A stroll through the worlds of animals and men: A picture book of invisible worlds*

JAKOB VON UEXKÜLL (1934)[1]

Introduction

This little monograph does not claim to point the way to a new science. Perhaps it should be called a stroll into unfamiliar worlds; worlds strange to us but known to other creatures, manifold and varied as the animals themselves. The best time to set out on such an adventure is on a sunny day. The place, a flower-strewn meadow, humming with insects, fluttering with butterflies. Here we may glimpse the worlds of the lowly dwellers of the meadow. To do so, we must first blow, in fancy, a soap bubble around each creature to represent its own world, filled with the perceptions which it alone knows. When we ourselves then step into one of these bubbles, the familiar meadow is transformed. Many of its colorful features disappear, others no longer belong together but appear in new relationships. A new world comes into being. Through the bubble we see the world of the burrowing worm, of the butterfly, or of the field mouse; the world as it appears to the animals themselves, not as it appears to us. This we may call the *phenomenal world or the self-world of the animal.*

To some, these worlds are invisible. Many a zoologist and physiologist, clinging to the doctrine that all living beings are mere machines, denies their existence and thus boards up the gates to other worlds so that no single ray of light shines forth from all the radiance that is shed over them. But let us who are not committed to the machine theory consider the nature of machines. All our useful devices, our machines, only implement our acts. There are tools that help our senses, spectacles, telescopes, microphones, which we may call *perceptual tools.* There are also tools used to effect our purposes, the machines of our factories and of transportation, lathes and motor cars. These we may call *effector tools.*

Now we might assume that an animal is nothing but a collection of

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perceptual and effector tools, connected by an integrating apparatus which, though still a mechanism, is yet fit to carry on the life functions. This is indeed the position of all mechanistic theorists, whether their analogies are in terms of rigid mechanics or more plastic dynamics. They brand animals as mere objects. The proponents of such theories forget that, from the first, they have overlooked the most important thing, the subject which uses the tools, perceives and functions with their aid.

The mechanists have pieced together the sensory and motor organs of animals, like so many parts of a machine, ignoring their real functions of perceiving and acting, and have even gone on to mechanize man himself. According to the behaviorists, man's own sensations and will are mere appearance, to be considered, if at all, only as disturbing static. But we who still hold that our sense organs serve our perceptions, and our motor organs our actions, see in animals as well not only the mechanical structure, but also the operator, who is built into their organs, as we are into our bodies. We no longer regard animals as mere machines, but as subjects whose essential activity consists of perceiving and acting. We thus unlock the gates that lead to other realms, for all that a subject perceives becomes his *perceptual world* and all that he does, his *effector world.* Perceptual and effector worlds together form a closed unit, the *Umwelt.* These different worlds, which are as manifold as the animals themselves, present to all nature lovers new lands of such wealth and beauty that a walk through them is well worth while, even though they unfold not to the physical but only to the spiritual eye. So, reader, join us as we ramble through these worlds of wonder.

Anyone who lives in the country and roams through woods and brush with his dog has surely made the acquaintance of a tiny insect which, hanging from the branches of bushes, lurks for its prey, be it man or animal, ready to hurl itself at its victim and gorge itself with his blood until it swells to the size of a pea (Fig. 1). The tick, though not dangerous, is still an unpleasant guest of mammals, including men. Recent publications have clarified many details of its life story so that we are able to trace an almost complete picture of it.

From the egg there issues forth a small animal, not yet fully developed, for it lacks a pair of legs and sex organs. In this state it is already capable of attacking cold-blooded animals, such as lizards, whom it way-lays as it sits on the tip of a blade of grass. After shedding its skin several times, it acquires the missing organs, mates, and starts its hunt for warm-blooded animals.

After mating, the female climbs to the tip of a twig on some bush. There she clings at such a height that she can drop upon small mammals that may run under her, or be brushed off by larger animals.

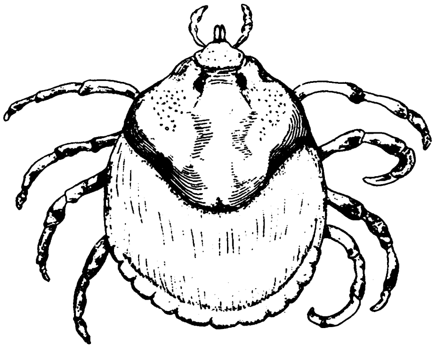


Figure 1. *Tick*

The eyeless tick is directed to this watchtower by a general photosensitivity of her skin. The approaching prey is revealed to the blind and deaf highway woman by her sense of smell. The odor of butyric acid, that emanates from the skin glands of all mammals, acts on the tick as a signal to leave her watchtower and hurl herself downwards. If, in so doing, she lands on something warm — a fine sense of temperature betrays this to her — she has reached her prey, the warm-blooded creature. It only remains for her to find a hairless spot. There she burrows deep into the skin of her prey, and slowly pumps herself full of warm blood.

Experiments with artificial membranes and fluids other than blood have proved that the tick lacks all sense of taste. Once the membrane is perforated, she will drink any fluid of the right temperature.

If after the stimulus of butyric acid has functioned, the tick falls upon something cold, she has missed her prey and must again climb to her watchtower.

The tick's abundant blood repast is also her last meal. Now there is nothing left for her to do but drop to earth, lay her eggs and die.

The tick's life history provides support for the validity of the biological versus the heretofore customary physiological approach. To the physiologist, every living creature is an object that exists in his human world. He investigates the organs of living things and the way they work together, as a technician would examine a strange machine. The biologist, on the other hand, takes into account each individual as a subject, living in a world of its own, of which it is the center. It cannot, therefore, be compared to a machine, but only to the engineer who operates the machine. If we ask whether the tick is a machine or an operator, a mere object or a subject, the physiologist will reply that he finds receptors, that is, sense organs, and effectors, that is, organs of action, connected by an integrating device in the central nervous system. He finds no trace of an operator.

To this the biologist will reply, 'You mistake the character of the organism completely. No single part of the tick's body has the nature of a machine; everywhere operators are at work'. The physiologist will continue, undeterred, 'We can show that all the actions of the tick are reflex[2] in character and the reflex arc is the foundation of all animal machines (Fig. 2). It begins with a receptor, which admits only certain influences such as butyric acid and warmth, and screens out all others. It ends with a muscle which moves an effector, a leg or proboscis. The sensory cells that initiate the nervous excitation and the motor cells that elicit the motor impulse serve only as connecting links to transmit the entirely physical waves of excitation (produced in the nerves by the receptor upon external stimulation) to the muscles of the effectors. The entire reflex arc works by transfer of motion, as does any machine. No subjective factor, no engineer or engineers appear anywhere in this process'.

'On the contrary,' the biologist will counter, 'we meet the operator everywhere, not merely machine parts. For all the cells of the reflex arc are concerned, not with the transfer of motion, but with the transfer of the *stimulus*. And the stimulus must be "perceived" by a subject; it does not occur in objects'. Any machine part, such as the clapper of a bell, produces its effect only if it is swung back and forth in a certain manner. To all other agents, such as cold, heat, acids, alkalies, electric currents, it responds as would any other piece of metal. The action of living organs is fundamentally different from this. Since the time of Johannes Müller we know that a muscle responds to all external agents in one and the same way — by contraction. It transforms all external interference into the same effective stimulus, and responds to it with the same impulse, resulting in contraction. Johannes Müller showed also that all external influences affecting the optic nerve, whether ether waves, pressure, or electric currents, elicit a sensation of light. Our visual sensory cells produce the same perception whatever the source of stimulation. From this we may conclude that each living cell is an engineer who perceives and acts, and has *perceptual or receptor* signs (*Merkzeichen*) and impulses or

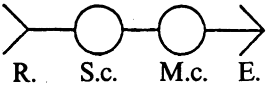


Figure 2. *Reflex arc.* R. *Receptor*; S.c. *Sensory cell*; M.c. *Motor cell*; E. *Effector*

effector signs (*Wirkzeichen*) which are specific to it. The manifold perceiving and acting of the whole animal may thus be reduced to the cooperation of all the tiny cells, each of which commands only one receptor sign and one effector sign.

In order to achieve an orderly collaboration, the organism uses the brain cells (these, too, are elementary mechanics) and groups half of them as 'receptor cells' in the stimulus-receiving part of the brain, or 'perceptive organ', into smaller or larger clusters. These clusters correspond to groups of external stimuli, which approach the animal in the form of questions. The other half of the brain cells is used by the organism as 'effector cells' or impulse cells, and is grouped into clusters with which it controls the movements of the effectors. These impart the subject's answers to the outer world. The clusters of receptor cells fill the 'receptor organs' (*Merkorgan*) of the brain, and the clusters of effector cells make up the contents of its 'effector organs' (*Wirkorgan*).

The individual cells of the perceptor organ, whatever their activity, remain as spatially separate units. The units of information which they separately convey would also remain isolated, if it were not possible for them to be fused into new units which are independent of the spatial characters of the receptor organ. This possibility does, in fact, exist. The receptor signs of a group of receptor cells are combined outside the receptor organ, indeed outside the animal, into units that become the properties of external objects. This projection of sensory impressions is a self-evident fact. All our human sensations, which represent our specific receptor signs, unite into perceptual cues (*Merkmal*) which constitute the attributes of external objects and serve as the real basis of our actions. The sensation 'blue' becomes the 'blueness' of the sky; the sensation 'green,' the 'greenness' of the lawn. These are the cues by which we recognize the objects: blue, the sky; green, the lawn.

A similar process takes place in the effector organ. The isolated effector cells are organized into well-articulated groups according to their effector signs or impulses. The isolated impulses are coordinated into units, and these self-contained motor impulses or rhythmical impulse melodies act upon the muscles subordinated to them. And the limbs or other organs activated by the separate muscles imprint upon the external objects their effector cue or functional significance (*Wirkmal*).

Figuratively speaking, every animal grasps its object with two arms of a forceps, receptor, and effector. With the one it invests the object with a receptor cue or perceptual meaning, with the other, an effector cue or operational meaning. But since all of the traits of an object are structurally interconnected, the traits given operational meaning must affect those bearing perceptual meaning through the object, and so change the object itself. This is best expressed briefly as: *The effector cue or meaning extinguishes the receptor cue or meaning.*

Beside the selection of stimuli which the receptors let through, and the arrangement of muscles which enables the effectors to function in certain ways, the most decisive factor for the course of any action is the number and arrangement of receptor cells which, with the aid of their receptor signs, furnish the objects of the *Umwelt* with receptor cues, and the number and arrangement of effector cells which, by means of their effector signs, supply the same objects with effector cues.

The object participates in the action only to the extent that it must possess certain qualities that can serve as perceptual cue-bearers on the one hand and as functional cue-bearers on the other; and these must be linked by a connecting counterstructure.

The relations between subject and object are best shown by the diagram of the functional cycle (Fig. 3). This illustrates how the subject and the object are dovetailed into one another, to constitute a systematic whole. If we further consider that a subject is related to the same or to different objects by several functional cycles, we shall gain insight into the first principle of *Umwelt* theory: all animals, from the simplest to the most complex, are fitted into their unique worlds with equal completeness. A simple world corresponds to a simple animal, a well-articulated world to a complex one.

And now let us set into the schema of the functional cycle, the tick as subject, and the mammal as her object. It shows at a glance that three functional cycles follow each other in well-planned succession. The skin glands of the mammal are the bearers of perceptual meaning in the first cycle, since the stimulus of butyric acid releases specific receptor signs in the tick's receptor organ, and these receptor signs are projected outside as an olfactory cue. By induction (the nature of which we do not know)

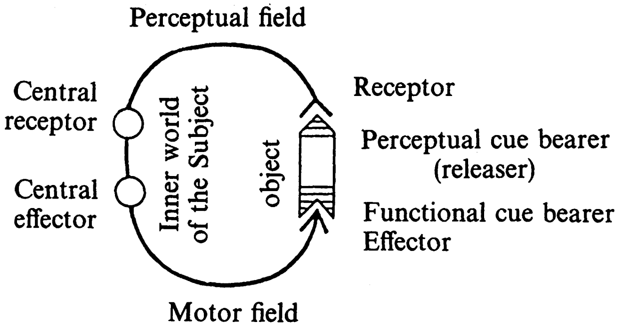


Figure 3. *Functional cycle*

the processes that take place in the receptor organ initiate corresponding impulses in the effector organ, and these impulses induce the tick to let go with her legs and drop. The tick, falling on the hairs of the mammal, projects the effector cue of shock onto them. This in turn releases a tactile cue, which extinguishes the olfactory stimulus of the butyric acid. The new receptor cue elicits running about, until it in turn is replaced by the sensation of heat, which starts the boring response.

We are admittedly confronted here with three successive reflexes. Each is elicited by objectively demonstrable physical or chemical stimuli. But anyone who is content with this statement and assumes that it solves the problem proves only that he has not grasped the basic question. We are not concerned with the chemical stimulus of butyric acid, any more than with the mechanical stimulus (released by the hairs), or the temperature stimulus of the skin. We are concerned solely with the fact that, out of the hundreds of stimuli radiating from the qualities of the mammal's body, only three become the bearers of receptor cues for the tick. Why just these three and no others?

What we are dealing with is not an exchange of forces between two objects, but the relations between a living subject and its object. These occur on an altogether different plane, namely, between the receptor sign of the subject and the stimulus from the object.

The tick hangs motionless on the tip of a branch in a forest clearing. Her position gives her the chance to drop on a passing mammal. Out of the whole environment, no stimulus affects her until a mammal approaches, whose blood she needs before she can bear her young.

And now something quite wonderful happens. Of all the influences that emanate from the mammal's body, only three become stimuli, and those in a definite sequence. Out of the vast world which surrounds the tick, three stimuli shine forth from the dark like beacons, and serve as guides to lead her unerringly to her goal. To accomplish this, the tick, besides her body with its receptors and effectors, has been given three receptor signs, which she can use as sign stimuli. And these perceptual cues prescribe the course of her actions so rigidly that she is only able to produce corresponding specific effector cues.

The whole rich world around the tick shrinks and changes into a scanty framework consisting, in essence, of three receptor cues and three effector cues — her *Umnwelt*. But the very poverty of this world guarantees the unfailing certainty of her actions, and security is more important than wealth.

From the example of the tick we can deduce the basic structural traits of the *Umwelt*, which are valid for all animals. However, the tick possesses another most remarkable faculty, which affords a further insight into these worlds.

The lucky coincidence which brings a mammal under the twig on which the tick sits obviously occurs very rarely. Nor does the large number of ticks ambushed in the bushes balance this drawback sufficiently to ensure survival of the species. To heighten the probability of a prey coming her way, the tick's ability to live long without food must be added. And this faculty she possesses to an unusual degree. At the Zoological Institute in Rostock, ticks who had been starving for eighteen years have been kept alive.[3] A tick can wait eighteen years. That is something which we humans cannot do. Our time is made up of a series of moments, or briefest time units, within which the world shows no change. For the duration of a moment, the world stands still. Man's moment last 1/18 of a second.[4] We shall see later that the length of a moment varies in different animals. But whatever number we wish to adopt for the tick, the ability to endure a never-changing world for eighteen years is beyond the realm of possibility. We shall therefore assume that during her period of waiting the tick is in a sleepless state, of the sort that interrupts time for hours in our case, too. Only in the tick's world, time, instead of standing still for mere hours, stops for many years at a time, and does not begin to function again until the signal of butyric acid arouses her to renewed activity.

What have we gained by realizing this? Something extremely significant. Time, which frames all happening, seems to us to be the only objectively stable thing in contrast to the colorful change of its contents, and now we see that the subject sways the time of his own world. Instead of saying, as heretofore, that without time, there can be no living subject, we shall now have to say that without a living subject, there can be no time.

In the next chapter we shall see that the same is true of space: without a living subject, there can be neither space nor time. With this, biology has ultimately established its connection with the doctrine of Kant, which it intends to exploit in the *Umwelt* theory by stressing the decisive role of the subject.

Space in the *Umwelt*

Like a gourmet who picks the raisins out of a cake, the tick has selected butyric acid alone from among the things in her environment. We are not interested in knowing what taste sensations the raisins give the gourmet. We are interested solely in the fact that the raisins become sign stimuli in his world, because they have special biological meaning for him. Nor do we ask how butyric acid smells or tastes to the tick; we merely register the fact that butyric acid, because it is biologically meaningful to the tick, becomes a receptor cue for her.

Suffice it to say that in the tick's receptor organ there must be receptor cells which send out their signs, as we assume that the gourmet's receptor cells send out theirs. The tick's receptor signs give the stimulus of butyric acid a meaning in her own world, by transforming it into a perceptual cue, as the gourmet's receptor signs give the raisin stimulus a meaning in his world.

The *Umwelt* of any animal that we wish to investigate is only a section carved out of the environment which we see spread around it — and this environment is nothing but our own human world. The first task of *Umwelt* research is to identify each animal's perceptual cues among all the stimuli in its environment and to build up the animal's specific world with them. The raisin stimulus leaves the tick quite cold, whereas the indication of butyric acid is of eminent importance to her. In the gourmet's world, on the other hand, the stimulus of raisins, not of butyric acid, is accented.

As the spider spins its threads, every subject spins his relations to certain characters of the things around him, and weaves them into a firm web which carries his existence.

Whatever the relations between a subject and the objects in his environment, they always take effect outside the subject, and that is where we must look for the perceptual cues. In some way, therefore, these are spatially fixed and, since they follow each other in a certain sequence, they are time-bound as well.

We are easily deluded into assuming that the relationship between a foreign subject and the objects in his world exists on the same spatial and temporal plane as our own relations with the objects in our human world. This fallacy is fed by a belief in the existence of a single world, into which all living creatures are pigeonholed. This gives rise to the widespread conviction that there is only one space and one time for all living things. Only recently have physicists begun to doubt the existence of a universe with a space that is valid for all beings. That such a space cannot exist is evident from the fact that all men live in three distinct spaces, which interpenetrate and complement, but in part also contradict one another.

Operational space

When we move our limbs freely with our eyes shut, we know the exact direction and extent of these motions. Our hands trace paths in a space called our *motor sphere*, or our *effector space*. We measure all these paths by infinitesimal units, which we shall call *directional steps*, since we know the direction of each step perfectly, through kinesthetic sensations or *direction signs*. We distinguish six directions, or three pairs of opposites: right and left, up and down, forward and backward.

Comprehensive experiments have shown that the shortest steps which we can measure with the index finger of an outstretched arm are of about 2 cm. These steps evidently do not provide a very precise measurement for the space in which they are taken. Anyone may easily find out how inaccurate they are by trying to bring together the forefingers of both hands with his eyes closed. He will find that the attempt usually fails, and they miss one another by anything up to 2 cm.

It is of the utmost importance to us that paths once traced are retained very easily. This is what makes writing in the dark possible. This faculty is called *kinesthesia*, a word that explains nothing.

However, effector space is not merely a motor space built up of a thousand intersecting directional steps. It contains and is ruled by a system of planes placed perpendicularly to one another, the familiar coordinate system, which is the basis of all spatial definitions.

It is imperative for anyone who deals with the problem of space to become aware of this fact. Nothing could be simpler. By holding one's hand vertically, at right angles to the forehead, and moving it right and left with eyes closed, the boundary between the two becomes obvious. It coincides approximately with the median plane of the body. By holding one's hand horizontally and moving it up and down in front of the face, the boundary between above and below can easily be ascertained. For most people, this boundary is at eye level, though many people locate it at the height of the upper lip. The boundary between in front and behind shows the greatest variation. It is found by holding up one's hand palm forward and moving it back and forth at the side of the head. Many people indicate this plane near the ear opening, others indicate the zygomatic arch as the border plane, and by some it is even placed in front of the tip of the nose. Every normal person carries around with him a coordinate system composed of these three planes and firmly connected with his head (Fig. 4), thus providing his operational space with a solid framework for his directional steps.

Into the changing throng of directional steps which, as motor elements, cannot give the effector space any solidity, the static planes introduce a firm scaffolding that ensures order in functional space.

Cyon's great contribution is that he traced the three-dimensional character of our space to a sense organ situated in the middle ear, the so-called semicircular canals (Fig. 5), whose position roughly corresponds

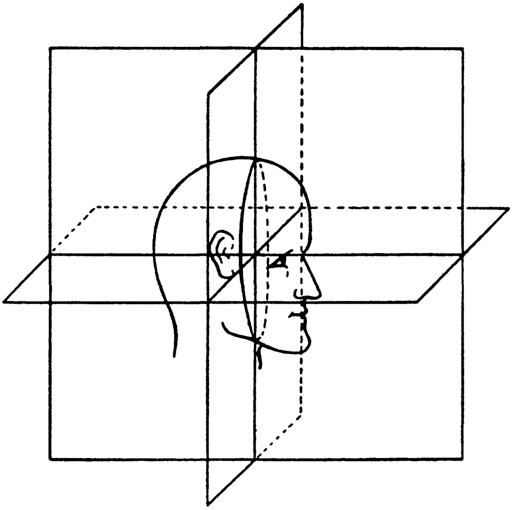


Figure 4. *The coordinate system of man*

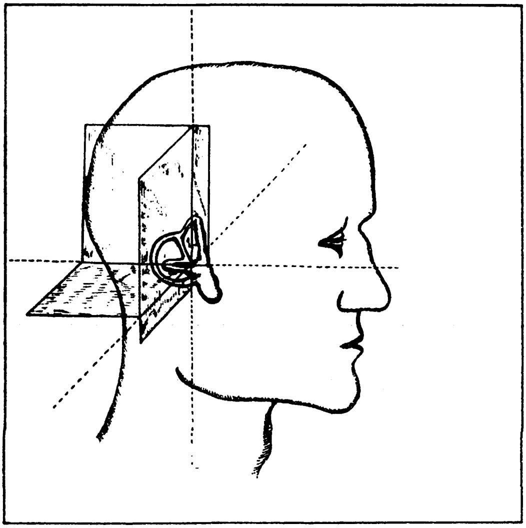


Figure 5. *The semicircular canals of man*

to the three planes of operational space. This relationship is so clearly proven by numerous experiments that we can make the assertion: all animals possessing the three canals also have a three-dimensional operational space.

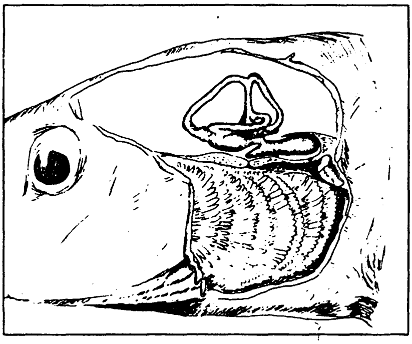


Figure 6. *The semicircular canals of a fish*

Figure 6 shows the semicircular canals of a fish. It is obvious that they must be of paramount importance to the animal. This is further evidenced by their internal structure, a tubular system in which a liquid moves under nervous control in the three spatial directions. The motion of the liquid faithfully reflects the movements of the whole body. This indicates that the organ has an added significance beyond projecting the three planes into the animal's effector space. It is apparently destined to act as a compass — not as a compass that always points to the North, but as a compass for the fish's own 'front door'. If all the movements of the whole body are analyzed and marked according to three directions in the canals, then the animal must be back at its starting point whenever it has reduced the nervous markings to zero as it moves about.

There is no doubt that a compass for the front door is a necessary implement for all animals with a fixed home, be it a nesting place or a spawning ground. Determination of the front door by visual cues in visual space is insufficient in most cases, since the entrance must be found even if its aspect has changed.

The ability to find their front door in a purely operational space can also be demonstrated in insects and molluscs, although these animals have no semicircular canals.

The following is a very convincing experiment. A beehive is shifted to a location of 2 meters from its original site while most of the bees have flown out. It will then be found that the bees gather in the air, at the spot where the flight hole — their front door — was previously located. Not until five minutes later do the bees turn and fly toward the hive.

In a later stage of these experiments, it was found that bees whose antennae were cut off immediately flew toward the hive in its new position. This means that their orientation is mainly operational only while they possess antennae. Without these, they orient themselves by optical impressions in visual space. In normal life, therefore, bees' antennae must somehow assume the role of a compass for the front door, which shows them the way home with greater certainty than do visual impressions.

Even more striking is the 'homing' of the snail, *Patella* (Fig. 7). *Patella* lives on the rocky ground between the zones of ebb and flood tides. The big specimens use their hard shells to scoop a bed out of the rock. Here they spend the time of ebb, pressed hard onto the rock. At high tide they begin to wander and graze over the rocks around them. As soon as the tide recedes, they return to their beds. In so doing, they do not always use the same route. The eyes of *Patella* are so primitive that with their aid alone the snail could never find its way home. It is equally unlikely that it could be guided by a scent cue. The only alternative left is to assume the existence of a compass in the animal's operational space, although we do not know its nature.

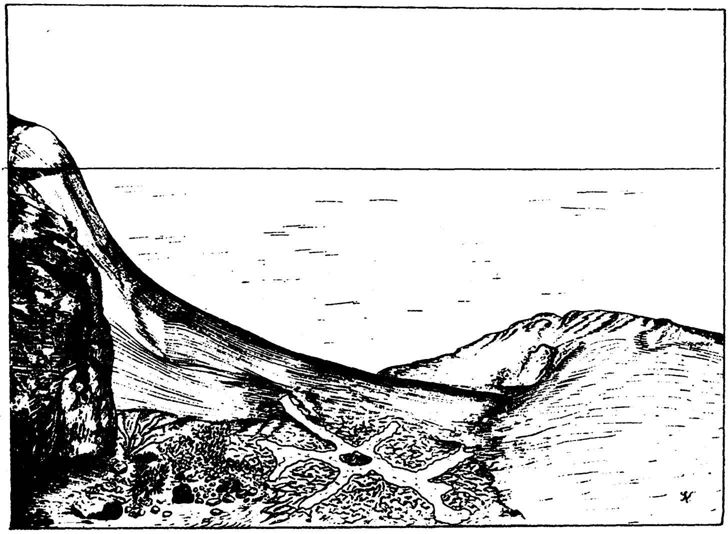


Figure 7. *Homing of the snail* Patella

Tactile space

In tactile space, the elementary structural unit is a stationary one: the *locus*, not a motor magnitude as is direction. Locus also owes its existence to a subjective receptor sign; it is not a configuration inherent in surrounding substances. This has been proved by Weber. If the points of a compass are placed on the nape of a subject's neck at a distance of more than 1 cm, the two are clearly distinguished. Each of them is in a different place. If they are now moved down the subject's back without changing the distance between them, they come closer and closer together in his tactile space, until they finally coincide.

It follows that, in addition to the receptor sign of tactile sensation, we also have receptor signs for location. These are called *local signs*. Each local sign, projected into the outside world, furnishes a *place* or *site* in tactile space. The skin surfaces that release the same local sign in us when touched, vary exceedingly in size, according to their importance in touch. Next to the tip of the tongue, which explores the oral cavity, the fingertips contain the smallest units and are therefore able to differentiate the largest number of places. When we finger an object, our exploring fingers cover its surface with a delicate mosaic of sensory units. The *place-mosaic* of objects in an animal's world, both in tactile and visual space, is given by the subject to the things in his *Umwelt*, and does not exist in his environment.

When fingering an object, the places or *loci* are combined with the directional units, and both serve to give it form.

In many animals, tactile space is of prime importance. Rats and cats remain quite unhampered in their motions even if they have lost their vision, so long as they have their tactile hairs. All nocturnal animals and all cave dwellers live primarily in tactile space, which represents a blending of places with orientational units.

Visual space

Eyeless animals who, like the tick, have a photosensitive skin probably have identical skin regions to produce local signs for both light stimuli and tactile stimuli. Visual and tactile *loci* coincide in their world.

Only in animals with eyes are visual and tactile space distinctly segregated. In the retina of the eye, very small elementary sections, the visual elements, lie close together. Each element of vision has a corresponding place in the *Umwelt*, since there is a local sign for each visual element.

Figure 8 illustrates the visual space of a flying insect. It is clear that, owing to the global structure of the eye, the section of the environment that reaches one visual element grows with increasing distance, and that ever more comprehensive parts of the environment are covered by one place. In consequence, objects receding from the eye become smaller and smaller, until they shrink to a single locus, at which point they vanish.

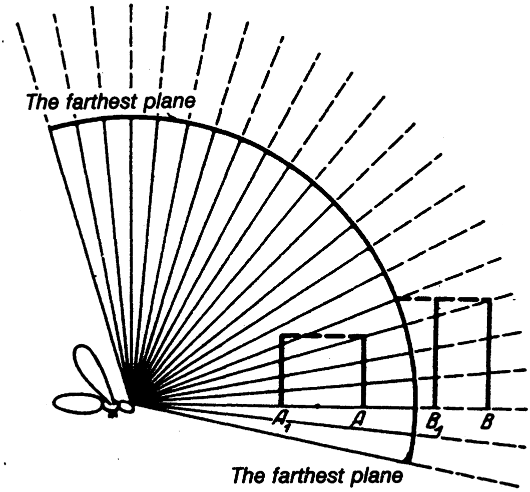


Figure 8. *The visual space of an insect in flight*

For the place or locus represents the smallest spatial vessel within which there are no differences.

In tactile space, objects do not grow smaller. And this is where visual and tactile space enter into conflict. A cup grasped with the outstretched arm and guided to the lips grows in visual space, but does not change its size in tactile space. In this case tactile space predominates, because an impartial observer does not see the cup grow.

The roving eye, like the feeling hand, spreads a subtle mosaic of places or sites over all the things in the subject's world. The delicacy of this mosaic depends on the number of visual elements which grasp the same sector of the environment.

Since the number of visual elements varies greatly in the eyes of different animals, the place-mosaics in their environments must differ correspondingly. The coarser the place-mosaic, the more details will be lost, and the world as seen through the eyes of a fly must appear considerably cruder than it does to the human eye.

Since any image can be transformed into a place-mosaic by superimposing a fine mesh or lattice on it, this method makes it possible to render the differences between the place-mosaics of various animal eyes.

By diminishing a picture more and more, photographing it again with the same lattice, and then re-enlarging it, we shall obtain a progressively coarser mosaic. Since the lattice photographed with the picture is disturbing, the coarser mosaic-images have been reproduced as water colors, without the lattice. Figures 9a to 9d were made by the lattice method.

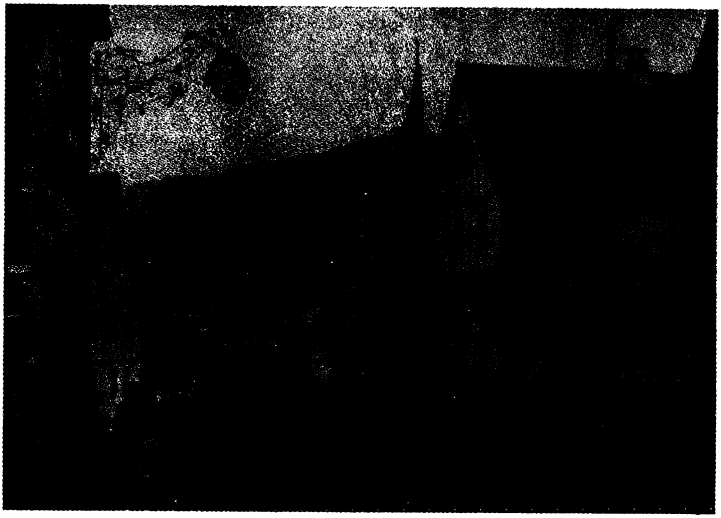


Figure 9a. *A village street, photograph*

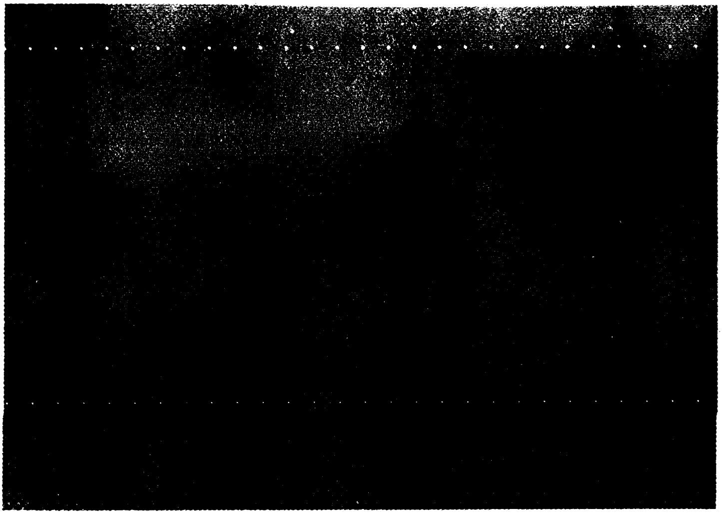


Figure 9b. *The same village street, photographed through a screen*

They enable us to gain insight into the world of an animal if we know the number of visual elements in its eye. Figure 9c corresponds roughly to the image furnished by the eye of a housefly. It is easy to see that in a world which contains so few details, the threads of a cobweb must

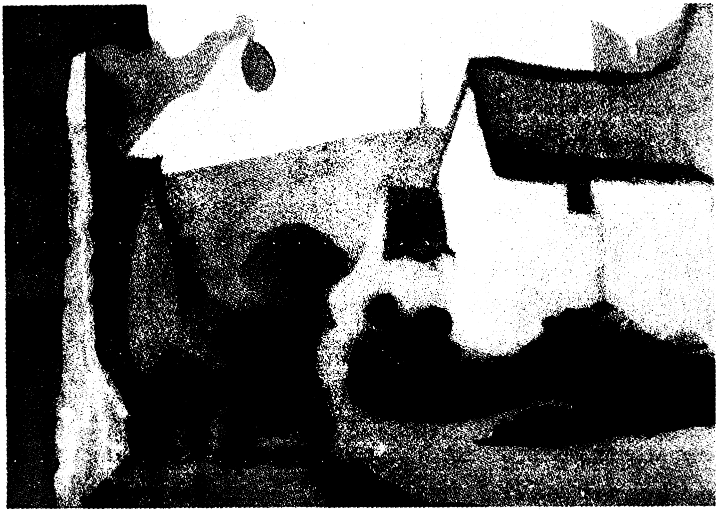


Figure 9c. *The same village street as seen by a fly*

Figure 9d. The same village street, seen by a mollusc

vanish completely, and we may say: the spider spins a web that remains totally invisible to its prey. Figure 9d corresponds approximately to the image registered by a mollusc eye. It shows that the visual space of snails and clams contains nothing beyond a number of light and dark areas.

In visual as in tactile space, connections between places are established by directional steps. When preparing an object under a reducing glass, which acts by condensing a large number of places onto a small area, we find that not only the eye, but also the hand which guides the dissecting needle, takes much smaller direction steps corresponding to the points that have been drawn close together.

The farthest plane

Unlike operational and tactile space, visual space is surrounded by an impenetrable wall, which we call the horizon or the farthest plane.

Sun, moon and stars wander without any difference in depth on the same most distant plane, which surounds all visible things. The location of the farthest plane is not rigidly fixed. When I took my first walk out of doors after a serious case of typhoid, the farthest plane hung down before me at a distance of about twenty meters, like a colorful tapestry on which all visible things were depicted. Beyond the twenty meters, there were no nearer and farther objects, only larger and smaller ones. Even the cars that drove past me did not become more remote, only smaller as soon as they reached the farthest plane.

The lens of the human eye has the same function as the lens of a photographic camera — namely, to focus the objects before it sharply onto the retina, which is the counterpart of the photosensitive plate. The lens of the human eye is elastic and can be bent by special ciliary muscles. This curving has the same effect as focusing the lens in a camera.

When the lens muscles are contracted, 'forward' directional signs appear. When the elastic lens distends the relaxing muscles, directional signs appear which signal 'backwards'. When the muscles are totally relaxed, the eye is set for a range of from ten meters to infinity.

Through the muscular movements, we recognize the things in our environment as being near or far within a radius of ten meters. Outside this orbit, objects at first become only larger or smaller. The infant's visual space ends here with a farthest plane that encompasses his entire world. Only gradually, step by step, do we learn to push back the most distant plane with the aid of distance signs, until, at a distance of 6 to 8 km., it sets a limit to the adult's visual space, too, and the horizon begins.

The difference between the visual spaces of a child and a grownup is portrayed in Figure 10, which reproduces an experience described by Helmholtz. He reports that as a little boy he was passing the Potsdam garrison church, and noticed some workmen on the gallery. Thereupon he asked his mother to reach down some of the little dolls for him.

Figure 10. *The farthest plane of a child and of an adult*

Church and workmen were already on his farthest plane, and so were not distant, but small. Thus he had every reason to believe that his mother could fetch the puppets down from the gallery with her long arm. He did not know that in his mother's world the church had altogether different dimensions and that the people on the gallery were not small, but far away. It is hard to decide where the farthest plane begins in the *Umwelt* of an animal, for it is difficult to determine experimentally at what point an object approaching the subject in his environment becomes nearer as well as larger in his specific world. Attempts at catching flies show that the approaching human hand makes them fly away only when it is about half a meter from them. Accordingly, it would seem justifiable to suppose that their farthest plane is at this distance.

But other observations suggest that the most remote plane also appears in other ways in the housefly's world. We know that flies do not simply circle around a hanging lamp or chandelier, but interrupt their flight abruptly whenever they have flown half a meter or so away, and then fly close by or under it again. This behavior is like that of a yachtsman who is anxious to stay within sight of an island.

Now the eye of a fly (Fig. 11) is built in such a way that its visual elements (rhabdoms) are long nerve configurations, which must intercept the image projected by their lenses at varying depths, depending on the distance of the object seen. Exner has surmised that we might here be dealing with a substitute for the muscular lens apparatus of the human eye. Assuming that the optic apparatus made up of the fly's visual elements functions as a portrait lens, the chandelier would vanish at a certain distance, and thus cause the fly to return. As an illustration of this phenomenon, compare Figures 12 and 13, which represent a chandelier photographed without and with a portrait lens.

Whether the farthest plane encloses visual space in this or another manner — it is always there. We may therefore picture all the animals around us, be they beetles, butterflies, flies, mosquitoes or dragonflies that people a meadow, enclosed within soap bubbles, which confine their visual space and contain all that is visible to them. Each soap bubble harbors different *loci*, and in each there exist the directional planes of operational space, which give its space a solid framework. The fluttering birds, the squirrels leaping from branch to branch, or the cows that

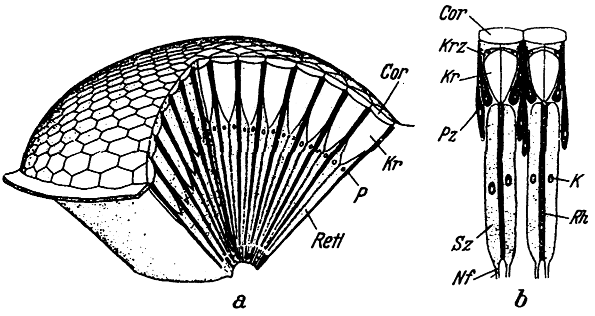


Figure 11. *Structure of the compound eye of a fly (schematic)*:
(a): *Whole eye, from which a section is dissected on the right (according to Hesse)*
(b): *Two ommatidia*
Cor: *Chitincornea*; K: *nucleus*; Kr: *crystalline lens*; Krz: *lens cell*; Nf: *nerve fiber*; P: *pigment*; *Retl: retinula*; Rh: *rhabdom*; Sz: *visual cell*

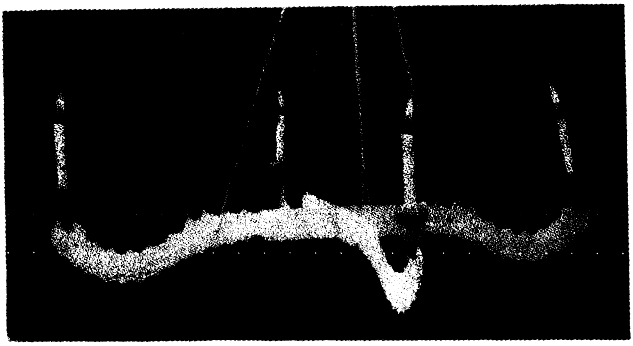


Figure 12. *Chandelier as seen by man*

Figure 13. *Chandelier as seen by fly*

browse in the meadows — all remain permanently surrounded by their soap bubbles, which define their own space.

Only when this fact is clearly grasped shall we recognize the soap bubble which encloses each of us as well. Then we shall also see all our fellow men in their individual soap bubbles, which intersect each other smoothly, because they are built up of subjective perceptual signs. There is no space independent of subjects. If we still cling to the fiction of an all-encompassing universal space, we do so only because this conventional fable facilitates mutual communication.

Receptor time

Karl Ernst von Baer has made it clear that time is the product of a subject. Time as a succession of moments varies from one *Umwelt* to another, according to the number of moments experienced by different subjects within the same span of time. A moment is the smallest indivisible time vessel, for it is the expression of an indivisible elementary sensation, the so-called *moment sign.* As already stated, the duration of a human moment amounts to 1/18 of a second. Furthermore, the moment is identical for all sense modalities, since all sensations are accomplished by the same moment sign.

The human ear does not discriminate eighteen air vibrations in one second, but hears them as one sound.

It has been found that eighteen taps applied to the skin within one second are felt as even pressure.

Kinematography projects environmental motions onto a screen at their accustomed tempo. The single pictures then follow each other in tiny jerks of 1/18 second.

If we wish to observe motions too swift for the human eye, we resort to slow-motion photography. This is a technique by which more than eighteen pictures are taken per second, and then projected at a normal tempo. Motor processes are thus extended over a longer span of time, and processes too swift for our human time-tempo (of 18 per second), such as the wing-beat of birds and insects, can be made visible. As slow-motion photography slows motor processes down, the time contractor speeds them up. If a process is photographed once an hour and then presented at the rate of 1/18 second, it is condensed into a short space of time. In this way, processes too slow for our human tempo, such as the blossoming of a flower, can be brought within the range of our perception.

The question arises whether there are animals whose perceptual time consists of shorter or longer moments than ours, and in whose *Umwelt* motor processes are consequently enacted more slowly or more quickly than in ours.

The first experiments of this kind were made by a young German scientist. Later, with the collaboration of another, he studied especially the reaction of the fighting fish to its own mirror image. The fighting fish does not recognize its own reflection if it is shown him eighteen times per second. It must be presented to the fighting fish at least thirty times per second. A third student trained the fighting fish to snap toward their food if a gray disc was rotated behind it. On the other hand, if a disc with black and white sectors was turned slowly, it acted as a 'warning sign', for in this case the fish received a light shock when they approached their food. After this training, if the rotation speed of the black and white disc was gradually increased, the avoiding reactions became more uncertain at a certain speed, and soon thereafter they shifted to the opposite. This did not happen until the black sectors followed each other within 1/50 second. At this speed the black-and-white signal had become gray. This proves conclusively that in the world of these fish, who feed on fast-moving-prey, all motor processes — as in the case of slow-motion photography — appear at reduced speed.

An instance of time contraction is given in Figure 14, borrowed from the above-mentioned work. A vineyard snail is placed on a rubber ball which, carried by water, slides under it without friction. The snail's shell is held in place by a bracket. Thus the snail, unhampered in its crawling movements, remains in the same place. If a small stick is then moved up to its foot, the snail will climb up on it. If the snail is given one to three taps with the stick each second, it will turn away, but if four or more taps are administered per second, it will begin to climb onto the stick. In the snail's world a rod that oscillates four times per second has become stationary. We may infer from this that the snail's receptor time moves at a tempo of three to four moments per second. As a result, all motor processes in the snail's world occur much faster than in ours. Nor do its own motions seem slower to the snail than ours do to us.

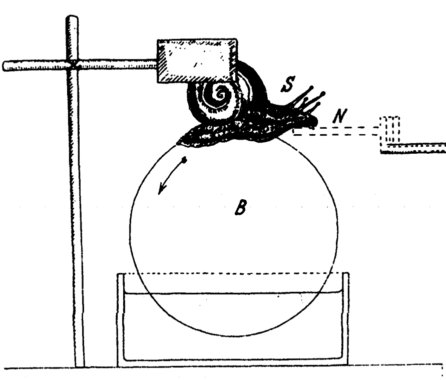


Figure 14. *The snail's movement*:
B: *ball*; E: *eccentric wheel*; N: *rod*; S: *snail*

The simple *Umwelten*

Space and time are of no immediate use to the subject. They become significant only when numerous receptor cues, which would vanish without the temporal and spatial framework of the *Umwelt*, must be discriminated. In very simple *Umwelten*, however, which harbor but a single perceptual cue, there is no need for a framework of this kind.

In Figure 15, the environment and the *Umwelt* of the *Paramecium* are shown side by side. *Paramecium* is covered with dense rows of cilia, whose lashing drives it swiftly through the water, while it revolves continually on its longitudinal axis. Of all the different things in its environment, its *Umwelt* takes in only the ever-identical receptor cue which, whenever, wherever, and however the *Paramecium* is stimulated, impels it to the motion of escape. The same obstacle cue always elicits the same fleeing reaction. This consists of a backward motion, followed by a lateral deflection, whereupon the animal again begins to swim forward. By this, the obstacle is removed. We may say that in this case the same receptor

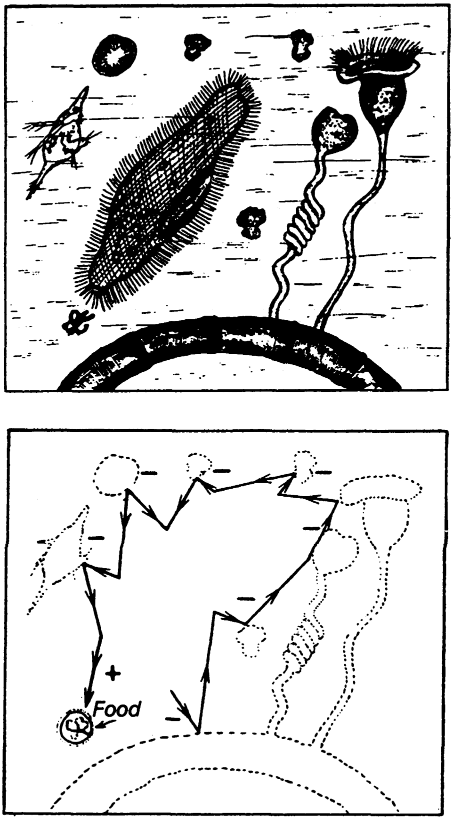


Figure 15. *Environment and* Umwelt *of the* Paramecium

cue is always extinguished by the same effector cue. The small animal comes to rest only when it reaches its food, the bacteria of putrefaction, which alone of all things in its world do not emit stimuli. These facts show how nature is able to fashion life according to her plan, with a single functional cycle.

A few multicellular animals, such as the marine medusa *Rhizostoma*, are also able to get along with a single functional cycle. Here the entire organism consists of a swimming pump mechanism, which draws the plankton-filled sea water into itself unfiltered, and ejects it again, filtered. The sole manifestation of life consists in the rhythmic up-and-down swinging of the elastic umbrella. The ever-constant pulsation keeps the animal floating on the surface of the ocean. At the same time the stomach distends and contracts alternately, driving the sea water in and out through fine pores. The liquid content of the stomach is propelled through labyrinthine digestive canals, whose walls absorb the nourishment and the accompanying oxygen. Swimming, feeding, and breathing are carried out by the same rhythmic contraction of the muscles on the edge of the umbrella. To ensure continuity of this motion, eight bell-shaped organs are located on the periphery of the umbrella (represented symbolically in Fig. 16), whose clappers strike a nerve end at each beat. The stimulus thus produced elicits the next umbrella-beat. In this way the medusa gives herself her own effector cue, and this releases the same receptor cue, which again elicits the same effector cue *ad infinitum*. In the medusa's world, the same bell signal rings all the time, and dominates the rhythm of life. All other stimuli are cut off.

In the case of a single functional cycle, as in *Rhizostoma*, we can speak of a reflex animal, for the same reflex runs all the time from each bell to the muscular band at the umbrella's edge. Moreover, the term may even be extended to animals with several reflex arcs, such as other medusae, so long as these reflex arcs remain mutually independent. Thus there are medusae which have tentacles with self-contained reflex arcs. Moreover, many medusae have a mobile mouth (*manubrium*) with a muscular system of its own, which is connected to the receptors on the umbrella's edge. All these reflex arcs operate quite independently and are not directed by a central organ.

An external organ that contains a complete reflex arc is aptly termed a *reflex person*. Sea urchins possess a large number of such reflex persons, each of which performs its own reflex function by itself, without central control. To illustrate the contrast between animals built in this way and higher animals, I have coined the phrase: when a dog runs, the animal moves its legs; when a sea urchin runs, the legs move the animal.

Sea urchins, like porcupines, carry a large number of spines which,

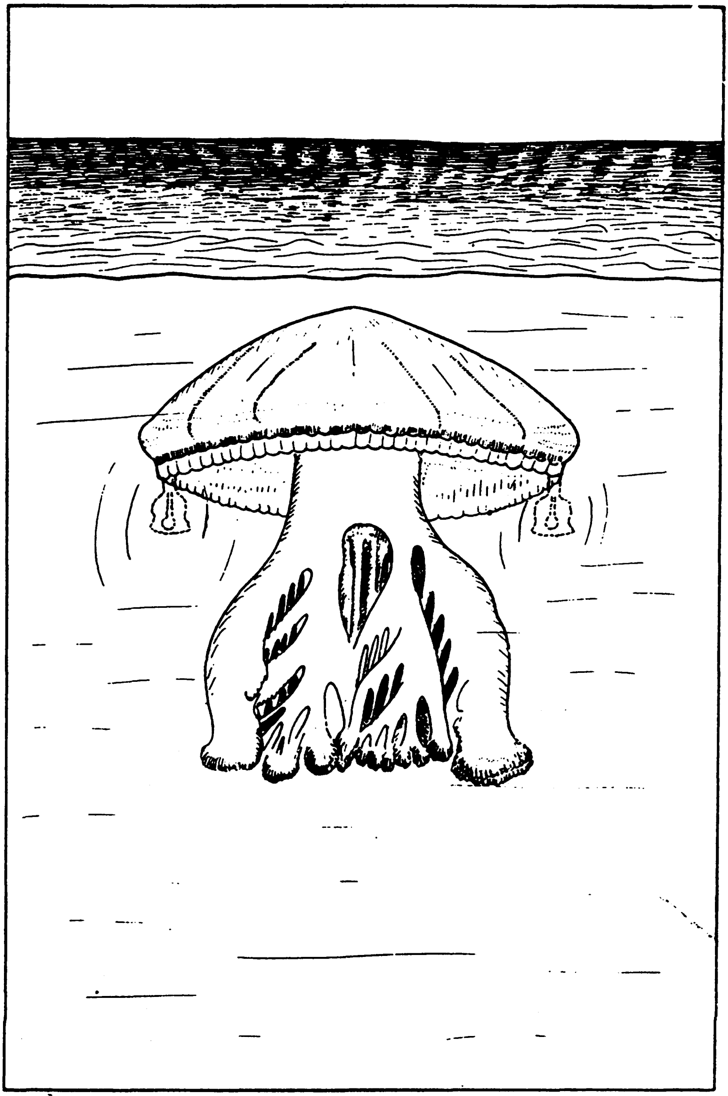


Figure 16. *A marine medusa with peripheral organs*

however, are developed as independent reflex persons. Besides the hard, pointed spines, which are attached to the lime shell by means of a ball bearing and are able to turn a forest of spears against any stimulus-emitting object that approaches the skin, there are delicate, long, muscular tube-feet for climbing. Furthermore, certain sea urchins have four kinds of claws (cleaning claws, clapping claws, snapping claws, and poison claws or *pedicellariae*) scattered over their surface.

Although some of these reflex persons act in unison, they work quite independently of each other. Thus in response to one and the same chemical stimulus emitted by the sea urchin's enemy, the starfish, the spines part, the poison fangs spring forth in their stead and bury themselves in the enemy's suction feet.

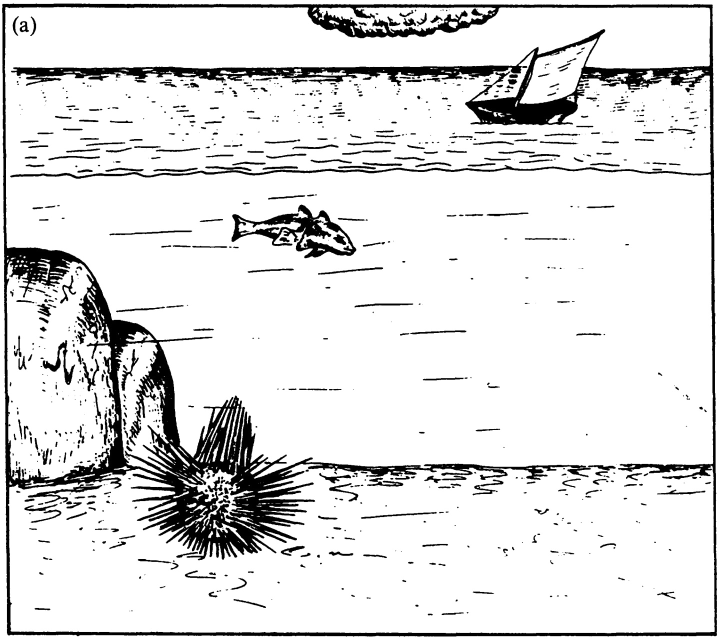
We may therefore refer to a *reflex republic* in which, despite the utter independence of each reflex person, absolute domestic peace reigns. For the tender tube-feet are never attacked by the sharp snapping fangs, which normally seize every approaching object. This peace is not dictated by a central organization, as in our case, where our sharp teeth are a constant danger to the tongue, avoided only by the appearance of the receptor signal of pain in the central organ. For pain inhibits the pain-eliciting action. In a sea-urchin's reflex republic, which has no superior center, domestic peace must be secured differently. It is achieved by the presence of autodermin, a substance secreted by the skin. Undiluted, autodermin lames the receptors of the reflex persons. It is diffused throughout the skin in such great dilution that, upon contact of the skin with a foreign body, it remains ineffective. As soon as two skin surfaces meet, however, it becomes effectual and prevents release of the normal reflex of snapping by the *pedicellariae*.

A reflex republic such as a sea urchin may well have numerous receptor cues in its *Umwelt*, if it consists of numerous reflex persons. But these receptor cues must remain completely cut off from each other, since each functional cycle operates in utter seclusion.

The tick's life manifestations, as we have seen, consist substantially of three reflexes. Even this represents a superior type of organism, since the functional cycles, instead of using these isolated reflex arcs, have a common receptor organ. In the tick's world the prey may therefore possibly exist as an entity, even though consisting only of butyric acid stimulus, tactile stimulus and heat stimulus.

For the sea urchin, this possibility does not exist. Its receptor cues, which are composed of graduated pressure stimuli and chemical stimuli, constitute totally isolated magnitudes.

Some sea urchins respond to any darkening of the horizon by a movement of spines which, as shown in Figures 17a and b, is displayed equally toward a cloud, a ship, and the real enemy, namely, a fish. Even so, our representation of its *Umwelt* is not sufficiently simplified. We cannot think in terms of the sea urchin projecting the receptor cue of darkness outward into space, since it has no visual space. What actually



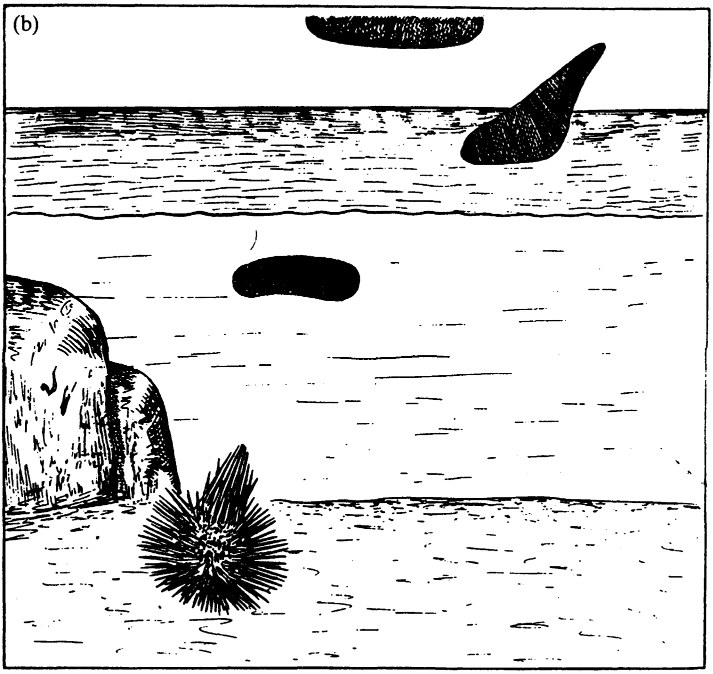


Figure 17a. *The sea urchin's environment*

Figure 17b. *The sea urchin's* Umwelt

happens is better conveyed by the analogy of a wad of cotton passing lightly over its photosensitive skin.

Form and motion as perceptual cues

Even supposing that each receptor cue of the various reflex persons is provided with a local sign and that thus each is in a separate place in the sea urchin's world, it would still be impossible to join these *loci*. Consequently this *Umwelt* must of necessity lack the receptor cues of form and motion, which presuppose a combination of several places.

Form and motion appear only in higher perceptual worlds. Now, thanks to experiences in our own world, we generally assume that the shape of an object is the receptor cue originally given, and that motion is added only as an attendant phenomenon, a secondary receptor cue. However, for many animal worlds this is not true. Not only are static form and moving form two mutually quite independent receptor cues, but motion may even appear as an independent receptor cue, without form.

Figure 18 shows the jackdaw on the hunt for grasshoppers. It simply cannot see a sitting grasshopper. The jackdaw does not snap after it unless it hops. One is at first inclined to suppose that the jackdaw is familiar with the form of the grasshopper in repose, but that owing to the intersecting blades of grass it cannot recognize the grasshopper as an entity, as we have difficulty in finding a familiar form in a puzzle picture. According to this hypothesis, the form only separates from the interfering subsidiary images at the time of the jump.

In the light of further observation, however, we may assume that the jackdaw does not know the form of the stationary grasshopper at all, but is adapted to the moving form only. This would explain the 'death-

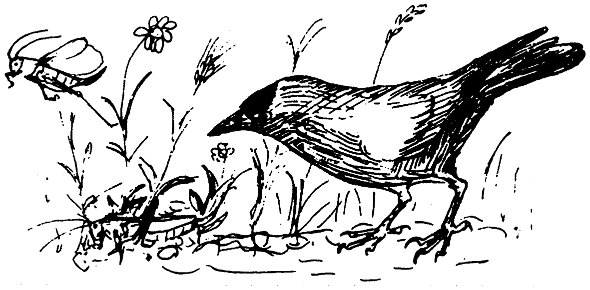


Figure 18. *Jackdaw and grasshopper*

feigning' reaction of many insects. If their static form does not exist in the perceptual world of the pursuing enemy, then by 'pretending to be dead' they disappear entirely from their enemy's sensory world and cannot even be found if sought.

I have built a 'fly rod' consisting of a small stick from which a pea is suspended on a thin thread. The pea is covered with a sticky gum. If by a slight motion of the stick the pea is swung back and forth in front of a sunny window sill on which a number of flies are sitting, many of them will invariably throw themselves on the pea, and some will remain stuck to it. These are always males. The whole process represents a misdirected nuptial flight. The flies circling around a chandelier, too, are males lunging at females flitting by. The swinging pea deceptively imitates the perceptual cue of the female in flight. In repose it is never taken for a female. We may well conclude from this that static female and female in flight are two different receptor cues.

Figure 19 proves that motion without form can feature as a perceptual cue. It presents the scallop in its environment and in its *Umwelt*. In its environment, within range of its hundred eyes, is the scallop's most dreaded enemy, the starfish, *Asterias*. So long as the starfish is at rest, it affects the scallop not at all. The starfish's characteristic form is no sensory cue for the scallop. As soon as the starfish moves, however, the scallop responds by pushing out its long tentacles, which act as olfactory organs. They approach the starfish and receive the new stimulus. Thereupon the scallop rises and swims away.

Experiments have shown that shape and color of a moving object are wholly indifferent. The object appears as a perceptual cue in the scallop's world only if its motion is as slow as that of the starfish. The scallop's eyes are not set for either form or color but solely for a certain motor tempo, which corresponds exactly to that of its enemy. However, even this does not characterize the enemy precisely enough. First, a scent cue must intervene, to elicit the second functional cycle, which removes the scallop by flight from the vicinity of its enemy, and by this effector cue conclusively extinguishes the enemy's receptor cues.

The existence of a receptor cue for form was long surmised in the *Umwelt* of the earthworm. Darwin early pointed out that earthworms handle both leaves and pine needles according to their shapes (Fig. 20). The earthworm drags leaves and pine needles into its narrow cave. They serve it both for protection and for food. Most leaves spread out if one tries to pull them into a narrow tube petiole foremost. On the other hand, they roll up easily and offer no resistance if seized at the tip. Pine needles, on the other hand, which always fall in pairs, must be grasped at their base, not their tip, if they are to be dragged into a narrow hole with ease.

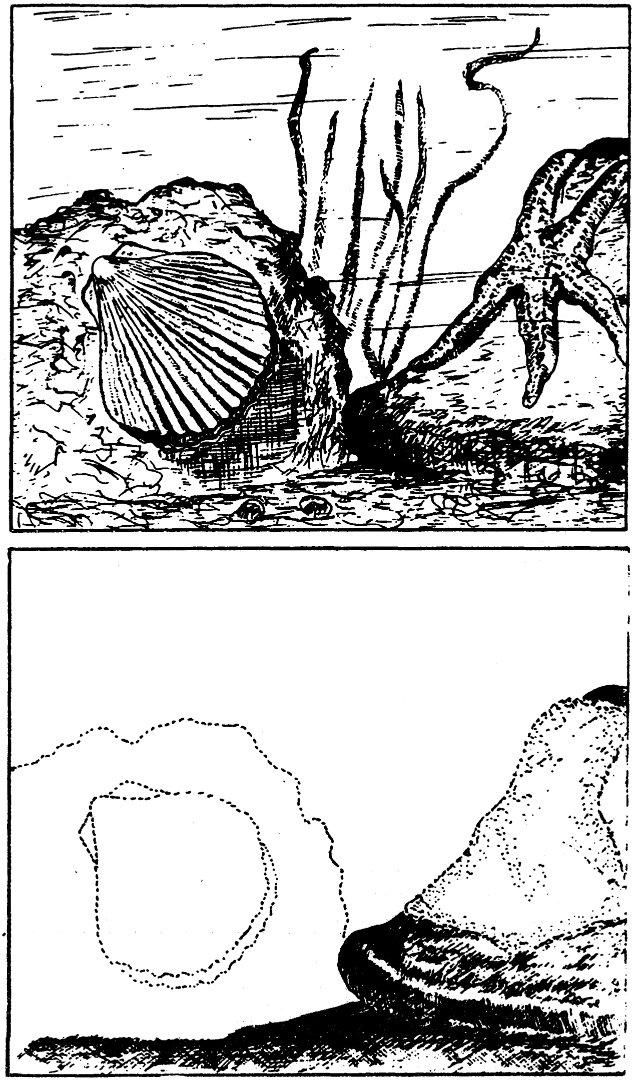


Figure 19. *Environment and* Umwelt *of the scallop*

It was inferred from the earthworm's spontaneously correct handling of leaves and needles that the form of these objects, which plays a decisive part in its effector world, must exist as a receptor cue in its perceptual world.

This assumption has been proven false. It was possible to show that identical small sticks dipped in gelatine were pulled into the earthworms'

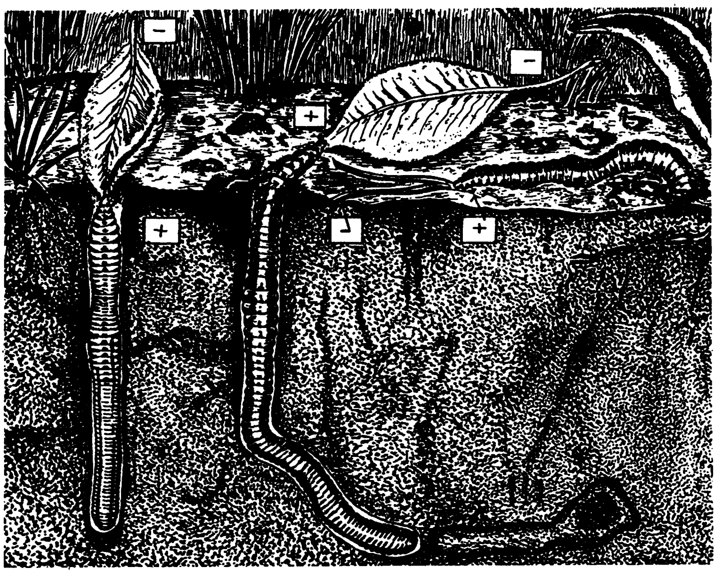


Figure 20. *Taste discrimination in earthworms*

holes indiscriminately by either end. But as soon as one end was covered with powder from the tip of a dried cherry leaf, the other with powder from its base, the earthworms differentiated between the two ends of the stick exactly as they do between the tip and base of the leaf itself. Although earthworms handle leaves in keeping with their form, they are guided not by the shape but by the taste of the leaves. This arrangement has evidently been adopted for the reason that the receptor organs of earthworms are built too simply to fashion sensory cues of shape. This example shows how nature is able to overcome difficulties which to us seem utterly insurmountable.

Thus the hypothesis of form perception in earthworms had to be abandoned. It became even more urgent to answer the question: what are the lowest animals in whose *Umwelt* we may expect to find form as a perceptual cue?

This question has since been solved. It has been possible to show that bees alight by preference on figures that exhibit broken forms, such as stars and crosses, whereas they avoid compact forms, such as circles and squares. Figure 21, which was designed on this basis, contrasts a bee's environment with its *Umwelt*. The bee is seen in its environment, a blooming field, in which blossoming flowers alternate with buds. If we put ourselves in the bee's place and look at the field from the point of

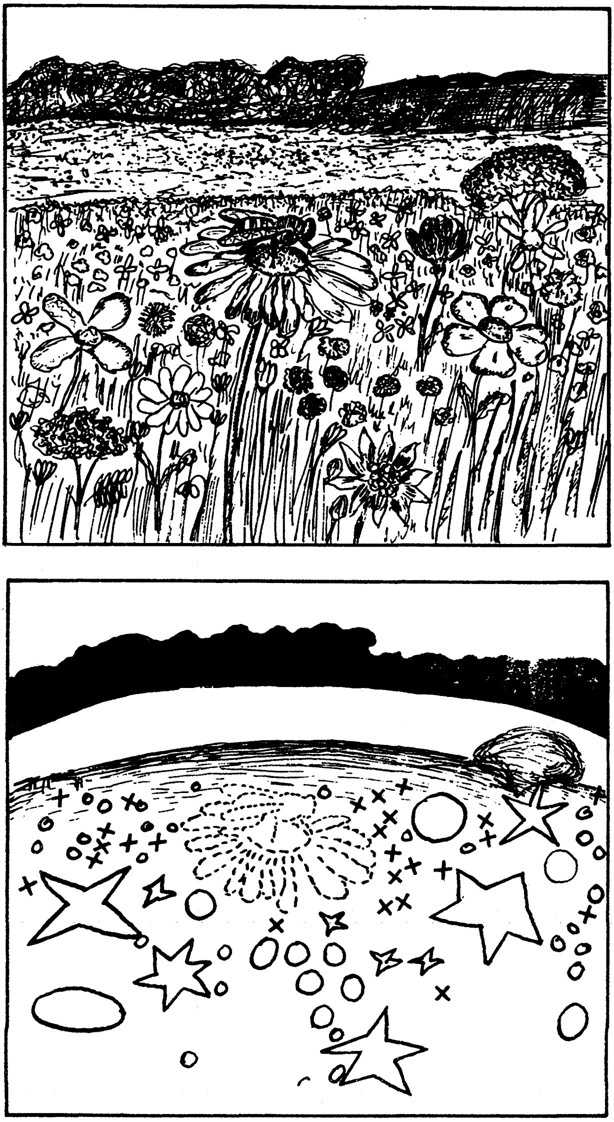


Figure 21. *Environment and* Umwelt *of the honey bee*

view of its *Umwelt*, the blossoms are changed to stars or crosses according to their form, and the buds assume the unbroken shape of circles. The biological significance of this newly discovered quality in bees is evident. Only blossoming flowers have a meaning for them; buds do not.

Now, as we saw in the case of the tick, relations of meaning are the only true signposts in our exploration of *Umwelten*. Whether the broken forms are physiologically more effective, does not matter from this aspect.

These studies have reduced the problem of form to the simplest formula. It is enough to assume that the receptor cells for local signs in the receptor organ are segregated into two groups, those in one according to the schema 'broken', those in the other according to the schema 'compact'. There are no further differentiations. If the schemata are projected outward, 'receptor images' of a very general nature result. Excellent new investigations reveal that in the case of bees these are filled with colors and scents.

The earthworm, the scallop, or the tick have no such schemata. Consequently there are no true perceptual images in their worlds.

Goal and plan

Since we humans are accustomed to carry our existence laboriously from one goal to the next, we are convinced that animals live in the same fashion. This is a fallacy which has led research astray again and again.

True, no one will attribute goals to a sea urchin or an earthworm. But even in describing the life of the tick, we spoke of it as waylaying its prey. By this expression we have already, albeit unintentionally, smuggled our petty everyday worries into the life of the tick, which is dominated by a pure plan of nature.

It must therefore be our first objective to extinguish the will-o'-the-wisp of a goal in our comtemplation of *Umwelten*. This can only be accomplished by coordinating the life manifestations of animals under the viewpoint of a plan. Perhaps later certain actions of the highest mammals may prove to be teleological actions, which in turn are dovetailed into the over-all plan of nature.

Actions directed toward a goal do not occur in any other animals at all. To prove this assertion, the reader must be given insight into a few *Umwelten*, which preclude all doubt. According to information I have received concerning the sound perception of night moths, it makes no difference whether the sound to which the animals are adjusted be the sound manifestation of a bat or one produced by rubbing a glass stopper — the effect is always the same. Night moths which, owing to their light coloring, are easily visible, fly away upon perceiving a high tone, while species which have protective coloration alight in response to the same tone. The same sensory cue has the opposite effect in their case. It is striking how the two opposite kinds of action are governed by a plan.

There can be no question of discrimination or purposiveness, since no moth or butterfly has ever seen the color of its own skin. The plan revealed in this instance appears even more admirable when we learn that the artful microscopic structure of the night moth's hearing organ exists solely for this one high tone of the bat. To all else, these moths are totally deaf.

A fine observation by Fabre revealed the contrast between goal and plan long ago. He placed an eyed hawk moth female on a sheet of white paper, where she moved her abdomen about for some time. He then put her under a glass bell next to the sheet of paper. During the night, swarms of males of this very rare species came flying in through the window and crowded together on the white paper. Not a single male heeded the female who sat next to it under the glass bell. Fabre was unable to ascertain what kind of physical or chemical stimulus emanated from the paper.

Experiments made with grasshoppers and crickets have been more instructive in this respect. Figure 22 is an illustration of these experiments. A specimen, fiddling in lively fashion, is sitting in a room before a microphone. In a neighboring room the sex partners gather in front of a loudspeaker and pay not the slightest attention to a specimen sitting under a glass bell, who fiddles in vain, since the sounds she makes cannot

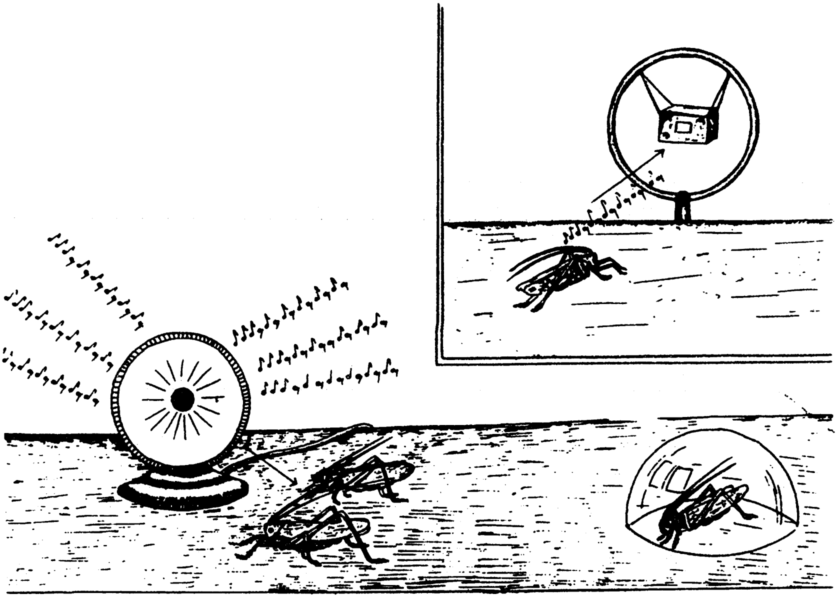


Figure 22. *Grasshoppers before a microphone*

be heard. Thus the partners make no advances whatever. The optical image is ineffectual.

Both experiments show the same thing. No goal is pursued in either case. But the seemingly strange behavior of the males is easily explained if examined under the aspect of a governing plan. In both cases a specific receptor cue initiates a functional cycle, but, since the normal object is eliminated, the proper effector cue, which would be necessary to extinguish the first perceptual cue, is not produced. Normally, another receptor cue should intervene at this point and activate the next functional cycle. The nature of this second receptor cue must be investigated more closely in both cases. In any event, it is a necessary link in the chain of functional cycles which lead to mating.

All right, the reader will say, we must give up purposive action for insects. They are ruled directly by the plan of nature, which determines their perceptual cues, as we have seen in the case of the tick. But no one who has ever observed a mother hen hastening to the aid of the chicks in a poultry yard can doubt the existence of true goal actions. Very fine experiments have fully clarified this particular case.

Figure 23 illustrates the results obtained in these experiments. If a chick is tied to a peg by one leg, it peeps loudly. This distress call makes the mother hen run immediately in the direction of the sound with ruffled plumage, even if the chick is invisible. As soon as she catches sight of the chick, she begins to peck furiously at an imaginary antagonist. But if the fettered chick is set before the mother hen's eyes under a glass bell, so that she can see it but not hear its distress call, she is not in the least disturbed by the sight of him.

Here again, we have an interrupted chain of functional cycles, not a goal action. The perceptual cue of peeping normally comes indirectly from an enemy who is attacking the chick. According to plan, this sensory cue is extinguished by the effector cue of beak thrusts, which chase the foe away. The struggling, but not-peeping chick is not a sensory cue that would release a specific activity. It would be quite incongruous if it were, too, as the mother hen is in no position to loosen a noose.

The hen shown in Figure 24 behaved even more oddly and aimlessly. Together with a clutch of eggs of a white stock, she had also hatched one egg of her own black breed. Toward this chick, which was her own flesh and blood, she behaved quite inconsistently. She hurried in the direction of the black chick's peeping, but when she perceived it among the white ones, she pecked away at it. The auditory and the visual cues of the same object elicited two contradictory functional cycles in her. Evidently the chick's two sensory cues had not been fused into an entity in the hen's world.

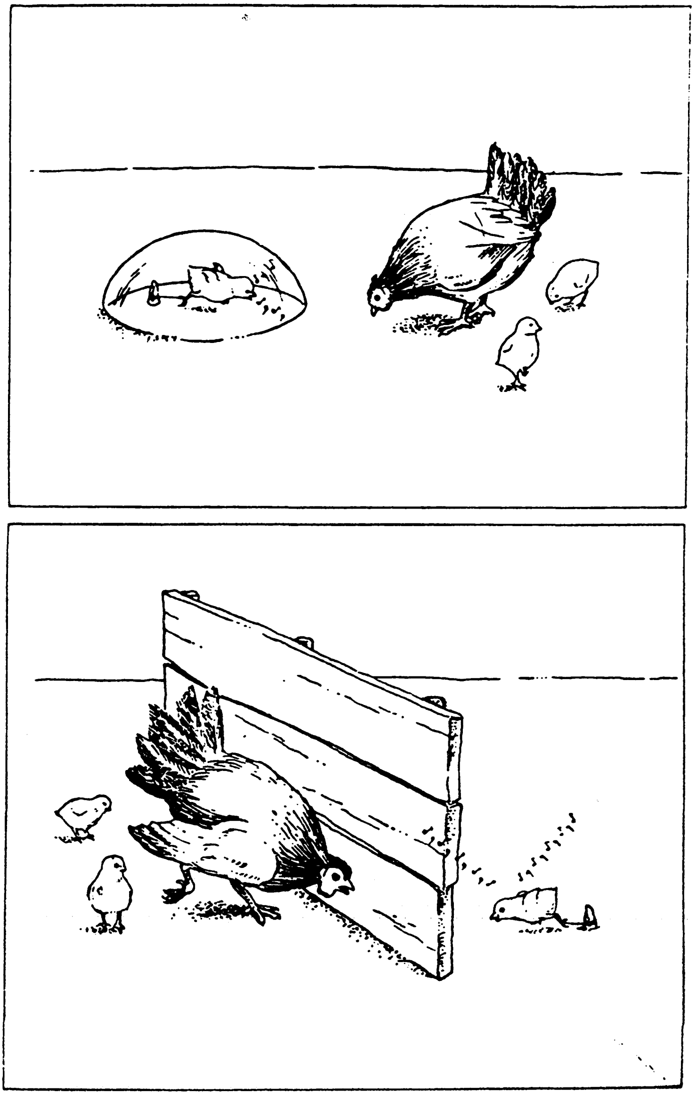


Figure 23. *Hen and chicks*

Receptor image and effector image

If we contrast nature's plan with the subject's goal, we will not have to discuss the question of instinct, which does not really get anyone anywhere. Does the acorn need an instinct to grow into an oak tree, or does

Figure 24. *Hen and black chick*

a host of bone-forming cells work instinctively to form a bone? If we deny this and substitute a plan of nature as a regulating factor, then nature's designs will also be recognized as swaying the spinning of a cobweb or the building of a bird's nest, since no subjective goal is involved in either case.

Instinct is merely a product of perplexity, a concept which must answer if we gainsay the superindividual plans of nature. These plans are disputed because it is hard to conceive the nature of a plan, since it assuredly is neither matter nor force. Yet it is not so difficult to gain an idea of the plan, if one bears a concrete example in mind.

The most beautiful plan will not drive a nail into the wall, if you have no hammer. But the finest hammer is not enough either, if you have no plan and rely on chance. Then you hit your fingers.

Without plans, that is, without the sovereign ordinances of nature, there would be no order in nature, only chaos. Every crystal is the product of a plan of nature, and when physicists present Bohr's beautiful atom models, they exemplify the plans of inanimate nature which they seek.

The sovereignty of nature's living plans is expressed most clearly in the study of *Umwelten*. To trace them is one of the most enthralling pursuits. We shall therefore not let ourselves be turned aside, but will calmly continue our stroll through the *Umwelten*.

The processes illustrated in Figure 25 give a series of findings gleaned from studies of the hermit crab. It has been found that the hermit crab requires an extremely simple spatial schema as a receptor image. Any object of a certain order of magnitude with a cylindrical to conical outline can assume meaning for it.

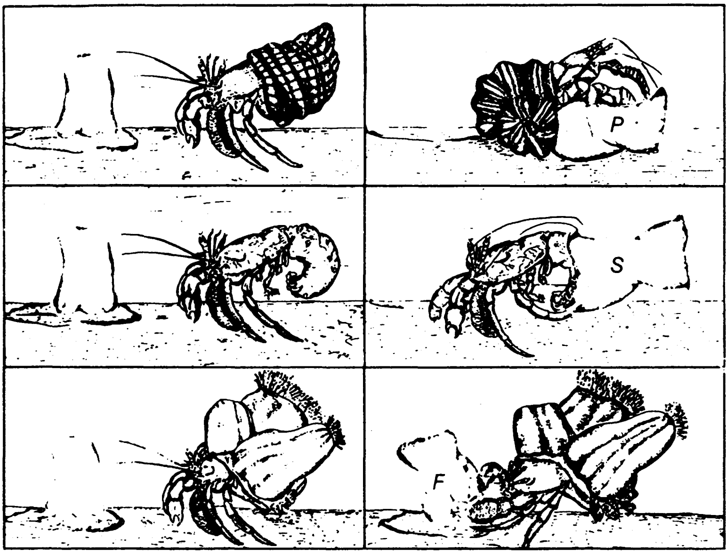


Figure 25. *Changes in significance of* Actinia *in the* Umwelt *of the hermit crab*
P = Protection; S = Shell; F = Food

As the figures show, one and the same cylindrical object — in this case, a sea anemone — changes its meaning in the crab's world according to the crab's prevailing mood.

The same crab and the same sea anemone are before us all the time. But in the first case the crab had been robbed of the actinians which it had carried on its shell. In the second case even its shell had been taken from it, and in the third case a crab that wore both shell and actinians had been left to starve for some time. This is enough to put the crab into three different moods. According to these moods, the sea anemone changes its meaning for the crab. In the first case, where the crab's shell lacks the protective mantle of actinians, which repel its enemy, the cuttlefish, the receptor image of the sea anemone assumes a 'defense tone'. This is expressed in the action of the crab, which plants the sea anemone on its shell. If the same crab is robbed of its shell, the sea anemone's receptor image gains a 'dwelling tone', which is expressed in the crab's attempt, albeit a futile one, to crawl into it. In the third case, that of the starving crab, the receptor image of the sea anemone assumes a 'feeding tone', and the crab begins to devour it.

These observations are of especial value because they show that, even at the level of arthropod worlds, the perceptual image furnished by the sense organs can be supplemented and changed by a 'functional image' (effector image) dependent on the action which it elicits.

To clarify this remarkable state of affairs, experiments were carried out on dogs. The problems was stated very simply and the answers of the dogs were unequivocal. A dog had been trained to jump up on a chair before it at the command, 'chair'. Then the chair was removed and the command repeated. It was found that the dog now treated as chairs all the objects on which it could sit, and jumped up on them. Let us put it this way: a series of other objects, such as crates, shelves, overturned stools, assumed a 'sitting tone'. Moreover, this was a 'dog sitting tone' and not a human sitting tone. For many of these 'dog chairs' were not at all suitable as human seating accommodations. It could also be shown that 'table' and 'basket' assumed a special tone for the dog, a tone that depended entirely on the actions which it performed with them.

But the real problem, in all its implications, can only be analyzed in man. How do we manage to see *sitting* in a chair, *drinking* in a cup, *climbing* in a ladder, none of which are given perceptually? In all the objects that we have learned to use, we see the function which we perform with them as surely as we see their shape or color.

I had taken a young, very intelligent and agile Negro with me from the heart of Africa to Dar-es-Salaam. The only thing which he lacked was a knowledge of European tools. When I bid him climb a short ladder, he asked me: 'How am I to do that, I see nothing but rods and holes?' As soon as another Negro had shown him how to climb the ladder, he could do it easily. From then on, the perceptually given 'rods and holes' held a climbing tone for him, and he recognized them everywhere as a ladder. The *receptor image* of rods and holes had been supplemented by the effector image of his own action; through this it had acquired a new meaning. The new meaning manifested itself as a new attribute, as a *functional* or *effector tone*.

This experience with the Negro indicates that we have developed an effector image for each of the functions which we perform with the objects in our specific *Umwelt*. This effector image we inevitably fuse so closely with the receptor image furnished by our sense organs, that in the process the objects acquire a new quality, which conveys their meaning to us, and which we shall briefly term the *functional tone*.

If an object is used in different ways, it may possess several effector images, which then lend different tones to the same perceptual image. A chair may occasionally be used as a weapon. It then assumes another functional image, which manifests itself as a 'thrashing tone'. In this strictly human case, as in that of the hermit crab, the subject's mood determines which functional image will lend its tone to the perceptual image. Effector images can be surmised only in animals whose actions are controlled by central effector organs. All animals that operate on a purely reflex plan, such as the sea urchin, must be excluded. Elsewhere, however, the influence of effector images reaches far down into the animal kingdom, as shown by the hermit crab.

If we wish to use the functional images to paint the *Umwelten* of animals further removed from us, we must constantly bear in mind that they are the performances of animals, projected into their *Umwelt*, and that they lend meaning to perceptual images only by their effector tone. The vital things in an animal's world furnish a perceptual image. To reproduce these vital things, and to grasp the full significance of their perceptual images, we shall supply these images with a functional tone. Even at a level where there are as yet no spatially articulated receptor images, as in the tick, we may say that the meaning of the only three effective stimuli that reach her from her prey stems from the functional tones (connected with the stimuli) of dropping down, of running around and of boring in. To be sure, the selective activity of the receptors, these entrance gates of the stimuli, plays the lead; but what lends this activity unerring certainty is the functional tone connected with the stimuli.

Since functional images can be deduced from the easily recognizable performances of animals, the objects in the *Umwelt* of a foreign subject become more tangible and gain new meaning.

If a dragonfly flits toward a branch to perch on it, the branch not only exists as a receptor image in its world, but is also distinguished by a sitting tone, which marks it above all other branches.

The *Umwelt* only acquires its admirable surety for animals if we include the functional tones in our contemplation of it. We may say that the number of objects which an animal can distinguish in its own world equals the number of functions it can carry out. If, along with few functions, it possesses few functional images, its world, too, will consist of few objects. As a result its world is indeed poorer, but all the more secure. For orientation is much easier among few objects than among many. If the *Paramecium* had a functional image of its performance, its entire world would consist of homogeneous objects, all of them bearing the same obstacle tone. To be sure, such an *Umwelt* would leave nothing to be desired as far as certitude is concerned.

As the number of an animal's performances grows, the number of objects that populate its *Umwelt* increases. It grows within the individual life span of every animal that is able to gather experiences. For each new experience entails a readjustment to new impressions. Thus new perceptual images with new functional tones are created.

This may be observed especially in dogs, who learn to handle certain human implements by turning them into canine implements. Nevertheless, the number of dog objects remains considerably smaller than that of our objects. To illustrate this fact, let us imagine a room in terms of the functional tones connected with the objects in it, first by man (Fig. 26), secondly by a dog (Fig. 27), and thirdly by a housefly (Fig. 28).

In the world of man, the functional tones of the objects in a room can be represented by a sitting tone for a chair, a meal tone for the table, and by further adequate effector tones for plates and glasses (eating and drinking tone). The floor has a walking tone while the bookcase displays a reading tone and the desk a writing tone. The wall has an obstacle tone and the lamp a light tone.

If we represent the recurrent similar functional tones by identical colors in the dog's world, only feeding, sitting, running, and light tones are left. Everything else displays an obstacle tone. Owing to its smoothness, even a revolving piano stool does not have a sitting tone for a dog.

Finally, for the fly, everything assumes a single running tone, except for the lamp whose significance has already been pointed out, and the crockery on the table.

Flies orient themselves with great ease in the environment of our room. As soon as a pot of hot coffee is set down on the table, they gather around it, because its heat acts as a stimulus to them. They wander over the surface of the table, which for them has a running tone. And since

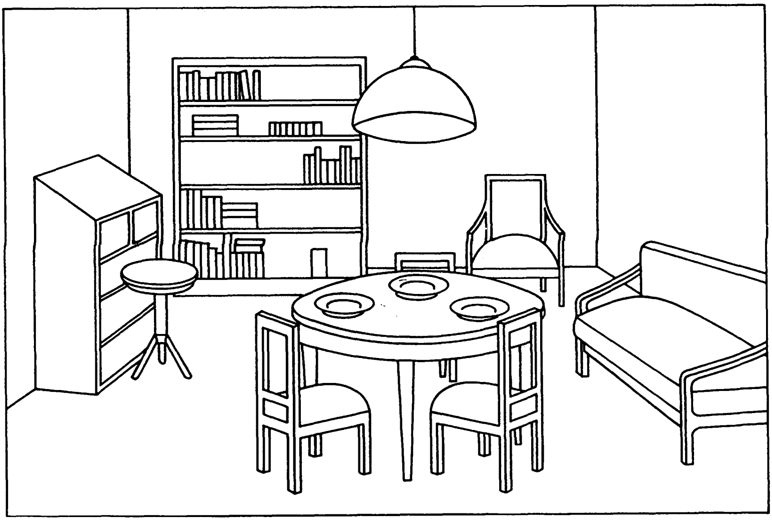


Figure 26. *The room in terms of the functional tones connected with its objects by man*

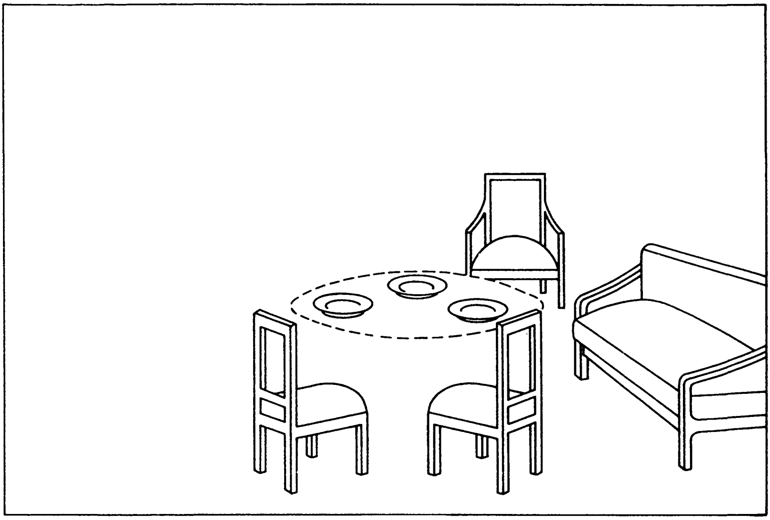


Figure 27. *The room in terms of the functional tones connected with its objects by a dog*

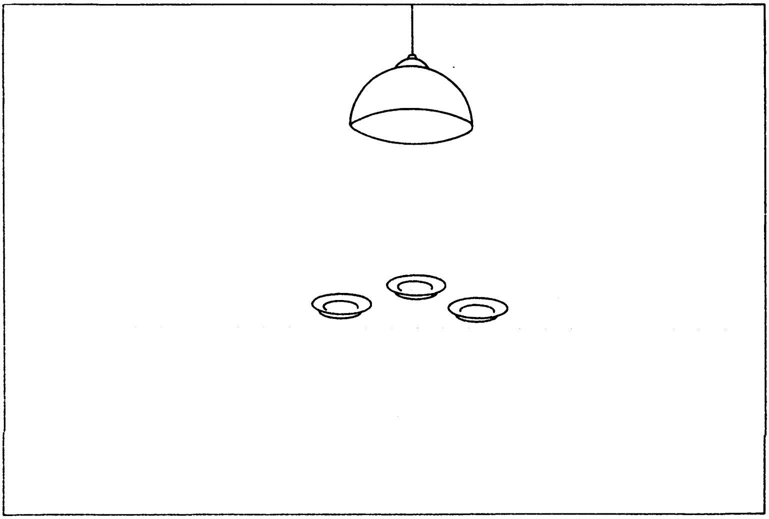


Figure 28. *The room in terms of the functional tones connected with its objects by a housefly*

flies' feet are equipped with taste organs, whose stimulation releases a protruding of the proboscis, they are held fast by their food, while all other objects induce continued wandering. Here it is particularly easy to lift the fly's *Umwelt* out of its environment.

The familiar path

The best way to find that no two human *Umwelten* are the same is to have yourself led through unknown territory by someone familiar with it. Your guide unerringly follows a path that you cannot see. Among all the rocks and trees in the environment there are some which, strung together in sequence, stand out as landmarks from all the others, although they are not apparent to a stranger.

The familiar path is entirely dependent on the individual subject. It is therefore a typical *Umwelt* problem. The familiar pathway is a spatial problem, and draws both on the subject's visual and functional space. This is evident from the way in which a familiar path is described — something like this: turn right behind the red house, then straight ahead for a hundred paces, and on to the left. Three kinds of sensory cues are used to describe a route: (1) visual cues, (2) the direction planes of the coordinate system, (3) directional steps. In this case we do not use the elementary directional pace, i.e., the smallest possible motor unit, but the customary summation of elementary impulses required to take one walking step.

The walking pace, that is, the regular motion of a leg forward and backward, is fixed so definitely and is of the same approximate length in so many people, that until quite recently it served as a common length measure. If I tell someone to walk a hundred paces, I mean that he is to give his leg the same motor impulse a hundred times. The result will always be the same approximate distance traversed. If we travel over a certain stretch repeatedly, the impulses given while walking remain in our memory as directional signs, so that we automatically stop at the same place, even if we have paid no attention to visual cues. Thus the orientational signs are of great importance for the familiar path.

It would be highly interesting to determine how the problem of the familiar path is worked out in the *Umwelten* of animals. Scent cues and tactile cues are surely decisive factors in building up the familiar path in many of their *Umwelten*. Thousands of experimental series have been made in the past decades by numerous American scientists who tried to determine how soon an animal was able to learn a certain pathway, through requiring widely varied animals to orient themselves in a maze. They have not seen the point: the problem of the familiar path. They have neither investigated the visual, tactile or scent cues, nor given thought to the application of the coordinate system by the animal — that right and left is a problem in itself, has never struck them. Nor have they ever debated the question of the number of paces, because they did not see that in animals, too, the pace may serve as the measure of distance.

In short, the problem of the familiar path must be attacked all over again, despite the prodigious amount of observations available. Beside its theoretical interest, the way a dog retraces the familiar path in his *Umwelt*, for example, also has eminent practical value in view of the tasks which face the seeing-eye dogs of the blind.

Figure 29 shows a blind man led by his dog. The blind man's world is a very limited one: it extends only as far as he can feel his way with his feet and cane. As far as he is concerned, the street through which he passes is plunged in darkness. His dog, however, must guide him home over a certain path. The difficulty of training the dog lies in introducing into the dog's *Umwelt* specific perceptual cues which serve the blind man's interests, not the dog's. Thus the route along which the dog leads the blind man must be plotted along a curve around obstacles against which the man might stumble. It is especially hard to teach a dog the meaning of a mailbox or an open window — to give it perceptual cues for things which it would normally pass by unheeded. The edge of the curb, over

Figure 29. *Blind man and his dog*

which the blind man might stumble, is equally hard to introduce into the dog's world, since under ordinary circumstances a freely running dog scarcely notices it.

Figure 30 portrays an observation made with young jackdaws. As may be seen, the jackdaw flies around the whole house, but then wheels and retraces its former, familiar course for the return flight to its starting point, which the jackdaw did not know again when it approached it from the other side.

It has recently been found that rats long continue to use an accustomed detour, even when the direct path is open to them.

Now the problem of the familiar path has been taken up anew in fighting fish, and the following results were obtained: in the first place, it was found that the unfamiliar has a repellent influence on these fish. A glass plate with two round holes, through which the fish could glide with ease, was placed in the aquarium. If the food was presented behind the hole, the fish took quite a while to glide hesitantly through the hole and snatch the food. Next the bait was shown laterally from the window — the fish soon followed after. Finally, the lure was presented behind the second window. Nevertheless, the fish invariably swam through the familiar hole and avoided using the unfamiliar.

Then, as shown in Figure 31, a partition was built into the food side

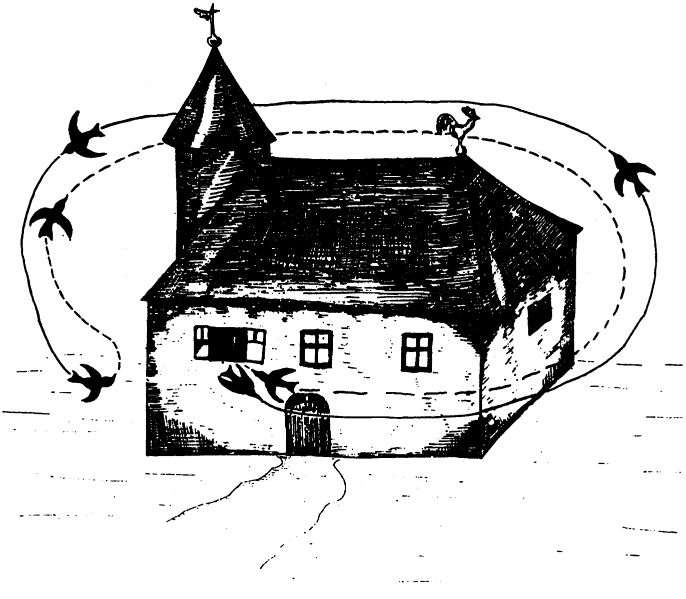


Figure 30. *The jackdaw's familiar path*

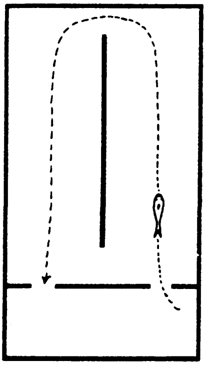


Figure 31. *The familiar path of the fighting fish*

of the tank at right angles to the glass plate, and the fish lured around the partition by means of the food. If the food was now shown on the other side of the partition, the fish swam straightway around it, still following the long familiar path, even if it could have reached the bait by swimming toward it in front of the partition. The familiar route here involved visual and orientational cues, and possibly directional steps as well.

On the whole, we may say that the familiar path works as a stretch of lightly fluid medium within a refractory mass.

Home and territory — *Heim und Heimat*

The problem of home and territory is closely related to the familiar pathway.

As a starting point, it will be best to choose the experiments with sticklebacks. The male stickleback builds himself a nest, whose entrance he likes to mark by a colored thread — a visual path cue for the young? The young grow up in the nest under the father's care. This nest is his home. But his territory reaches beyond the nest. Figure 32 shows an aquarium, in opposite corners of which two sticklebacks have built their nests. An invisible borderline crosses the aquarium and divides it into two regions, each of which belongs to one nest. This area, which belongs with the nest, is the stickleback's territory, which he defends vigorously and successfully even against bigger sticklebacks. In his own territory the stickleback always wins.

Territory is a pure *Umwelt* problem. It is an entirely subjective product,

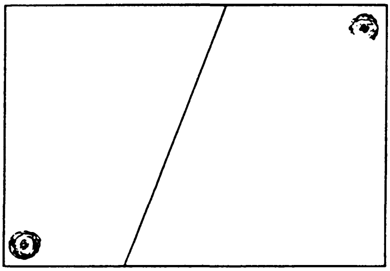


Figure 32. *Nest and territory of the stickleback*

for even the closest knowledge of the environment does not give the slightest clue as to its existence.

The question now is, which animals possess a territory and which ones do not? A housefly, which, in flying back and forth, covers a certain section of space around the chandelier, does not, by virtue of this fact, necessarily have a domicile.

A spider, on the other hand, which builds a cobweb in which it is constantly active, possesses a home that is at the same time its territory.

The same is true of the mole. It, too, has built itself a home and a territory. An orderly system of caves is spread out underground like a cobweb. But, in addition to the single tunnels themselves, its domain also comprises the whole section of earth encompassed by them. In captivity, it plots its tunnels so that they resemble a cobweb. We were able to demonstrate that the mole, thanks to its highly developed scent organ, not only finds its food easily within the tunnel, but that it can also smell food in the solid earth beyond the tunnel, up to a distance of some 5 to 6 cm. In a close-knit system of passages, such as the mole builds in captivity, the entire area of soil extending between the passages would be controlled by its senses. In nature, where the mole draws its tunnels farther apart, it can control the earth within a certain radius around each tunnel by scent cues. Like the spider, the mole travels repeatedly through this network of passages and gathers up everything in the way of prey that has strayed there. In the midst of this network of tunnels, the mole builds itself a cave padded with dry leaves — its home proper, where it spends its leisure hours. The underground passages are all familiar pathways to the mole; it runs forward and backward along them with equal speed and skill. Its field of prey extends as far as its passages reach. This whole field is at the same time the mole's territory, which it defends unto death against all neighboring moles.

The faculty with which the mole, a blind animal, finds its way unerringly in a medium which to us seems completely homogeneous, is astonishing.

If trained to a certain place where the mole gets its food, it will find this place again, even after the passages leading to it are totally destroyed. The mole cannot possibly be guided by olfactory cues in so doing. Its space is a purely operational space. One must assume that, by reproducing its orientational steps, a mole is able to retrace a pathway that it has once traveled. As in all blind animals, tactile cues connected with the directional steps must here play an important part. It may be assumed that orientational cues and directional steps unite to form the basis of a spatial schema. If the mole's network of passages, or part thereof, is destroyed, it is able, with the aid of a projected schema, to re-create a new network resembling the old.

Bees also build themselves a home, but the area all around the hive, where they seek their food, while being their field of prey, is not a territory which they would defend against intruders. In magpies, on the other hand, we may speak of home and territory, for their nest is built within a region inside of which they tolerate no other magpies.

Eventually, we shall probably find that countless animals defend their field of prey against members of their own species, thereby making it their territory. Any tract of land, if the territories were drawn into it, would resemble a political map for each species, their borderlines determined by attack and defense. It would also appear that there is no free land left, but that everywhere territory touches territory.

It is most interesting to observe that between the nests of many birds of prey and their hunting grounds, a neutral zone is inserted, where they strike no prey at all. Ornithologists are probably right in supposing that this arrangement was made by nature to prevent birds of prey from striking their own brood. When, so to speak, the nestling has become a branchling and spends its day around the parental nest, hopping from limb to limb, it might easily incure the danger of being struck by its own parents by mistake. As it is, the nestling spends its days unmenaced in the neutral zone of the protected territory. This protected territory is sought out by many songbirds as a nesting and brooding site, where they can bring up their young in safety under the great robber's protection.

Special consideration should be given to the ways and means by which dogs mark their territory for members of their own species. In a park were certain spots where two large hounds urinated in their daily outings. The places which they marked with their scent cues were always spots particularly conspicuous to the human eye also. Whenever both dogs were walked at the same time, a urinating competition ensued.

As soon as a high-spirited dog meets a strange dog, the former invariably shows a tendency to furnish the nearest conspicuous object with 'his visiting card'. Moreover, if a dog penetrates into the territory of another dog, which is earmarked by that dog's scent signals, he will successively seek these out and paint them over carefully. A spiritless dog, on the other hand, will pass shyly by a strange dog's scent marks in the latter's territory, and not betray his presence by any scent signals.

As shown in Figure 33, the great bears of North America also have a habit of marking their territory. Standing erect to its full height, the bear rubs off the bark of a lone, far-visible pine with its back and snout. This acts as a signal to other bears to give the pine a wide berth, and avoid the whole district where a bear of such dimensions defends its territory.

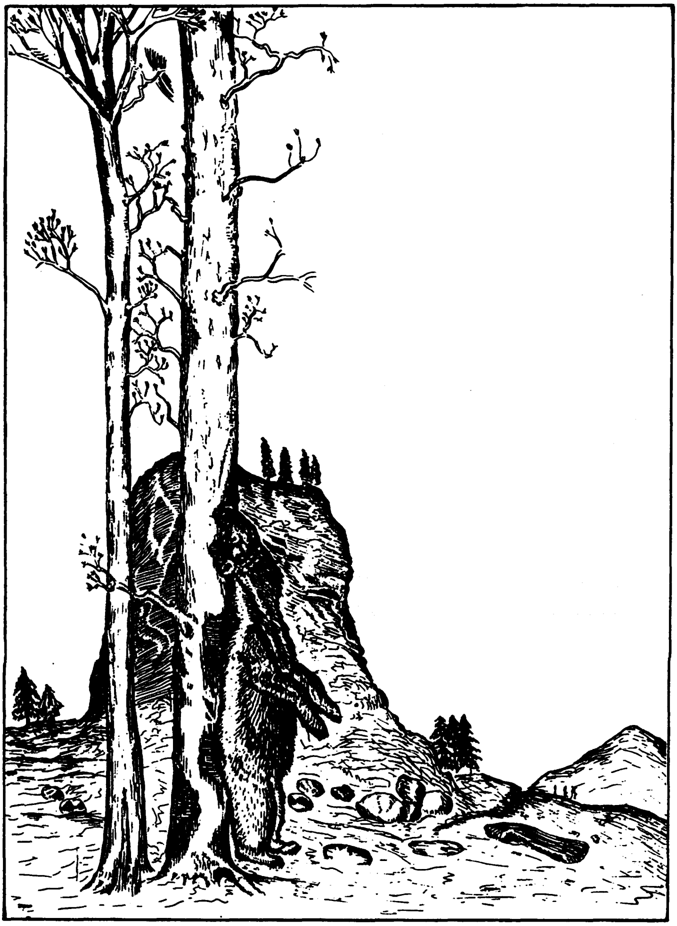


Figure 33. *A bear marking his territory*

The companion

I recall vividly the picture of a rumpled duckling that had been hatched together with turkey chicks and had attached itself so closely to the turkey family that it never went into the water, and painstakingly avoided other small ducks that came from it, fresh and clean.

Soon thereafter, someone brought me a very young wild duck, which followed me about at every step and turn. When I sat down, it leaned its head on my foot. I had the impression that my black boots were the attraction, for sometimes it also ran after the black dachshund. I concluded from this that a black moving object was enough to replace the image of the mother for it, and had the young duck put out near its maternal nest, that it might find its family again.

Today I have come to question whether this ever happened, for I have been informed that goslings of the greylag goose, when just taken from the incubator, must be pocketed and taken to a grey goose family at once if they are to attach themselves willingly to members of their own species. If they remain a little longer in human company, they will reject all companionship with their own kin.

The phenomenon we are dealing with in all these cases is a confusion of perceptual images. This occurs frequently, especially in the world of birds. What we know about the receptor images of birds is as yet insufficient to draw positive conclusions.

In Figure 18 we watched the jackdaw on the hunt for grasshoppers. We got the impression that the jackdaw possesses no receptor image whatsoever for the grasshopper in repose, and that therefore the grasshopper does not exist in the jackdaw's *Umwelt.*

Figures 34a and b illustrate another observation concerning the receptor images of jackdaws. Here a jackdaw is seen in a posture of attack

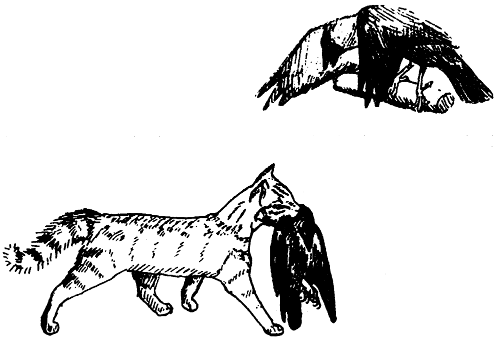


Figure 34a. *Jackdaw in posture of attack against cat*

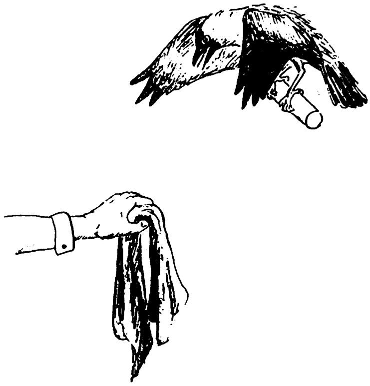


Figure 34b. *Jackdaw in posture of attack against bathing trunks*

against a cat carrying another jackdaw in its mouth. Jackdaws never attack a cat when it is not carrying any prey. Only when the cat's dangerous teeth are put out of action by holding the prey between them does the cat become an object of attack to the birds. This seems to be a highly judicious action by the jackdaw. As a matter of fact, however, it only conforms to a plan of nature, and runs its course independently of insight. For the bird assumed the same posture of attack when a pair of black bathing trunks was carried by. Nor was the cat attacked when it carried a white jackdaw. The receptor image of a black object being moved past the jackdaw promptly releases a posture of attack.

A receptor image held in such general terms can always give rise to mistakes. This has already been shown in the sea urchin, in whose world cloud and ship are constantly confused with the enemy fish, because the sea urchin responds in the same way to any darkening of the horizon.

In birds, however, we cannot get away with such a simple explanation. As regards social birds, we have a wealth of contradictory observations involving a confusion of receptor images. Only recently have we succeeded in analyzing out the main principles in the typical case of a tame jackdaw, 'Jock'.

Jackdaws living in a colony have a lifelong 'companion' with whom they carry out the most widely varied activities. If a jackdaw is raised in isolation, it by no means relinquishes the companion. If the jackdaw finds none of its own species, it will adopt 'substitute companions'. Moreover, a new substitute companion may take over for each new activity. Lorenz was kind enough to send me Figure 35, wherein the different companion relationships may be seen at a glance. In her youth, the jackdaw Jock had Lorenz himself for a mother companion. She followed him every-

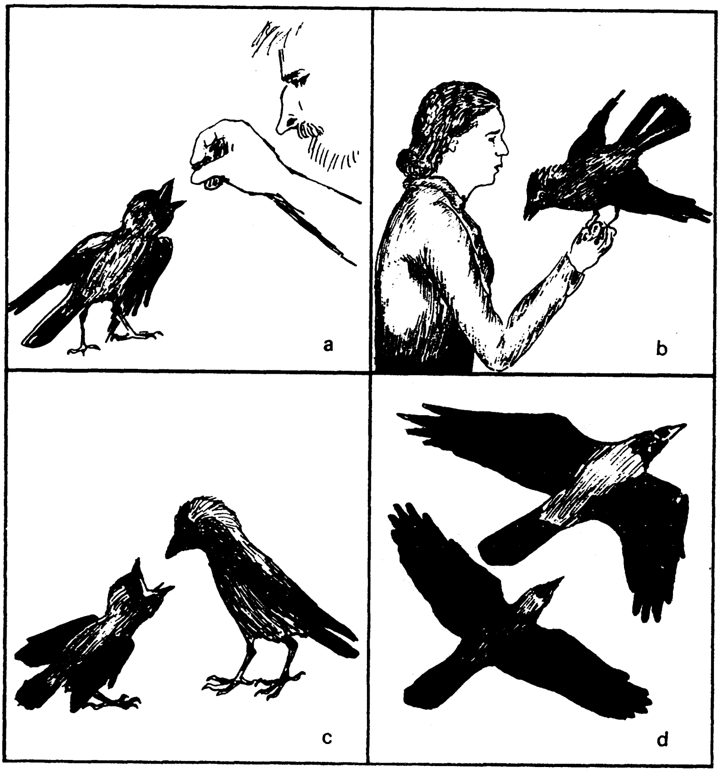


Figure 35. *The jackdaw 'Jock' and her four companions*

where; she called him when she wanted to be fed. After Jock had learned to get her own food, she chose the maid for her love companion and performed the characteristic courting dances in front of her. Later on Jock found a young jackdaw who became her adoptive companion and whom she fed in person. When Jock prepared for long flights, she tried, in the manner of jackdaws, to make Lorenz fly with her, by taking off close behind his back. When this attempt failed, Jock attached herself to flying crows, which now became her flight companions. Clearly, there is no uniform perceptual image for the companion in the jackdaw's world. Nor could there be one, since the role of the companion changes all the time.

In most cases, the receptor image of the mother companion is not determined at birth as to form and color. On the other hand, the mother's voice frequently is.

'One should,' Lorenz writes, 'determine, in a specific case of a mother companion, which mother signs are innate and which ones are individually acquired. The uncanny thing is that, if the fledgling is only taken from its mother a few days, or even hours after hatching (grey goose, Heinroth), the acquired mother signs are engraved so deeply that one would swear they were innate'.

The same thing happens in choosing the love companion. Here, too, the acquired signs of the substitute companion are so definitely engraved that an inconvertible perceptual image of the substitute companion is created — once the first exchange has occurred. In consequence, even animals of the same species are rejected as love companions.

This is shown very clearly by a delightful experience. In the Amsterdam Zoo there was a pair of bitterns, whose male had 'fallen in love' with the director of the Zoo. So as not to hinder their mating, the latter did not appear for a considerable length of time. The result was that the male became accustomed to the female. A happy union ensued, and when the female was sitting on her eggs, the director risked showing himself again. But what happened? No sooner had the male caught sight of his former love companion, than he chased the female away from the nest and seemed to hint with repeated bows that the director was to occupy the place due him and continue the business of brooding.

The receptor image of the child companion seems in general to be outlined more firmly. Here the gaping bills of the young are probably the most important factor. But here again, one may find that hens of pure strain, such as orpingtons, will mother young kittens and baby bunnies.

Again, as Jock shows, there is more leeway in the case of the substitute companion for free flights.

If we consider that the jackdaw treats bathing trunks in motion as an enemy, that is, they obtain the functional tone 'enemy', we may say that they are a substitute foe. Since there are many enemies in the jackdaw's world, *the appearance of a substitute enemy, especially if it only happens* occasionally, does not affect the perceptual images of the jackdaw's real enemies. Not so with the companion. The latter exists only singly in the *Umwelt*, and once a functional tone is lent to a substitute companion, it is impossible for a true companion to make a later appearance. Once the perceptual image of the maid had acquired the sole 'love tone' in Jock's world, all other perceptual images had become ineffectual.

If we consider (a phenomenon not without analogy in primitive people) that in the world of jackdaws all living creatures, that is, moving things, are divided into jackdaws and non-jackdaws, and furthermore, that the borderline between them is drawn differently according to personal experience, it will perhaps be possible to understand that such grotesque mistakes as the ones just described should occur. It is not the perceptual image alone that decides whether one is faced with a jackdaw or non-jackdaw, but the functional image of the subject's own attitude. This alone determines what perceptual image will acquire the prevailing companion tone.

Search image and search tone

Again I begin with two personal experiences, which will best illustrate what is meant by the search image, a factor of great importance in the *Umwelt*. When I spent some time at the house of a friend, an earthenware water pitcher used to be placed before my seat at luncheon. One day the butler had broken the clay pitcher and put a glass water bottle in its place. When I looked for the pitcher during the meal, I failed to see the glass carafe. Only when my friend assured me that the water was standing in its usual place, did various bright lights that had lain scattered on knives and plates flock together through the air and form the water bottle. Figure 36 conveys this experience. The search image annihilates the perceptual image.

The second experience is this: One day I stepped into a store where I had a large bill to pay, and drew out a 100 Mark bill. It was quite new and slightly bent, so that it did not lie flat on the counter, but stood on its edge. I asked the cashier to give me my change. She declared I had not yet paid. I tried in vain to point out to her that the money was right under her nose. She became irritated and insisted on immediate payment. At this point I touched the bill with my forefinger, so that it fell over and came to lie the right way. The lady uttered a small cry, then took the bill and felt it, full of apprehension that it might dissolve into thin air again. In this case, too, the search image had obviously extinguished the perceptual image.

All my readers have probably had similar experiences of seeming magic.

Figure 37 was published in my 'Biology'. It symbolizes the different processes that interlock in human perception. If a bell is set up before someone and sounded, it appears in his environment as a source of stimulation, from which air waves penetrate to his ear (physical processes). In the ear, the air waves are transformed into nervous excitation, which is conveyed to the receptor organ of the brain (physiological processes). Now the receptor cells intervene with their receptor signs and

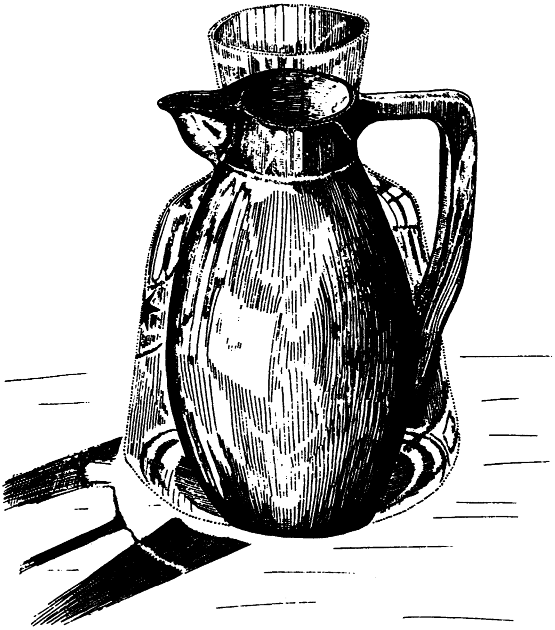


Figure 36. *The object sought obscures the perception*

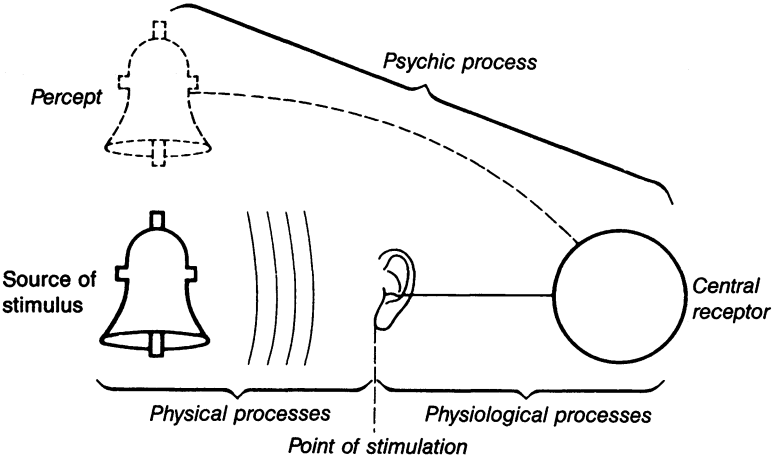


Figure 37. *The processes in noting*

project a perceptual cue or meaning into the *Umwelt* (psychological process).

If besides the air waves coming to the ear, ether waves also reach the eye, which in its turn sends excitation to the receptor organ, then their receptor signs of sounds and colors are combined to form an entity which, projected into the phenomenal world, becomes a perceptual image.

The same graphic illustration can be used to explain the search image. In this case we will assume that the bell lies outside the visual field. The receptor signs of the sounds are projected directly into the *Umwelt*. But connected with it is an invisible optical receptor image, which serves as a search image. If after searching, the bell enters the visual field, then the perceptual image now resulting is fused with the search image. If they differ too widely, it may happen that the search image eliminates the perceptual image, as in the aforesaid instance.

Search images undoubtedly exist in the *Umwelt* of dogs. When the master orders his dog to retrieve a stick, the dog, as shown in Figure 38, has a quite specific search image of the stick. Here we may also examine how closely the search image corresponds to the perceptual image.

It is reported that, if a toad has consumed an earthworm after a prolonged period of starvation, the toad will immediately throw itself on a match that bears a certain resemblance in shape to the earthworm. This leads us to believe that the recently consumed earthworm acts as a search image — as indicated in Figure 39. On the other hand, if the toad has allayed its first hunger with a spider, it has a different search image, for now the toad will snap after a bit of moss or an ant, which, however, does not agree with it very well.

Now we do not always look for a definite object with a single receptor image, but far more often for one that corresponds to a specific functional image. Instead of a specific chair, we look around for something to sit on, that is, for a thing that may be connected with a certain performance tone. In this case we cannot speak of a search image, but only of a search tone.

The earlier example of the hermit crab and sea anemone demonstrates how important a part the search tone plays in the *Umwelt* of animals. What we referred to as the hermit crab's different moods there, can now be much more accurately termed the varying *search tone* with which the crab approached the same perceptual image, giving it at one time a protective tone, at another time a dwelling tone, and again an eating tone.

The hungry toad at first sets out to seek food with just a general feeding tone. Only after it has consumed an earthworm or a spider does it acquire a more specific search image.

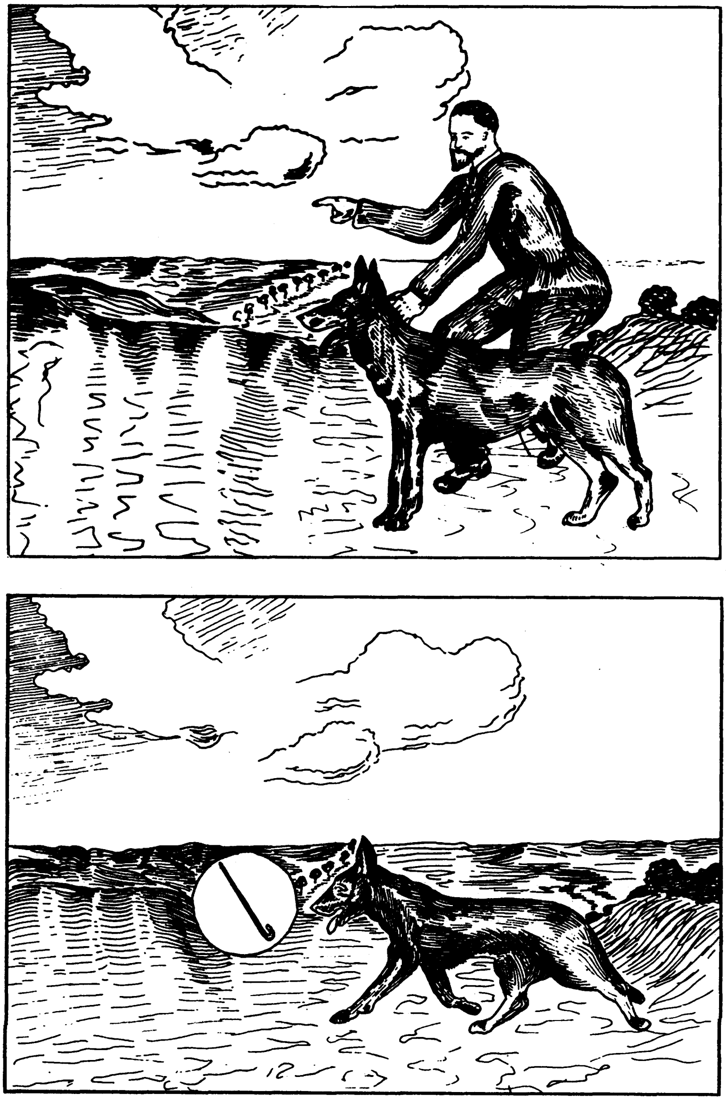


Figure 38. *The dog and his search image*

The magic *Umwelten*

There can be no doubt that a fundamental contrast prevails everywhere between the environment which we see spread around animals, and the *Umwelten* that are built up by the animals themselves and filled with the

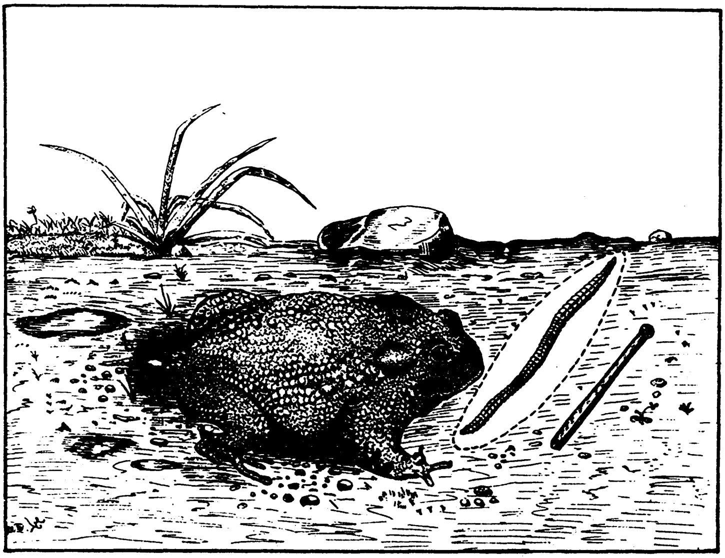


Figure 39. *The toad's search image*

objects of their own perception. In our study so far, these *Umwelten* have as a rule been the product of receptor signs roused to activity by external stimuli. We have already seen exceptions to this rule: the search image, the tracing of the familiar pathway, and the demarcation of the territory, which could not be attributed to external stimuli, but were free subjective products. They evolved as a result of repeated personal experiences by the subject.

If we now continue on our way, we shall enter worlds that feature very effective phenomena which, however, are visible to the subject alone and are bound to no experiences, or at most are related to one single experience. We shall call *Umwelten* of this kind *magic* worlds.

An example may illustrate how deeply many children live in magic worlds. In his *Paideuma*, Frobenius tells of a little girl who was quietly acting out for herself the fairy tale of Hansel and Gretel, the wicked witch and the gingerbread house, with a matchbox and three matches. Suddenly she cried out: 'Take away the witch, I can't bear to look at her horrid face any more.' This typically magical experience is indicated in Figure 40. Undoubtedly, the wicked witch appeared bodily in the little girl's *Umwelt*.

Explorers have often come upon experiences of this kind among primitive peoples. It is maintained that they live in a magic world, where fantastic phenomena mingle with the perceptually given things around

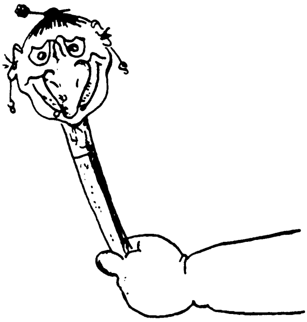


Figure 40. *The magical appearance of the witch*

them. If we look more closely, we shall meet the same magic formations in the *Umwelt* of many a highly cultured European.

The question now arises: do animals also live in magic *Umwelten*? Magical experiences are frequently reported in dogs. But these reports have not hitherto been sifted critically enough. On the whole, however, it will probably have to be conceded that dogs relate their experiences in a manner that is magical rather than logical. The role which the master plays in the dog's world is surely conceived magically, not broken down into cause and effect.

A zoologist friend of mine tells about an undoubtedly magic phenomenon in the *Umwelt* of a bird: He had brought up a young starling in a room. The bird never had a chance to see a fly, let alone to catch one. One day he saw the starling suddenly rush toward an invisible object, catch it in mid-air, return with the object to its perch, peck away at it with its bill as any starling will do with a captured fly, and finally swallow the invisible thing (Fig. 41). There was no doubt that the starling had had the apparition of an imaginary fly in its *Umwelt*. Evidently the starling's whole world had been so charged with the 'feeding tone', that even without the appearance of a sensory stimulus, the functional image of fly-catching, which was in readiness, forced the perceptual image to appear, and this released the entire action chain. This experience indicates that otherwise utterly puzzling actions by various animals should be interpreted magically.

Figure 42 portrays the behavior of the pea-weevil larva, which was studied by Fabre. In good season, the larva bores a channel into the still soft flesh of a young pea, all the way to the surface. This tunnel is not used until, after the larva's metamorphosis, the grown beetle crawls out of the pea, which has hardened in the meantime. It is quite sure that we are here dealing with an activity which, though conforming to a plan, is

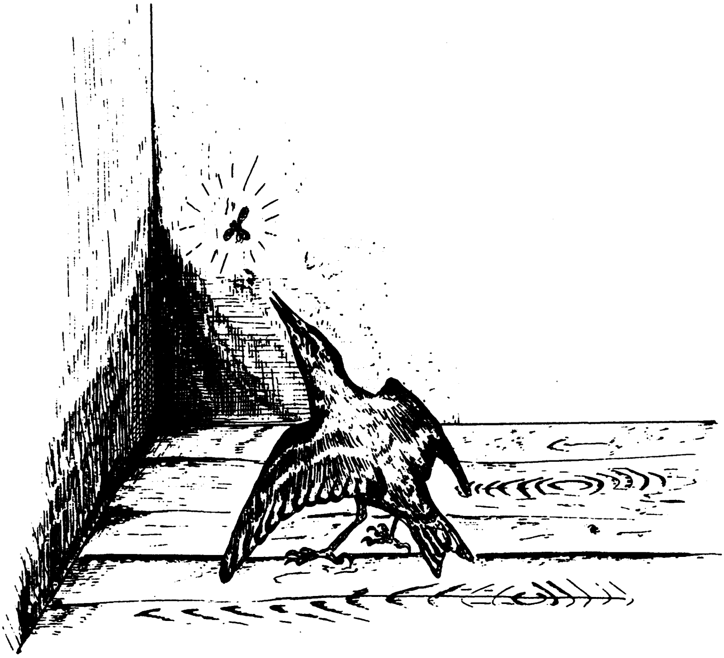


Figure 41. *Starling and imaginary fly*

Figure 42. *The magical path of the pea-weevil larva*

yet utterly senseless from the weevil larva's point of view, for no sensory stimulus of the feature beetle can possibly reach its larva. No receptor sign shows the larva the path which it has never trodden and that it must nevertheless take, unless it is to perish miserably after its transformation into a beetle. The way lies before it, clearly written, as in magic characters. The familiar path, acquired through experience, is here replaced by the innate pathway.

Figures 43 and 44 show two further instances of the innate pathway. The female of the funnel-roller begins to cut an intricately curving line of prescribed form along a birch leaf at a specific point (which she may possibly recognize by its taste). This enables her afterwards to roll the leaf into a funnel, into which she will lay her eggs. Although the beetle has never followed the path and the birch leaf shows no indication of it, the path must yet lie before her perfectly clearly, as a magic phenomenon.

The same applies to the flight routes of migratory birds. The continents bear the innate route, which only birds can see. This is certainly true of young birds, who set out unaccompanied by their parents, whereas for the others the acquisition of a familiar path is not beyond the realm of possibility.

Like the familiar pathway, with which we have dealt extensively, the innate way also leads through both visual and functional space. The soie difference between the two is that in the case of the familiar path a series

Figure 43. *The magical path of the funnel-twister*

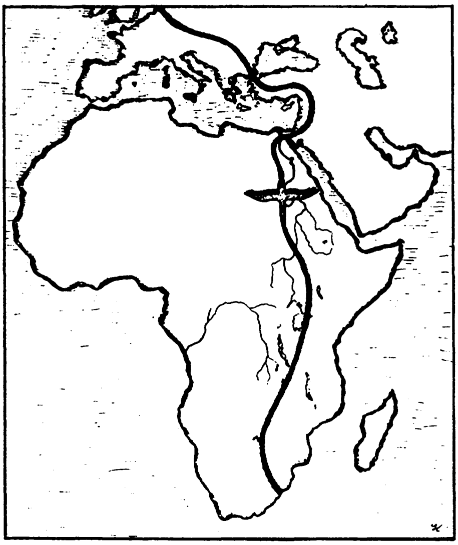


Figure 44. *The magical path of the migratory bird*

of receptor and effector signs, which have been established by previous experience, succeed one another, while in the case of the innate path the same series of signs is given directly, as a magic phenomenon. To the uninitiated observer a familiar path in a foreign *Umwelt* is just as invisible as is the innate path. And if we assume that the familiar pathway becomes manifest to the foreign subject in his own *Umwelt* — of which there is no doubt — then there is no reason to deny the phenomenon of the innate pathway; since it is composed of identical elements, the projected perceptual and functional signs. In the one case they are elicited by sensory stimuli, in the other they chime in harmonious succession, like an inborn melody.

If a certain route were innate in a man, it could be described in the same terms as a familiar path: a hundred paces to the red house, then round to the right, and so forth.

If we choose to call significant only what is given to the subject by the evidence of his senses, then, of course, only the familiar path will be called meaningful, not the innate. Even so, it remains planful to the highest degree.

A strange experience reported by a contemporary scientist indicates that magical phenomena play a far greater part in the animal world than we suspect. He had fed a hen in a certain stall, and let a guinea pig into the stall while the hen was picking up the grains. The hen was beside herself and fluttered about frantically. From then on, she could never again be persuaded to consume food in this stall. She would rather have starved amid plenty of the finest grain. Evidently the apparition of the first experience hovered above the stall like a magical shadow, as Figure 45 attempts to convey it. This occurrence corroborates the surmise that when a mother hen rushes toward the peeping chick and chases away an imaginary enemy by violent bill-pecks, a magic apparition has similarly arisen in her *Umwelt*.

As we have progressed farther in our study of the *Umwelten*, the conviction has grown on us that effective factors occur in them, to which no objective reality can be ascribed. We met the first of these in the place-mosaic, which the eye imprints on the things in its *Umwelt*, and which is no more present in the environment than are the directional planes that support space in an *Umwelt*. It has been equally impossible to find an environmental factor to correspond to the subject's familiar pathway. The distinction between territory and hunting ground does not exist in the environment. No trace of the *Umwelt's* vital search image can be found in the environment. Now we have finally come upon the magical phenomenon of the innate path, which mocks all objectivity and yet gears designfully into the *Umwelt*.

There are, then, purely subjective realities in the *Umwelten*; and even the things that exist objectively in the environment never appear there as

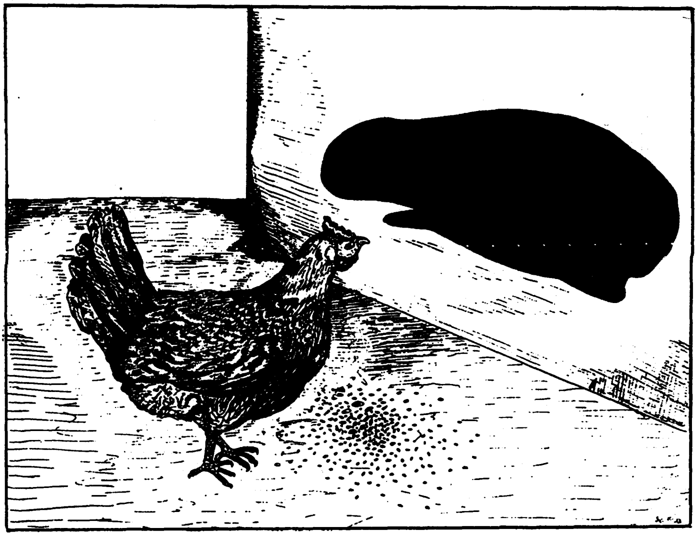


Figure 45. *The magical shadow*

their objective selves. They are always transformed into perceptual cues or perceptual images and invested with a functional tone. This alone makes them into real objects, although no element of the functional tone is actually present in the stimuli.

And finally, the simple functional cycle teaches us that both receptor and effector cues are the subject's manifestations, and that the qualities of objects included in the functional cycle can be regarded as their bearers only. Thus we ultimately reach the conclusion that each subject lives in a world composed of subjective realities alone, and that even the *Umwelten* themselves represent only subjective realities.

Whoever denies the existence of subjective realities, has failed to recognize the foundations of his own *Umwelt.*

The same subject as an object in different *Umwelten*

The foregoing chapters described single strolls into various regions in the unexplored territory of the *Umwelt.* They were arranged according to problems, to obtain a uniform view in each case. Even though we have dealt with some fundamental problems, no completeness has been achieved or aimed at. Many problems await conceptual formulation, while others have not yet developed beyond the stage of formulating questions. Thus we know nothing so far of the extent to which the subject's own body enters into his *Umwelt.* Even the question of the significance of one's own shadow in visual space has not been experimentally attacked.

The pursuit of single problems is indeed important for *Umwelt* research: but it is not enough if we wish to gain a comprehensive view of the relationship between different *Umwelten.* In a limited field, such an overall picture can be obtained by answering the question: How does the same subject show up as an object in different *Umwelten,* in which it plays an important part? As an example, I choose an oak tree, which harbors many animal subjects, and is destined to play a different role in the *Umwelt* of each. Since the oak also appears in various human *Umwelten,* I shall begin with them.

Figures 46 and 47 are reproductions of two drawings, which we owe to the artist Franz Huth. In the thoroughly rational world of the old forester, who must decide which trees of his forest are ready to be felled, the oak doomed to the ax is nothing more than a few cords of wood, which he seeks to measure accurately (Fig. 46). The knobby bark, which happens to resemble a human face, goes unheeded by him. Figure 47 shows the same oak in the magical world of a little girl, whose forest is

Figure 46. *Forester and oak tree*

Figure 47. *Little girl and oak tree*

still inhabited by gnomes and hobgoblins. The little girl is terribly frightened when the oak tree looks at her with its evil face. The whole oak has become a threatening demon.

In the grounds of my cousin's castle in Estonia there stood an old

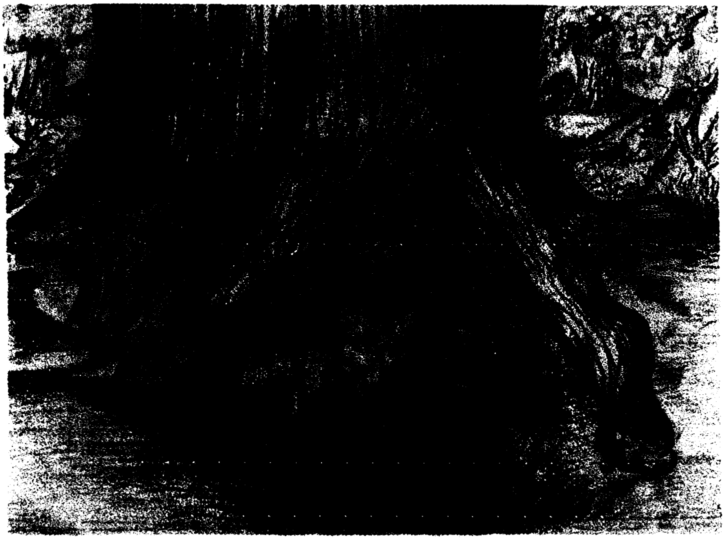


Figure 48. *Fox and oak tree*

Figure 49. *Owl and oak tree*

Figure 50. *Ant and oak tree*

apple tree. A huge lichen had grown on it, which vaguely resembled the face of a clown, but no one had ever noticed this resemblance. One day my cousin had a dozen Russian seasonal laborers brought in, who discovered the apple tree and thereafter gathered before it daily for worship, murmuring prayers and crossing themselves. They declared that the fungus must be a wonder-working image, because it was not made by hand of man. To them, magic processes in nature appeared quite natural.

But let us return to the oak tree and its inmates. To the fox (Fig. 48), which has built its lair between the roots, the oak tree has come to mean a solid roof, which protects the fox and its family from the hazards of the weather. It has neither the utility tone of the forester's world, nor the danger tone of the litte girl's, but solely a protective tone. How it is shaped beyond that, does not matter in the fox's world.

In the owl's world (Fig. 49) the oak tree also has a protective tone.

Figure 51. *Bark-boring beetle and oak tree*

Only this time it is not the roots, which lie wholly outside the owl's realm, but the mightly limbs that serve it as a protecting wall.

To the squirrel, the oak tree, with its many ramifications, providing a wealth of comfortable jumping boards, gains a climbing tone, and to the songsters which build their nests in its farthest crotches and branches, it offers the supporting tone which they need.

Corresponding to the different functional tones, the perceptual images of the oak tree's numerous inmates, too, are differently shaped. Each *Umwelt* carves a specific section out of the oak, whose qualities are

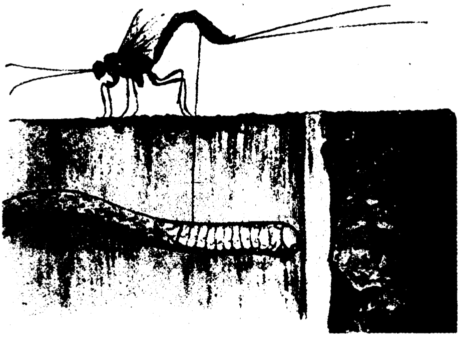


Figure 52. *Ichneumon fly and oak tree*

suitable bearers for both the receptor and effector cues of their respective functional cycles. In the ant's world (Fig. 50) all the rest of the oak vanishes behind its gnarled bark, whose furrows and heights become the ant's hunting ground.

The bark-boring beetle seeks its nourishment underneath the bark which it blasts off (Fig. 51). Here it lays its eggs. Its larvae bore their passages underneath the bark. Here, safe from the perils of the outside world, they gnaw themselves farther into their food. But they are not entirely protected. For not only are they persecuted by the woodpecker, which splits off the bark with powerful thrusts of its beak; an ichneumon fly, whose fine ovipositor penetrates through the oakwood (hard in all other *Umwelten*) as if it were butter, destroys them by injecting its eggs into the larva (Fig. 52). Larvae slip out of the ichneumon eggs and feed on the flesh of their victims.

In all the hundred different *Umwelten* of its inmates, the oak tree as an object plays a highly varied role, at one time with some of its parts, at another time with others. Sometimes the same parts are large, at others they are small. At times its wood is hard, at others soft. One time the tree serves for protection, then again for attack.

Should we attempt to epitomize all the contradictory properties which the oak tree as an object displays, only chaos would result. And yet they are all but parts of a subject firmly structured in itself, which bears and harbors all these *Umwelten* — not comprehended and never discernible to all the builders of these *Umwelten*.

Conclusion

What we have found on a small scale in the oak tree is enacted on the life tree of nature in vast dimensions.

Out of the millions of *Umwelten*, whose abundance would result in confusion, we shall pick out only those dedicated to the investigation of nature — the *Umwelten* of different scientists.

Figure 53 shows the *Umwelt* of an astronomer, which is the easiest to portray. High on his tower, as far as possible from the earth, sits a human being. He has so transformed his eyes, with the aid of gigantic optical instruments, that they have become fit to penetrate the universe up to its most distant stars. In his *Umwelt*, suns and planets circle in festive

Figure 53. *The astronomer's* Umwelt

procession. Fleet-footed light takes millions of years to travel through his *Umwelt* space.

And yet this whole *Umwelt* is only a tiny sector of nature, tailored to the faculties of a human subject.

With slight alterations, the astronomer's image can be used to gain a conception of the deep-sea researcher's *Umwelt.* Only here, instead of constellations, the fantastic shapes of deep-sea fish wheel around his sphere with their uncanny mouths, long tentacles and radial light organs. Here again, we glance into a real world, which constitutes a small sector of nature.

The *Umwelt* of a chemist, who tries to read and write the enigmatic context of nature's substance-words with the aid of the elements, as with 92 letters, is hard to render distinctly.

We shall succeed better in representing the *Umwelt* of a nuclear physicist, for the electrons cycle around him in much the same way as the constellations wheel around the astronomer. Only here no cosmic calm reigns, but a mad rush of infinitesimal particles, from which the physicist blasts off even tinier ones by bombarding them with diminutive projectiles.

If another physicist investigates the ether waves in his own *Umwelt*, he again resorts to entirely different means, which furnish him a picture of the waves. Now he can ascertain that the light waves, which stimulate the human eye, combine with all other waves, without displaying any differences. They are just waves, nothing more.

Light waves feature altogether differently in the *Umwelt* of a physiologist who studies the senses. Here they become colors, with laws of their own. Red and green fuse into white, and shadows, thrown onto a yellow surface, become blue. Processes unheard-of in waves, and yet the colors are just as real as are the ether waves.

The same contrast exists between the *Umwelten* of a student of air waves and of a musician. In the one there are only waves, in the other only sounds. Yet both are equally real.

So it goes on. In the behaviorist's *Umwelt* the body produces the mind, and in the psychologist's world the mind builds the body.

The role which nature plays as the object of different scientists' worlds is highly contradictory. Should one attempt to combine her objective qualities, chaos would ensue. And yet all these diverse *Umwelten* are harbored and borne by the One that remains forever barred to all *Umwelten.*

Behind all the worlds created by Him, there lies concealed, eternally beyond the reach of knowledge, the subject — Nature.

Note

1. Illustrated by G. Kriszat.
2. Reflex originally means the intercepting and reflecting of a light ray by a mirror. Transferred to living creatures, the reflex is conceived as the reception of an external stimulus by a receptor and the stimulus-elicited response by the effectors. In the process the stimulus is converted into nervous excitation, which has to pass through several stations on its way from the receptor to the effector. The course thus described is referred to as a reflex arc.
3. The tick is built for a long period of starvation. The sperm cells harbored by the female during her waiting period remain bundled in sperm capsules until mammalian blood reaches the tick's stomach — they are then freed and fertilize the eggs, which have been reposing in the ovary. The perfect fitting of the tick to her prey-object, which she finally seizes, contrasts strikingly with the extremely low probability that this will actually ensue. Bodenheimer is quite right in speaking of a *pessimal* world in which most animals live, that is, the most unfavorable one conceivable. But this world is not their *Umwelt*; it is their environment. An *optimal Umwelt*, that is, one as favorable as possible, and a *pessimal environment* may be considered the general rule. The point is always survival of the species, no matter how many individuals perish. Because of the optimal *Umwelt*, the environment of a species must be *pessimal* or the species would gain ascendancy over all others.
4. This is corroborated by motion picture technique. When a film strip is projected, the single pictures must jerk forward successively, and then stand still. To show them distinctly, the jerky motion must be concealed by interposing a screen. The human eye does not perceive the blackout involved if the eclipse of the picture occurs within 1/18 of a second. If the time is lengthened, insufferable flickering ensues.