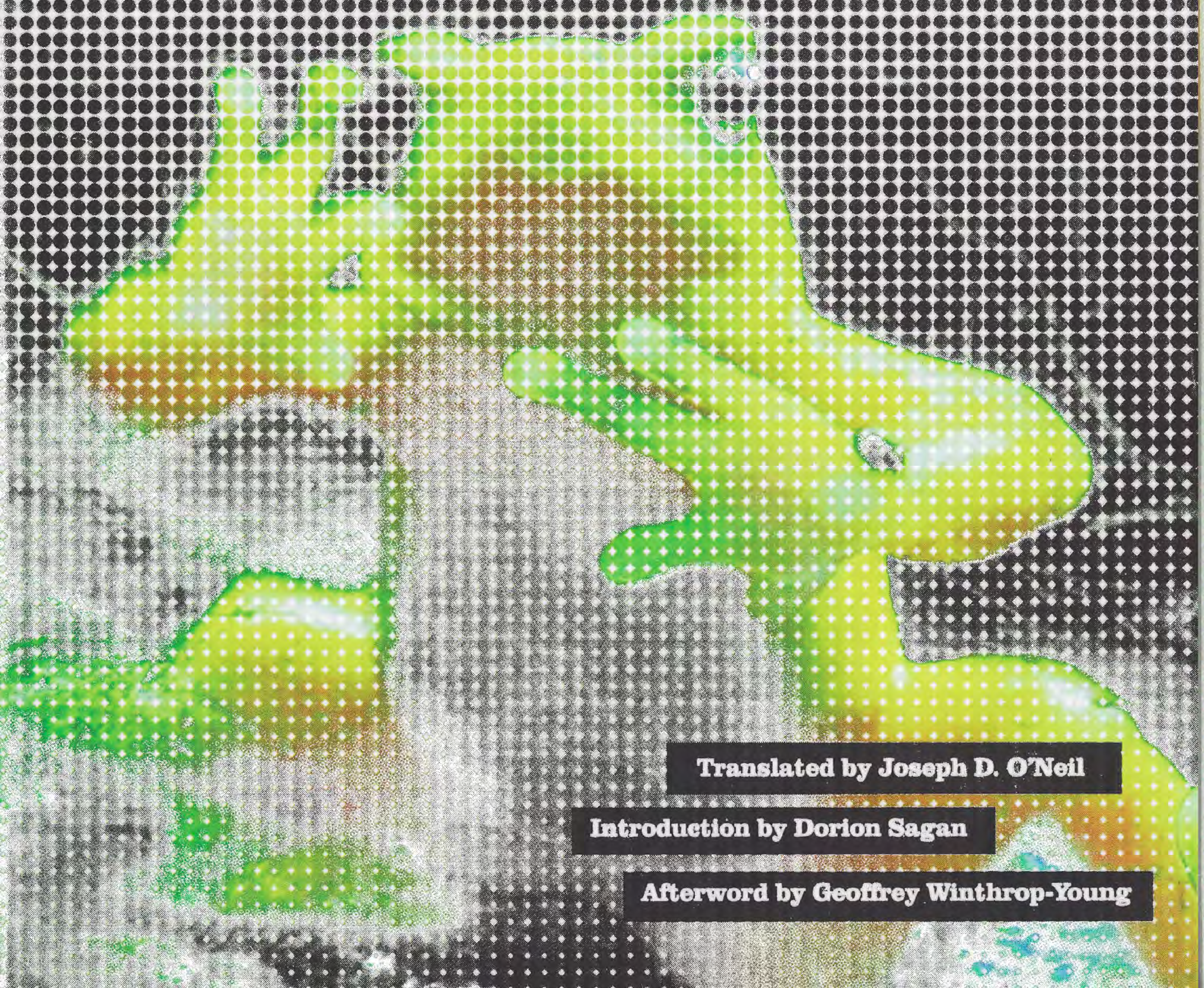
Jakob von Uexküll

A FORAY INTO THE WORLDS OF ANIMALS AND HUMANS

WITH *A THEORY OF MEANING*



Translated by Joseph D. O'Neil

Introduction by Dorion Sagan

Afterword by Geoffrey Winthrop-Young

Philosophy

"AT ONE AND THE SAME TIME JAKOB VON UEXKÜLL IS A KIND OF BIOLOGIST–SHAMAN ATTEMPTING TO CROSS THE RUBICON TO NONHUMAN MINDS, AND A HUMBLE NATURALIST CLOSELY OBSERVING AND RECORDING HIS FELLOW LIVING BEINGS." *—DORION SAGAN, FROM THE INTRODUCTION*

……

The pioneering biophilosopher Jakob von Uexküll (1864–1944) embarks on a remarkable exploration of the unique social and physical environments that individual animal species, as well as individuals within species, build and inhabit. This concept of the Umwelt has become enormously important within posthumanist philosophy, influencing such figures as Heidegger, Merleau-Ponty, Deleuze and Guattari, and, most recently, Giorgio Agamben, who has called Uexküll "a high point of modern antihumanism."

A key document in the genealogy of posthumanist thought, **A FORAY INTO THE WORLDS OF ANIMALS AND HUMANS** advances Uexküll's revolutionary belief that nonhuman perceptions must be accounted for in any biology worth its name. It also contains his arguments against natural selection as an adequate explanation for the present orientation of a species' morphology and behavior. **A THEORY OF MEANING** extends his thinking on the Umwelt, while also identifying an overarching and perceptible unity in nature.

……

JAKOB VON UEXKÜLL WAS BORN IN ESTONIA AND EDUCATED AT THE UNIVERSITY OF HEIDELBERG AND THE ZOOLOGICAL CENTER IN NAPLES. IN 1926 HE FOUNDED THE INSTITUTE FOR ENVIRONMENTAL RESEARCH AT THE UNIVERSITY OF HAMBURG.

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Dorion Sagan

Although life both transforms matter and processes information, the two are not proportional: the touch of a button may ignite a hydrogen bomb, while the combined military efforts of Orwellian nations will fail to make a little girl smile. Thus life is not just about matter and how it immediately interacts with itself but also how that matter interacts in interconnected systems that include organisms in their separately perceiving worlds—worlds that are necessarily incomplete, even for scientists and philosophers who, like their objects of study, form only a tiny part of the giant, perhaps infinite universe they observe. Nonetheless, information and matter-energy are definitely connected: for example, as I was jogging just now, hearing my own breathing, I was reminded to share the crucial fact that the major metabolism that sustains us perceiving animals is the redox gradient,[1] which powers the flow of electrons between the hydrogen-rich carbon compounds of our food and the oxygen we take in from the atmosphere, a chemical difference which itself reminded me, in one of life's circumlocutionary moments, of its own existence.

Once upon a time, says Nietzsche, in a cosmos glittering forth innumerable solar systems, there was a star "on which clever animals invented knowledge [however] . . . After nature had drawn a few breaths the star grew cold, and the clever animals had to die." Their knowledge did not preserve their life-form or lead to its longevity but only gave its "owner and producer . . . [a feeling of great] importance, as if the world pivoted around it. But if we could communicate with the mosquito [some

INTRODUCTION

ANY COUNTRY DWELLER who traverses woods and bush with his dog has certainly become acquainted with a little animal who lies in wait on the branches of the bushes for his prey, be it human or animal, in order to dive onto his victim and suck himself full of its blood. In so doing, the one- to two-millimeter-large animal swells to the size of a pea (Figure 1).

FIGURE 1. Tick

Although not dangerous, the tick is certainly an unwelcome guest to humans and other mammals. Its life cycle has been studied in such detail in recent work that we can create a virtually complete picture of it.

Out of the egg crawls a not yet fully developed little animal, still missing one pair of legs as well as genital organs. Even in this state, it can already ambush cold-blooded animals such as lizards, for which it lies in wait on the tip of a blade of grass. After many moltings, it has acquired the organs it lacked and can now go on its quest for warm-blooded creatures. Once the female has copulated, she climbs with her full count of eight legs to the tip of a protruding branch of any shrub in order either to fall onto small mammals who run by underneath or to let herself be brushed off the branch by large ones. The eyeless creature finds the way to its lookout with the help of a general sensitivity to light

in the skin. The blind and deaf bandit becomes aware of the approach of its prey through the sense of smell. The odor of butyric acid, which is given off by the skin glands of all mammals, gives the tick the signal to leave its watch post and leap off. If it then falls onto something warm—which its fine sense of temperature will tell it—then it has reached its prey, the warm-blooded animal, and needs only use its sense of touch to find a spot as free of hair as possible in order to bore past its own head into the skin tissue of the prey. Now, the tick pumps a stream of warm blood slowly into itself.

Experiments with artificial membranes and liquids other than blood have demonstrated that the tick has no sense of taste, for, after boring through the membrane, it takes in any liquid, so long as it has the right temperature.

If, after sensing the butyric acid smell, the tick falls onto something cold, then it has missed its prey and must climb back up to its lookout post.

The tick's hearty blood meal is also its last meal, for it now has nothing more to do than fall to the ground, lay its eggs, and die.

The clearly known life processes of the tick afford us a suitable criterion in order to demonstrate the soundness of the biological point of view as opposed to the previously common physiological treatment of the subject. For the physiologist, every living thing is an object that is located in his human world. He investigates the organs of living things and the way they work together just as a technician would examine an unfamiliar machine. The biologist, on the other hand, takes into account that each and every living thing is a subject that lives in its own world, of which it is the center. It cannot, therefore, be compared to a machine, only to the machine operator who guides the machine.

We ask a simple question: Is the tick a machine or a machine operator? Is it a mere object or a subject?

Physiology declares the tick to be a machine and says that one can differentiate receptors, i.e., sensory organs, and effectors, i.e., activity organs, in the tick. These are connected with one another through a control apparatus in the central nervous system. The whole thing is a machine, with no trace of a machine operator.

"Exactly therein lies the mistake," says the biologist. "Not one part of the tick's body has the character of a machine. There are machine operators at work all over the place."

The physiologist will continue unperturbed: "Precisely in the tick, it can be shown that all actions depend solely on reflexes,[2] and the reflex arc forms the foundation of every animal machine (Figure 2). It begins with a receptor, i.e., with an apparatus that admits only certain external influences, such as butyric acid and heat, and disregards all others.

"The arc ends with a muscle which sets an effector into motion, whether this is the apparatus for locomotion or for boring.

"The sensory cells, which activate sensory stimulation, and the motor cells, which activate the movement impulse, are only connectors which transmit the completely physical waves of excitation, produced by the receptor in the nerves in response to an external impulse, to the muscles of the effector. The whole reflex arc works with the transfer of motion, just like any machine. No subjective factor, as one or more machine operators would be, is apparent anywhere."

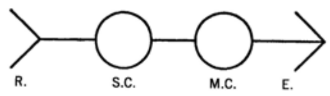


FIGURE 2. Reflex arc: receptor, sensory cell, motor cell, effector

"Exactly the opposite is the case," the biologist will reply. "Everywhere, it is a case of machine operators and not of machine parts, for all the individual cells of the reflex arc act by transfer of stimuli, not by transfer of movement. But a stimulus has to be *noticed* [*gemerkt*] by the subject and does not appear at all in objects."

Any machine part, for example the clapper of a bell, only operates in a machine-like manner if it is swung back and forth in a certain way. All other interventions, such as, for example, cold, heat, acids, alkalis, electrical currents, it responds to as any other piece of metal would. But we know since Johannes Müller,[3] however, that a muscle behaves in a completely different way. It responds to all external interventions in the same way: by contracting. Any external intervention is transformed by the muscle into the same stimulus and responded to with the same impulse, by which its body of cells is made to contract. Johannes Müller showed further that all external effects that hit our optic nerve, whether these are waves in the ether, pressure, or electric currents, cause the sensation of light, i.e., our sight-sense cells answer with the same "perception sign" ["*Merkzeichen*"].[4]

From this, we can conclude that every living cell is a machine operator that perceives and produces and therefore possesses its own particular (specific) perceptive signs and impulses or "effect signs" ["*Wirkzeichen*"]. The complex perception and production of effects in every animal subject can thereby be attributed to the cooperation of small cellular-machine operators, each one possessing only one perceptive and one effective sign.

In order to make an orderly cooperation possible, the organism uses brain cells (which are also elementary machine operators), grouping half of them in differently-sized groups of "perception cells" in the part of the brain that is affected by stimuli, the "perception organ." These groups correspond to external groups of stimuli, which present themselves to the animal subject in the form of questions. The organism uses the other half of the brain cells as "effect cells" or impulse cells and arranges them in groups by means of which it controls the movements of the effectors, which impart the animal subject's answers to the outside world. The groups of perception cells fill up the "perception organs" of the brain, and the groups of effect cells form the "effect organs" of the brain.

If we may, on this account, imagine a perception organ as the site of changing groups of these cell-machine operators, which are the carriers of different perceptive signs, they are still spatially separated individuals. Their perceptive signs would remain isolated if it were not possible for them to coalesce into new units outside the spatially fixed perception organ. This possibility is in fact present. The perceptive signs of a group of perception cells come together outside the perception organ, indeed outside the animal's body, in units that become qualities of the object that lie outside the animal subject. We are all quite familiar with this fact. All our human sensations, which represent our specific perception signs, join together to form the qualities of the external things which serve us as perception marks for our actions. The sensation "blue" becomes the "blueness" of the sky, the sensation "green" becomes the "greenness" of the lawn, and so forth. We recognize the sky by the feature "blue" and the lawn by the feature "green."

Exactly the same thing takes place in the effect organ. Here, the effect cells play the role of the elementary machine operators, which in this case are arranged into well-articulated groups according to their impulse or productive sign. Here, too, it is possible to group the isolated effect signs into units that, in the form of self-contained motor impulses or rhythmically arranged melodies of impulses, produce effects in the muscles subject to them. At this, the effectors activated by the muscles impress their "effect mark" ["*Wirkmal*"] on the objects that lie outside the subject.

The effect mark that the effectors of the subject impart to the object is immediately recognizable, just like the wound which the tick's mouthparts inflict upon the skin of the mammal on which it has landed. But only the laborious search for the features of butyric acid and warmth completes the picture of the tick as active in its environment.

Figuratively speaking, every animal subject attacks its objects in a pincer movement—with one perceptive and one effective arm. With the first, it imparts each object a perception mark [*Merkmal*] and with the second an effect mark. Certain qualities of the object become thereby carriers of perception marks and others carriers of effect marks. Since all qualities of an object are connected with each other through the structure of the object, the qualities affected by the effect mark must exert their influence through the object upon the qualities that are carriers of the perception mark and have a transformative effect on the perception mark itself. One can best sum this up this way: The effect mark extinguishes the perception mark.

In addition to the selection of stimuli that the receptors allow to pass and the order of muscles which give the effectors certain potentials for activity, the decisive factors for any action by every animal subject are above all the number and order of perception cells that distinguish the objects of the environment by assigning them features with the help of their perception signs, and the number and order of the effect cells that furnish the same objects with effect marks.

The object only takes part in this action to the extent that it must possess the necessary properties, which can serve on the one hand as feature carriers and, on the other, as effect sign carriers, and which must be in contact with each other through a reciprocal structure.

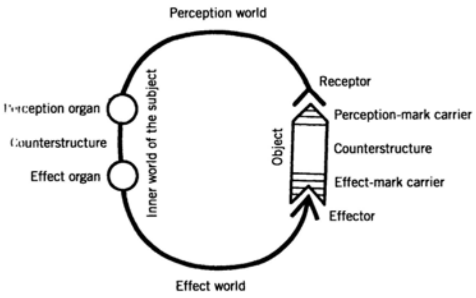


FIGURE 3. Functional cycle

The connection of subject to object can be most clearly explained by the schema of the functional cycle (Figure 3). The schema shows how subject and object are interconnected with each other and form an orderly whole. If one further imagines that subjects are linked to the same object or different ones by multiple functional cycles, one can thereby gain insight into the fundamental principle of the science of the environment: All animal subjects, from the simplest to the most complex, are inserted into their environments to the same degree of perfection. The simple animal has a simple environment; the multiform animal has an environment just as richly articulated as it is.

Now, let us place the tick into the functional cycle as a subject and the mammal as its object. It is seen that three functional cycles take place, according to plan, one after the other. The mammal's skin glands comprise the feature carriers of the first cycle, since the stimulus of the butyric acid sets off certain perception signs in the [tick's] perception organ, and these signs are transposed outward as olfactory features. The processes in the perception organ bring about corresponding impulses by induction (we do not know what that is) in the [tick's] effect organ which then bring about the releasing of the legs and falling. The falling tick imparts to the mammal's hairs, on which it lands, the effect mark "collision," which then activates a tactile feature which, in its turn, extinguishes the olfactory feature "butyric acid." The new feature activates the tick's running about, until this feature is in turn extinguished at the first bare patch of skin by the feature "warmth," and the drilling can begin.

This is no doubt a case of three reflexes, each of which is replaced by the next and which are activated by objectively identifiable physical or chemical effects. But whoever is satisfied with that observation, and assumes he has therefore solved the problem, only proves that he has not seen the real problem at all. It is not a question of the chemical stimulus of the butyric acid any more than it is of the mechanical stimulus (activated by the hair) or of the thermal stimulus of the skin. It is only a question of the fact that, among the hundreds of effects that emanate from the mammal's body, only three become feature carriers for the tick. Why these three and no others?

It is not a question of a contest of strength between two objects but, rather, of the connection between a living subject and its object. These take place at an entirely different level: between the subject's perception signs and the object's stimulus.

The tick hangs inert on the tip of a branch in a forest clearing. Its position allows it to fall onto a mammal running past. From its entire environment, no stimulus penetrates the tick. But here comes a mammal, which the tick needs for the production of offspring.

And now something miraculous happens. Of all the effects emanating from the mammal's body, only three become stimuli, and then only in a certain sequence. From the enormous world surrounding the tick, three stimuli glow like signal lights in the darkness and serve as directional signs that lead the tick surely to its target. In order to make this possible, the tick has been given, beyond its body's receptors and effectors, three perception signs, which it can use as features. Through these features, the progression of the tick's actions is so strictly prescribed that the tick can only produce very determinate effect marks.

The whole rich world surrounding the tick is constricted and transformed into an impoverished structure that, most importantly of all, consists only of three features and three effect marks—the tick's environment. However, the poverty of this environment is needful for the certainty of action, and certainty is more important than riches.

As one can see, the fundamental aspects of the structure of the environments that are valid for all animals can be derived from the example of the tick. But the tick has one more remarkable capability that allows us a greater insight into environments.

It is immediately evident that the happy occasion that brings a mammal to pass beneath the branch on which the tick sits occurs most seldom. Even the great number of ticks lying in wait in the bush does not compensate for this disadvantage in such a way as to secure the reproduction of the species. In order to increase the probability that its prey will pass by, the tick must be capable of living a long time without nourishment. And the tick is capable of this to an unusual degree. At the Zoological Institute in Rostock, they kept ticks alive that had gone hungry for eighteen years.[5] The tick can wait eighteen years; we humans cannot. Our human time consists of a series of moments, i.e., the shortest segments of time in which the world exhibits no changes. For a moment's duration, the world stands still. A human moment lasts one-eighteenth of a second.[6] We shall see later that the duration of a moment is different in different animals, but, no matter what number we assign to the tick, it is simply impossible for an animal to endure an unchanging environment for eighteen years. We shall therefore assume that the tick is, during its waiting period, in a state similar to sleep, which also interrupts our human time for hours. But time stands still in the tick's waiting period not just for hours but for years, and it starts again only when the signal "butyric acid" awakens the tick to renewed activity.

What have we gained by this knowledge? Something very significant. Time, which frames all events, seemed to us to be the only objectively consistent factor, compared to the variegated changes of its contents, but now we see that the subject controls the time of its environment. While we said before, "There can be no living subject without time," now we shall have to say, "Without a living subject, there can be no time."

We shall see in the next chapter that the same is true of space: Without a living subject, there can be neither space nor time. With this observation, biology has once and for all connected with Kant's philosophy, which biology will now utilize through the natural sciences by emphasizing the decisive role of the subject.

ENVIRONMENT SPACES

Just as a gourmet picks only the raisins out of the cake, the tick only distinguishes butyric acid from among the things in its surroundings. We are not interested in what taste sensations the raisins produce in the gourmet but only in the fact that they become perception marks of his environment because they are of special biological significance for him; we also do not ask how the butyric acid tastes or smells to the tick, but rather, we only register the fact that butyric acid, as biologically significant, becomes a perception mark for the tick.

We content ourselves with the observation that perception cells must be present in the perception organ of the tick that send out their perception signs, just as we assume the same for the perception organs of the gourmet. The only difference is that the tick's perception signs transform the butyric acid stimulus into a perception mark of its environment, whereas the gourmet's perception signs in his environment transform the raisin stimulus into a perception mark.

The animal's environment, which we want to investigate now, is only a piece cut out of its surroundings, which we see stretching out on all sides around the animal—and these surroundings are nothing else but our own, human environment. The first task of research on such environments consists in seeking out the animal's perception signs and, with them, to construct the animal's environment. The perception sign of raisins does nothing for the tick, while the perception mark of butyric acid plays an exceptional role in its environment. In the gourmet's environment, on the other hand, the accent of significance falls not on butyric acid, but on the perception mark of raisins.

Every subject spins out, like the spider's threads, its relations to certain qualities of things and weaves them into a solid web, which carries its existence.

The relations of the subject to the objects of its surroundings, whatever the nature of these relations may be, play themselves out outside the subject, in the very place where we have to look for the perception marks. Perception signs are therefore always spatially bound, and, since they take place in a certain sequence, they are also temporally bound.

We comfort ourselves all too easily with the illusion that the relations of another kind of subject to the things of its environment play out in the same space and time as the relations that link us to the things of our human environment. This illusion is fed by the belief in the existence of one and only one world, in which all living beings are encased. From this arises the widely held conviction that there must be one and only one space and time for all living beings. Only recently have physicists raised doubts as to the existence of one universe with one space valid for all beings. That there can be no such space comes already of the fact that every human being lives in three spaces, which interpenetrate and complete but also partially contradict each other.

Effect Space

When we close our eyes and move our limbs, these movements are known exactly by us in their direction and their extension. Using our hand, we find our way in a space that one can designate the free space of our movements, or, in other words, our effect space [*Wirkraum*]. We measure these paths out in the shortest steps, which we will call directional steps, since the direction of each and every step is known exactly to us through the sensation of direction or *directional sign*. We distinguish six directions, in pairs of opposites: to the left and to the right, upward and downward, forward and backward.

Thorough experiments have shown that the smallest step we can execute, as measured by the index finger of the outstretched arm, is approximately two centimeters in length. As one can see, these steps constitute no precise measurement of the space in which they are executed. Anyone can convince himself of this imprecision if he attempts, with closed eyes, to make his fingertips meet. He would see that this generally fails and that the fingertips miss each other by a distance of up to two centimeters.

It is of the utmost significance for us that we can retain these paths, once executed, very easily in our memory, which makes it possible to write in the dark. This skill is called "kinesthesia," which adds nothing new.

However, effect space is not just a space of movement constructed of a thousand crisscrossing directional steps. Rather, it possesses a system by which it is controlled, the well-known coordinate system, consisting of levels that are vertically arranged, one on top of the other. This serves as the basis of all spatial determinations.

It is of fundamental importance that everyone who is concerned with the problem of space persuade himself of this fact. Nothing is simpler. One need only close one's eyes and move one's hand, held perpendicular to the forehead, back and forth in order to establish with certainty where the boundary between right and left lies. This boundary practically coincides with the body's median plane. If one moves one's horizontally held hand up and down in front of one's face, one can easily establish where the boundary between up and down lies. This boundary is located at eye level in most people. Nonetheless, a great number of people place this boundary at the height of the upper lip. The boundary between front and back differs the most; it can be found by moving the forward-facing palm of the hand. A large number of people say that this plane is located at the opening of the ear, while others designate the zygomatic arch as the boundary plane, and others still place it in front of the tip of the nose. Every normal human being carries a coordinate system around with him that is made up of these three planes and is firmly connected to his head (Figure 4) and thereby confers a solid frame upon his effect space, in which these directional steps lurch and reel.

Into the shifting tangle of directional steps, which as elements of movement can give no solidity to the effect space, these resting planes project a firm scaffolding that guarantees the order of the effect space.

It was the great achievement of [Elie von] Cyon[7] to attribute the three-dimensionality of our space to a sense-organ located in the inner ear, the so-called semicircular canals (Figure 5), the location of which corresponds approximately to the three planes of the effect space. This connection has been demonstrated so clearly by numerous experiments that we can make the following assertion: All animals that have these three semicircular canals also have available a three-dimensional effect space.

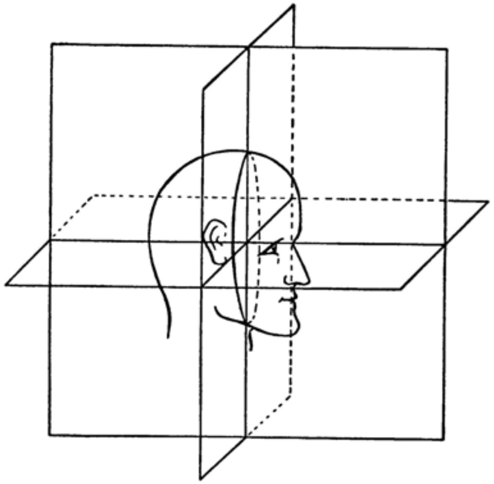


FIGURE 4. Coordinate system of a human being

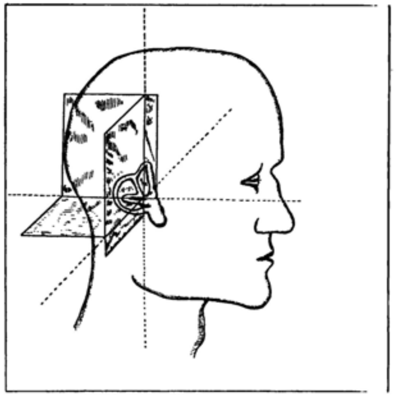


FIGURE 5. Semicircular canals of a human being

Figure 6 shows the semicircular canals of a fish. It is evident that these must be of great importance for this animal. Their inner structure also supports this conclusion; it presents a system of tubes in which liquid, controlled by nerves, moves in the three spatial directions. The movement of liquid faithfully reflects the movements of the whole body. That indicates to us that, in addition to the task of transposing the three planes into the effect space, another meaning can be assigned to this organ. It seems to be called to play the role of a compass as well—not a compass that only ever points north, but a compass for the "house door." If all the movements of the entire body are analyzed and marked in the semicircular canals, then the animal must be back at its starting point when, in the course of swimming around, it has brought these nerve markings back to zero.

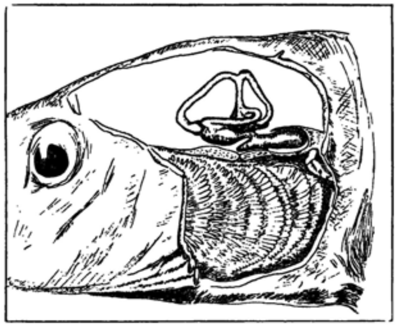


FIGURE 6. Semicircular canals of a fish

It is beyond all doubt that such a house-door compass is a necessary aid for all animals, whether the house door is a nesting or a spawning place. The establishment of the house door through optical features in visual space is in most cases not adequate, since it must be found even if it has changed its appearance.

The ability to find the house door in effect space can also be demonstrated in insects and mollusks, even though these animals have no semicircular ear canals. The following is a very convincing experiment (Figure 7): When most of the bees have flown out, a beehive is moved two meters. As it happens, the bees gather again at that place in the air where the exit hole—their house door—was previously located. After five minutes, the bees shift course and fly toward the hive.

These experiments have been carried further, with the result that bees whose feelers have been cut off fly immediately toward the relocated hive. This means that, as long as they are in possession of their feelers, they orient themselves

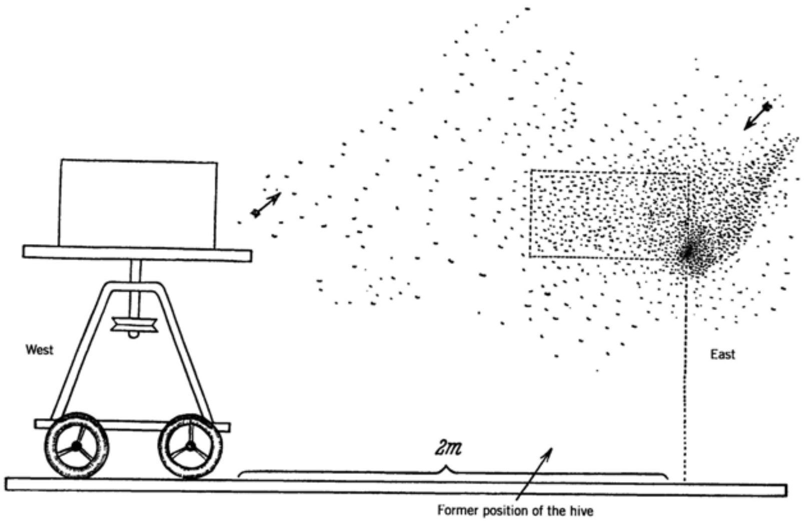


FIGURE 7. Effect space of the bee

foremost in effect space. Without them, they guide themselves by the optical impressions of visual space. The bees' feelers must therefore play in normal life the role of the house-door compass, which shows them the way home more surely than do visual impressions.

Even more conspicuous is the same homing behavior in the case of the common limpet (Figure 8). The limpet lives within the tidal zone on the cliff bottom. The largest individuals dig themselves a bed in the rock with their hard shells, in which they spend the low tide pressed close against the cliff. At high tide, they wander about and graze the cliff rock around themselves bare. When low tide arrives, they return to their beds, but they do not always choose the same path home. The limpet's eyes are so primitive that this snail could never find the house door with their aid alone. The presence of an olfactory perception mark is just as unlikely as that of a visual one. There remains only the supposition of a compass in effect space, of which, however, we can have no conception.

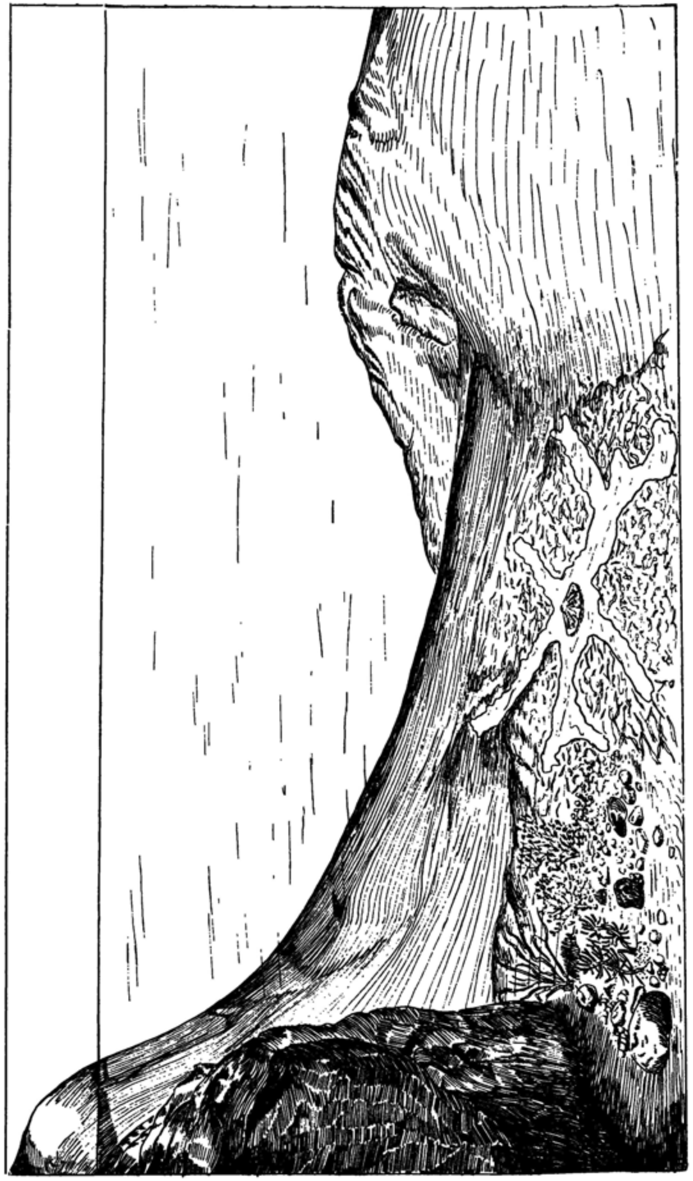


FIGURE 8. The limpet finds its way home

Tactile Space

The basic building block of tactile space is not a unit of movement such as the directional step, but a fixed one, place [*der Ort*]. Place also owes its existence to a perception sign belonging to the subject and is not a configuration dependent upon the matter of its surroundings. [Ernst Heinrich] Weber provided the proof of this.[8] If one places the points of a compass more than one centimeter apart on the nape of an experimental subject's neck, the subject can clearly distinguish between the two points (Figure 9). Each point is located at another place. If one moves the points down toward the back without changing the distance between them, they get closer and closer in the tactile space of the experimental subject until they seem to be at the same place.

FIGURE 9. Weber's compass experiment

There results from this that, besides the perception sign for the sense of touch, we also possess a perception sign for the sense of place, which we shall call local signs. Transferred outward, each local sign delivers a place in tactile space. The areas of our skin that produce the same local sign in us when touched change extraordinarily in size according to the meaning that the part of the skin concerned has for touching. After the tip of the tongue, which feels around the inside of the mouth, the tips of our fingers have the smallest areas and are therefore able to differentiate the most places. As we feel out an object, we confer a fine mosaic of place upon its surface with the touch of our finger. The mosaic of place of the objects of the places of an animal is a gift from the subject to the things in its environment in visual as well as in tactile space, one which is not at all available in its surroundings.

In feeling out [an object], places connect themselves with directional steps, and both serve the process of image-formation.

Tactile space plays a very prominent role in some animals. Rats and cats are completely unhindered in their movements even when they have lost the sense of sight—as long as they have their *vibrissae* [whiskers]. All nocturnal animals and all animals living in caves live predominantly in tactile space, which represents a melding of places and directional steps.

Visual Space

Eyeless animals that, like the tick, have skin that is sensitive to light will most likely possess the same skin areas for the production of local signs for light stimuli as well as for tactile stimuli. Visual and tactile places coincide in their environments.

Only with animals that have eyes do visual and tactile places clearly separate. In the eye's retina, the very small elementary areas—the visual elements—close together. To each sight element there corresponds a place in the environment, for it so happens that one local sign is assigned to each visual element. Figure 10 represents the visual space of a flying insect. It is easy to see that, as a consequence of the spherical construction of the eye, the region of the outside world that strikes a visual element grows larger as distance increases and ever more encompassing parts of the outside world are covered by one place. As a result of this, all the objects that move away from the eye grow smaller and smaller until they vanish into one place, for the place represents the smallest spatial vessel inside of which there are no distinctions.

In tactile space, the objects' growing smaller does not take place. And that is the point at which visual and tactile space come into competition. If one reaches out one's arm to

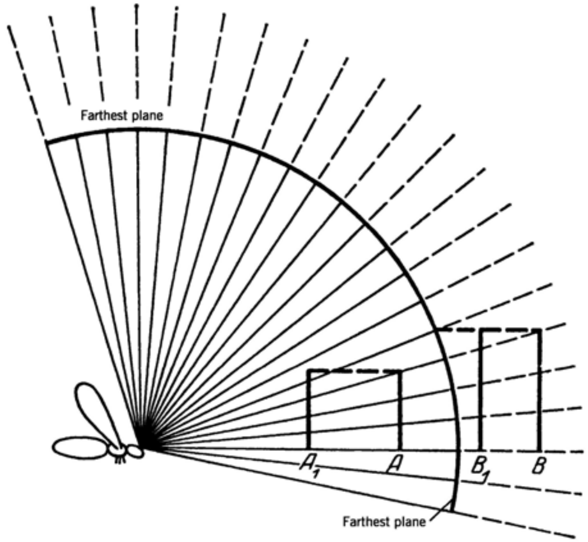


FIGURE 10. The visual space of a flying insect

grasp a cup and bring it to one's mouth, it will become larger in visual space, but its size in tactile space will not change. In this case, tactile space predominates, for the cup's growing in size will not be noticed by an impartial observer.

Like the hand that feels, the eye that glances about spreads a fine mosaic of places over all the things in its environment, the fineness of which depends on the number of visual elements that take in the same segment of the surroundings.

Since the number of visual elements changes extraordinarily in the eyes of different animals, the mosaic of places of their environment must show the same distinctions. The coarser the mosaic, the greater the loss of the details of the things, and the world as seen through a fly's eye must seem significantly coarsened as compared to its being seen through a human eye.

One need only to reduce the same image more and more, photograph it each time against the same grid, and enlarge it again. It will then change itself into an ever more coarse mosaic. Since the grid is too bothersome, we have reproduced here the coarser mosaic images as a watercolor without a grid. Figures 11 a–d were produced with the grid method. They offer the chance to gain an intuition of an animal's environment if one knows the number of visual elements in its eye. Figure 11c corresponds approximately to the image provided by the eye of the housefly. One can easily understand that in an environment that displays so few details, the threads of a spider's web are completely lost to sight, and we may say that the spider weaves a net that remains completely invisible to its prey.

The last figure (11d) corresponds to the image impressed upon the eye of a mollusk. As one can see, the visual space of snails and mussels contains nothing but a number of dark and light surfaces.[9] Just as in tactile space, the connections from place to place in visual space are produced through directional steps. If we prepare an object under the magnifying glass, whose purpose it is to join a large number of places on a small surface, we can realize that not only our eye but also our hand guiding the dissecting pin executes much shorter directional steps that correspond to the places that are now close to each other.

THE FARTHEST PLANE

Unlike effect space and tactile space, visual space is walled about by an impenetrable wall, which we shall call the horizon or farthest plane.

Sun, moon, and stars wander about on the same farthest plane with no difference in depth; this plane includes all visible things. The position of the farthest plane is, however, not firmly fixed. When I took my first steps out of doors after a bad bout of typhus, the farthest plane hung about twenty meters in

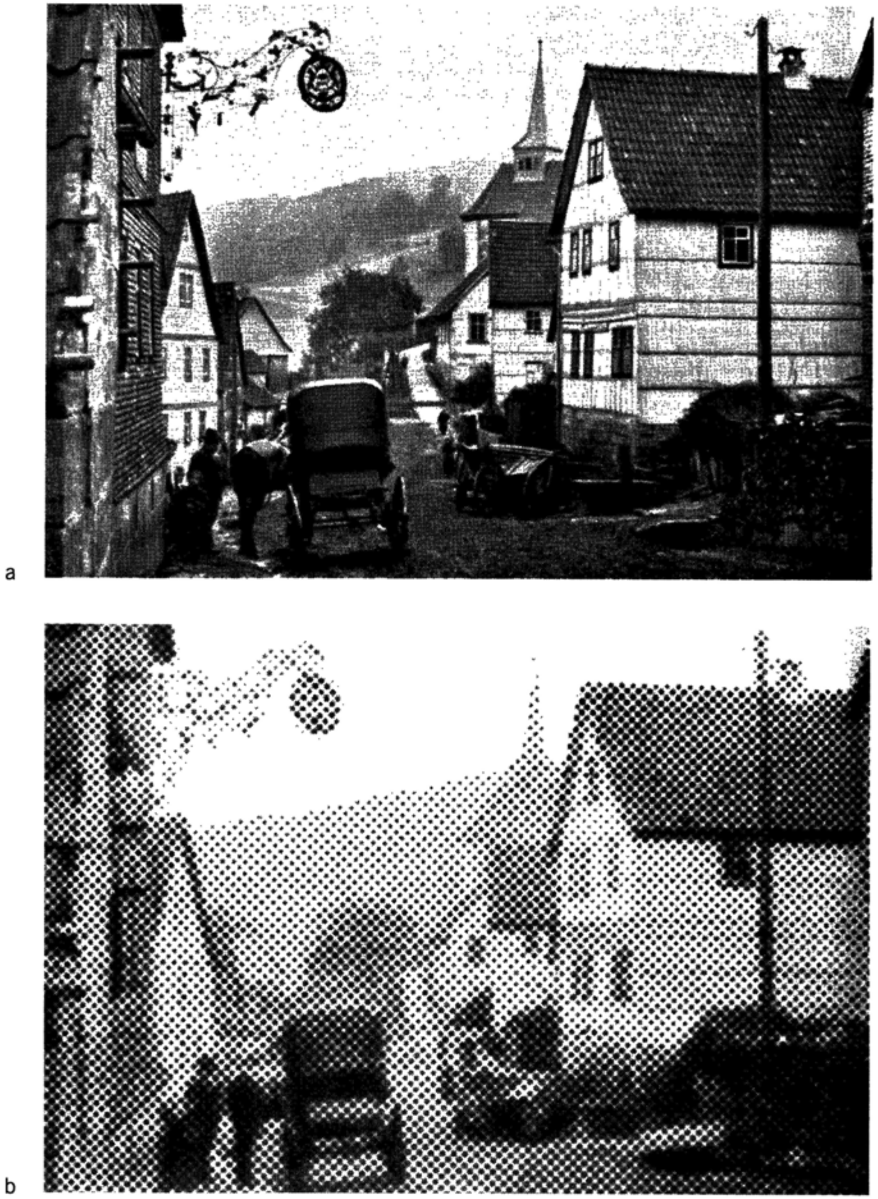


FIGURE 11. a. Photograph of a village street
b. Village street photographed through a screen

FIGURE 11. c. The same village street for a fly's eye
d. Village street for a mollusk's eye

front of me like colorful wallpaper on which all visible things were portrayed. Past twenty meters, objects were neither closer nor farther away, only larger and smaller. Even the coaches that drove past me became not farther away but only smaller as soon as they had reached the farthest plane.

The lens of our eye has the same task as the lens of a photographic camera, namely to focus the objects found in front of the eye on the retina, which corresponds to the photosensitive plate in the camera. The lens of the human eye is elastic and can be bent by special lens muscles (which has the same effect as adjusting the lens on the camera). In contracting the lens muscles, directional signs appear for the direction back to front. As the relaxing muscles of the elastic lens are stretched, there appear directional signs that give the direction from front to back. If the muscles are completely relaxed, the eye is focused on the distance from ten meters to infinity.

Within a radius of ten meters, the things in our environment are known to us through this muscular movement in terms of near and far. Outside this radius, there is originally only an enlargement or shrinking of objects. The infant's visual space ends here with an all-encompassing farthest plane. Only bit by bit do we learn to push the farthest plane ever farther with the help of distance signs, until the adult's visual space ends at a distance of six to eight kilometers and the horizon begins.

The difference between the visual space of a child and that of an adult is explained in Figure 12, which reproduces visually an experience related by [Hermann von] Helmholtz.[10] He reports that, as a small boy, he was walking by the Garrison Church in Potsdam and noticed some workers in the gallery. He then asked his mother if she might take a couple of the little dolls down for him. The church and the workers were already located in his farthest plane and were therefore not far away, only small. He therefore had every reason to assume that his mother, with her long arms, could bring the dolls down from the gallery. He did not know that the church had entirely different dimensions in his mother's environment and that the people in the gallery were for her not small but far away. The situation of the farthest plane is difficult to demonstrate in the environments of animals because it is generally not easy to establish experimentally when an object approaching the subject in the latter's environment is becoming not just larger but nearer.

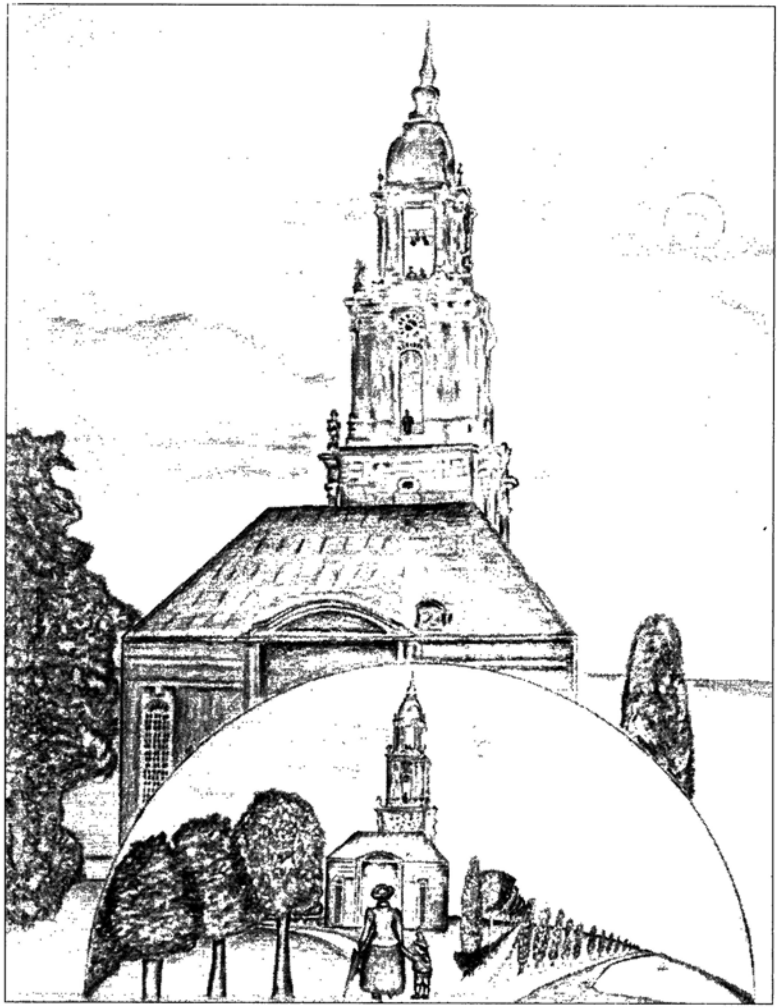


FIGURE 12. The farthest plane of an adult (below) and a child (above)

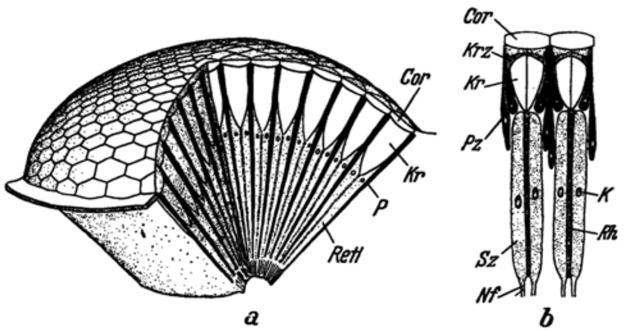


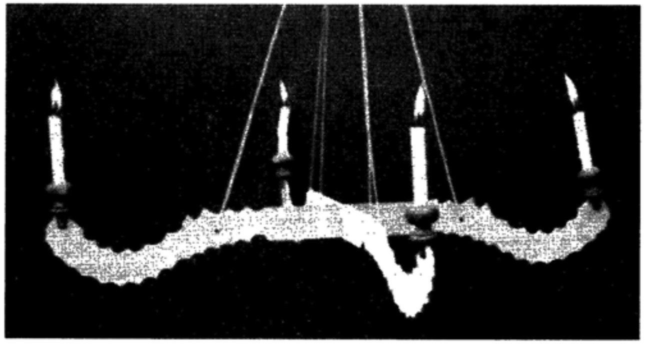
FIGURE 13. Schematic structure of the compound eye of a fly.
a: The whole eye, out of which a piece is cut *(right)* (after Hesse).
b: Two ommatidia. *Cor*: chitin cornea; *K*: nucleus; *Kr*: crystal cone; *Krz*: crystal cone cell; *Nf*: nerve fiber; *P*: pigment; *Pz*: pigment cell; *Retl*: retinula; *Rh*: Rhabdom; *Sz*: photoreceptor.

Experiments in catching houseflies show that the approaching human hand only causes them to fly away when it is at a distance of about half a meter. By this, one might assume that the farthest plane is to be sought at this distance.

But other observations in the case of the housefly make it seem likely that the farthest plane appears in a still different way. It is well known that flies do not only circle around a hanging lamp or chandelier but always break off their flight suddenly once they are half a meter away from it, in order then to fly away close to or below the light. In this, they behave like a boater in a sailboat who does not want to lose sight of an island.

The eye of a fly (Figure 13) is built in such a way that its visual elements (rhabdoms) present long nerve structures that must catch the image projected by their lenses at varying depths, corresponding to the distance from the perceived object. [Siegmund] Exner[11] has expressed his supposition that this could be a replacement for the muscular lens apparatus of our eye.

If one supposes that the optical apparatus of the visual elements functions like an accessory lens, then the chandelier would disappear at a certain distance and cause the fly to return. One can compare Figures 14 and 15, which show the chandelier photographed with and without an accessory lens.



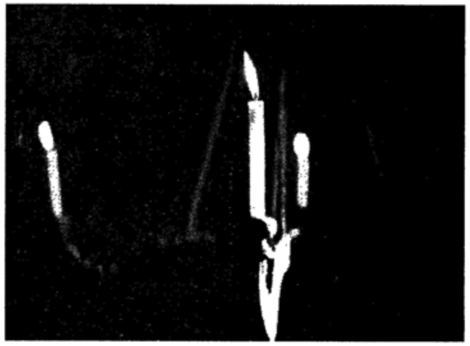


FIGURE 14. *(above)* Chandelier for human beings

FIGURE 15. *(left)* Chandelier for the fly

Whether the farthest plane closes off visual space in this or in some other way, this plane is always present. We must therefore imagine all the animals that animate Nature around us, be they beetles, butterflies, gnats, or dragonflies who populate a meadow, as having a soap bubble around them, closed on all sides, which closes off their visual space and in which everything visible for the subject is also enclosed. Each bubble shelters other places, and in each are also found the directional planes of effective space, which give a solid scaffolding to space. The birds that flutter about, the squirrels hopping from branch to branch, or the cows grazing in the meadow, all remain permanently enclosed in the bubble that encloses their space.

Only when we can vividly imagine this fact will we recognize in our own world the bubble that encloses each and every one of us on all sides. Then, we will see each of our fellow human beings as being enclosed in bubbles that effortlessly overlap one another because they are made up of subjective perception signs. There is no space independent of subjects. If we still want to cling to the fiction of an all-encompassing world-space, that is only because we can get along with each other more easily with the help of this conventional fable.

PERCEPTION TIME

To KARL ERNST VON BAER[12] belongs the merit of making time intuitively understandable as a product of the subject. Time as a sequence of moments changes from environment to environment, according to the number of moments that the subjects experience in the same amount of time. Moments are the smallest indivisible vessels of time because they are the expression of indivisible elementary sensations, so-called moment signs. For the human being, as we already said, the length of a moment is one-eighteenth of a second. And the moment is in fact the same for all areas of sensation, since these are all accompanied by the same moment sign: Eighteen vibrations of the air are no longer perceived distinctly but rather heard as a single note. It has also been shown that human beings perceive eighteen impacts on their skin as an even pressure.

Cinematography offers us the possibility of projecting movements in the outside world onto the screen in the speed to which we are accustomed. Therein, the individual images succeed each other in brief jerks of one-eighteenth of a second.

If we want to follow movements that occur too quickly for us, we use slow motion. Slow motion is the process by which a great number of images is recorded per second in order then to show them at a normal speed. Thereby we stretch the processes of movement over a longer span of time and gain the possibility of making visible processes that are too quick for our human time-speed, such as the beating of a bird's or an insect's wings. Just as slow motion slows down the processes of motion, so does time-lapse photography accelerate them. If we record a process once an hour and then show it at a speed of one-eighteenth of a second, we compress it into a brief span and gain the possibility of making visible for ourselves processes that are too slow for our speed, such as the blooming of a flower.

The question arises as to whether there are animals whose perception time has shorter or longer moments than ours, and in whose environments the motion processes occur more quickly or more slowly than they do in ours.

A young German researcher has conducted the first experiments in this area. Later, in collaboration with another researcher, he used the reaction of a fighting fish to its own mirror image. The fighting fish does not recognize its own image when it is shown to him eighteen times a second; it must be shown at least thirty times a second.

A third researcher trained the fish only to snap at their food when a gray disc was rotated behind it. If, on the other hand, a disc with black-and-white sectors was rotated slowly, this served as a "warning sign," for, in that case, the fish got a light blow when they approached the food. If the black-and-white disc was rotated more rapidly, the reactions of the fish became more unsure at a certain speed until finally they reacted in the opposite manner. That happened only when the black-and-white sectors succeeded each other at a speed greater than one-fiftieth of a second. The black-and-white warning sign then became gray.

One can conclude with certainty that in the case of these fish, which live on fast-moving prey, all processes of motion appear more slowly in their environment, as in slow motion.

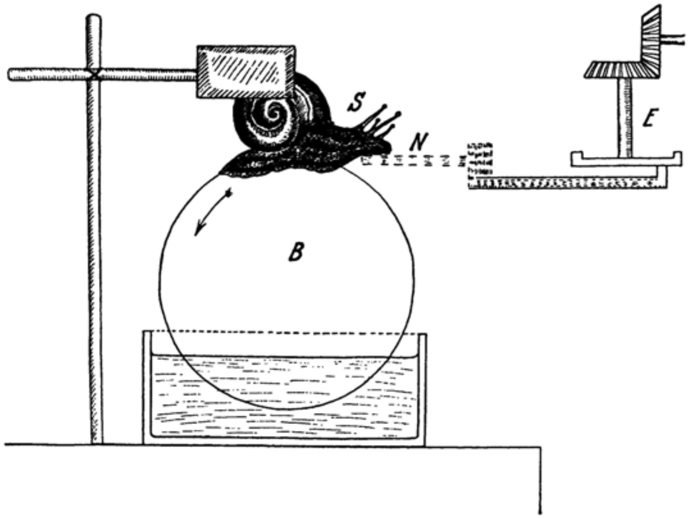


FIGURE 16. The snail's moment. *B* = ball, *E* = eccentric, *N* = stick, *S* = snail

An example for fast motion is given in Figure 16, which is taken from the abovementioned research. A snail [*Helix pomatia*] is placed on a rubber ball which, because it is floating on water, can slide freely past beneath the snail. The snail's shell is held in place by a clamp. The snail is thereby free to crawl and also stays in the same place. If one places a small stick at the foot of the snail, it will crawl up on it. But if one strikes the snail from one to three times a second with it, the snail will turn away. However, if the blows are repeated four or more times a second, the snail begins to crawl onto the stick. In the snail's environment, a stick that moves back and forth four or more times a second must be at rest. We can conclude from this that the perception time of the snail takes place at a speed of between three and four moments a second. This has as a result that all processes of motion take place much more quickly in the snail's environment than they do in our own. Even the snail's own movements do not seem slower to it than ours do to us.

SIMPLE ENVIRONMENTS

Space and time are of no immediate use to the subject. They only become meaningful when numerous perception marks (features) must be distinguished that would otherwise, without the spatiotemporal framework of the environment, coincide. However, such a framework is not needed in simple environments, which harbor only one perception sign. Figure 17 shows the surroundings of the paramecium. It is covered with thick rows of cilia, and it moves through the water by the motion of these cilia while rotating constantly on its long axis.

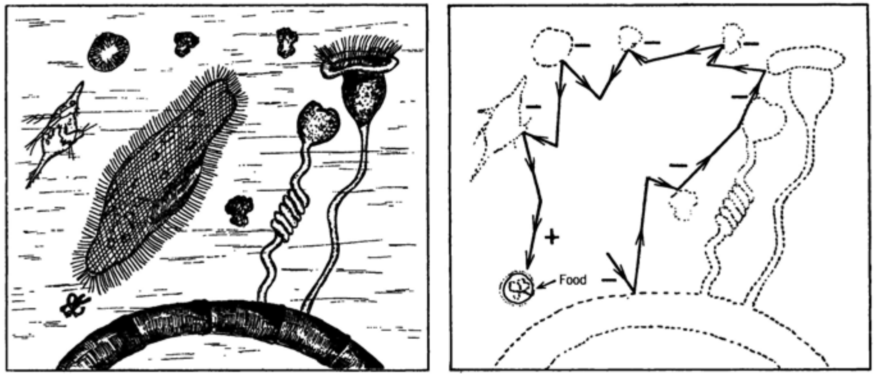


FIGURE 17. Surroundings and environment of the paramecium

Of all the various things located in its surroundings, its environment only ever notes the same perception mark through which the paramecium, when stimulated, is caused to flee. The same perception mark, hindrance, always brings forth the same movement of flight. This consists in a backward movement with subsequent lateral turning, following which the paramecium resumes swimming forward. The hindrance is thereby placed at a distance. One may say that, in this case, the same perception