely dissipated that the burials were discontinued.

Wilson believes that the scent language of some animals has a syntax of its own. Combinations of pheromones convey different information from that of individual substances. The frequency of the repetition of scent cue, or its intensity, also appear to be relevant to the information communicated. For example, fire ants depend on the pheromones of Dufour's gland for marking their trails. But if a nest is treated with a large quantity of this pheromone, almost all the ants, including the queens, will leave the nest to set off on their trails. Large doses of "roadway" pheromones presumably mean, "Let's move to another place".

In addition to conveying information, pheromones regulate the development of conspecifics and, thus, contribute to the mysterious group effect.

For example, adult male locusts secrete through their chitin integument a volatile agent that enhances the growth of the young. As soon as the larvae perceive it, their antennae, legs, and mandibles start vibrating rapidly. During swarming, this substance causes locusts to congregate. In termites, the workers and soldiers add regulator pheromones that determine the further fate of the larvae to the food of the young. If they receive this supplemental substance, the larvae will never grow into workers or soldiers, but will join the ranks of other termite castes.

One can see that the functions of pheromones vary broadly. We shall familiarize ourselves with these later on.

Snakes, Crocodiles, Fishes

The pheromones of vertebrates have received less attention than those of insects. Sex attractant pheromones have been found in fishes, urodele amphibians, and reptiles. Alarm pheromones have also been found in fishes and tadpoles. No pheromones have been discovered in birds. They are known to be present in mammals, but have not yet received enough study.

Sex attractant pheromones have been discovered in snakes and crocodiles. In snakes, the glands that secrete these pheromones are located in the cloaca; in crocodiles, they are secreted by anal and maxillary glands.

According to the famous zoologist Karl Frisch, fishes "... if deprived of vision may find food and identify conspecifics exclusively by scent". The eel is, perhaps, the finest taster of odours in the underwater world. "By his sense of smell he ranks among dogs".

The Vyg River flows into the White Sea. Once a marked salmon was caught in this river. It has been marked in Norway on June 10, 1935, and Russian fishermen caught this fish seven weeks later. The salmon was a female and had been hurrying to spawn in the upper reaches of the Vyg River where it had been born six years before.

Who could have imagined that salmon travel so far from the estuaries of native rivers. Indeed, in order to reach the western coast of Norway, off which it was first caught, it covered two and a half thousand kilometres! The fish travelled back covering the same distance, but then it was in a particular hurry, because the Norwegians had detained it for marking. The fish covered 50 kilometres per day.

This implies that the salmon that was late for spawning had only one thing on her "mind": to reach the river, as soon as possible, where her irresistible instinct was leading her. Along the salmon's way there were hundreds of rivers quite suitable for spawning, but she was looking for the one where she had frolicked as a fry. She swam straight ahead, without vascillating or searching, as if she knew the route well; otherwise, this heroic voyage would have taken much more time. Fifty kilometres per day is a very rapid pace for salmons (the record is one hundred kilometres per day).

A similar episode was recorded in Kamchatka. There, a marked dog salmon was found in a barrel of salted fish. The fish had been marked one month before on the Unga Island off the coast of Alaska. It was found at the other end of the ocean after a little more than four weeks.

Such records, which are numerous, indicate that salmonid fishes swim far into the sea after abandoning their rivers.

In April 1958, in the state of Oregon in the United States, many thousands of fry of the marked steelhead fingerlings from the Alsea River fish hatchery on the coast of Oregon were released into the river. After five months, one of the fish was captured off the coast of Alaska, that is, 3,200 kilometres from the point of release. She was re-marked and released again. Seventeen months passed, and again this fish got trapped in a net. But this time she was captured at the same hatchery where her life had begun nearly two years before.

In another similar experiment, approximately half a million male Pacific salmon were marked and released into Cultus Lake (in British Columbia), their spawning ground. During spawning season, traps were set in the lake and 4,995 marked blue-backed salmon were retrieved (another 11,558 of their conspecifics were captured by nets in the neighbourhood of the lake).

It has long been known that salmon and its Pacific relations (dog salmon, humpback salmon, silver salmon, blue back salmon and other salmonids) ascend from seas to spawn in clean rapid rivers or streams. Their grown-up young return to the sea for two to seven years, this period varying with species. After some years of sea life, the adult salmon return to the rivers, exclusively to those where they had hatched.

An interesting point is that if eggs are collected at the spawning sites and hatched elsewhere, fish grown in the sea return to where they hatched rather than where the eggs were deposited. This means that their route to their native parts is not genetically programmed but is rather a case of imprinting, the phenomenon with which we are already familiar.

Many interesting experiments have revealed that nostalgic fish swim to their spawning grounds not because they remember their way back. It is smell, rather than memory, that guides them to a river lost in forest-covered mountains, or to a stream that may be one thousand miles away from the sea.

Salmon that have been deprived of their olfactory organs wander about in search of "home" and never find it. (For this experiment, the olfactory pits of the fish are usually merely plugged with cotton. An even safer method is to stop up the pits with vaseline or benzocaine ointment. Vaseline prevents odoriferous agents from reaching the olfactory pits, and benzocaine anesthesizes them.)

Another interesting experiment was performed: some salmon that had already found the waterway to their spawning site were marked, taken upstream, and released. But now they did not proceed to ascend the river. After they had lost the guiding scent, the salmon "decided" to get back to the site where they had lost it. And they set off downstream rather than upstream, towards the schools migrating to the spawning sites.

What the scent is that guides salmon—what its chemical composition is—is yet obscure. It is not water of a specific temperature with salts and carbon dioxide dissolved in it as was previously thought. Many experiments have been conducted and it has been found that the odour does not depend on the mineral substances contained in the water and it is lost if the water is boiled.

R.H. Wright has described the scent. It persists year in and year out, irrespective of the seasons. It is not affected by timber rafting or logging, or by changes in the agricultural specialization of the adjacent areas. Even urban or industrial sewage water cannot change it considerably. Hence it is hardly probable that the specific scent of a particular river depends on the soil or vegetation characteristic of its basin. Rather this odour is determined by the river itself, that is, by its vegetation and the constancy of the resident fish population.

It is even more difficult to understand how fish find their way in the open sea to the river estuaries where they spawn. The scent is of no use here, since it fades away at a distance of 800 km from the estuary.

Only sun navigation reveals the mystery. In fact experiments have demonstrated that at least some fishes do take their bearings from the sun and stars.

Mammals and Birds

Even fairly recently it was believed that birds do not have a good sense of smell. It is now known that at least some avian species are an exception to this rule.

The renowned New Zealand kiwis is one bird with a good sense of smell. The nostrils of kiwis are not at the base of the beak (according to the normal evolutionary pattern) but at the tip of the beak. The kiwis thrusts its long and flexible nose into the soil to find worms and insects by smell.

Asiatic vultures appear to be totally devoid of the sense of smell. They are unable to find carrion covered by a sheet of paper or a piece of fabric. But the American vultures solve this problem without difficulty. This is explained by the fact that the former look for prey soaring high in the sky: they rely totally on their acute vision. But the latter do not trust their eyes, since they live in the jungle where dense canopy prevents them from seeing carrion.

The turkey vulture flies low to sniff out carrion. Or else they perch on a tree nosing out the dead flesh. Both turkey vultures and black vultures (a similar species) flock in suburbs, in fishing villages, and on seashores and river banks to feed on garbage. There, from the borders of Canada to Patagonia, in the jungle and in human settlements, the turkey vulture is important as a scavenger. Its undiscriminating voracity is of great use in making the environment cleaner.

A good sense of smell is typical of titmice and ducks. Ducks find meat under snow; they also scent a hunter if he approaches downwind. And the blue titmouse is not inferior to man in distinguishing some smells.

One investigator even trained doves to identify different smells. It appears that further study will reveal that other birds, too, have a keen sense of smell. This problem has merely not received enough attention.

Certainly, in mammals the sense of smell is more sensitive than in birds that depend on their sense of smell to find food. For example, one simply cannot imagine what a keen nose the dog has. In detecting certain scents it is one million times more sensitive than humans. Dogs can perceive the odour of table salt or quinine. If a handful of salt is dissolved in a bucket of water a dog can still detect the salt. A dog can smell a partridge at 50 metres away downwind. Geologists even train dogs to find, by smell, gold and other precious metals and ores in mountain rocks.

Dogs led on leashes by plainclothed policemen in the hustle and bustle of airports or railway stations can detect drugs in the luggage of passengers. So as not to arouse the criminal's suspicions, lap dogs are used. Such a dog will stop in front of the criminal carrying drugs, give a small bark and walk on. And the criminal will be detained by the watchful detectives.

Tracking dogs have a very difficult task. Things are much simpler for hounds: they follow the trail of a specific animal, and it is only this particular animal's smell that they must distinguish among many others. The tracking dog, however, must be able to discriminate among other scents (and there may be millions of millions of these on the route) not a certain species, such as Homo sapiens, but a definite person. In addition, a criminal resorts to various tricks to lure the dog off the trail: he will not walk through a forest or through a field, but rather along a thoroughfare or a road trodden by thousands of feet. This road is often asphalted and hence has a very strong smell (to a dog), and the exhaust of traffic overwhelms the dog's nose. In a word, it seems inconceivable that under such conditions a police dog is able to pick up and follow the trail.

There are other mammals that may not be inferior to the dog in olfaction. For example, moose and boars can smell a hunter from five hundred foodsteps downwind; roe deer, from 50 metres; and a hedgehog can smell a beetle and an enemy (e.g. a fox) from one and nine metres, respectively.

Mammals are well equipped with scent glands. Usually, these are located where the beasts rub themselves against a bush or grass. The scent glands of voles, and particularly, water voles, are on the sides; those of hares, rabbits, and some carnivores are on the lips. The scent glands of the fox are on the tail (at its upper base) and on the feet (between the digits). In wolves and dogs, the glands are also located interdigitally. In the sable and marten they are on the soles of the feet; in the desman, in the lower portion of the tail; in damans and peccaries, on the back. Why damans have their scent glands on the back is not understood. But as to the peccary, there is no mystery whatsoever. This wild American pig dwells on river banks in the reeds and wades knee-deep in shallow water. It can only scent-mark the reeds and bushes through which it makes its way by rubbing its back against the branches. The scent glands of a camel are on the neck. And those of chamois and goats are behind the horns.

In many deer, antelopes, and elephants the odorous glands are on the head: anterior to the eyes (the four-horned and other antelopes), over the eyes (the barking deer), between an eye and the ear (the elephant). The male musk deer has a fairly large sac on the lower belly. This sac contains musk.

In bats, scent glands vary in location: they may be on the forehead, under the lower jaw, on the neck, on the chest, on the shoulders, on the underside of the wing membrane, etc.

Mother shrews lead their broods in Indian file. Each baby runs directly after another with its nose at the brother's or sister's tail. And if it lags behind, it finds its way by the mother's scent trail.

Scent glands are found in many other mammals. Unfortunately, the sensitivity of the sense of smell in mammals has not been thoroughly investigated. But the dog is an exception; therefore, let us discuss it.

Dogs have been tested in many ways for their ability to find various objects. For example, twenty well-cleaned sticks were baked in an oven to descent them completely. They were removed from the oven with pre-heated tongs. Then, one of these sticks was handled by a man whose hands had been washed. The dog was given the task of picking out the stick that had been handled by the man.

The dog had no difficulty in selecting the right stick if the man had handled it with the tips of his fingers for at least two minutes. If the stick had been in contact with the whole of the man's hand, it took the dog only a few seconds to solve the problem.

In another experiment, the dog was to pick out one of many freshly laundered and ironed handkerchiefs. The experiment involved human monozygotic twins, that is, ones genetically identical. The dog was allowed to sniff the hand of one twin, and the other twin touched the handkerchief. The dog selected the handkerchief touched by the twin. Among other things, this experiment proved that monozygotic twins have a similar scent (at least to a dog) despite the fact that they used different perfumes, dressed differently, and had not been in close contact. But unrelated people were readily distinguished by the dog, even members of the same family that were wearing the same perfume.

R.H. Wright explained that it appears that dogs recognize an individual's scent pattern, whatever part of the body it comes from, and whether or not it is covered by an alien scent. The scent pattern must be genetically fixed because only identical (monozygotic) twins have the same genetic constitution, and their scents are clearly very similar. The scent cannot depend on diet, clothing, or home environment.

An even more complicated performance, compared with the selection of objects, is the one of a tracking dog. Many aspects of this ability are not yet understood.

The biologists K. Most and D. Brückner developed a very ingenious method of throwing a tracking dog off the trail. In their experiment a man that was pursued by a dog walked on soft earth so that his footprints were clearly visible. Then the man was "removed", i. e. he was carried away with a trolley attached to an overhead table. His trail was continued further on by a large wheel with shoes fixed at one-step intervals around the rim. Now what did the dog do? It continued on the trail, following the tracks left by the wheel.

It would be erroneous to infer that a tracking dog only relies on its eyes to follow the trail. Other experiments have shown that a dog is actually guided by footprints or disruption of the grass as signs supplemental to its sense of smell. The wheel experiments failed, since the dog was inexperienced and ill-trained. In this case, the dog takes the line of least resistance and relies on vision, which is much easier than being guided by olfaction. It might as well pursue a man walking on stilts although he leaves no scent.

A well-trained dog behaves quite differently: it relies almost entirely on its sense of smell. It has been noted that the dog is not misled if the pursued person wears shoes part of the way and then continues barefoot. If the feet are wrapped in thick paper, the dog is thrown off the trail. But should the paper wear through even slightly, the trail is followed again. In this experiment the dog did not lose the trail if its master's shoes were worn by another person. It would fail to follow the trail if its master was wearing new shoes or rubber shoes. But one to two days sufficed for the shoes to take on the individual scent.

What is this scent? There are numerous glands in human skin, but the soles of the feet have only sweat glands. But they are very abundant there: one thousand per square centimetre. Overall they secrete 16 ml of sweat per day. Even if one thousandth of this amount penetrated the soles, there would be one million times more than the required amount for a dog to recognize an individual smell.

Of course, "scent dose" evaporates readily. The rate of evaporation is a function of both temperature and structure of the surface trodden by the pursued individual. But it has been found that under favourable conditions a well-trained dog with a keen nose can follow a trail that was laid down twenty-four hours before. On the average, dogs can follow a two to four-hour old track.

R.H. Wright wrote: "A good tracking dog is a precision instrument and must be treated like one."

Now that we familiarise ourselves with the olfactory capacities of animals, let us dwell on the specific functions of various odours and their role in behaviour.

Sex Attractant Pheromones: Love Pheromones

These types of pheromones were mentioned in passing in the section on insect scents. Many of the above-mentioned secretions of mammals are also sex attractant pheromones, since they attract males or females.

In May one can see heavy shaggy bumblebees circling near trees. One will alight on the bark as if it were searching for something there. Then it takes off to settle down on a tree again. Take a close look, and it seems that the bumblebee is biting the tree. After it has flown another several metres it alights on a branch to bite on a leaf and then takes off again. After it has circumscribed a circle and bitten many trees and bushes, the bumblebee returns to where it started to begin a fresh round. In this way it flies day and night, applying fresh scent marks and restoring old ones along the same route.

If a bumblebee is caught and kept in a box and then released, it will not fly over to the flowers to sip the sweet nectar; instead it will fly again in its mysterious circles from which it was removed just an hour before. Sometimes hunger impels the bumblebee to hurry to flowering clover crops to take a few sips of nectar. And then some irresistible force leads it again to the "bitten" bushes.

It is only recently that science has solved the puzzle of the mysterious behaviour of the bumblebee. As it happens, this creature leaves its love letters on trees and bushes and on the grass and flowers to date its mate. It is not the female bumblebee but the male that does this. A scent gland is located at the base of their mandibles. When it flies on sunny days in a forest or over a meadow the male bumblebee bites blades of grass and leaves, leaving on them its male scent. When the females detect it, they hurry to the marked sites to wait for the ardent admirer.

Bumblebee scents differ. In addition, to avoid misunderstanding, "different species", writes the famous ethologist Karl Frisch, "stick to different routes on their sentimental journeys". Some mark the lower branches of trees and their roots, others are attracted by the leaves near the top. Still others prefer the stretches of crop pastures and the rustle of meadow herbs where they invite their mates.

In a similar fashion, but in the autumn rather than in the spring, the deer buck dates his adored ones. In contrast to the bumblebee, he has not one, but at least ten, scent glands: two at the internal corner of each eye, one on each hoof, two on the "soles" of the hind feet (on the tarsal joints), one under the tail, and one on the belly. The buck rubs these glands against the bushes and trees, leaving his scent. The secretions of these glands readily solidify upon exposure to the air and, hence, are not washed off by the rain or blown off by the wind, and the bushes scent-marked by the buck retain the memory of his visit for a long time.

"The secretions of mammalian scent glands", explains Ya.D. Kirshenblat, "are a paste-like mass with a heavy smell occasionally of a definite colour."

The substrate of this mass is secreted by sebaceous glands, and the sex attractant pheromones, by specific scent glands. These are far from being in an equal ratio: there is a large amount of the paste-like mass, while the odorous substance accounts for only 0.5 per cent as, for example, in the musk deer sex attractant pheromone.

How many smugglers have died for this substance—musk—on dangerous mountain trails. It is located in a sac, forty grams in weight, on the belly of a male musk deer. It attracts the female during the breeding season and is used for leaving scent marks at the territory boundaries. The sac is filled with musk, which is a reddish brown jelly-like substance, and it can be detected by the female from two kilometres away.

The Chinese manufacture a tonic drug from musk, and when added to a perfume, it imparts a unique persistent smell. A mosque built in Iran six hundred years ago on a mortar with an admixture of musk is fragrant even today. For these properties a pound of musk from the musk deer is highly valued on the international market—as high as a small displacement car.

The active component of musk is muscone. Its odour and its chemical composition are similar to the odorous compounds of the musk rat (exaltone) and of various viverrids (civetone).

Kirshenblat reports that the sex attractant pheromones of desmans, palm civets, marmosets, musk peccaries, bats, perching ducks and some crocodiles smell like musk.

Marker Pheromones

Marker pheromones are like road posts indicating the route home or to the quarry. They are also scent marks at the territory boundaries. This function was briefly mentioned in the chapter on individual territory.

As they travel through the maze of herbaceous jungle, ants find their way back home or to the quarry, holding on as Theseus to Ariadne's thread; however their thread is not from a king's daughter but from nature. This is the thread of subtle odours.

Wilhelm Götsch, a university professor in the Austrian city of Graz, has performed many experiments with ants. He writes that if a fly is pinned to a sheet of paper near an ant nest, it is soon found by the first scout ant. The scout will fuss a little around the fly before running back to the nest, and, then, as many as eight ants will come to the quarry. They will try to pull the fly off the pin, but satisfied that this is beyond their ability, they will run back to the nest again. After a very short time, a new and more numerous detachment will turn up, and the ants will carry the fly to their nest in parts.

When it scent-marks the trail, the ant now and then presses its abdomen against the ground, leaving its odour. What simple experiment could demonstrate that ants indeed scent-mark their trails?

Take a sheet of paper and place it on the route of an ant returning home with a message of good quarry. As the ant crawls along the sheet, mark its route with a pencil and bend the paper at a small angle. The ants lured out of the nest will run along the trail to the edge of paper where the trail would have passed from the ground to the sheet until they find the break. The ants will fuss at the break searching for the trail, and as soon as they find it they will run in a straight line again. It will be evident that the route of the ants coincides with the line marked in pencil.

Ants do not use formic acid to mark their trails. They spray formic acid where they have bitten their enemy in order to increase his pain. In various ant species marker pheromones are produced either by Dufour's gland (it is situated at the posterior end of the abdomen, somewhat above the "vial" containing poison), or by Pavane's gland (it is somewhat below the "vial"), or by some other glands.

The trails constantly used by ants turn into highways. They radiate along all sides from the anthill, and one can see, even with the naked eye, the drops of the scent marks. The continuous streams of six-legged travellers move along these well-trodden trails. Where they end and beyond the limits of the ant "civilization" there begins the wilderness of herbaceous jungle, where ants scatter in various directions. And there where the roads that are permeated with various odours are destroyed by natural calamities, such as disturbances caused by humans, traffic jams occur, just as in urban streets during rush hours. But soon these jams are cleared and new columns of ants hurry along the bridges constructed by the "engineers" to mend the break.

Anthills are often situated so close that their routes intersect like entangled threads. How can one find the right way here without getting lost? It has been demonstrated that the routes of ants of different species as well as of members of the same nest are scented by nest-specific compounds rather than by the same marker pheromones. The same applies to termites and bees.

To identify the marks, ants sniff and feel them with their antennae. Their feelers are not called antennae by chance: they perceive major information about the environment from the surroundings and transmit it to the nerve centres. There are numerous receptors of the main sense organs—of olfaction and touch—at the tips of the antennae. If one is patient enough one can count over two hundred olfactory bulbs and about two thousand tactile bristles in each antenna of the common black ant. Blind species have a still greater number of these structures.

The antennae are very mobile and an ant constantly feels and sniffs all the surrounding objects with them. Since his impressions of the shape and odour of the object are received simultaneously, the ant appears to have difficulty in distinguishing between these two concepts, that is, shape and scent, and it perceives them as an integrated topochemical sensation. In other words, the ant appears to perceive the world in categories unusual to humans, such as a round or square scent, a smooth or rugged scent, or a hard versus soft scent. This interpretation is however so far only a hypothesis.

The odour of the marks fades out very quickly: in some ants of the northern latitudes, as early as within 104 seconds. And in the hot sands of the deserts or semi-deserts the ant marks must instantly evaporate.

One may ask whether the fluid drops are suitable for marking under such conditions. The answer is no, they are not. But nature has resolved this problem created by the hot sun in a very original way. Moreover, the sun even helps ants to establish road igns. When they move about, ants raise their abdomens rather than scrape the ground with its surface. Thus, marker pheromones are discharged directly into the air. And the brighter the sun, the sooner the drops of pheromones evaporate. A so-called scent corridor is created, which in windless weather—and this weather is not infrequent in the desert—persists for a long time. It is known that bees, too, mark their air trails when they fly for nectar. These marks provide supplementary information to that specified by their dances. There is a small pouch, or a pocket on the abdomen of the worker bee, which may be turned inside out to release a certain odour. This pouch contains the scent gland called Nasonoff's gland after its discoverer.

Bees that do not communicate by dancing (for example, melipons) show their conspecifics the way to nectar-rich plants by nibbling the leaves and stalks of plants as the bumblebee does. The scent glands of melipons are at the base of their mandibles.

The scent glands of bumblebees are located in the same place. In the spring, during the breeding season, the secretions from the mandible glands of bumblebees function as love pheromones (they attract females), while in the summer, when they are nurturing their offspring, the secretions function as marker pheromones (route signs). The members of each family nibble blades of grass, leaves and tree branches to lay down scent trails to nectar-bearing plants and back home again. And near the home everything is scented with specific nest odours.

The tree-shrew, a squirrel-like lemuroid and close relative of the monkey is found in South and Southeastern Asia. Every pair has its own territory that is vigorously defended. Several times a day the male tree-shrew patrols its home range making fresh scent-marks and restoring old ones.

Like some insectivores the tree-shrew has special scent glands. This fluffy-tailed host of the bush presses his throat here and there within the boundaries of his territory. He rubs his throat gland against stones or other objects. And this is not enough: while walking or running about in small nervous steps, he squirts his urine on branches (sparingly, as a wolf, so that the entire supply is not expended at once). He also wipes urine on his soles. Thus equipped he sets off to inspect his territory, marking his domain en route.

Lemurs (the slender loris and galago), and the capuchin (a monkey) scent-mark their cages in captivity and tree branches in the wild with their urine-moistened palms.

The slow loris marks the boundary of its territory or cage differently from the slender loris. It does not stain its soles, but merely moves slowly from bough to bough, spraying urine wherever necessary.

The major organ of communication in the Madagascan ring-tailed lemur is its tail. It is like a flag with black and white stripes, which excites its conspecifics. When the ring-tailed lemur directs its "tail" at conspecifics, they purr and mew with satisfaction. But before this, the lemur scents its tail. It thrusts its tail under its belly between each of its four limbs. The tip of the tail is then pressed against the inner right and left forearms where it is rubbed against the odorous glands that have corneous spines and that are located there. When its tail is scented the animal raises and waves it to propagate the scent. Then, standing on its hind legs, the lemur brings its tail forward and alternately rubs it against the right and left forelimbs. It also rubs the glands of the limbs, armpits and anus against branches. Scent glands on the limbs are also found in other lemurs, for example, in the gentle lemur and black lemur.

In honey gliders, both the male and female have glands that secrete marker pheromones. But in the male they are located on the forehead, and in the female, on the breast. Why? The reason for this is that before setting off to patrol the territory, the male rubs his forehead against the breast of the female. Thus, he also receives the female's scent, and he scent-marks the area to convey two messages to his conspecifics: the boundaries of his territory, and the fact that he has a mate and therefore another male would be a nuisance.

The Indian blackbuck antelope and various other antelopes have scent glands located anterior to the eyes. The antelope can purposely either dilate or contract the ducts of the gland so that a person can insert the tip of his index finger into it. The territory is marked in the following way: the antelope finds a dry branch or the stout stalk of a plant and slightly inserts the tapered tip into the dilated ducts of its orbital glands. To the onlooker it appears that the antelope has decided to poke out its eyes with a sharp twig.

Professor Kirshenblat explains that in cows, goats, sheep and many other Artiodactyla "... the secretions of the interdigital glands serve not only to lubricate the hoof surface; they also contain marker pheromones for scent-marking en route".

Alarm Pheromones

While investigating auditory organs, Karl Frisch once trained a school of gudgeons to assemble at a particular site where he fed them. Once he marked one fish: he captured it and scratched a muscle slightly with a needle causing the tail to turn dark. The gudgeon was then released, and as soon as it joined the school, something quite unexpected happened: the other gudgeons scattered in all directions and hid in the sand at the bottom. Then they formed a school again and swam away as far as they could. They would not return for a long time, no matter how much they were enticed to the spot. After some time they returned for feeding.

The question arised, Could the wounded gudgeon have informed its conspecifics about the unpleasant experience? Evidently, it could not. Then what frightened them so? Perhaps the wounded fish cried with pain: in fact, it is now common knowledge that fish can "cry".

Another gudgeon was captured. It was cut into pieces, and the pieces were thrown into the water. The gudgeons again dashed away in panic. Perhaps it was the sight of the corpse that scared them?

Still another gudgeon was cut into pieces. This time the pieces were minced in a mortar and the juice was filtered and then added to the water drop by drop. The resulting panic was like that among people in a theatre that has been struck by fire. All the gudgeons hid.

Thus, it was established that the skin of wounded gudgeons produces a substance that causes their conspecifics to flee in panic. The biological significance of this wonderful adaptation is clear. If a pike catches a small fish, the prey's skin will inevitably be scratched, and the prey will convey the "farewell" warning signal to its conspecifics. When they receive the signal, the conspecifics will have enough time to hide.

It has also been noted that the chemical alarm released by, say, a gudgeon, frightens other related fishes, such as the chub or undermouth. However, the more distantly related the fishes, the worse they understand another.

The investigation on gudgeons further established that gudgeons discriminate well between the scent cues of 15 other fish species. They even recognize by smell different members of their own schools. Understandably, the scent of pike is more familiar to gudgeons than any other odour. If some water from a tank containing a pike is removed with a pipette and added to an aquarium with gudgeons, the effect is equivalent to that of an exploded bomb. Terror-stricken, the gudgeons descend to the bottom and freeze. Their response is quite explainable: the pike pursues anything that moves and glitters, but does not notice objects that are immobile.

In another experiment, Karl Frisch took 0.2 g of minnow skin and kept it for some time in a vessel containing 200 ml of water. Then the water was diluted by a factor of 50, 100, 500, and 1,000, and was added to an aquarium containing minnows. In the first case, 83 per cent of all the minnows were "frightened"; in the second, 74 per cent; and in the third, 41 per cent. A 1,000-fold dilution elicited fright in only a few individuals that were particularly sensitive. Newly hatched minnow fry are not afraid of alarm pheromones. Only at an age of between 46 and 65 days do they become sensitive to the fright scent.

It has now been found that alarm pheromones are produced in special flask-like cells of the skin in many fishes, both marine and freshwater.

Salmonids show another interesting response, called "the beast hide factor". If one places one's hand in the water at the bottleneck of a stream, that is being ascended by salmon en route to their spawning grounds, the fish will dash away, and turn back, disrupting the close-rank school formation.

The same response is elicited by the submerged paw of an animal, such as a bear, or by a piece of the hide of a sea lion.

Fish are not frightened by the water undulations or the frightful sight of the object itself; they are frightened by the odour of the intruder. This was proved by a simple experiment. A researcher rinsed his hand for one to two minutes in a litre of water. Then the water was poured out into tanks with fish. This evoked a well-defined alarm response.

Amphibians also release alarm pheromones. Tadpoles of the common toad produce alarm pheromones in their skin cells. Even a small injury of the skin in a single tadpole scares all its conspecifics. Some drop to the bottom, others dash away to escape the frighting scent. If a tadpole is pinched slightly with pincers, the other tadpoles flee in panic. As soon as tadpoles emerge from the "shell", they respond to the scent of fright. It is perceived by olfactory organs. If the nerves leading to these organs are cut, no alarm response is elicited.

Ants use formic acid to signal alarm. In addition to its major purpose, this acid communicates the alarm call. When it signals alarm, the excited ant spins on one spot with its mandibles spread apart and abdomen slightly raised. From time to time, the formic acid is released from the abdomen. In some species of ants the secretions of other glands—submandibular, anal or Dufour's—communicate alarm. The pungent smell of formic acid excites commotion as the call: "Stand from under" on a sinking ship. In alarm postures, the ants dash about through all the floors of their home adding their individual drops of poison to the atmosphere heavy with the smell of panic. And this stirs up still greater agitation.

Some of the ants then rush to repel the enemy. Others, caught by the alarm call in the rooms where eggs are stored, carry the eggs to a safer site. Still others will mend the damage caused by the enemy.

And it is long before the retreat is sounded.

The size and persistence of the alarm pheromones released by harvester ants was determined. Within 13 seconds after it is discharged, the odorous substance acquires the shape of a globe and is largest in size: its radius reaches 6 cm. After 35 seconds it evaporates to such an extent that the ants practically take no notice of it.

The small volume of the alarm pheromone and the fact that it rapidly disappears is very important biologically. Ant nests are often invaded by various insects and other animals. If the intruders are small in number, their expulsion and mending the damage does not involve many ants. Hence, the alarm pheromones of a single or several ants is limited to a small area of the anthill so that the normal life of the nest is not disturbed. But when ants are dealing with a big enemy, and damages are large, the bulk of the nest's population is agitated. Hundreds of ants assemble in the intervention zone and the pheromone "pellets" sent into the air merge into a sizeable "cloud".

In migratory eciton ants the mandibular glands give off the alarm scent. When they scent it, the ants rush to where the smell is strongest and there they devour whatever living beings they encounter. If there are no animals around they lacerate one another: they are rendered insane by the alarm pheromone.

In addition to ants, other insects, such as wasps and bees, emit alarm pheromones. The honeybee secretes them together with the poison when she stings; the same is true of wasps. This explains why other bees immediately attack the victim and try to sting it near the spot that has been already stung. If one slightly squeezes a bee that is crawling at the entrance to the beehive, she will immediately show her sting, flutter her wings and run about among other worker bees. This produces feverish agitation among them.

The bee alarm pheromone is a more persistent agent than that of ants: it normally fades through evaporation within ten minutes. Queens, drones and young bees do not produce any alarm pheromones.

The ichneumon fly has a special kind of alarm pheromone, which scares off rather than attracts conspecifics. When it deposits its eggs into an insect, the ichneumon fly immediately marks the insect with a repellent agent. As a result, other ichneumons do not touch the parasite-infected insect; otherwise, their offspring would have to starve.

Alarm is also communicated by odorous substances in many mammals, such as viverrids, pole cats, and the American pronghorn antelope. The last emit a particularly powerful alarm pheromone. Large glands are concealed under the long white fur on the pronghorn's sacrum. When a· pronghorn is frightened, the sacrum muscles involuntarily press on the glands, and the glands secrete a pungent agent, an alarm pheromone. Even humans can detect this smell from several hundred metres away, and pronghorns can detect it from one and a half kilometres away.

Metamorphosis Pheromones

Termites, "white ants", are the scourge of tropical countries. These insatiable insects devour tons of timber. They eat wood, a product whose nutritive value is as low as that of paper. They also eat paper! How do they digest all these things?

Investigations on the digestive system of termites have revealed some rather striking phenomena. It has been found that in the special pockets and gut outgrowths of the termite abdomen there exists a whole world of microorganisms: there are infusoria, flagellates, and bacteria, over two hundred various species of protists and plants. Their total weight is equal to almost half that of the termite itself! These are the microorganisms that digest cellulose. They transform it into sugars to be assimilated by the insects. Some scientists believe that cellulose is only broken down by bacteria, while infusoria and flagellates are unwelcome visitors in the intestines of this insect. It is possible that they provide the host with protein: the animal digests them in large amounts.

As they assimilate cellulose with the aid of commensals, termites only receive a carbohydrate diet. But protein is as vital to a termite as to any other animal. How do they obtain these nutrients?

Protein is provided to all members of the nest, and primarily, larvae and the male and the female that give rise to the family, by cultivating fungi. Adult termites, workers, and soldiers do not consume fungi directly: it is consumed after being semi-digested by other termites. In fact, all the members of the nest, including the larvae, workers, soldiers, and the male and the female, are one common ... intestine divided into separate sections—the intestines of every individual termite. Any, even a minute, piece of food is not fully digested in the intestines of an individual termite. No! As regurgitated food, exudate on the abdomen, or other excretions, food is relayed from one termite to another, passing through all the stages of digestion. Digestion is not completed until the food finds itself in the intestines of many termites. This is why one meal is common to all the members of a termitarium.

The products provided by the fungi, although only eaten by the king and queen, are finally received by all termites. The substances produced by the male and female—the metamorphosis pheromones—are also received by all termites.

Like a silent order, these pheromones make some termites put on a soldier's uniform after they have moulted, while others continue to wear their worker overalls. These pheromones handicap the sexual development of those that may undesirably become rivals to yet quite viable parents.

It is not until the family expands greatly that the magic substance of submission reaches the periphery dwellers. Then at the edge of termitarium, the so-called "substitute sexual individuals" develop rapidly from the larvae and nymphs. They are much smaller than the average males and females, and have underdeveloped eyes and short rudimentary wings. These individuals give up their usual occupation to deposit eggs.

The same occurs if the fertility of the queen declines or in the case of her death. The "subjects" themselves often hasten her death. They avidly approach the huge belly of the queen, and if they do not find anything in it, they gnaw into it with their mandibles. The old queen may be eaten completely. The termites also devour the "extra substitute sexual individuals", leaving only two of them—a male and a female—to continue the colony.

In a normal nest, however, where all the termites receive the needed doses of metamorphosis pheromones, and the male and the female are yet quite viable, "substitute sexual individuals" do not arise.

An interesting point is that the pheromones of the male and the female cooperate. The male pheromone does not handicap the metamorphosis of nymphs into "substitute sexual individual". And the female pheromone hinders this to only a small extent. But when they operate jointly, they arrest this metamorphosis completely.

In some species, the termites of other castes, such as the females and the soldiers, also secrete pheromones preventing the metamorphosis of the larvae into the termites of this particular caste. During its first year, a termite colony of the genus Zootermopsis is protected by a single soldier. When researchers removed it from the nest, one of the young termites, as early as after the second molt, already revealed the well-defined features of a future soldier. This "recruit" was also removed from the termitarium and yet another soldier appeared. This was repeated endlessly. As soon as a soldier disappears from the family, one of the family members is ready to replace him.

Ants, which are similar to termites in their mode of life (but not closely related!), have the same functional system of inhibiting the development of males and females. As long as the worker ants sip the exudate of the queen's abdomen no new female will appear in the nest. Her pheromones suppress the development of the ovaries in the worker ants. However, as soon as the ovipositary female dies, some worker ants begin to deposit eggs. Quite normal winged males and females develop from their eggs.

In 1954 R. Butler discovered that the mandibular glands of a queen bee secrete a special matrix substance, which the queen spreads over her body and permits worker bees to lick off. Thus, by means of tropholaxis (food relay), this pheromone is spread throughout the entire nest population in no more than three hours, informing about the female's condition and needs. Its major purpose, however, is to depress the development of the ovaries in the worker bees. As soon as the queen and her mysterious substance disappear, many ordinary members of the family begin developing ovaries, after which these bees deposit eggs. But these eggs are not fertilized, and unfertilized eggs only yield drones. Hence these bees are called laying workers.

The same occurs when the matrix pheromone is not enough to meet the needs of all the members of the bee family.

Kirshenblat explains that this substance has a very high biological activity and stability. It can be autoclaved twice at 120 °C without decomposing and was found on the body surface of a dead female that was part of an entomological collection for three years.

The biological activity of this pheromone is so high that brief contact between the proboscis of the worker bee and the body of a dead or live queen inhibits the development of the ovaries.

The stony shoals of the Mediterranean provide a habitat for the worm Bonellia, which looks like a bottle with a very narrow neck rather than like a worm. Bonellia is fairly long, reaching 115 cm in size. But the bottleneck, that is, the anterior part of the worm—its bifurcated proboscis—accounts for no less than one metre.

Bonellia has one striking feature. The sex of most animals that develop from eggs is determined as early as at fertilization, but the larvae of Bonellia do not exhibit the traits of any particular sex and can develop into either males or females. Their sex is determined by whether they alight on the proboscis of an adult female or not. If they attach themselves to the proboscis, in three days they will turn into dwarf males of one millimetre in size. With an undulatory motion of the cilia that cover their bodies they swim to the mouth of the female and squeeze themselves through, landing in the intestine. Up to 85 dwarf males have been found here. From the intestines, the males make their way to the oviducts where they fertilize the female's eggs.

The larvae that did not attach themselves to the Bonellia proboscis have a different fate. They grow, and gradually, in a year's time, turn into females.

If, after several hours, the larvae that became attached to the proboscis are removed and placed into an aquarium with no females, they will develop into intersexes (hermaphrodites). The anterior part of the body of the intersex is male, and the posterior part is female.

The chemical nature of the pheromones secreted by the female proboscis is unknown.

The marine multi-setal worm Ophryotrocha also undergoes interesting sexual metamorphosis. At the onset of life all the worms of this species are males. After some time they transform into females. If the posterior two-thirds of the female's body is cut off, the remaining third soon heals to turn into a male again.

These invertebrates demonstrate another interesting feature. The adult females of these worms release their pheromone into the water, and the latter promotes the transformation of females into males. The gastropod (snail) of the genus Crepidula behaves similarly. When young they are also males. At a later age they acquire all the internal and external attributes of females. The pheromone secreted by females inhibits this process. Even if the snail has already begun to metamorphose into a female, the pheromone arrests this process, and promotes the development of male traits.

The sex of some vertebrates, which is determined genetically (that is, when the egg cell is fertilized), can be changed by a hormonal injection of the opposite sex during embryonic development. This has been repeatedly accomplished by injecting female hormones to genetically male chickens in the egg stage. When they emerged from the egg, the chickens developed into hens. In some rodents treated with male hormones, female embryos turn into males.

Maturation Pheromones

The palolo lives on the ocean bottom, preying on crustaceans and worms. It is a worm itself, but a very unusual one.

In the autumn the palolos surface to swarm: but only their hind parts surface. They get dressed up: the males take on a yellow colour and females turn red. Along the sides of the hind half of the palolo are long legs that function as oars, and over them are eyes. The traveller has no head, but it has to see where it is swimming.

Rowing with their legs-oars, the half-palolos surface. The first palolos appear before dawn. More and more halves arrive, and as the sun rises, the sea is teeming with palolos. There are millions of them! The water turns yellowish brown. The female worms are filled with eggs, and the males, with milt. The females burst and scatter the eggs like shot. The males also eject spermatozoa, but this was found to happen only under the influence of substances from the female halves.

People hurry to the palolo breeding site carrying large baskets. Palolos can be captured with nets, scoops or with one's bare hands. One must hurry to catch the palolo, because within an hour or two the swarming is over: the palolos drop to the bottom, and there they are preyed on by other hunters, such as fish, cuttlefish, and squids.

And on the shore, fires have already been started and the feast begins. The palolos are fried, dried, pickled, or salted. It is said that they taste like the most delicate oysters seasoned with nutmeg.

The two palolo species are found in opposite parts of the world. The Pacific palolo lives in coral reefs off the Samoa and Fiji archipelagoes, and the Atlantic palolo lives on the reefs of the Bermuda and the Caribbean Islands. The former swarm in October, though only to a small extent (the locals call it "mblalolo lialai"), and in November, on a large scale, (called "mblalolo levu"). The latter swarm between June 29 and July 28.

In addition to palolos, autonomous reproduction of the posterior part of the body is also characteristic of other marine bristle worms. The only difference is that the surfacing half of the worm develops a new head.

The "female halves" of the worm Odontocillius are first to surface during the night, their luminescent organs shimmering to lure the male halves. The male halves also shimmer but once they are illuminated by a female they switch off their lights and, impelled by the female maturation pheromones, eject spermatozoa.

Another marine bristle worm of the genus Grubea is peculiar in that the males rather than the females secrete maturation pheromones that induce the females to lay eggs. If there are no males around, the eggs remain in the oviducts and are soon to perish.

The males in many insects (flies, crickets, grasshoppers, cockroaches, beetles, etc.) carry, in different parts of their bodies, glands, whose secretion stimulates reproduction in the females. And adult males of the desert locust rely on male pheromones to hasten the maturation of their young.

The bitterling fish looks very much like an underdeveloped crucian. In the spring a bitterling female develops a long and thin tube at the base of the tail. This is an ovipositor, which is similar to that of a grasshopper, although somewhat longer—about 5 cm in length. The male's scales begin to glow in rainbow colours. He clings to the female tenderly and together they search the bottom for a suitable cradle for their offspring that are soon to emerge. This cradle is a living anodont—the largest mussel in our rivers. The female inserts her egg-filled tube between the valves of the mussel and deposits several yellowish beads into the gill cavity of the mollusc. It is always clean there and there is a lot of clean water available, which the mussel constantly pumps through. The bitterling eggs develop there in complete safety.

The ovipositor, which ensures this safety appears in the bitterling female only when there is a male around, whose maturation pheromone, called copuline, promotes the growth of the ovipositor. Other fishes have similar pheromones, stimulating the development of ovipositors and secondary sexual characteristics in females.

Mammalian maturation pheromones, which are mainly detected by smell, also play a large part in reproduction. Mice have received the greatest attention in this respect.

If several dozens of female house mice are kept together in a cage, they soon show various disturbances in their reproductive cycle such as a long estrus delay. If a male is added to the cage, all the reproductive disturbances cease.

Another very interesting phenomenon has been demonstrated. If a pregnant female is caged 5 days after fertilization with a male other than the sire of her future offspring, a most incredible thing happens. Gestation is discontinued: the embryos are resorbed and estrus sets in again. Moreover, exposure to a male is unnecessary: his scent alone suffices. If a pregnant female is put into a cage where a strange male has recently been kept, her embryos will also be destroyed.

Collective Action Pheromones or Organization Pheromones

Large and small predators, insects, wild pigs, reptiles, and humans all flee in panic from the route columns of driver ants

(Ecitons in South America and members of the genera Anomma and Durilus in Africa). Humans are not sensitive to the distant rumble or the rustling of the feet of millions of running ants, nor do they detect their foul smell, but more sensitive creatures scatter in various directions.

Anne Putnam, who came across the driver ants in Africa, relates that the first to respond was a dog that whined in the hut. Then a monkey became restless in its cage, a large scorpion dropped to the floor and crawled away, a centipede also hurried away, and a mouse dashed out.

All living beings retreat in terror. And those that cannot, face a horrible death. Once driver ants tore to bits a leopard in his cage. They also devoured a python that was not agile enough after a hearty meal.

Ant inroads have left behind the bare skeletons of leashed dogs, and of hens, goats and pigs confined in a farmyard. One criminal that was left locked up in jail by his panic-stricken guardians was stung to death. Certainly, however, the danger of driver ants to humans is invariably overestimated.

Many Eciton species have been described, and according to Henry Bates, one of the first investigators studying these insects, every species has a war strategy of its own. Some move in broad columns; others, in a single file; still others, in close phalanxes that spread over the surface like a flood of dark red liquid. Some can be approached without fear within several inches. Others are better avoided, since they can climb up one's legs with amazing speed and bite very painfully into the skin with their sharp mandibles. And one can only remove a clinging ant by breaking it in half: the head with the mandibles cling so firmly that there is no getting them out of the wound. According to Bates, the only thing left to humans is to take to their heels, since there is no other escape from driver ants.

But an attempt to escape is also sometimes useless. Some marching armies of ants stretch for hundreds of metres up to a kilometre, advancing like thousands of rabid wolves moving like an avalanche. It is not easy to break through their ranks, particularly in the jungle, where one cannot run fast and does not see in what direction the ants are advancing.

Whence and where are they travelling? Apparently being natural nomads, they cannot conceive of life without migration. No matter whether food is available or not, they will not linger. They move in combat formation with scouts in advance, escort soldiers at the flanks, and the queen, together with her suite of worker ants, at the bottom of the column.

The marching ants carry their larvae, protecting them from the sun with their bodies. And while they carry them they keep licking the larvae. When there is nothing to lick, that is, when the larvae stop secreting the enigmatic substances that are so attractive to the carrier ants, the drive for roaming subsides. It means that the time has come for the larvae to pupate, and this requires absolute rest.

Ants find a nook near a big stone or in the hollow of a rotting moss-covered trunk and construct a globe there as do bees. This living ball is their nest, their camp home. This camp nest is completely porous. The pores lead to the centre of the nest, where the queen hurriedly lays her eggs. Over several days of rest she manages to lay thirty thousand eggs. Not all of the ants are engaged in building the nest: they run about in search of food for the whole community of a million and a half. Once it was estimated that after ten days of camping the foragers of African driver ants had brought into their improvised nest over a million and a half insects of various kinds.

In the meantime, the larvae pupate and turn into young ants. The eggs deposited during the halt hatch, yielding fresh larvae, which immediately secrete the substance that impels Ecitons to set off on a new journey.

As soon as this happens, the globe disintegrates, and, in route formation, the ants set off on their travels. (Some species of

American driver ants migrate for 18 or 19 days nonstop and then camp for 19-20 days.)

And what are the mysterious agents that are secreted by the larvae of driver ants?

These substances are pheromones that induce animals to perform particular actions, regulating their behaviour (they are similar to releasers in this respect).

These types of pheromones are very common in the world of ants. They are of by far greater importance in ant life, in particular, in the coordination of family life, than acoustic or visual cues. Larval pheromones, for example, make ants nurture the larvae. When unfavourable conditions occur in some chambers of the ant nest containing larvae, for example, excessive dryness or excessive light, the larvae cease secreting pheromones, and the disturbed ants transfer the larvae to wetter and darker chambers.

The odour of pheromones is specific for each nest and makes it possible for ants to discriminate between their own nest and foreign ones. If a member of a family is stained with the pheromone of another family, it will be immediately killed or driven away from its own nest.

Dead ants release pheromones for some time. We already know what happens when live ants find such a corpse or when live ants are stained with these substances.

The American ethologist E. Wilson claims that a dozen different pheromones, operating separately or jointly, suffice for the normal life of the nest.

In fact, some pheromones, just like genes, may serve other purposes in addition to their major function. A fine example is the pheromone released by the queen bee that depresses the development of ovaries in worker bees, impels the workers to groom the queen, and prevents the construction of new queen cells.

Pheromones regulating behaviour are found not only in insects. For example, the fry of fish of the genus Chemichromis (and perhaps all other members of cichlids) discharge into the water an agent that impels the parents to take care of their offspring. The male and the female fearlessly attack all fish or aquatic insects that trespass on their territory. Even if there are no fry there, but several drops of water are added from a tank where they were kept, the aggressive behaviour of the parents continues.

When the fry have grown up and reached the age of three weeks, the secretion of these pheromones is discontinued. The parents immediately leave their children to the mercy of fate. But if another portion of water containing fry pheromones is added, the behavioural response of territory defence reappears.

Tasty Substances

When scientists first dug up a nest of sanguinary ants they were much surprised to find some very strange small beetles (5 to 6 millimetres in length) that were reddish brown, with short reddish wing covers. With their abdomens lifted, they were running about quickly among the ants, imitating their behaviour. When a beetle encountered an ant it would tap the ant with its antennae. No matter, whether the ant was in a hurry or not, it would stop immediately to regurgitate food from its proboscis to feed the beggar. The beetles were called lomechusas.

Lomechusas are only found in ant nests. Naturalists discovered still more striking things when they constructed artificial ant nests. Through the glass wall of such nests one could watch all the goings-on in the ant home. One ant after another would run up to a beetle, pull at the yellow bristles along the sides of its abdomen and then avidly lick the drops of a liquid that was flowing down these bristles. Often, a hungry crowd of ants would surround a lomechusa, and while squeezing and pushing each one would strive to get ahold of the desired bristles to quench its thirst. It is said that ants long for the yellow bristles of lomechusas, just as incorrigible drunkards long for a bottle.

Ants raise and nurture lomechusa larvae together with their own offspring without differentiating between them. But the naturalists observed quite a "sacrilege": the lomechusa larvae suck out ant eggs, and as they grow up they also eat the larvae.

The beetle itself eats them! And what do the ants do in the meantime? They feed the robbers.

I. A. Khalifman writes: "Their generosity is boundless. They feed beetle larvae with the eggs layed by the female ant, and moreover, give them the food that they robbed from their own larvae. They look like drunkards capable of depriving their children of milk for a glass of vodka."

Ants even take less care of their own larvae. Moreover, when danger threatens and the enemy is destroying the nest, it is the lomechusa larvae that the ants save first, and then their own. And why does the cheeky lomechusa attract the ants?

The beetle's yellow bristles, called trichomes, grow along the sides of the anterior segments of the abdomen. Many ant guests appear to have such yellow or reddish yellow trichomes. Their location varies widely. In the beetle Claviger testaceus, for example, that inhabits the nests of the meadow ant, bundles of trichomes are clearly visible on the outer edges of the wing covers. In some beetles they even grow on the antennae.

Under the trichomes are skin glands and fat bodies that produce a volatile odorous fluid, the so-called exudate. This is what the ants are after.

Paussid beetles are found in the tropics and Mediterranean countries. They are related to the carabid beetles but differ from them in the shape of their antennae. They are small beetles, the largest being about one centimetre long. They are renowned for their friendship with ants. Two-thirds of all paussids (and they include over 200 species) live in ant nests. A South-African ant alone provides shelter for as many as 12 paussid beetles.

The beetle Paussus tauricus sits at the entrance to the nest of the feidole ant. It is surrounded by a crowd of hosts. Some lick it, others tap it with their antennae, begging for fresh portions of the pheromone. The beetle looks very phlegmatic. Alternately ants grab it and drag it away unceremoniously, while others closely follow it to lick it.

If the beetle is removed from the nest, the ant will find it immediately and, by joint effort, try to pull it back to the anthill. The beetle does not resist.

Similar narcotic or intoxicating agents are produced by ant females, particularly of those species where there are no workers (this is a feature of their evolution). For example, a female ant of the genus Vilierella, whose wings have been broken after her nuptial flight, will creep into the nest of the Monomorium ants. They receive her quite willingly. They surround her and lick her. The guest soon becomes the sole mistress of the nest. She deposits eggs, the ants tend them as if they were their own, and they also nurture the freshly hatched larvae, pupae, and young foreign ants.

The something unheard of happens! Monomorium kill their own mother and begin paying overwhelming attention to their guest. They lick her endlessly: apparently her pheromones are more fragrant and tastier than those of their mother.

And this is not the only "criminal" case associated with this type of pheromone. Many other instances are known where females of certain ant species inhabit the nests of other species. Moreover, there are worker ants of certain species that secrete pheromones attractive to ants of another species and they live very well in the foreign host's nest.

Termites, which are so similar to ants in their behaviour, also receive guests, both welcome and unwelcome. These guests also have exudative glands that secrete these types of pheromones. But they are less conspicuous and are not always marked by reddish bristles. This is readily understandable: the majority of termites are blind, living underground, and they would not notice a sign inviting them to lunch.

Irrespective of their origin, all the guests visiting termite nests (no matter whether they are beetles, mosquitoes or flies) have a very peculiar feature. Their abdomens are extremely swollen and slung over their backs in a very bizarre manner. Sclerites, that is, chitin rings of deformed armour appear on the abdomen as dark spots on stretched white skin.

What function does this physogastry (as this condition is termed) serve? Two interpretations are possible: either it is necessary for the secretion of pheromones or its function is to enhance the similarity in appearance to a bulky female termite.

Of course this swelling of the abdomen evolved gradually. For millions of years the guests became adapted to their hosts, and as a result of natural selection acquired this condition, which looks like the hypertrophied abdomen of a female termite. This similarity appears to induce termites to feed their guests with the same food that they give to the queen. At any rate the happy owners of a swollen abdomen invariably dwell in the same chamber (or an adjoining one) with the queen and are tended by the termites that feed the queen.

Termite guests are predominantly beetles, but there are also caterpillars and flies; however, one can hardly identify these ugly wingless creatures, because they look like arthropod lumps rather than flies.

And one South African termite is a host to a mosquito that reminds one of a turnip rather than an insect. Its abdomen is swollen like a ripe root, and its head and legs look like pathetic inconspicuous appendices.

The relationships between termites and their guests are not yet completely understood. Termites have been seen to feed some beetles from their mouths, and in their turn, sip the drops of exudate from their guests. But the more intimate details of their life remain to be investigated.

Among the guests of termites are regular killers! An example is the larvae of the carabid beetle Orthogonius. They begin their life in the termitarium by killing and eating the beloved queen of the termites. Their purpose is to seize the queen's chamber. And the termites narcotized by the pheromone and unaware of the fraud feed the impostor as generously as they used to feed their mother. But this does not satisfy the beetle: it grabs and eats the termites themselves.

Defence Substances

The bombardier beetle is a regular gunner. He fires a pungent fluid that is propelled from the posterior end of his abdomen like a shell from a tiny gun. This fluid turns into a small poisonous cloud like a burst of shrapnel. When several such red and blue grenadiers open fire, the scene reminds one of a battlefield as seen from a bird's-eye view. When he defends himself against a carabid beetle, the bombardier fires from 10 to 12 shells in short sequence. As soon as the last salvoes of this mini-cannonade cease, the beetle is no longer in view: he has gone into hiding, covering his retreat with a burst of poisonous gas.

Recently it has been found that among the defence substances that are relied upon by the bombarder even firedamp is formed. And after the explosion, water remains.

Quite a number of insects have been endowed with defence substances. These agents are produced by beetles, bugs, cockroaches, earwigs, common harvest spiders, ants, caterpillars of the handmaid moth and of the European processionary moth, dipterans (flies, bot-flies and gadflies), hymenopterans (ants, wasps, bees, ichneumon flies), orthopterans (grasshoppers, crickets, mole crickets), and many others.

The glands that secrete these substances are located in diverse parts of the body: on the head, chest, and abdomen. Some substances are malodorous; others are very offensive, irritating the skin and eyes. And still others are paralyzing, and even lethal, poisons.

Bed bugs have many types of defence substances, including propenal, propanal, butanal, pentenal, hexenal, heptenal, octenal, furan, methylfuran, methylquinone, etc. All these chemicals affect insects so severely that they cause immediate paralysis, and in large doses, are lethal.

Among the poisonous substances of insects there are a variety of agents, including metacrylic acid, tiglic acid, formic acid, methacresol, parabenzoquinone, methylquinone, benzoic acid, salicyl aldehyde, and even iodine and hydrocyanic acid. These are mentioned only to demonstrate the sophistication of nature.

It is best not to touch an oil beetle. Its blood contains a virulent poison. Thirty milligrams of it can kill a man. If this poison gets on the skin, it will produce blisters and burns. In the blood (hemolymph) of other insects there is a still more virulent poison. When an enemy approaches, the hemolymph of these insects appears on the skin surface like sweat and occasionally squirts as far as half a metre.

A small portion, 220 milligrams, of the poison dissolved in the blood of the larvae of the leaf Diamaphidia and Blepharida can kill 200 rabbits. South African negroes use this poison to stain arrowheads.

The tarantula, the largest and most poisonous spider in the Soviet Union defends itself like the skunk (see below). This spider discharges a spray of white fluid (guanine) from the posterior end of its abdomen as from a fire extinguisher.

I. Lepekhin, one of the first Russian investigators of tarantulas, wrote in 1795: "In the steppe, the tarantulas presented us with a new sight. When we dug up their nests we discovered the weapon this creature employs against its pursuers. When it sees that there is no escape, it freezes, swells up and sprays a white fluid from its back to a distance of some four feet, as if it were using a pump".

The bristles that make the bird-eating spider so shaggy are thin and brittle. If one touches this spider, the venomous bristles break off and pierce one's skin, causing inflammation and intense itching. But this is not enough for the spider! Moreover, it seems to be aware of how nasty its microspears are. The spider scratches its back with its legs to release a whole cloud of bristle fragments into the air. If they are inhaled, a fit of coughing results, and one will never approach the bird-eating spider again.

In addition to insects and spiders, centipedes also produce these types of substances. They use hydrocyanic acid as a chemical defence agent. Some sea urchins, fishes, and amphibians (newts, toads and salamanders) do the same.

The body of a moray eel, a close relative of the conger eel, is long and snake-like. Its mouth is fitted with long and sharp teeth. Some of them are venomous.

The snake-like fish swims, wriggling lazily, at the very bottom of the sea. It pokes its head under every stone, sniffing as if it were searching for something.

Now he seems to have smelled an octopus in an aquarium, the octopus sits terror-stricken under an artificial cliff in the corner of the tank. Slowly and inexorably the moray eel approaches its prey. If the octopus's nerves fail, it dashes away from its hiding place, discharging a cloud to cover its retreat.

The moray sets off in pursuit. Now it breaks through the dark cloud and almost manages to intercept the octopus. The octopus drops to the bottom. It turns into a ball and freezes. The moray is quite near, but strangely, it searches for the octopus although the octopus is right in front of it. True, it is difficult to notice the octopus; one can hardly distinguish it from a stone. But its smell must have betrayed it; after all, the moray followed its "trail".

But there is something wrong with the predator's sense of smell: the moray pokes its nose into the motionless octopus (and the latter does not budge—what restraint!), pushes it once again, and then swims on.

What has happened to the ferocious eel?

The American biologist MacGinity raised this question many times. He conducted a series of experiments on the octopus and moray eel, and discovered that the octopus's ink exerts a drug effect. It paralyses the olfactory nerves of the moray. After the moray passes through the ink cloud, it loses its ability to smell the hiding mollusk, even when it stumbles upon the octopus. The effect of the drug lasts for over an hour.

The American skunk, a fluffy mustelid mammal, ranks highest in its ability to fire chemical shells. It is so self-confident that it never fires without warning. The warning posture is very amusing; although only those, who have not experienced the effect of its weapon, smile.

The skunk is a nice-looking animal, but one should know better than to try to fondle it. Evolution has endowed the skunk with a very unusual, and equally efficient, weapon. It turns its back on its victim and ejects a yellow oily fluid whose is so offensive that it has no parallel. The heavy spray hits the target accurately within a distance of four or five metres away, though the skunk fires without even looking: its glands are under its tail. And to fire its shot it has to turn its back to the enemy. The skunk may fire single shots or bursts of six shots, which hit the target in several seconds.

The basic chemical used by the skunk is ethylmercaptan. Humans can perceive its smell even if only 2×10^{-12} grams are inhaled.

A spray of mercaptan even damages wool and leather footwear. If it hits the eyes it temporarily blinds; when the throat or lungs are affected, haemorrhage results. One's vision and sense of smell are regained only after two days.

But the smell ... the smell is worse than any poison! This is a devilish mixture, combining the aromas of ammonia, carbon disulfide, and sulfuric acid, and, of course, mercaptane and a dirty kennel. Upwind one can detect this smell from a mile away and if a skunk has ejected its spray in a room, the offensive smell does not fade away for months.

One who has been unlucky enough to receive a drop of skunk spray will not dare approach other people for several days, even after washing well and changing one's clothes: the smell is so powerful that it is impossible to get rid of it.

Dogs, with their keen noses, faint after being sprayed by a skunk. They even fall ill: they become poisoned as if after a gas attack, and it takes them some time to recover.

Well protected from its enemies, the skunk is never in a hurry. Even when pursued by a pack of inexperienced hounds, it will not quicken its pace. As soon as the dogs approach beyond a safe distance, the skunk suddenly turns to face them and displays its first warning signal. It stamps its feet. Then it raises its tail, but its tip is yet half-bent. The battle flag is halfdown, The third, and the last, signal normally precedes the gas attack: the tail is raised and ruffled. This means: "Run for life—otherwise I will fire!" Then the skunk accomplishes a quick turnabout and fires.

The spotted skunk demonstrates its last signal in a very peculiar fashion: it stands on its forefeet with its head down and hind legs up. Raising its head slightly, it observes the response of the enemy to this acrobatic stunt.

Combat Substances and Parasite Pheromones

Combat substances are poisons of various kinds that animals use to kill their prey. They also rely on venom to repel their enemies. The reader is already familiar with similar substances, but while the latter are only designed for defense, combat substances are largely offensive weapons. There are many animals that are armed with venom, i.e. with pheromones designed for aggression. In addition to snakes (there are over 410 venomous species) and spiders, venomous glands are found in two species of American lizards (poisonous lizards), scorpions, centipedes, some wasps and ichneumon flies, many gastropods (polyps, jellyfishes, actiniae, corals), nemertean worms, moray eels, and even octopuses.

Interestingly, the combat substances of

some animals have a very clever effect: first they attract the prey, like tasty substances, and then they kill it. An example is the bug Ptylocerus. The glands of its abdomen secrete a substance that is irresistibly attractive to ants. The ants run up to the bug, lick the secretion from its gastral glands, and soon freeze as if they were drunk. The bug takes advantage of this to suck the ants with its sharp proboscis.

Parasite pheromones have three main functions as follows: First, they disintegrate the host tissues where these pheromones are incorporated or where they spread along the tissues. They also function as enzyme inhibitors by depressing the action of the host's digestive fluids. Thus, various kinds of helminths are not digested in the abdomen and intestines of the host. The enzyme inhibitors of helminths (parasites that live in the tissues and blood) block the action of the enzymes of the host's phagocytes.

Blood-sucking leeches, bedbugs, ticks, mosquitoes, gadflies, and vampire bats secrete enzyme inhibitors that prevent coagulation of the blood in the wound that they have caused in the host. Moreover, their pheromones affect the physiological processes of the victim in such a fashion that the nutrients required by the bloodsuckers flow in larger amounts to the site that they are attacked to.

Finally, with the help of additional substances called tylacogens, parasites encase themselves into a capsule of overgrown, and hence transformed, tissues of the host. These overgrowths are called galls in plants and tylacoids in animals.

Tylacoids appear in animals of different types and classes, from sponges to mammals. The causative agents of tylacoids may be members of a broad range of parasites: sporozoans, flukes, Cestoidea and round worms, molluscs, crustaceans and insects.

Other Means of Communication

Acoustic Signals

We have discussed the role of smell in animal communication. But there are other senses that serve the purpose of communication: hearing and vision.

Humans used to communicating by means of vocal cords are not surprised to hear animal calls. But the diversity of these calls is literally boundless. There are whistles, croaks, bellows, squeals, chirps, howls, etc.

It has been estimated that dogs alone utter about thirty different sounds, including growls, yelps, whimpers and barks, which vary in timbre and nuances. The wolf has 20 sounds to convey his emotions; the cock, fifteen; the jackdow, about 12, the rook, also a dozen; and the goose, 23. Songbirds also have a number of calls. According to Soviet ornithologists, the chaffinch has over 20 calls; five convey information about the environment; nine are used for intra-familial communication during the nesting season; seven serve as identification; and another seven concern orientation.

The South American bird seriema has a much more diverse repertory including 170 sounds!

By contrast, monkeys and apes have a relatively meager repertory of sounds. Monkeys have between 15 and 20, while apes, for example, the chimpanzee have between 22 and 32 cues.

Even the crocodile, which is universally believed to be a very dumb creature, can speak its crocodile language. Four crocodiles were kept in an experimental laboratory of the Museum of Natural History (New York), and it was found quite accidentally that, if one strikes a steel rail placed near the crocodiles, they growl. They puff up, raise their heads and pull in their bellies to emit a deep roar. This must be a combat call, since following this the crocodiles immediately pounce on each other.

Now what role does the rail have to play here? It was discovered that some rails sound in the same octave as the crocodile roar.

Female crocodiles bury their eggs in sand or in a pile of decaying leaves, which they cover with silt. The little crocodiles inform their mother that they have hatched by softly grunting, "yumf-yumf-yumf". The mother crocodile immediately rakes up the pile to free the babies. Then she leads them to the water uttering "yumf-yumf-yumf" so that they do not get lost.

In the lives of many nonsocial insects, hearing is as vital as the sense of smell. (Over 10 thousand species of chirping insects are known.) They are particularly many among orthopterans (grasshoppers, locusts, crickets) and cicadas. If one lends one's ear (using some special tools) to the seemingly monotonous chirps of these insects, one can distinguish such tones, rhythms, and various nuances that the sounds of grasshoppers, cicadas, and their kin can be readily likened to bird songs.

The musical instruments of all orthopterans are the two serrated surfaces of their chitin "skin" rubbing against each other. Grasshoppers, for example, chirp by rubbing one wing against the other. They have their fiddlestick on the left wing and a plate that it strokes with the bow on the right. The locust's "violin" is designed differently. Its two bows are the hind legs. Their thighs are serrated. In order to chirp, the locust rubs its legs against the wings.

Rémy Chauvin writes,

"It has long been known that the males of hopping orthopterans attract females with their chirp. In 1910, Gegen demonstrated that a grasshopper can "telephone" his mate. If a microphone is brought near a chirping grasshopper, and connected to a loudspeaker installed in another room, the female will fly up to the loudspeaker and will even try to get into it."

Other insects have been found, whose males attract females with their songs. The songs have been studied and divided into five groups: the inviting song of a male, the inviting song of a female, the "enticement" call uttered by males in the immediate vicinity of a female, the threat song (it is also uttered by males), and alarm calls uttered by both males and females.

And another interesting discovery has been made: the inviting call of male crickets attracts not all females, but only unfertilized ones. Fertilized females do not respond to it. The number of characteristic calls in crickets has been estimated. Some have a dozen of them. The Chinese are fond of cricket songs and they breed crickets that are particularly polyphonic.

The threat call is uttered by the male when he hears the chirp of another male. The territorial male walks towards the stranger. If the grasshoppers are equal in rank, a squirmish ensues. Otherwise, the higher ranking cricket chirps louder and at shorter intervals than the rival. The latter responds with a series of hesitant muffled chirps or falls silent. Then the threat song of the winner gradually turns into an inviting call.

Cicadas are the most marvellous musicians among insects. Some of them spend seventeen years underground as larvae so as to fill the surroundings with their deafen-

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ing chirps during the last weeks of their life.

Tropical cicadas sing so loudly that their songs sound like the shrill whistle of a locomotive. The voices of others screech like a circular saw. It is only the males that sing. (It has been found though that female European leafhoppers also sing, but so softly that special instruments are needed to hear them.) The lower surface of the first segment of the male abdomen has a pair of convex plates, i.e. cymbals. When a cicada sings the strong muscles quickly contract to pull the cymbals up to the insect body and then let them go; and this is repeated. The cymbals vibrate at a rate of 600 oscillations per second to emit a sound whose power we already know.

In some countries (Japan, China, Indonesia, and even, France) cicadas are kept, like canaries, in cages so that people can enjoy their singing. Ancient Greeks were also fond of cicadas, claiming that Muses themselves have taught these insects their marvellous art. By contrast, the Romans did not enjoy them at all.

In the tropics there are cicadas that sing in chorus. And the choir has a director, who gives the tune. After a while, another male, "the accompanist", joins in. And then all the cicadas in the surroundings break into a song. If the director falls silent, the entire choir soon ceases singing, but when the "accompanist" is silent, the singing continues.

If you pluck a string, it will vibrate producing a sound. The higher the frequency of the vibration, the higher the pitch; and the greater the amplitude, the louder the sound.

Similarly, insect wings vibrate in flight, buzzing at different pitches. If we could wave our hands as fast as insects beat their wings, we would buzz when walking. But even the most mobile muscles can hardly contract at a higher rate than nine to twelve times per second. The muscles of insects raise and lower the wings hundreds of times per second.

Every insect species has a specific pitch at which they buzz. This means that the rates of their wingbeats differ. Using sophisticated electronic instruments it has been established that mosquitoes beat their wings at a rate of 300 to 600 times per second (in some up to 1,000 times per second); wasps, 250 times per second; bees, 200 to 250 (and up to 400) times; flies, 190; bumblebees, 130 to 170; gadflies, 100; ladybirds, 75; cockchafers, 45; dragonflies, 38; locusts, 20; and butterflies, 5-12. We don't hear the buzz of butterflies because it is ultrasonic.

This evidence suggests that it is not by chance that every insect has a buzzing code of its own. Presumably, in addition to their main purpose, the wings serve some other function: one equivalent to human language, i.e. communication.

And this is indeed so. Insect wings are not only an aircraft device but also a telegraph. And similarity does not confine itself to buzzing alone.

The summoning call of mosquitoes is a specific drone. These insects fly in thousands to where these sounds are coming from. Mosquito males are particularly attracted by sounds at a frequency of 500 to 550 vibrations per second, and their mates' wings beat at this same rate. Even when it is very noisy, these cues are detected by mosquitoes. In fact, they have acoustic selectors and amplifiers: thin and long hairs on their antennae. They vibrate in time to the vibrations of the particular frequency at which mosquito females beat their wings. Waving in time to them, the tuning fork hairs convey information about the sounds relevant at any one moment to the specific auditory nerves.

Electrical engineers complain that high-voltage transformers are often filled with mosquitoes. The death of the insects is due to their romantic attraction to the fairer sex: it has been found that many transformers buzz in time to the wingbeats of female mosquitoes. And this kills the misled males.

But when a mosquito is escaping from a human hand raised to smash it, its "motor" buzzes at quite a different pitch from the one used when it is socializing. This serves as a cue for other mosquitoes.

But the noise of a mosquito choir is by far less loud than the crash of the wings of locusts that are taking off or alighting. When they are gaining height and flying in a straight line, however, the noise is less loud.

According to Darwin, the noise of locust wings is like the rumble of combat chariots. The buzz of locust wings is said to be discernible from the cockpit of a landing aircraft.

To humans, this throbbing rumble of billions of fluttering wings warns of an approaching catastrophe from which there is no escape. But for the locust this is a takeoff signal. In the language of the most voracious insects in the world the whistle of the wind cut by their wings means "Attention everyone! Time for take off"

If a locust has been deafened by plugging its ears, located on its abdomen, with wax, it will not join its conspecifics that are setting off on a long voyage. It does not seem to be aware that the flock is leaving. But a locust that is not deaf soars up again, oblivious of rest or forage as soon as it hears an amplified tape recording of the sounds of locusts taking off.

In 1959 a spying device was designed for eavesdropping on the communication of bees. The device could relay messages to the beekeeper like: “Bees are considering flight. Remove swarm until it is too late!”

Like mosquitoes, bees do not always buzz at a single frequency. When they are travelling light or collecting nectar by flying about from flower to flower their wings beat at a definite rate. But when they are returning to the nest with a heavy load they increase the wingbeat rate, making their “engines” roar at the highest-pitched tone. This is why the bees guarding the entrance to the hive, on hearing the signal from afar, allow the collector bees to enter without examination: they are delivering something, thus, they cannot be robbers. But the bees that are flying in without cargo (they buzz at a lower pitch) are sniffed and examined carefully to check whether they are friends or foes.

Alarmed bees buzz quite differently from those that are quiet. Their buzz is a signal of alert and total mobilization. Prior to swarming, the hive resounds with a particular rumble. Thus, the electronic spying device was so designed that the buzzing of the swarm ready for takeoff was relayed by a ringing bell in the beekeeper’s home.

Dr. Esch, a student of Karl Frisch, has found that when bees are performing the waggle dance, they buzz to provide supplementary information about where nectar-bearing plants can be found. These signals are reminiscent of the drone of a motorcycle engine. If the engine buzzes for about half a second, the nectar-rich flowers are located two hundred metres away. The louder the noise, the higher is the quality of the food that has been found.

By varying the buzzing tones, bees also give orders of another type. Once researchers witnessed an amusing episode. They had designed an electronic model of a bee that could circle in the hive. They set the model in motion and near it a small loudspeaker played back the tape-recorded sound accompaniment to the dance.

First, all went well. The bees were trying to understand the robot. But then they suddenly pounced on it and "killed" it. The dummy was stung all over. What had happened was that with a special buzz of their wingbeats, the collectors had asked the electronic bee to produce a nectar sample from its crop so that they would know by smell which plants had nectar. But the model had continued to buzz, "Two hundred metres, two hundred metres, two hundred metres... ." The bees must have decided that they had encountered an idiot, and dealt with it like Spartans. Subsequently, more sophisticated man-made bees were designed.

Humans do not pay attention to changes in the intonation of insect speech. But the insects themselves, their friends, and their foes listen attentively. For example, defenseless flies that mimic bees and wasps in their colour pattern also use higher-pitched buzzing tones. In this way they deceive their enemies, and the latter do not harm the impostors, taking them for ones of their own kind.

The males of some species of the Drosophila fruitfly (a common experimental animal in genetic laboratories) also rely on their wings to sing serenades as they court their females. In flight, their wings beat 200 times per second. And the same wingbeat rate creates the nuptial song of the male.

Male Drosophila court their females in a rather ceremonious manner. Enticing a female with his serenade, the male first caresses her fondly and taps on the female's abdomen with his feet. Then he walks around her fluttering his wings: this is an indication of his desire to marry her. If the female rejects his courting, she buzzes loudly, and the confused male retreats.

H. Maxim, the inventor of the machine gun, was the first to notice that wingbeats in insects is a means of communication. He was a very inquisitive man. In 1878, Maxim erected a line of electric lamps to illuminate the grounds of the Grand Union Hotel in Saratoga Springs, New York. The network was connected to a transformer from which sounds were heard, similar to the buzzing of winged insects. One evening Maxim was surprised to see that there was a swarm of mosquitoes around the transformer. He closely examined the captured mosquitoes and was struck by the fact that all the insects that had gathered around the transformer were males. He recognized them by their feathery antennae (in females, the antennae do not branch and they look like sticks with a few small hairs).

And on the following days, as soon as the transformer started operating, it attracted mosquitoes from the neighbourhood. Maxim decided that the mosquito contains organs of hearing in the antennae and that they only fly to the transformer because its drone is similar to the buzzing of the wings of females.

To investigate this more thoroughly, Maxim transferred his experiment indoors. There he made use of a tuning fork that was tuned to the buzzing of the female mosquito. When he struck the tuning fork, the female "voice" was reproduced. A male placed in the neighbourhood would immediately turn to the tuning fork as soon as he heard it, raise his antennae, and pay attention to where the sound was coming from.

According to R. Burton, a scientific journal rejected Maxim's communication on the grounds that his evidence was too primitive, and Maxim had his findings published as a letter to the editor of *The New York Times*.

It has now been proved that Maxim was right: the mosquito relies on its antennae to hear.

Of the amphibians, toads and frogs are the noisiest. Their voices, which are amplified by resonator sacs that swell out at the corners of their mouth or on the throat, are familiar to everyone. But do the amphibians hear their own voices? Not so long ago scientists were still debating this point. It has been established to date that these amphibians are not deaf, though their hearing is worse than that of mammals and even fishes.

Rémy Chauvin explains what kind of sounds amphibians emit: "The structure of the auditory signal in amphibians is by far more complex than in chirping insects: individual cues can vary not only in frequency, but also in timbre, which is a function of the ratio of overtones, and in the duration of individual signals and the number of repetitions. The most clear-cut reactions are commonly evoked by the latter property rather than by the frequency of oscillations or the signal's timbre".

The croaking of frogs and toads serves various purposes: it is both a mating call for a female and a warning call aimed at a rival. It is also possible that it is an auditory landmark pointing out to females the direction to the pond where spawning occurs year in and year out. All these calls are uttered with a closed mouth. When the frogs in the neighbourhood hear them, they all leap into the water.

Like some insects frogs sing in chorus (creating a sound familiar to everyone). Some scientists claim that this choir has a director of its own, just as cicadas do. But observations have revealed that the noisiest frog or toad is no leader or tunesetter. Generally, amphibians have no leaders, nor do they have an hierarchy.

But some of them sing duets (for example, tree frogs). Occasionally a third singer joins in to form a well-coordinated trio. They sing strictly in turn, each singer emitting his own specific note.

In a previous chapter on territory, the role of bird songs in protecting the territory and attracting a female was discussed. Birds also rely on their calls to warn one another of danger. As soon as an adult thrush emits an alert call, its nestlings (even those that are one-day old) become silent, cease peeping, and hide in the nest. Seagull nestlings, in a similar situation, flatten themselves against the ground.

When seagulls relieve their mates on the nest, they communicate their intentions not only by offering twigs or blades of grass but also by special calls. If the mate disregards this call, the parent that came to take over the duties will chase it off the eggs to incubate them itself. Many birds have special calls saying, "Let me sit on the nest". The calls of seagulls, terns, geese, ducks and others sound similar to humans, but actually they are not.

Terns, both the male and the female, take turns brooding. They relieve each other at roughly hour intervals. Hundreds of other birds circle over the tern sitting on the nest, but it pays no attention to their calls. However, should the male call, even if from afar and softly, the brooding female will immediately raise its head to look. At time, the tern may even doze off while brooding, but it wakes up as soon as its mate utters a distant call.

Birds can even discriminate their nestlings by voice. When biologists used soot to draw some extra spots on the backs and heads of nestlings in order to change their appearance, the parents were at first very much surprised to see their offspring changed beyond recognition. They assumed threat postures and were ready to chase off their own children. But once the nestlings peeped, things got back to normal. The parents calmed down, and readily accepted their babies in disguise.

Avian parents and children exchange diverse auditory cues. These include the alarm calls that we already know about, summoning calls, feeding calls, and even simple expressions of affection and pleasure. A hen is cackles in a characteristic manner when she invites her chicks to follow her. When a chick lags behind, it peeps to its mother. She returns, searching actively for her offspring. If the chick that lagged behind is enclosed in a bell jar, in spite of the fact that the hen sees the chick, she will pass by nonchalantly, because she does not hear its peep.

Some birds, such as seagulls and ducks, emit a feeding call not only to their offspring but also to adult conspecifics. If a seagull finds a little bit of food, it will eat it in silence, but when the food is in abundance, it will give a characteristic feeding call to summon other seagulls to share the food.

Rémy Chauvin writes:

"Both in birds and mammals alarm calls are invariably shrill and either long or repeated. Warning calls are not that high-pitched, but also sharp, as, for instance the growl of dogs (incidentally it is little known that in similar situations, sparrows emit a very queer sound, reminiscent of growl). Summoning songs performed by parents are usually tender, in a low frequency range and repeated."

Ultrasonic Communication

It has long been known how mammals communicate with cries, mooing, howling, growling, etc. But mammals also have an inaudible, ultrasonic language. This language was first discovered in bats.

According to physics, sound is vibratory movement propagated as waves in an elastic medium. The more vibrations that an oscillatory body (or an elastic medium) accomplishes per second, the higher is the frequency of the sound. The lowest-pitched human voice (bass) has a frequency of about 80 cycles per second, or as physicists put it, its vibration frequency reaches 80 Hz. The highest-pitched voice (for example the voice of the Peruvian soprano Ima Sumak) reaches about 1,400 Hz.

Nature and technology know sounds of yet higher frequencies: hundreds, and even millions, of hertz. The human ear perceives sounds at frequencies up to only 20,000 Hz. Higher frequency acoustic vibrations are called ultrasonics. These sound waves are used by bats to scan the surroundings.

Ultrasonics usually originate in the bat's pharynx. Here the vocal cords are stretched like peculiar strings that vibrate to produce sounds. In fact the pharynx is similar in structure to a common whistle. Air is exhaled from the lungs like a tornado to produce a very high-pitched whistle at a frequency of up to 150 thousand Hz, which is too high for the human ear to pick up.

The bat periodically arrests the flow of air, which then is expelled as if by a blast. The pressure of the air expelled through the pharynx is twice as much as that in a steam boiler. And this is no small achievement for an animal weighing between 5 and 20 grams.

The pharynx of bats produces brief high-frequency auditory vibrations: ultrasonic pulses. From five to sixty, and in some species, up to two hundred pulses per second are produced. Every "blast" pulse lasts from 0.002 to 0.005 seconds (in the horseshoe bat they last from 0.05 to 0.1 second).

The brevity of the auditory signal is a very essential physical factor. It is only brevity that makes possible accurate echo sounding, that is, ultrasonic orientation.

If a target is located 17 metres away, the sound bounces off it and returns in roughly 0.1 second. If the auditory signal were to last longer, its echo reverberated by targets closer than 17 metres away would be perceived concurrently with the original sound. And the bat depends on the time elapsed between the end of the signal and the first sounds of the reflected echo in order to instinctively receive information about the distance from the target. Therefore, the pulse is brief.

The echo sounder of bats is a precision navigation instrument: it can locate even minute objects only 0.1 millimetre in diameter. In one experiment, only when wires that were suspended indoors were 0.07 millimetres in diameter (the thickness of a human hair), did the animals hit them.

Bats increase the rate of sonar signals at roughly two metres away from the wire. Hence the animal detects the wire with its squeaks from two metres away, but it does not change direction immediately. It flies directly towards the target, and then, with a sharp stroke of the wing, swerves abruptly, being as close as several centimetres.

By means of echo sounders, or sonars* that nature endowed them with, bats not only orient in space but also hunt mosquitoes, moths, and other nocturnal insects. Echo sounders also serve bats as a means of communication. In some experiments, bats were made to catch mosquitoes in a large laboratory room. They were photographed and weighed, that is, their performance was monitored. One bat that weighed 7 grams caught 1 gram of insects in an hour. Another little bat that only weighed 3.5 grams swallowed mosquitoes so quickly that within a quarter of an hour it had gained weight by 10 per cent. A mosquito weighs roughly 0.002 grams; therefore, 175 mosquitoes were captured in 15 minutes of hunting, i.e. one mosquito per every six seconds. This is some rate!

Donald Griffin, an investigator of bat sonars, claims that if not for the echo sound-

* Underwater echo sounders that were designed in the late 1930s and used successfully during World War Two to detect enemy submarines were called sonars.

ers, a bat might fly all night long, with its mouth open only to accidentally catch a single mosquito.

Originally it was thought that only small insectivorous bats like the myotes and pipistrelles, that are found in the Soviet Union, have natural sonars, while large flying foxes and fruit bats that devour tonnes of fruit in tropical forests were deprived of them. Perhaps this is actually so, but then rousettes are an exception, since bats of this genus have echo sounders.

While in flight, rousettes click with their tongues all the time. The sound produced by the tongue rather than by the pharynx is emitted through the corners of the mouth, which in rousettes is always half-open. This click is very much reminiscent of the sound uttered by the human tongue. The primitive sonar of a rousette (alias a fruit bat, a flying fox, or a pipistrelle) operates very efficiently: it detects a one-millimetre-thick wire at a distance of several metres.

All small bats of the suborder Microchiroptera without exception have echo sounders. But these instruments differ in design: There are three types of natural sonars-whispering, scanning, and chirping (or frequency-modulated).

Whispering bats dwell in the tropics of America. Many of them, like rousettes, either feed on fruit or suck blood (vampires).

They also capture insects on plant leaves, rather than in the air. Their echo sounder signals are very soft and brief clicks. Every sound lasts 0.001 second and is very weak. Only very sensitive instruments can detect them. Of course, at times, whispering bats whisper so loudly that they can even be heard by humans, but normally their sonar operates in a frequency range of 150 kHz.

Horseshoe bats scan. Some of them live in the south of the Soviet Union: in the Crimea, in the Caucasus, and in Central Asia. They have been named horseshoe bats because of the outgrowths on the snout that look like a skin horseshoe surrounding their nostrils and mouth in a double circle. These processes are no mere decorations: they are loudspeakers that concentrate the sound signals into a narrow beam in the direction where the bat looks (horseshoe bats emit ultrasonics through the nostrils rather than through the mouth).

Compared with the squeaks of other bats, hunting horseshoe bats send out long and monotonous sounds. Every signal lasts one tenth or one twentieth of a second and its frequency range does not change, remaining at between 85 and 120 kHz, depending on the species.

By contrast, common bats in the Soviet Union and their relatives in North America use frequency-modulated sounds like the best man-made sonars as their echo sounders. The signal's tone and the frequency of the reflected sound along with it varies constantly: this implies that at any particular moment the pitch of the sound perceived does not coincide with the tone of the signal sent out. Clearly, this device greatly facilitates echo sounding.

The American little brown bat starts chirping at a frequency of about 90 kHz and ends with a 45-kHz signal. In the 0.002 second of its call, it sweeps down a range that is two times longer than the entire spectrum of the sounds perceived by man. This "cry" covers about 50 wavelengths, with not one pair of them of the same length. Every second, between ten and twenty frequency-modulated signals are emitted. As it approaches an object or an escaping mosquito, the bat increases its pulsing rate. Now it chirps two hundred rather than ten to twenty times per second.

Over millions of years of evolution, nocturnal animals have evolved a number of defense adaptations to counter ultrasonics. For example, many nocturnal moths have a dense cover of small hairs. Soft materials, such as down, cotton, wool, and also female hair, absorb ultrasonics. This means that hair-covered moths are more difficult to detect than hairless ones.

Some nocturnal insects have developed auditory organs sensitive to ultrasonics that inform them in time about approaching danger. When they find themselves within the range of a bat echo sounder, they dash about trying to get away from the dangerous zone. Nocturnal butterflies and beetles located by a bat even resort to the following strategy: they fold their wings and drop to the ground where they freeze.

The organs of hearing of these insects usually perceive sounds of two different frequency ranges: a low frequency at which they communicate with their conspecifics, and a high-frequency one, at which bat sonars operate. And they are deaf to intermediate frequencies between these two ranges. Moreover, it has been found that some nocturnal butterflies themselves emit ultrasonics. And strangely, these ultrasonics ... scare off bats.

When it overtakes such a butterfly, a bat flies off at a tangent two metres away from it to escape. The same occurs if one plays back the tape-recorded clicks of such butterflies when a bat is approaching an insect with no such ability: the bat turns tail.

Why do insect ultrasonics scare the bat? Nobody knows. It has been suggested that moth clicks warn the bat that the communicating insect has a nasty taste or is poisonous, and is therefore best avoided.

In addition to bat sonars, dolphin echo sounders have received the most extensive study. These clever animals are very talkative: they are not silent for a moment.

Most of their sounds are speech units, serving the purposes of communication. Other sounds service the sonars.

The bottle-nosed dolphin whistles, clicks, grunts, barks, and squeaks at different wavelengths and at different frequencies. But as it swims in silence, its sonar constantly scans the surroundings with a "rain" of rapid cries or clacks. These last no longer than several milliseconds and are commonly repeated 15 to 20 times per second and, at times, hundreds of times per second.

If there is a slight splash on the surface, the dolphin immediately sends out signals at a faster rate in order to feel the sinking object. The dolphin echo sounder is so sensitive that even a small shot carefully dropped into the water is noticed by the animal. A fish thrown into the water is immediately detected. The dolphin pursues it very efficiently though it does not see it in the turbid water. It precisely changes its course to follow the fish. If several dozens of vertical rods are allowed to sink in a small tank, the dolphin will swiftly swim between them without touching any of the rods. Large-meshed nets are apparently beyond the range of the dolphin sonar, while it easily copes with small-meshed ones. Apparently, large-meshed nets let the sound waves pass through, but small-meshed ones reflect them almost as a solid object.

It is believed that clacks are used for close-range orientation. For general reconnaissance and detecting heavier objects, the dolphin depends on whistles. These whistles are frequency-modulated: they begin in a low frequency range and end at high frequencies. (As we know, the situation in bats is quite the reverse.)

Other cetaceans, such as sperm-whales, finwhales, bluewhales and white whales, also communicate and orient by ultrasonics. It is not quite clear how they emit these sounds. There are two conflicting hypotheses: one has it that these animals use their blowholes, i.e. the nostrils and air sacs of the respiratory channel; but according to the other, ultrasonics are produced in the throat. Whales have no true vocal cords. They are believed to be successfully replaced by bizarre outgrowths on the internal pharynx walls. But it is possible that both the blowhole and pharynx equally service the sonar transmittal system.

It was not until recently that biophysicists discovered, to their surprise, that nature was fairly lavish in endowing its creatures with sonars. Scientists investigated a wide range of subjects for echo sounding ranging from bats to dolphins, and including fishes, birds, rats, mice, monkeys, guinea pigs and beetles. And they found echo sounders in many of these animals, Many birds are equipped with sonars. Sounds in a low frequency range (20-80 kHz) are emitted by guinea pigs, rats, honey-bliders and even some South American monkeys.

In experiments, mice and shrews would send out their fast scouts—ultrasonic cries—before they set off on their journies along the dark branches of the mazes that the ethologists used to test their memory. In complete darkness, the animals easily find their burrows. Apparently, the sonar is also instrumental here: echoes do not reverberate from these holes.

Vision

Vision is a vital sense in many animals, particularly birds, fishes, octopuses, cuttlefish, squids, monkeys and apes, and human beings, who descended from the latter.

Of all animals, the eye of the frog seems to have received the most extensive study. On receiving visual information, its retina immediately evaluates it and 90 per cent of the signals received are transmitted to the reflectory part of the brain as commands, from where action impulses follow automatically. In contrast, only 10 per cent of the visual perceptions in the cat are forwarded directly to the reflectory centre, while the rest are sent out to the cortex to be processed. Thus, one can infer that as it is receiving visual information the frog's brain is not considering whether to grab, to flee, or to stalk. The decision has already been made by the retina, and on command, the brain immediately mobilizes the muscles of the body.

But since the retina is merely part of the brain, and undoubtedly, an "unsophisticated" computer, the frog often errs. This is particularly the case when the decision should take into account some fine details, such as whether a particular living or non-living moving object is food. The frog's eye here makes immediate decisions that often impel the animal to grab inedible objects, for example, a bead pulled with a string or a moving dark patch. But there is nothing to worry about: the frog will spit out whatever is not food, and possibly will become more discriminating next time. Conversely, this physiological arrangement—the responsibility in decision-making that the retina is endowed with—accelerates reactions substantially, and this is very essential when an animal depends on insects for food.

Success in hunting is ensured by specialized retinal cells, the so-called ganglionic cells. The cat has only two types of such cells, while the frog has four of them. Each one serves its specific function. Some register the dark patches in the adjacent surroundings, i.e. the shaded places of the landscape. They seem to monitor the reserve sites for retreat and protection from enemies or heat. Others, conventionally called "outline detectors", only monitor the sharp boundaries between light and dark, presumably acting as guards. In fact, an enemy emerges as a dark patch with a preceding or accompanying shadow. "Event detectors", the ganglionic cells of the third type, register any movement in general, for example, whether a dark patch is approaching or is motionless. They correct the appraisal of what is happening, whereupon the frog's response follows. These cells, which register the earliest warnings, co-operate with the fourth type of cells—the "insect detectors"—which monitor the displacement of small objects.

Thus, there is a physiological explanation why the frog acts automatically. Each of the categories of cells has a trigger mechanism of its own, which is always ready for action. This mechanism responds to what has been seen immediately and automatically, that is, in a purely reflexive fashion.

The frog eye has other powerful means of perception. These are provided by other highly sensitive optic structures that are capable of estimating, at lightning speed, the velocity of a moving object, even if this object approaches or retreats directly along the sagittal line, i.e. to or from the eye. No human can do this as skilfully as the frog. Of course, when the most experienced and capable drivers pass other cars, their brains operate somewhat similarly (and this is a special gift). The frog eye accurately evaluates both the speed, direction, pattern of movement (progressive, random, oscillatory), and acceleration of any object that finds itself in its field of vision.

Various kinds of optic refinements are also found in the eyes of fish. The freshwaters of Central America and the northern areas of South America are inhabited by a most amusing fish—the four-eye. The fish naturally swims in the water, but its eyes are above the surface. They are divided into two chambers: the upper ones, that have a flatter crystalline lens, monitor the air, while the lower ones look into the water.

The eyes of the deep-dwelling relatives of common salmon are not inferior. Bathylychnops, the largest of them (it is up to half a metre in size) has two eyeballs in each eye. The larger one sees the objects above it, and the other one looks down and to the side. Other abyssal salmons are endowed with telescopic eyes. They are elongated upward cylindrically, and their fields of vision are close to each other, which renders them binocular.

Even in pure-water areas of the ocean, illumination declines by roughly ten-fold with every 50 metres. The sun does not reach 400 metres down from the sea surface. In this eternal darkness some fish are born blind and do without vision. Others, by contrast, have evolved huge eyes with very powerful lenses and exceptionally sensitive retinae that contain 25 million photosensitive cells per square millimetre. This has no parallel among terrestrial animals.

According to Robert Burton, at great depths eyes may be of use only for detecting light irradiated by fishes or other animals.

Interestingly, the animal kingdom provides a convergence analogy with four-eyes.

In summer one can hardly find a pond or backwater uninhabited by whirlgigs. These small black beetles glide in a joyful dance over the water surface as if it were ice.

The whirlgigs are hunting. They are simultaneously looking for prey both above and under the water. And they do not have to change their vantage points: their eyes are divided into underwater and overwater lobes. They seem to have four eyes: two of them watch out for any interesting developments under the water, and the other two monitor the air.

Male mayflies also have two eyes on both sides: one with large facets and the other with small facets. These facets are elongated ocular units (ommatidia) that make up the compound, or faceted, eye of an adult insect.

Every ommatidium contains an optic receptor cell connected to the brain by a nerve. Above it is an elongated crystalline lens. Both the photosensitive cell and the crystalline lens are surrounded by a light-proof sheath of pigment cells. There is an aperture above, where the crystalline body is covered by a transparent cornea. On the external surface, the cornea is distinct for each ommatidium, and they closely adjoin one another to make up a single faceted eye. An eye may contain only 300 ommatidia, as in a female glow-worm; 4,000 in a housefly; 9,000 in a water beetle, 17,000 in a butterfly, and as many as between 10,000 and 28,000 in various dragonflies.

Every ommatidium conveys to the brain but a single unit of the complex picture of the surrounding world. The multitude of separate units perceived by each ommatidium makes up, in the insect brain, the mosaic of various items of the landscape.

Some Examples of Behaviour

Invertebrates

The primary form of mental activity is the ability of animals to learn, that is, to be conditioned. Regarding invertebrates, our knowledge in this respect is scarce. Ascending the Tree of Life from the roots to the top, one can see that the most well-defined reactions to learning are those of actiniae (relatives of jellyfishes and corals).

Once some actiniae were offered quite inedible pieces of filter paper: the researchers touched their tentacles with these. First the actiniae grabbed the paper avidly into their mouths and then quickly threw it away. But as early as within five days, they had learned that paper is not food, and they would not pick it up. The acquired experience was retained in their memory for six to ten days, after which they could be deceived again, although it took them by far less time to learn to reject the paper compared with their performance at the beginning of the experiment.

Actiniae also display some still more complicated behaviour. The friendship between the hermit crab and the actinia that it carries on its shell for protection is well known: the actinia's tentacles have cells that sting like nettle to scare off the crab's enemies. Some crabs will grab an actinia from a rock in order to plant it on top of their own shells. But, frequently, actiniae themselves climb onto a crub's shell, the entire process taking them from fifteen to thirty minutes.

Strangely enough, actiniae, not infrequently climb into vacant shells, which is apparently quite needless. Moreover, they will settle down on the fragments of snail shells: such shells may be used by hermit crabs as a home after they have driven out the host. Apparently, it is not the shell, or its shape or appearance that impel the actiniae to settle down on it, but some chemical substance characteristic of gastropod shells.

Planarians (flatworms) are, among other things, of interest because of their ability to undergo exceptionally complex regeneration. If a planarian head is excised, its entire body will soon be restored. Similarly, a headless body will acquire a head with a new brain, or to be more exact, the neural nodes (ganglia), substituting for the brain.

In one experiment, planarians were conditioned to certain light and electrical stimuli. Then the worms were cut in half, and the halves were placed into separate vessels. The animals were then tested for the responses to the conditioned reflexes established in the planaria before the operation. And what did the scientists discover? The parts that had regenerated retained the pre-operative reflexes. Even those worms that had to grow a new head demonstrated the reflexes.

Apparently, during the learning experiments, planarians produce a substance that is distributed throughout their entire bodies. It is hypothesized that this substance is RNA (ribonucleic acid), which is responsible for memory retention.

The earthworm spends almost its entire life in the soil, appearing on the earth surface only during the night. An earthworm burrow is a narrow channel (in the hot summer it is no more than 1.5 metres in size) with a small distention at the end—the chamber where the earthworm turns around. It is surprising how this soft-bodied creature can dig through soil that may be very hard and dry.

The earthworm can solve this difficult problem by three methods. When the soil is loose the worm bores into it as if it were using an air hammer. Its pharyngeal sac has hard and thick walls and can be quickly protruded. Over and over again it strikes from inside into the anterior part of the body, driving the body into the ground like a hammer.

But, in this way, even soft earth in front of the worm's head becomes hardened by the ramming. Then the earthworm applies another method: it tears off pieces of earth with its lips and swallows them up. After it has swallowed enough of the earth, it crawls to the surface where it deposits the soil that has passed through its intestines. But if it encounters particularly dense and dry soil, the earthworm moistens it with drops of saliva. As each section of soil gets soaked, the earthworm swallows it, repeating this until, gradually, and with much effort, the earthworm constructs its home.

In the daytime, it takes cover in the burrow, with its head towards the entrance. The entrance is covered with leaves, needles and other litter. At dusk, the earthworm comes to life again. It crawls out onto the surface almost with its entire body, with only the terminal end being anchored to the edge of the hole. The upper portion of its body makes circular movements, somewhat rising over the ground and feeling everything around. The worm may feel a fallen tree leaf with its lips and may carry it into its burrow. Why does it do this?

Jan Dembowski explains: "In his study of the life of earthworms, and their effect on the properties of soil, Darwin was the first to pay attention to a sort of mental activity in earthworms... No doubt, the interpretation of Darwin is fantastic. The grounds on which he attributed to the earthworm the ability to act intelligently are grossly insufficient. Nevertheless, Darwin brought up a very interesting issue and pointed out a way for its solution."

Darwin was struck by the observation that earthworms pull leaves into their burrows by the apex rather than by the stem. Thus, they take the line of least resistance, since the apex of the leaf is more narrow than its base. By contrast, pine needles are invariably pulled in by the common stem. In this case, too, the object shows the least resistance. If they were held by the tip of one of the needles, both needles would get stuck at the entrance to the earthworm's burrow, because the other needle would lie across the hole's entrance and the worm would not be able to pull it in.

In his experiments, Darwin offered earthworms paper triangles and the worms would pull them in the most expedient manner: by one of the acute angles. Thus, worms must have wits! But subsequent experiments showed that it is not intelligence that guides the worm.

When ethologists modified the shape of a linden leaf, carving it so that the apex was obtuse, and the base, acute, again the worms would pull the leaf in by the apex. This time the operation was handicapped by the obtuse apex. When the acute tips of pine needles were fixed together so that, irrespective of what end the worm would grasp with its lips to pull the needles in, the resistance would be the same, the worms would still pull the needles into their burrows base first. These experiments demonstrated that it is not the shape of the object that attracts the worms, but presumably the chemicals contained in the tip of the leaf or in the base of the twin pine needles.

In another experiment, the tips and stems of cherry-tree leaves were removed. They were allowed to dry and then were minced into powder in two different mortars: the dry tips of the leaves in one, and the stems in the other. Both powders were mixed with gelatine. The mixture obtained was used to stain thin twigs. One end of the twigs was stained with the mixture containing the extract of the tips of the leaves, while the other was stained with the substance from the leaf bases. The shape of the sticks was identical at both ends and, hence, their resistance when being pulled into the burrows was also the same. Almost all the worms grasped those ends of the sticks that were stained with the mixture containing the substance from the tips of the leaves.

In still another experiment, straws that were the same size as pine needles were stained at one end with the extract of the needle bases, and on the other end, with that of the needle tips. The worms clearly preferred those tips of the straw that were stained with the former extract.

But there is another hypothesis to explain this phenomenon: the worm relies on trial and error to pull the leaf in. The worm does not choose which end of the leaf to grasp; it sticks to any leaf edge that it first comes across. If it is impossible to pull, the worm grasps another end. If the resistance continues to be great, it tackles other ends of the leaf, manipulating them until it finds another side of the leaf that proves easy to pull into its burrow.

The investigators inferred that, in most cases, there are two factors responsible for the preference of a particular end of the leaf or pine needles: odour and resistance. In different situations one or the other factor is given priority. First the worm grasps the object by the end containing attractive substances. But if, in this case, the leaf shows strong resistance, the worm applies the trial and error method: it grasps any parts of the object, and sticks with the one that shows the least resistance.

Let us now return to the problem brought up early in our discussion about worms: Why do they drag leaves, needles, and other objects into their holes?

Darwin believed that the worm stops its holes with leaves in order to keep them warm. But this idea is in contradiction with the worm's mode of life. In fact, worms crawl out of their holes at night when it is much cooler than during the day. And the burrows are covered with leaves during the hottest part of the day.

Perhaps the worm plugs up its entrance in the daytime to protect it from enemies. This can hardly be the case. In fact, thrushes and other birds readily find the homes of earthworms by the piles of leaves covering the holes. And the mole, their deadly enemy, does not reach them from the earth surface.

"It is more plausible", says Jan Dembowski, "that earthworm's holes are food stores. The leaves and needles gradually decay in the moist holes to become good food for earthworms."

Earthworms are capable of learning. In one experiment they were placed in the longest branch of a T-maze. As they reached its end they were offered an option of turning either to the right or to the left. On the right they found darkness and food, while on the left they were exposed to an electric shock. After a series of such tests, the earthworms learned to turn to the right inerringly.

Cephalopods, such as squids, cuttle fishes, and particularly, octopuses are the most gifted of marine invertebrates. This has been demonstrated in a number of experiments.

A glass hollow cylinder that was open at the top was placed in an aquarium with an octopus. The cylinder contained a crab, the octopus's favourite food. The mollusc soon caught sight of the crab, since the cylinder was one and a half metre away. The octopus attacked, but the glass prevented it from reaching the prey.

The octopus was twisted about in vain attempts to grasp the coveted prey that seemed within easy reach. Showing its ferocity, various colours flashed through its skin. It would have sufficed to move 30 centimetres up the glass and the octopus would have readily reached over the open top of the cylinder to the crab's home. But the octopus could not, if only for a brief moment, take its avid eyes off the prey, and would try to take the shortcut. It is unknown how long these fruitless attempts would have continued. What happened is that one of its arms accidentally slipped over the edge and touched the crab. Momentarily, the octopus changed its tactics: the tip of the tentacle sensed the crab and the "blind led the sighted". Reaching over the edge of the cylinder, the tentacle extended further and further, inexorably approaching the crab, and the octopus followed it, moving up the glass. At last the tentacle touched the crab and immediately withdrew. But only for a moment. The next moment the octopus dashed over the glass wall and grappled with the crab.

Now the octopus knew how to reach the crab from beyond the wall. A single successful attempt was enough for the octopus to be conditioned to act on the programme that had become imprinted in its brain cells after the successful experiment.

But it would not try to reach the crab in the optimum way, i.e. directly over the edge of the cylinder. Instead it would first rush towards the crab as before, trying to seize it through the glass. Only after such an attempt, would it then crawl, following its tentacles, which appeared to know the way better. In other words, the mollusk unnecessarily repeated its first attempt, unexpectedly crowned with success.

In this experiment with the crab, the octopus behaved in a more rational way compared with the cuttlefish studied by de Haan in a similar test. De Haan placed a prawn in a glass jar and offered the cuttlefish a simple problem to solve: to get the prawn out of the jar (the jar, of course, was uncovered). The cuttlefish attacked the glass jar for thirty hours running, unable to guess that a small detour was needed, i.e. it had to rise a little, as did the octopus, in order to get the prey out of the jar (according to other evidence, adult cuttlefish give up on their attempts after an hour).

Ten days after the octopus had accomplished what its ten-armed cousin had failed at, the experiment was made more complicated. The cylinder with the crab was covered with glass. But the tentacles already knew the way and easily circumvented the obstacle. After several failures they found a minute slit between the flat cover and the cylinder's walls. They lifted the cover slightly to guide the octopus.

After a seven-day interval, the experiment was repeated. The octopus continued to correctly solve the problem that it had learned a week before: it would open the cylinder with the crab. The conditioned reflex that had not been fortified by a supplemental lesson, continued to operate effectively. By contrast, the cuttlefish that had learned to get food through the neck of the jar forgot within as early as 18 hours how to retrieve the reward from the jar without breaking the wall with its head.

Apparently, the members of the cephalopod clan vary in their capacities. The most gifted are octopuses. The reason is probably due to their tentacles. The tentacles of cuttlefish and squids are more specialized: they are exceptionally well adapted to swimming, serving as stabilizers and rudders, and also for seizing prey.

In octopuses, the functions of their tentacles are more diverse. They "walk" on them over the bottom, use them to carry heavy objects, build nests of stones, open mollusc shells, and attach eggs to stones, Also, when the octopus is asleep, some tentacles keep guard. Correspondingly, the tentacles differ in their respective roles.

The tentacles of the second pair from the top, which normally are longest, are used as weapons. When it attacks its prey and repels its enemies, the octopus tries to seize the victim with exactly these tentacles. In peaceful times, the "combat" arms are transformed into feet: they serve as stilts to walk on the bottom.

The topmost pair of arms are designed for feeling and examining the surrounding objects, and the lowest tentacles keep guard.

When the octopus is fast asleep, all the tentacles, except the two lowest ones, are pressed against its body, and the guard arms are extended to the sides. From time to time they stretch upward and slowly gyrate over the sleeping octopus like radar aerials. Now the octopus is fast asleep, it sees or hears nothing, but a splash of water or any object touching the guard tentacles (and them alone!) makes the animal start.

In animals, the development of organs capable of manipulating primitive tools leads to the evolution of an increasingly complex brain, expansion of its range of activity, and formation of diverse adaptive reflexes.

But let us get back to the octopuses that were tested for intelligence.

In one experiment, the investigator Joseph Sinel offered large oysters to hungry octopuses. They tried for hours to open the shells without success. A week later, the same oysters were offered, but now the octopuses knew better than to touch them. They did not even feel them as they normally do any new object.

Another scientist conditioned octopuses to electric light. At first an octopus was pricked with a piece of wire and at the same time an electric bulb was turned on. The animal responded by expanding its dark chromatophores so that its skin turned dark. The training continued for 16 days, and on the 17th day the light was turned on, but the octopus was not touched with the wire. But it turned dark all over as before. For 81 days the octopus brain retained the memory of being pricked after the light was turned on. Only by the end of the third month did the conditioned reflex to the light disappear, which was, during that time, never reinforced by the prick stimulus.

Experiments on the behaviour of octopuses and the physiology of the octopus brain were conducted by Boycott and Young at the Marine Station in Naples. These scientists came to the conclusion that octopuses are the most gifted animals among all invertebrates, and they are even superior to some vertebrates, such as fish.

Boycott and Young also demonstrated that octopuses can be trained. They rank equal to elephants and dogs in discriminating between geometrical figures, being able to distinguish between a small and a large square, a rectangle shown horizontally and vertically, a white circle and a black one of the same size, a black cross and a black square, a rhombus and a triangle. For every correct choice the scientists rewarded the octopuses with fish; for a wrong one they received a mild electric shock.

In another experiment, the octopuses were fed with crabs tied to a thread. When the octopuses became adapted to this, a small metal plate was put into the tank near the crab. Now the unsuspecting octopus emerged from its lair to attack the crab as usual, but it suddenly dashed back. It turned pale and moved quickly back to its lair, pumping jets of water at the treacherous crab. The investigators had electrified the crab and plate, and the shock had frightened the octopus.

About two hours later the crab and plate were again placed in the tank, but this time, instead of rushing from its lair and flinging itself on the crab as it had done before, the octopus behaved very differently. It emerged cautiously from the lair. It walked on the bottom of the tank with its tentacles outstretched, ready to retreat at any moment. Two conflicting motivations were at odds: the desire to seize the crab and fear. In trying to resolve this conflict, the octopus would alternately approach the crab and then retreat to get back again. Finally, the feeling of hunger triumphed and the octopus seized the crab. A shock followed. The octopus paled and retreated to its lair.

Now the conditioned reflex had been firmly established. The octopus seized crabs, but crabs with plates aroused no interest in it. The octopus would stick its head out of the lair to observe the tricks of these bizarre humans. When a dangerous crab approached it, the octopus would flash red and shoot a violent series of jets of water at its "enemy", using its natural jet engine.

But if the memory lobes of the octopuses were removed, the octopuses acted as if they had never been electrified. When such an octopus saw the crab and plate, it would hurriedly leave its lair, seize the crab, receive a shock, retreat and immediately return. The painful experience was not remembered and the octopus could not be conditioned. One octopus pounced on the crab ferociously for the 35 days of the experiment. Even at the end of a day on which it had received 15 shocks, the octopus emerged as readily as ever to attack the crab, which only gave it pain.

Surprisingly, octopuses can be hypnotized by people. This was proved by the Dutch scientist ten Cate. He tried several methods. The best method proved holding the octopus in one hand with its mouth upwards and its arms hanging downwards. The great difficulty was to hold the octopus in this awkward position until the spell worked. Also, one's hands had to be kept away from the tentacles, since the tentacles would immediately embrace the fingers: this would excite the octopus making it difficult to hypnotize it. But if the octopus could be held in such a position for a fairly long time, it could easily be hypnotized. When it was deeply hypnotized, anything could be done with it and it would not wake up. Its tentacles could be lifted, and when released they would fall as lifeless as a piece of rope.

Ten Cate would throw the octopus from hand to hand and it would show no more reaction than if it were a football. A heavy pinch with surgical nippers, or even more drastic treatment was required to awaken it. The fact that the octopus is easily hypnotized is indicative of a fairly high organization of its brain.

Now we shall discuss digger wasps. Being incorrigible outsiders, they do not live in large communities as do other wasps. They meet the rigours of life alone. Many digger wasps dig out holes in the earth. Then they set off hunting. They capture caterpillars, flies, spiders, and some of them, even bees. Wasps sting the bees to paralyze them and carry them into the burrow. They deposit one to two eggs on the prey. The immobilized prey is well preserved.

After the surgical operation that some wasps perform on their prey they rake soil over the burrow and never return to it. The food that they have stored is enough to feed the larvae up to the time they pupate. Others come to the burrows again and again to provide fresh food for their offspring.

The former do not have to remember the route to the burrow for long. Over their 80 hunting flights, they fill up their lards with food to be preserved. The latter, however, must not forget their location for many days and nights until the larvae grow up.

There is still another type of digger wasps: they rear their brood simultaneously in several burrows that are far apart. The burrows are small and inconspicuous, and when they fly away to hunt, some wasps rake sand and pebbles over the entrance. And they fly far away: dozens and even hundreds of metres. These animals have an outstanding memory.

The digger wasp Philanthus is called the bee wolf. It digs burrows on sand stretches, at the edges of dusty roads, and in sand dunes under pines. It kicks the sand between its legs as does a dog.

When the burrow is ready the bee wolf sets off to hunt. It knows where bees collect nectar and makes its way there. It intercepts the bee and stings her to immobilize its prey. The bee wolf holds the bee under its abdomen with its legs and carries her to the burrow.

But here it suddenly finds a change of landscape. While it was digging its burrow, some researchers encircled it with pine cones, which are abundant in the neighbourhood. And when the bee wolf was hunting bees, the circle of pine cones was transferred some distance away. The burrow is now outside the circle, not inside it as before.

Without hesitation the wolf carrying a bee alights inside the circle: it had remembered that the burrow was encircled with cones. It puts the bee down and looks for the nest. It searches inside the circle without crossing its borders. But this search is in vain: the burrow is beyond the cones, and the bee wolf cannot understand this. Now the researchers move the cones back and the wolf fly towards them alighting in the centre of the circle as soon as the researchers remove their hands. If the cones are laid out still farther away, the bee wolf appears again.

This experiment demonstrates the following: the wasp depends on various objects around it to determine its direction. It is exactly the disposition of the landmarks rather than the landmarks themselves that counts. If one replaces the cone ring with wooden pieces of matching colour, and puts the cones in a pile to the side, the wasp will fly towards the ring of wood chips and not towards the cones.

If the cones are arranged in the form of the Great Bear's Big Dipper, Philanthus will only fly into the "dipper" itself, which is distantly similar to a ring, while the "handle" is neglected.

When does the wasp memorize the landmarks: while it is digging the burrow, or in the air, or while it is taking off? Before they take off, many wasps circle around the nest for a minute or two. Apparently, as they fly about, they memorize the beacons. In fact, small objects at the burrow are invisible from a distance; hence, it would be difficult to find the way back without larger and more distant beacons. These landmarks are studied by the wasps, during locality study flights, which last only 30 to 100 seconds. It takes the wasp 10 minutes of flight over an unfamiliar locality to remember all the landmarks for several hours. The first beacons to attract its attention are trees. The wasp prefers to go hunting along some conspicuous alley, or along a natural border of bushes, using them as landmarks on the way back.

Experiments demonstrate that wasps give first priority to trees as landmarks.

One wasp got used to fly-hunting along an alley of trees planted by the researchers near its burrow. When the alley was displaced somewhat to the left, the wasp flew along it and naturally failed to find the burrow behind the last tree where it used to be. Then the alley was returned to its original site, and the wasp was captured and brought to where it had begun its original search along the false route. The wasp first followed its original route, then quickly turned right to the "thicket" and easily found its nest at the end of the alley.

Attempts were made to transfer wasps to various distances from the burrows. They would return in a straight line only when transferred short distances away. The farther they were removed, the more time was taken to choose the right direction and the more detours the wasps made on their flight home. If they were moved 27 metres away, the wasps returned to the nest without hesitation and in a straight line. But when they were released 35 metres away, they first described many loops. Then the random loops grew increasingly wider until the insect found itself in a familiar locality and began flying in a straight line.

For some wasps, largely ammophils, the problem of direction finding is also complicated by the fact that they cannot lift too large a prey and have to drag it along the ground. They memorize their bearings from the air, and get home by land! It is no easy problem to solve, even for human beings with their capacity for abstract comparison. But the wasp easily copes with this problem. It drags a heavy caterpillar along with such confidence that it is obvious that it knows the route perfectly. Occasionally though, doubts arise, and the small live aircraft drops its heavy burden and, fluttering its wings, climbs up a tree. It hurries up the bark to a higher vantage point to take a better look at the surroundings. After it takes its bearings, it lands, grasps the caterpillar, and drags it further on.

Rémy Chauvin described some experiments conducted by Thorpe:

"In one experiment Thorpe placed three rather tall walls of metal (50 to 120 cm wide) in front of an ammophil, that was carrying a caterpillar. He found that the wasp did not hesitate to circumvent the obstacles, and every time did this in an optimum way. No matter whether the wasp turned to the left or to the right, or got over the fence, it continues to drag the caterpillar along."

The excellent memory of the ammophil is also striking in that it digs not a single, but three, burrows. It digs out the first burrow and deposits an egg into it. After this, it digs out another hole and also lays an egg in it. Between one and three days after it examines the first burrow, and if everything is all right there (the larva has pupated), the wasp brings caterpillars to feed it. Then it inspects another sealed burrow, and if it finds a larva, it brings in food. After this, the wasp digs out a third burrow, but it does not forget to provide food every two to three days to the larvae in the first two holes, which it finds without error. When the larvae in the third burrow pupates, it is not left hungry either. All this time the ammophil remembers in which burrow and at which stage of development its larvae are.

Fish

When they put their ear to the breast of the ocean, hydroacousticians hear the vibration of its life. This is difficult for the layman to do, since almost all the sound energy of the ocean is absorbed at the boundary between the air and water.

There are no nightingales among fish. Their instruments are by far too primitive. To emit sounds they compress their swimming blades, click with the plates of their armour (if they have it) or with gill covers, grit their teeth or rub cartilage against cartilage. The sounds produced match the instruments: there are crashing, howling, crackling, chirping, and grunting sounds. The orchestra is, as you see, somewhat like the one in the famous fable by Krylov. And how do fishes themselves respond to it?

And they do hear all these calls, although one can hardly conceive of a fish moving its ears. But fish do have ears—internal ones. Posterior to its eye is a cartilaginous vesicle with little stones, often of various shape. These stones vibrate from the impact of sound waves and transmit these signals through the nerves to the brain.

Experiments on fish hearing were first conducted a long time ago. Over forty years ago the students of Academician I. P. Pavlov found that fishes hear the ringing of a telephone placed either under water or in the water.

In 1938 the famous German ethologist Karl Frisch published a paper entitled *The Sense of Hearing in Fishes* in which he related his experiments with gudgeons. The gudgeons were trained to receive food by the signal of a whistle or a tuning-fork. They could hear these signals from as far as 30 metres away. Next, the acuteness of their sense of hearing was investigated as compared with that of humans. A much larger tank was placed near the first one. A person submerged in this tank and at that moment a signal was sounded. According to the reaction of the gudgeons, it was found that they could hear him even somewhat better than did the person immersed in the other tank.

Then the ability of fish to hear musical tones was investigated. They found that fish distinguish two notes an octave apart. This is a fairly simple problem for humans, but to discriminate the differences between notes one tone apart is beyond the ability of humans without a musical ear. Gudgeons, however, can solve this problem quite easily.

It was noticed that when some rhythmical tune was played on the violin (in a bass register) gudgeons seem to dance, vibrating their pectoral fins in time with the music.

There is a story about an angler who used to play a gay tune on the violin before he cast a line. The fish would seem to awaken from drowsiness at the bottom and begin to dash about and bite even if they were not hungry.

Fish can also be taught to discriminate between colours. To be more precise, fish distinguish between colours innately and can be trained to swim for food by a definite signal. Pure colours, such as violet, green, and blue, are most easily discriminated. But these are not the only colours. How fish respond to the tints of various colours was investigated. Their performance was not inferior to that of humans. Fish can also easily discriminate the shape of the signal object, which they are presented, before they are fed in the aquarium. It is not difficult for them to discriminate between a square and a circle, or between a square and a cross. Moreover, they can even distinguish between a circle and an ellipse. Of the many types of fish, gudgeons have the best abilities in this respect.

If, in the course of learning, the investigator covers one eye of a perch, the fish will not forget all the procedures it learned when next time the "trained" eye is covered.

The African fish Tilapia was trained to receive food by pressing a pedal. In this experiment, the fish solved a more difficult problem than the one solved by rats or apes in a similar situation; after all, fish do not have limbs that they can easily manipulate. Tilapias retained the conditioned reflexes for months.

Rémy Chauvin writes:

"Some fish can be trained to circumvent an obstacle, even a glass one, which they do not see... Russel demonstrated that sticklebacks that accidentally found food in a bottle quickly learned to swim into and out of the bottle... As the learning curve showed, the number of errors declines so rapidly that this is clearly a case of insight."

The fighting fish Betta splendens quickly finds openings through which it can swim in an obstacle set up in front of it. It only needs to penetrate the obstacle once in order to remember the experience. Subsequently, it invariably follows the same route, even if there are easier options, such as the possibility of swimming under the obstacle when it is lifted. If the obstacle is lifted high so that the opening is above the water, the fish will even leap out of the water to get through the opening.

In another experiment, cichlid fish overcame an obstacle that was lifted two centimetres above the bottom: they would lie on one side and literally crawl under the wall.

Goldfish were trained to swim on command through a small ring or to describe consecutive loops in the water. Thus, fish can be trained. The perch, carp, and goldfish are the best students. Of course, there was a limited choice of fish used in the experiments: usually only freshwater fish were used. Perhaps, many marine fish could demonstrate still more spectacular talents.

Many fish have their own individual territory. They also have rank order (and not only the Malabar danio that we have already discussed). Studies of sun fish behaviour in an aquarium have revealed that the biggest fish are the leaders, and the whole school invariably follows them, particularly in a maze. Even the playful behaviour of the leader was mimicked, for example, the fish leapt out of the water or executed other stunts to imitate the movements of the leader.

And in general, fish are easily conditioned. A wide range of stimuli, such as sounds, objects, water temperature, salinity, and colour, scents, acidity level, and mechanical and electrical devices, may be used. Learning is particularly successful in fish that are in schools, and things are still better when there is a trained fish among them: they follow it and imitate its movements. This type of imitation was called the "reflex of following".

Many ethologists believe that because of the exceptional gift of imitation in fish their communities become specific pools of diverse information. In fact, once a single fish that is familiar with a site memorizes that the feeding ground is to the left and makes a quick movement to the left, this movement will be imitated by one neighbour, then by another, then by a third one, and finally by the whole school.

Amphibians and Reptiles

Move a toad from the pond where it was born to another that is quite suitable for life and the toad will set off in search of its native pond. And it will eventually find it, unless it has been taken too far away. Toads return and look for water stubbornly, even in the waterbodies that have dried up or were filled, if they lived there as tadpoles. Why and how they act like this is not understood.

Many amphibians have been shown capable of learning by conditioning. Toads and frogs (the former showing better performance) pass through fairly simple mazes, where in the end they are rewarded with food. A similar ability is shown by the axolotl (after 500 failures!), tree frogs, and toad tadpoles. Newts and salamanders are unable to solve this problem.

Tree frogs and frogs are not bad at distinguishing between a cross and a circle, a star and a triangle, a triangle and a quadrangle, and a curve and a straight line, if these figures are in motion.

Rémy Chauvin explains:

"Behavioural ontogenesis is entirely innate both in reptiles and amphibians. As early as several hours after they emerge from the egg, young turtles, for example, are capable of climbing out of deep depressions. They orient by vision very well and reach the ocean shore by land."

It has been proven that newborn turtles obtain their direction by the sun. In addition, they are not guided by the scent of the ocean or by the shore slope pattern, as was previously thought. Rather it is the illumination of the sea surface, which is more intense in daytime and during the night than on land, that guides them to the water, as was discussed previously.

Turtles emerge in the most ancient fashion: from an egg incubated by the heat of the earth. Some turtles lay hundreds of eggs; others lay only two or five. Some lay them once in several years; others, several times per year. Some bury their eggs deep in the earth; others, in rather shallow places. Some do not take care of their offspring and leave them to chance; the parents of others deposit their eggs in underground burrows and remain there until their young hatch, even helping them emerge from the shell.

After some time, and this period varies with the species, life emerges in the underground burrow. The baby turtles hatch and, here, on the eve of their long life, they face danger. For the world of beasts, birds, predatory fishes, and reptiles is, as well as the human world, aware of how tasty turtle meat is. They are pecked and swallowed, and time is not wasted on chewing. And a baby turtle that is still without a carapace is quite defenseless. Even ants are dangerous to it. They gather into numerous troops to attack the small hobbling turtle, leaving only its "hide."

Fortunately, turtles are more agile at birth than as adults. Marine baby turtles hurry towards the water in a businesslike manner, but only a few of them manage to escape from the numerous hunters. Freshly hatched turtles have a particularly tough time when they have only several metres to cover to reach the sea. Frigate birds swoop down on them, seize them on the wing, and then attack again. Often not a single one of the hundreds of hobbling turtles reaches the sea.

And how about their careless parents? They make for whence they swam. Some even cover thousands of kilometres to reach their foraging grounds where the Thalassia plant, their favourite food, grows. Occasionally they swim from the tropics to the Barents, Baltic and even Bering Sea. They cover one to two thousand kilometres one way, only to hatch their eggs on their own sand spit, although a similar spawning ground can be found in many other places.

And still every two to three years they leave the familiar shore where they used to hunt fish, molluscs, crabs and ascidians, and to feed on marine plants. They cover hundreds of kilometres forming communities that were so numerous in Columbus's times that they barred passage to vessels. In recent times, too, a ship on which a zoologist from Sri Lanka was travelling encountered an assembly of turtles that stretched 108 kilometres in the sea. The reptiles were swimming roughly 200 metres apart from each other, but all in the same direction.

These travellers were swimming to the sand beaches of the Antilles and Seychelles

Islands, and to the coasts of South Africa, Sri Lanka, Indonesia, Australia, and Brazil to bury their eggs, which during their travels had become ready to hatch. Strangely, during the breeding season, the green turtles dwelling off the coast of Brazil, swim in the opposite direction—into the open ocean. Their destination is Ascension Island in the central Atlantic, two thousand kilometres away. How they find their way to this minute islet lost in the boundless ocean is not clear. Perhaps, they take their bearings from the sun, and as they come near the target, they obtain their direction by the scent of the water. This phenomenon is as extraordinary as the one in salmon.

How well are reptiles trained? How quickly do they reach the target in maze experiments? Both turtles and lizards coped with this problem fairly well. It took one turtle 20 to 25 trials to find the right way in two intricate mazes with six dead lanes. Later it learned to choose the short cut.

Water snakes found their way very well in a less complex T-maze. But after moulting they lost this skill.

Turtles memorize colours and figures well even when these are drawn with a broken line or when the figure is turned at a small angle.

Turtles, which are considered to be rather dull animals, prove to vigorously establish and defend a territory. They also have a dominance hierarchy (at least some of them, such as the giant turtles of the Galapagos Islands). Aquatic turtles do not swim randomly through lakes or rivers. They only keep to their territories. If they are moved to another pond or lake, the turtles set off in search of their native waterbody, even if it is one and a half kilometres away and, surprisingly, they do find it.

Lizards, too, know where their home is. When an iguana is displaced about two hundred metres from its native area, it returns home after approximately two weeks, even if it has to cover strange territory. It has also been proven that iguana lizards have rank order.

The behaviour of some snakes of North America is not understood. For some unknown reason (which is not winter or summer hibernation) they gather at definite times and at definite sites, and many of them cover large distances to get there. These snakes were marked, and this demonstrated that the community under study comprised the same individuals year in and year out.

In the laboratory many snakes displayed behaviour characteristic of the most primitive vertebrates. But some zoologists report many interesting details about the behaviour of these animals in nature.

Let us consider, for example, common vipers, who have recently been studied by

Finnish ethologists. In spring, around mid-April (or, if the spring sets in early, in late March), when the snow has not yet melted everywhere, the first to emerge from under the ground are male vipers. They are greyish, with a dark zigzag pattern on the back. The females are brown, with the same pattern on the back. There are also black vipers (usually females) and reddish-brownish individuals without the zigzag band.

The males emerge to crawl to sunny sites on slopes facing to the south, or to dry clearings. Here they sunbathe for a week or two. Then the females appear. The males crawl after them and, as they court their ladies, quarrel with one another.

The duel ritual (combat dance) of vipers is fairly similar to that of rattlesnakes. It was previously thought that their movements are a mating dance performed by the male and female, but it has been proven that these are fights between males. The snakes raise their heads and sway them to a definite rhythm; they become entwined in a contest of strength, trying to press the opponent to the ground and turn him on the back. They almost never inflict bites.

In temperate climates vipers give birth every other year. The females do not crawl far off the sites where they used to sunbath; however, by contrast, the males travel a kilometre to five kilometres to their summer range, defending for years their hunting grounds (one to four hectares in size).

But how do they find their hunting grounds, which they are so used to? One can catch a viper where it lives in the summer (but not in the spring or autumn when these snakes migrate to their mating sites or wintering grounds and often traverse strange territories). If it is then displaced between 200 or 500 metres and a kilometre away, and released in similar forestland with similar living conditions, it still returns "home". Moreover, if one holds it in captivity for a few months, for example, in a terrarium, and then releases it not far away from the point of capture, it will return to its native area. The viper's homing ability in the forest is not yet understood.

Strangely, vipers have a good memory. Observing these snakes in large terraria has revealed that males and females are steadfastly faithful to each other. Year after year some vipers mate with the same conspecific, allowing them alone into their territories in the summer. Only these mates are permitted to approach during the breeding season. This ability to identify a conspecific is all the more striking, since in any season other than the nuptial one, the male is unable to determine the sex or even species of the snake he encounters.

Vipers hunt mainly at night if the air temperature is not lower than 3 °C. When it is colder they take cover in underground hideouts and become immobile. But even during seemingly warm nights (10-14 °C) they unwillingly crawl out from under stumps, mouse burrows and other depressions. On cold days vipers only appear on the earth surface in the morning, crawling onto sunny clearings, slopes, and cuttings. They will lie for hours, flattened against the ground to get more sun.

Pregnant females spend the largest part of the summer in sunny sites to ensure better development of their embryos. At night, they investigate, without crawling far away, the burrows of rodents and depressions under roots. They do not crawl fast; they search for and pursue their prey without much vigour. Usually, they bites only those voles, mice, frogs, lizards, and small birds that find themselves within reach without noticing the viper. They will rarely pursue unstung prey that is escaping. In contrast, the viper will never release a lizard or frog that has been stung: it swallows them up immediately.

A mouse that has received a fatal doze of poison is sometimes able to run some distance before the mortal agony begins. And the viper does not hurry to set off in pursuit—there is no hurry at all. It remains motionless for a minute or two as if it were considering the possible routes that the doomed rodent may follow. Then it crawls, leisurely following the trail with its head lowered to the ground. It seems to be caressing the earth with its bifurcate tongue. When it finds the prey, it quickly ejects its tongue to feel and sniffs the mouse, and then it swallows it up. If the site is not suitable for having a meal, the snake clasps the mouse in its mouth to move over to a quieter and more comfortable place.

Snakes are not voracious: on the average, a viper is sustained by an amount of food that is one hundred times less than its own weight. But this is an average annual figure. There are, of course, days when more food is available. After catching and eating two mice, the viper increases in weight by 50-75 per cent. And on the subsequent nights, it may not crawl out to hunt at all. Or it may try to hunt but will not be likely to catch any prey. And then moulting sets in: while they are changing their skin, vipers starve. They also fast in spring when they mate. Pregnant females do not care for food either. And then winter comes and it is time for vipers to take cover in various holes and cracks, occasionally at a depth of over two metres, to hibernate until spring.

A female viper becomes sexually mature at an age of about 5 years. Males attain maturity about a year earlier. The gestation period is about three months. Vipers give birth in late July to September to between 5 and 20 baby snakes. The young are 10 to 20 cm long. Before they are a day old they are able to hiss and are venomous.

Of other reptiles that have received much attention, the most interesting is the behaviour of crocodiles. These reptiles, at least some species, such as the American alligator, remove silt and excessively dense vegetation from waterbodies. They dig the bottom with their paws, dumping the excavated material on shore. Normally an alligator excavates such a pond for itself and for its brood. It protects the pond from other male crocodiles and allows only females in. A stretch of water and shoreline of half a kilometre or more is also part of their territory.

The property of a Nile crocodile consists of one hundred metres of the littoral and adjacent inland waterbodies. These crocodiles spend the night in the water and, in the morning, come on shore to lie in the sun. Only in the afternoon, when the sun is scorching, do they crawl into the water to take a swim, and after lying in the water for a while, they again bask in the sun. If it is hot and they are too lazy to swim, they cool themselves by gaping. Crocodiles may lie gaping for hours. But territory-owners cannot afford to fully enjoy the siesta as the young crocodiles that have no territory do. These crocodiles make up the majority of the population, and they lie, often in groups, at vacant sites. And those that hold territory are always on the alert, ready to rebuff a male trespasser. They periodically give up their siesta to take a patrol swim along their boundaries. Satisfied that no trespassing has occurred, they get back to the hot sand.

Intrusions are common during the rutting season, that is, during the nuptial period. Such intrusions lead to fierce and long fights that may last up to an hour. This sight normally attracts many crocodiles from the neighbourhood.

Females visit territorial males but give preference to "property", that is, to the sunniest and most comfortable nesting sites rather than to the territory-holders themselves. The arrival of females is usually expected before afternoon. Impelled by instinct, the males swim impatiently about their water stretch, bellowing. They gape to emit a long loud bellow, like the boom of a big drum. The musk glands, that the crocodile has at the base of the mandible and under the tail give off a pungent smell.

The bride is given a rough time from the very outset if she tries to escape coquettishly. The male catches up with her, begins to spin in the water, and makes her spin too by pushing her with his flank. He hugs her with one paw, then with the others...

Crocodiles bury their eggs in the sand, some pile up decaying leaves and stalks, building a sort of hothouse where the eggs are layed. The females are on duty at the nests but their care of the future brood is not confined to this. Alligators and estuarine crocodiles, like brush turkeys, regulate the temperature and moisture in the nest.

The nests of estuarine crocodiles may be one metre in height (up to 7 metres in diameter). Nearby the female digs out a hole in the mud for herself and from time to time flips her tail to splash mud on its nest mound. American alligator females build similar nests. The top of the pile has a depression containing several dozens of eggs with interlayers of grass and covered with a layer of plants a quarter of a metre in thickness. The crocodile female turns this layer over frequently to make it more compact, or, by contrast, loosens it so that the necessary moisture and temperature are maintained.

A Nile crocodile nest is quite different: if the sandbank slope is steep enough, the eggs are buried close to the water. If it is gentle and may be flooded, the nest holes are dug some twenty metres away from the water. A sunny site is chosen, though not where the sun is scorching. In shady areas, the holes are fairly shallow, while at sunny sites, they reach a depth of half a metre. The eggs are covered with a mixture of earth, leaves and grass. Occasionally, the earth gets so dry and compact that freshly hatched crocodile babies can hardly reach the earth surface unless the mother digs up the cover.

The eggs of Nile crocodiles are incubated in the earth for three to four months. During that time the mother remains close by and keeps guard. When it is hot, she moves to a shady area and watches from there, or she takes a break to swim and then gets back to the nest and stands over it. The water trickles down her cornified skin and moistens the earth over the clutch. The female practically doesn't eat because she cannot wander far from the eggs. Birds, reptiles, or mammals (marabout and other storks, hyenas, baboons, turtles, Nilotic monitors, mongooses) are quick to steal the eggs.

When it is time for them to emerge from under the earth, the babies "croak" and their calls are heard several metres away. The mother removes the earth and lets them out. They are still quite small (26-34 cm), but they are very mobile and restless: they croak, grunt, grab one another, try to get into crevices or bushes from which they are not yet able to get away, clamber up the back and the snout of their mother.

They cause their mother much trouble, but she is glad. She leads her brood to the water like a duck leading her ducklings. It's dangerous to come across this family: the mother attacks every animal or person even on shore. When they reach the water, different broods often intermingle. They try to keep as far as possible from the adult crocodiles, taking cover in tall grass and bushes or in burrows that they dig in steep banks.

While they are still young, many are killed by eagles, eagle owls, or birds of prey. Marabout storks, black-necked storks, saddle-bill storks, and other long-legged possessors of stout beaks, aquatic turtles, Nilotic monitors, cat fish, and finally, adult crocodiles destroy the little reptiles so vigorously that no more than 2 to 5 per cent survive to maturity.

Birds

Various aspects of the behaviour of birds have already been discussed. Now, some peculiar features shall be discussed. Without a doubt, the most complex behaviour is displayed by two far from related groups, i.e. bowerbirds and brush turkeys. The complexity of their behaviour manifests itself in tool-using skills and in their habit of building intricate structures, whose purpose will become clear from the discussion below.

Bowerbirds look fairly inconspicuous. Males are a bluish black, similar to their relative, the carrion crow, and females are a yellowish green. Incidentally, different species of bowerbirds have a characteristic coloration. The ones discussed here are the satin bowerbirds. The structures they build are small platforms laid out with twigs. A length of approximately one-half of a metre is taken up by a dense paling of twigs. Their upper portions are bent towards each other to form a kind of gabled roof. The bower is oriented southward. If it is turned 90°, the bird will reorient it as it was.

Hundreds of colourful knick-knacks, such as shells, dead cicadas, flowers, berries, mushrooms, stones, bones, feathers, fragments of snake skins, and other bizarre things, are scattered at the entrance to the bower.

There are 18 species of bowerbirds found in Australia, New Guinea, and the neighbouring islands. Almost all of them construct (around young tree) various kinds of bowers, sheds, or towers that occasionally reach up to three metres in height. It takes a bowerbird several years to build such a structure.

Two bowerbird species even stain their bowers with colours of their own making. The bird obtains charcoal from somewhere. It then chews it, adds the pulp of some fruit, and mixes this paste with saliva to produce a sort of black putty. Before it begins plastering, the bird gets a piece of soft bark, which it uses as a brush, spreading the paste over the bower inner walls.

Many bowerbirds stain their structures with the pulp of blue fruits. They may shamelessly steal bluing balls from laundresses. Strangely, they prefer decorations that are blue in colour: glass fragments, stones, feathers, and flowers. With mathematical precision they give preference to those objects that are coloured with the deepest blue tints.

But why blue? Many a scientist has been puzzled by this question. And the solution has yet to be found. As one hypothesis has it, the blue colour is attractive to bowerbird males because their mates' eyes are bright blue.

On dry plains in the south of the continent, and in shrubs among eucalypti in the east, European settlers in Australia frequently found large piles of leaves covered with earth. On analogy, they decided that these were burial mounds. The mounds were of considerable size, some reaching five metres in height, and up to 50 metres in perimeter. It took the settlers some time to realize that these mounds are constructed by birds called brush turkeys.

And what are these structures built for? Bewilderingly, these are incubators or hothouses in which fallen leaves, branches, and other litter decompose. This heats the birds' eggs, which are buried in this natural incubator.

For months, the cocks keep a constant watch at the mounds. They even sleep in nearby trees and bushes. From early in the morning till late at night they monitor the temperature conditions of the hothouse. If the temperature is too low, they add more earth to the top and decaying leaves inside the mound. If the temperature is higher than normal, the excess layer is removed or deep air vents are dug at the sides.

How do the birds measure the temperature of decomposing foliage? The "temperature sense" organs in brush turkeys appear to be on the tongue and the palate. The cock digs deep holes in the pile to reach inside with his head. With his beak he picks up the decomposing mass to check the temperature (the ideal temperature is 33 °C). And what will the bird do if the incubator is heated artificially? Its behaviour matches the season. In the spring, when it is still cool and the eggs are kept warm by the heat of decomposition, the cock covers the nest with an extra layer of earth. In the autumn, the eggs are largely heated by the sun, and in the same situation (artificial heating), the cock does not add more earth.

This means that the bird behaves quite logically, taking into account unexpected factors. But if the nest is heated in the middle of a hot summer, the cock will again add earth to the top instead of removing the insulating layer of sand. The cock pokes its head into the nest to measure the temperature, but since the temperature has not declined, but, by contrast, has increased, the bird is taken aback. It fusses near the nest and looks quite at a loss. It alternately removes the earth and then rakes it back over its hothouse. And if the nest is overheated for a long time, the cock will abandon the structure to build a new one.

The relationship of birds to their wounded conspecifics is of interest. When they hear cries of pain and see a wounded conspecific writhing on the ground, jays, crows, seagulls, terns and presumably other birds fly to the site and hover over it with cries. If a bird is dead and does not stir, the other birds will circle over it in silence and then fly away. If there is a wounded bird that has lost much blood, it is usually, but not always, killed. For instance, ravens have been observed to feed their helpless wounded or blind conspecifics. A blind pelican was observed living in a colony of its conspecifics, which tended it.

Still more striking instances of mutual help have been reported. In a zoo, crows were once seen feeding an American black vulture: they put food through the bars of the cage. And a finch was observed feeding a goldfish. The goldfish gaped as it surfaced and the finch filled its mouth with worms. It is thought that the gaping of the fish acted as a releaser, reminding it of the gaping mouths of its own nestlings that had died not long before.

Some birds are also known to raise the orphan nestlings of a nearby nest. Moreover, even nestlings of another species may be reared. A Sialia, which is related to the thrush, was observed tirelessly feeding fifteen nestlings of six different species at once. Even more bizarre is the fact that some birds are so fond of raising strange nestlings, not infrequently, of another species, that they neglect their own, which starve to death.

How is all this to be interpreted? Scientists believe that this is "an anomaly of parental instinct". And it remains to be understood what the cause of this suicidal anomaly is.

The Norway Rat

Jan Dembowski writes:

"The number of studies on rat psychology is very large and, at present, only specialists are well versed in them. Apparently, no other animal has been studied so extensively."

The Norway rat is also called the common rat, the brown rat, the sewer rat, or the Irish rat. The name "Norway rat" is the name that has been adopted in laboratories.

The doings of this rat are strange and often inexplicable. A female has up to three litters with up to 15 little rats a year: the average number per litter is seven. After three to four months the rats breed, and, thus, a single pair of rats gives rise to up to 15 thousand offspring annually.

A pregnant female starts to build her nest immediately. The male assists her by bringing straw and bits of fluff. If cold weather has or is soon to set in, the pair work more vigorously.

An interesting experiment was performed by one Polish scientist. He removed the thyroid in a female rat. After this operation, the rat lost all sense of proportion and proceeded to construct huge nests, using 150 metres of paper daily. In a healthy rat, the construction zeal abates when the nest is ready.

And now an average of twelve newborn youngs take position at the twelve nipples. They suck incessantly for the first two to three days. Their stomachs contract to a constant rhythm as if they were sending the order "eat". Their little mouths make sucking movements without interruption. The young do not yet hear anything but they already squeak.

On the fourteenth or fifteenth day, the little rats see the grey unsightly world, without yet perceiving its colours. But already at the very beginning of their lives the little rats show some proficiency. For example, they try to crawl where it is darker. Also, if a young is placed on an inclined plane, it chooses the most direct route as it climbs up. These are innate instincts, but the babies are yet to graduate from the mysterious school of rat life.

Scientists, however, have managed to throw some light on the education of rats. The best method they used proved simple and ingenious: the scientists themselves proceeded to train the rats. They were trained to find their way in specially designed mazes, and there was no maze that proved to be too intricate for them. After 200-300 runs the rats learned to find their way in the mazes without making any error.

Then, however, the rodent's task was made more complicated: the rats were deprived of vision, but they found the right route all the same. When they were descented, they again managed to solve the problem. The tactile nerves of the paws were anesthetized, and still the rats found the expected reward. Then, several sense organs were simultaneously switched off and still the rats reached the goal. The most interesting point is that the rodents became adapted to their deprivations so easily. When deprived of vision the rat feels its way with its paws and vibrissae (whiskers). When the vibrissae are cut off and the paws are anesthetized, it walks by touching the wall with its sides. But when the maze was turned 180 degrees, the rat got lost.

In another experiment, the rats were trained to climb up stairs to reach a higher shelf. The rats would on their own grasp the ladder connecting the two lower shelves and raise it onto the second shelf so that the upper step of the ladder leaned against the third shelf where they would find the reward. Thus, the rodents revealed a most remarkable talent.

Of course, at first the rats failed to cope with this problem. They were at a loss and would run about on the second shelf, which they had reached by climbing up the ladder connecting the first shelf to the second one. But after a long series of tests, one rat managed to raise the loosely fixed ladder from the first shelf to the second one and to lean it against the third shelf. This is clearly a case of insight. Immediately, the other rats learned this skill by imitation.

The rats were also trained to identify visual patterns and they soon demonstrated much skill. They were quick to memorize the pattern, which would yield a reward, and, subsequently, would identify it even if it was presented to them as part of another pattern. They could also identify the pattern when its size was changed.

Of course, investigations were also conducted on the sense organs of rats. It was found that the rat's sense of smell is not superior to that of humans and that olfaction is by far not the most important of its senses.

The rat's sense of taste has also been found to be inferior to that of human's, although it perceives the same flavours, such as sweet, bitter, salty and sour.

The auditory faculty of the rat is yet to be understood. It has been demonstrated that the rat can hear rustling noises better than humans can. The same applies to sounds at a frequency range less than 8,000 Hz (i.e. 8,000 sound vibrations per second). Humans are more sensitive to higher frequencies, but the highest frequency range perceived by the rat has not yet been established. It will be recalled that the human ear can hear sounds at frequencies between 20 and 20,000 Hz.

The lower frequency range is infrasonic, and the higher, ultrasonic.

The sensitivity of vision in rats has not received enough attention either. At any rate, studies of the rat eye have revealed that its structure is unusual for nocturnal animals, the rat sees very well during the day although it is very nearsighted.

The rat has a very high requirement for movement. If it is put into a revolving drum, an experimental rat "covers a distance" of 8-16 kilometres a day. A record was set at 43 kilometres per day. But the rat is not in motion all the time. It is a so-called polyphasic animal. It does not sleep at night or, by contrast, during the daytime, as do birds or other monophasic creatures. During the 24 hours, it passes through approximately 20 alternating rest and activity cycles.

Some readers may have seen a unique film clip where a Norway rat is making its way to a ship by a mooring line. The rope has a flat wooden muff that blocks its way. The rat, however, does not even try to pass over the muff. When it reaches the muff, it lets go of the rope and drops into the water. It swims until it reaches to where the rope sags to touch the water. Then the rat grabs the rope (beyond the muff), and in a minute it is on board. Although sailors see to it that their ships are tidy, they can't help travelling with these beasts on board. It seems that a port would be a wonderful habitat for a rat, but still these beasts climb on board ships.

Humans have invented many strategies for controlling rats, but none are radical enough. The reason is the rat's unheard-of adaptability. Food, which is the vital factor, is not hard for rats to obtain. They are omnivorous. The rat can eat whatever is consumed by humans. It can also devour bed-sheets, footwear, books, skin, bone, and bark: all this, of course, in the absence of Roquefort cheese, which it is particularly fond of.

The main danger that rats present for humans is not that they devour our food. The deadly danger, which became known as late as the beginning of this century, is that rats infect us with the plague. Further studies have revealed that in addition to the plague, rats are carriers of at least twenty dangerous diseases: typhoid fever, brucellosis, erysipetalous inflammation, trichinelliasis, salmonellosis, leptospirosis, Lassa fever (a very dangerous disease), and many others.

According to Earnest Walker, the diseases that are carried by rats have led over the last ten centuries to a greater loss of life than all the wars and revolutions put together.

Afterword

Now we have turned the last pages of the book. What have been the most important points?

My purpose was to inform the reader by presenting hundreds of examples from the lives of the most diverse animals about the gradual evolution of thinking, the increasing complexity of animal behaviour, the formation of and first manifestations of their mental activity, and its multiple, and ramified evolution from primitive invertebrates to primates.

The mental activity of animals, or to be more exact, groups of animals, followed an independent course of evolution. But at the same time they all had something in common. And these common features are shared by all animals, including the higher mammals, i.e. primates and Homo sapiens.

This "commonness", in the broad sense of the word, is the impact of a constantly varying environment and the differences in perception in different animals. Every animal has a unique characteristic response to this impact.

The new, unexpected, and unfamiliar situations that often arose, led animals to find the right solutions, adapt themselves to new conditions, and modify their behavioural responses. And the animals not only found the optimum solutions, but also remembered and retained them.

At some very early stage of their existence memory appeared in animals. Initially, it was a "memory of images", as it was termed by Academician I.S. Beritashvili, who devoted his whole life to investigating mental activity in animals. This type of memory was associated with visual or auditory perception of the environment. Then "short-term" and "long-term" memories evolved.

This book contains numerous examples of these types of memory. Of course, the capacity for learning and remembering experience, which arose gradually, was one of the most important factors for mental evolution. After all, animals are born without vital skills and habits. This was experimentally demonstrated by French scientists using the example of the domestic cat. Kittens that were weaned from their mother at a very early age when they had no skills for catching mice do not acquire these skills when they become adults. Moreover, it is very difficult, and occasionally impossible, to teach an adult cat to catch mice. The right time has passed.

Ethologists know of numerous examples of this kind. Hence, the capacity for learning in young animals and for retaining the experience, which manifests itself at a very early age, is a powerful motive force of mental evolution. In addition, all age classes have the capacity for imitation and for applying the experience of an entire population rather than a single animal. And, of course, in studies on the gradual refinement of mental activities in animals, ethologists should focus on both these factors.

It follows that without a most detailed study and thorough analysis of the thinking and behaviour patterns of each animal species at the various stages of their evolution, we shall not be able to understand the pathways of the evolution of human intelligence. And there is no doubt that the mental activity of humans has its beginnings in the mental activity of animals.

The late Jan Dembowski, a Polish zoopsychologist, who was the former President of the Polish Academy of Sciences and an Honorary Member of the USSR Academy of Sciences, wrote the following in his book *The Psychology of Animals*: "The psyche of man could not have arisen all of a sudden; it developed gradually and its evolution can only be understood on the basis of true knowledge of the psychic activity of animals". This cannot be more true!

In recent years abundant evidence is being accumulated both in this country and abroad. Throughout the world scientists are conducting large-scale ethological studies to solve this profound and complicated problem. Thousands of new research articles have been written, and scientific conferences on particular aspects of ethology have been held. But it will be a long time before all the problems faced by ethologists will be completely, or at least fundamentally, understood.

The outstanding physiologist Academician I.P. Pavlov commented on a chimpanzee's manner of solving problems during an experiment as follows: "You seem to be witnessing the genesis of our thinking (My emphasis—*I.A.*), its problems and techniques".

Following Pavlov, numerous ethologists throughout the world, have, during the last three decades, paid special attention to anthropoid apes, in particular, chimpanzees. These apes are the closest relatives of distant ancestors of humans, although they do not belong to this group. In recent years some very interesting and important data have been obtained. The chimpanzee has become an assistant to ethologists in many experiments elucidating the mystery of human intelligence. According to Academician I.S. Beritashvili, who studied the three types of memory in animals, i.e.

"image" memory, "short-term" memory and "long-term" memory, it is no mere chance that the latter two types of memory manifest themselves in apes, the most advanced animals that are the most closely related to man.

In the last years, ethological studies of apes, and primarily of the chimpanzee, have yielded some very important data. In the Soviet Union such studies have been conducted in part by L.A. Firsov at the Anthropological Centre of the I.P. Pavlov Institute of Physiology, USSR Academy of Sciences. Actually, these studies were initiated by Pavlov. His experiments with anthropoid apes led him to the important conclusion that it is impossible to interpret the behaviour of apes solely on the basis of conditioned reflexes. Many of their actions do not fit this interpretation. This very important inference gave impetus to further experiments.

Certainly, the origination, formation, and evolution of mental activity in animals, the evolution of thinking and of the capacity for remembering and, to a certain extent, accumulating experience, and the appearance of conditioning, learning and imitation of conspecifics occurred in a far more complicated and intricate way than was presented in this book. It was not my intention to cover the complexity, diversity and all the pathways of the evolution of thinking and higher nervous activity. The description of the already known processes of this evolution were also simplified in order to make the more basic things comprehensible. This is even more important, because it will still be a long time before we gain full insight into these issues. Difficult studies, diverse experiments and major conclusions still lie ahead.

To the Reader

Mir Publishers would be grateful for your comments on the content, translation and design of this book. We would also be pleased to receive any other suggestions you may wish to make.

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Another "Mir" Title to Come

THE LIVING SONARS
OF THE OCEAN

by
B.F. Sergeev

This book concerns that mysterious world that lies beneath the ocean waves. From antiquity until relatively recently people have thought it was a silent world, but scientists now realise that marine life is in fact quite noisy. Myriads of underwater creatures, such as dolphins, whales, and seals, obtain information in a way quite incomprehensible to us, Homo sapiens, for they use sonar or echolocation. Many terrestrial animals use echolocation to see and hear in conditions in which human beings are deaf and blind. 'What is echolocation?' and 'How do wild animals use it to obtain information?' are just some of the questions answered in this book.

SCIENCE FOR EVERYONE

Igor Akimushkin is widely known in the USSR as a popularizer of biology. He is the author of over sixty science fiction books, including some for children, and many have been translated into the languages of peoples of the USSR and foreign languages.
They describe the wonderful world of nature, awaken us to the marvels that exist just beyond the thresholds of our own homes, and explain the latest discoveries in biology. The series called "The Animal World" is particularly interesting having been awarded first Prize at a national contest held annually in the Soviet Union by the "Znaniye" society.

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