INTRODUCTION

This is a book about how we see. How do we see the environment around us? How do we see its surfaces, their layout, and their colors and textures? How do we see where we are in the environment? How do we see whether or not we are moving and, if we are, where we are going? How do we see what things are good for? How do we see how to do things, to thread a needle or drive an automobile? Why do things look as they do?

This book is a sequel to *The Perception of the Visual World,* which came out in 1950. It is rather different, however, because my explanation of vision was then based on the retinal image, whereas it is now based on what I call the ambient optic array. I now believe we must take an ecological approach to the problems of perception.

We are told that vision depends on the eye, which is connected to the brain. I shall suggest that natural vision depends on the eyes in the head on a body supported by the ground, the brain being only the central organ of a complete visual system.

When no constraints are put on the visual system, we look around, walk up to something interesting and move around it so as to see it from all sides, and go from one vista to another. That is natural vision, and that is what this book is about.

The textbooks and handbooks assume that vision is simplest when the eye is held still, as a camera has to be, so that a picture is formed that can be transmitted to the brain. Vision is studied by first requiring the subject to fixate a point and then exposing momentarily a stimulus or a pattern of stimuli around the fixation point. I call this *snapshot vision.* If the exposure period is made longer, the eye will scan the pattern to which it is exposed, fixating the parts in succession, unless the subject is prohibited from doing so. I call this *aperture vision,* for it is a little like looking at the environment through a knothole in a fence. The investigator assumes that each fixation of the eye is analogous to an exposure of the film in a camera, so that what the brain gets is something like a sequence of snapshots.

The headrest of the laboratory prevents the observer from turning his head and looking around, which provides what I will call *ambient vision.* It also, of course, prevents him from getting up and walking around, which provides *ambulatory vision.* Are these forms of vision? I suggest they are; in fact, they are the kind of vision we

need in life, not just pictorial depth perception. We need to see all the way around at a given point of observation and to take different points of observation. The crux of the matter is whether or not natural vision is compounded of units like the snapshot. I very much doubt that vision is simplest when the experimenter tries to make the eye work as if it were a photographic camera, even the kind that takes pictures in rapid succession.

Looking around and getting around do not fit into the standard idea of what visual perception is. But note that if an animal has eyes at all it swivels its head around and it goes from place to place. The single, frozen field of view provides only impoverished information about the world. The visual system did not evolve for this. The evidence suggests that visual awareness is in fact panoramic and does in fact persist during long acts of locomotion.

Part I of this book is about the environment to be perceived. Part II is about the information for perception. Part III is about the activity of perception. Finally, Part IV is about pictures and the special kinds of awareness that go with looking at them. Picture vision comes last because it can be understood only after we are clear about ambient vision and ambulatory vision.

First, the environment must be described, since what there is to be perceived has to be stipulated before one can even talk about perceiving it. This is not the world of physics but the world at the level of ecology. Second, the information available for perception in an illuminated medium must be described. This is not just light for stimulating receptors but the information in the light that can activate the system. Ecological optics is required instead of classical optics. Third (and only here do we come to what is called psychology proper), the process of perception must be described. This is not the processing of sensory inputs, however, but the extracting of invariants from the stimulus flux. The old idea that sensory inputs are converted into perceptions by operations of the mind is rejected. A radically new way of thinking about perception is proposed.

The ecological approach to perception was adopted in my book *The Senses Considered as Perceptual Systems*, which came out in 1966. Actually, it is a new approach to the whole field of psychology, for it involves rejecting the stimulus-response formula. This notion, borrowed from the so-called hard science of physiology, helped to get rid of the doctrine of the soul in psychology, but it never really worked. Neither mentalism on the one hand nor conditioned-response behaviorism on the other is good enough. What psychology needs is the kind of thinking that is beginning to be attempted in what is loosely called systems theory.

Environmentalism is a powerful movement nowadays, but in psychology it has generated more enthusiasm than discipline. There is no central core of theoretical concepts on which to base it. The right conceptual level has not yet been found. This book makes an effort to find the right level. A few psychologists, such as E. Brunswik

(1956) and R. G. Barker (1968), have moved in this direction, but none has ended with the sort of theory being put forward here.

The great virtue of the headrest, the bite-board, the exposure device, the tachistoscope, the darkroom with its points of light, and the laboratory with its carefully drawn pictorial stimuli was that they made it possible to study vision *experimentally*. The only way to be sure an observer sees what he says he does is to set up an experimental situation and check him out. Experimental verification can be trusted. These controls, however, made it seem as if snapshot vision and aperture vision were the whole of it, or at least the only vision that could be studied. But, on the contrary, natural vision *can* be studied experimentally. The experiments to be reported in Part III on perception involve the providing of optical information instead of the imposing of optical stimulation. It is not true that "the laboratory can never be like life." The laboratory *must* be like life!

It has to be admitted that the controlled displaying of information is vastly more difficult than the controlled applying of stimulation. Experimenters are just beginning to learn how to display information in a few scattered laboratories, at Cornell, Uppsala, the University of Connecticut, and Edinburgh. The experiments I will report in Part III are mostly my own, and the evidence, therefore, is scanty. Other students of information-based perception are at work, but the facts have not yet been accumulated. The vast quantity of experimental research in the textbooks and handbooks is concerned with snapshot vision, fixed-eye vision, or aperture vision, and it is not relevant. I do assure my readers that I know this body of research. I have even contributed to it. But they will have to take my word for it.

I am also asking the reader to suppose that the concept of space has nothing to do with perception. Geometrical space is a pure abstraction. Outer space can be visualized but cannot be seen. The cues for depth refer only to paintings, nothing more. The visual third dimension is a misapplication of Descartes's notion of three axes for a coordinate system.

The doctrine that we could not perceive the world around us unless we already had the concept of space is nonsense. It is quite the other way around: We could not conceive of empty space unless we could see the ground under our feet and the sky above. Space is a myth, a ghost, a fiction for geometers. All that sounds very strange, no doubt, but I urge the reader to entertain the hypothesis. For if you agree to abandon the dogma that "percepts without concepts are blind," as Kant put it, a deep theoretical mess, a genuine quagmire, will dry up. This is one of the main themes of the chapters that follow.

A whole set of interesting facts about retinal photographic vision will not be described in this book—facts about vision with a fixed eye or vision with a shutter; such facts as the blind spot, the entoptic phenomena, the gaps in the visual field (scotomas), the afterimages of prolonged fixation, the tests for so-called acuity, the

examining of the retina with an ophthalmoscope, the symptoms of eye disease, and the prescribing of corrective spectacles. These are the facts of ophthalmology and optometry and the psychophysiology of vision at the level of cells.

These facts all depend on the subject's being willing to hold his eye fixed like a camera. They are perfectly good facts, and they have their place. They are much better known than the facts with which this book is concerned, and their scientific status is such that those persons who specialize in them assume with confidence that physical and physiological optics provide the only basis for visual perception. But those persons have no conception of the perplexities to which their assumption leads. And there is a better basis for visual perception, as I shall try to show.

ONE

THE ENVIRONMENT TO BE PERCEIVED

ONE

THE ANIMAL AND THE ENVIRONMENT

In this book, *environment* will refer to the surroundings of those organisms that perceive and behave, that is to say, animals. The environment of plants, organisms that lack sense organs and muscles, is not relevant in the study of perception and behavior. We shall treat the vegetation of the world as animals do, as if it were lumped together with the inorganic minerals of the world, with the physical, chemical, and geological environment. Plants in general are not animate; they do not move about, they do not behave, they lack a nervous system, and they do not have sensations. In these respects they are like the objects of physics, chemistry, and geology.

The world can be described at different levels, and one can choose which level to begin with. Biology begins with the division between the nonliving and the living. But psychology begins with the division between the inanimate and the animate, and this is where we choose to begin. The animals themselves can be divided in different ways. Zoology classifies them by heredity and anatomy, by phylum, class, order, genus, and species, but psychology can classify them by their way of life, as predatory or preyed upon, terrestrial or aquatic, crawling or walking, flying or nonflying, and arboreal or ground-living. We are more interested in ways of life than in heredity.

The environment consists of the *surroundings* of animals. Let us observe that in one sense the surroundings of a single animal are the same as the surroundings of all animals but that in another sense the surroundings of a single animal are different from those of any other animal. These two senses of the term can be troublesome and may cause confusion. The apparent contradiction can be resolved, but let us defer the problem until later. (The solution lies in the fact that animals are mobile.) For the present it is enough to note that the surroundings of *any* animal include other animals as well as the plants and the nonliving things. The former are just as much parts of its environment as the inanimate parts. For any animal needs to distinguish not only the substances and objects of its material environment but also the other animals and the differences between them. It cannot afford to confuse prey with predator, own-species with another species, or male with female.

THE MUTUALITY OF ANIMAL AND ENVIRONMENT

The fact is worth remembering because it is often neglected that the words *animal* and *environment* make an inseparable pair. Each term implies the other. No animal could exist without an environment surrounding it. Equally, although not so obvious, an environment implies an animal (or at least an organism) to be surrounded. This means that the surface of the earth, millions of years ago before life developed on it, was not an environment, properly speaking. The earth was a physical reality, a part of the universe, and the subject matter of geology. It was a potential environment, prerequisite to the evolution of life on this planet. We might agree to call it a world, but it was not an environment.

The mutuality of animal and environment is not implied by physics and the physical sciences. The basic concepts of space, time, matter, and energy do not lead naturally to the organism-environment concept or to the concept of a species and its habitat. Instead, they seem to lead to the idea of an animal as an extremely complex object of the physical world. The animal is thought of as a highly organized *part* of the physical world but still a part and still an object. This way of thinking neglects the fact that the animal-object is surrounded in a special way, that an environment is ambient for a living object in a different way from the way that a set of objects is ambient for a physical object. The term *physical environment* is, therefore, apt to get us mixed up, and it will usually be avoided in this book.

Every animal is, in some degree at least, a perceiver and a behaver. It is sentient and animate, to use old-fashioned terms. It is a perceiver *of* the environment and a behaver *in* the environment. But this is not to say that it perceives the world of physics and behaves in the space and time of physics.

THE DIFFERENCE BETWEEN THE ANIMAL ENVIRONMENT AND THE PHYSICAL WORLD

The world of physics encompasses everything from atoms through terrestrial objects to galaxies. These things exist at different levels of size that go to almost unimaginable extremes. The physical world of atoms and their ultimate particles is measured at the level of millionths of a millimeter and less. The astronomical world of stars and galaxies is measured at the level of light-years and more. Neither of these extremes is an environment. The size-level at which the environment exists is the intermediate one that is measured in millimeters and meters. The ordinary familiar things of the earth

are of this size—actually a narrow band of sizes relative to the far extremes. The sizes of animals, similarly, are limited to the intermediate terrestrial scale. The size of the smallest animal is an appreciable fraction of a millimeter, and that of the largest is only a few meters.

The masses of animals, likewise, are measured within the range of milligrams to kilograms, not at the extremes of the scale, and for good physiological reasons. A cell must have a minimum of substances in order to permit biochemical reactions; living animals cannot exceed a maximum mass of cells if they are all to be nourished and if they are to be mobile. In short, the sizes and masses of things in the environment are comparable with those of the animals.

UNITS OF THE ENVIRONMENT

Physical reality has structure at all levels of metric size from atoms to galaxies. Within the intermediate band of terrestrial sizes, the environment of animals and men is itself structured at various levels of size. At the level of kilometers, the earth is shaped by mountains and hills. At the level of meters, it is formed by boulders and cliffs and canyons, and also by trees. It is still more finely structured at the level of millimeters by pebbles and crystals and particles of soil, and also by leaves and grass blades and plant cells. All these things are structural units of the terrestrial environment, what we loosely call the forms or shapes of our familiar world.

Now, with respect to these units, an essential point of theory must be emphasized. The smaller units are embedded in the larger units by what I will call *nesting*. For example, canyons are nested within mountains; trees are nested within canyons; leaves are nested within trees; and cells are nested within leaves. There are forms within forms both up and down the scale of size. Units are nested within larger units. Things are components of other things. They would constitute a hierarchy except that this hierarchy is not categorical but full of transitions and overlaps. Hence, for the terrestrial environment, there is no special proper unit in terms of which it can be analyzed once and for all. There are no atomic units of the world considered as an environment. Instead, there are subordinate and superordinate units. The unit you choose for describing the environment depends on the level of the environment you choose to describe.

The size-levels of the world emphasized by modern physics, the atomic and the cosmic, are inappropriate for the psychologist. We are concerned here with things at the ecological level, with the habitat of animals and men, because we all behave with respect to things we can look at and feel, or smell and taste, and events we can listen to. The sense organs of animals, the perceptual systems (Gibson, 1966*b*), are not capable of detecting atoms or galaxies. Within their limits, however, these perceptual

systems are still capable of detecting a certain range of things and events. One can see a mountain if it is far enough away and a grain of sand if it is close enough. That fact is sufficiently wonderful in itself to deserve study, and it is one of the facts that this book will try to explain.

The explanation of how we human observers, at least some of us, can *visualize* an atom or a galaxy even if we cannot *see* one will not be attempted at this stage of the inquiry. It is not so much a problem of perception as it is of thinking, and there will be more about this later. We must first consider how we can perceive the environment—how we apprehend the same things that our human ancestors did before they learned about atoms and galaxies. We are concerned with direct perception, not so much with the indirect perception got by using microscopes and telescopes or by photographs and pictures, and still less with the kind of apprehension got by speech and writing. These higher-order modes of apprehension will only be considered in Part IV of this book, at the end.

UNITS OF THE GROUND SURFACE

The literal *basis* of the terrestrial environment is the ground, the underlying surface of support that tends to be on the average flat—that is to say, a plane—and also level, or perpendicular to gravity. And the ground itself is structured at various levels of metric size, these units being nested within one another. The fact to be noted now, since it is important for the theory of perspective in Part II, is that these units tend to be repeated over the whole surface of the earth. Grains of sand tend to be of the same size everywhere, and so do pebbles and rocks. Blades of grass are all more or less similar to one another, and so are clumps of grass and bushes. These natural units are not, of course, perfectly uniform like the man-made tiles of a pavement. Nevertheless, even if their repetition is not metrically regular, it is stochastically regular, that is to say, regular in a probabilistic way. In short, the component units of the ground do not get smaller as one goes north, for instance. They tend to be evenly spaced; and if they are scattered, they tend to be evenly scattered.

THE TIME SCALE OF THE ENVIRONMENT: EVENTS

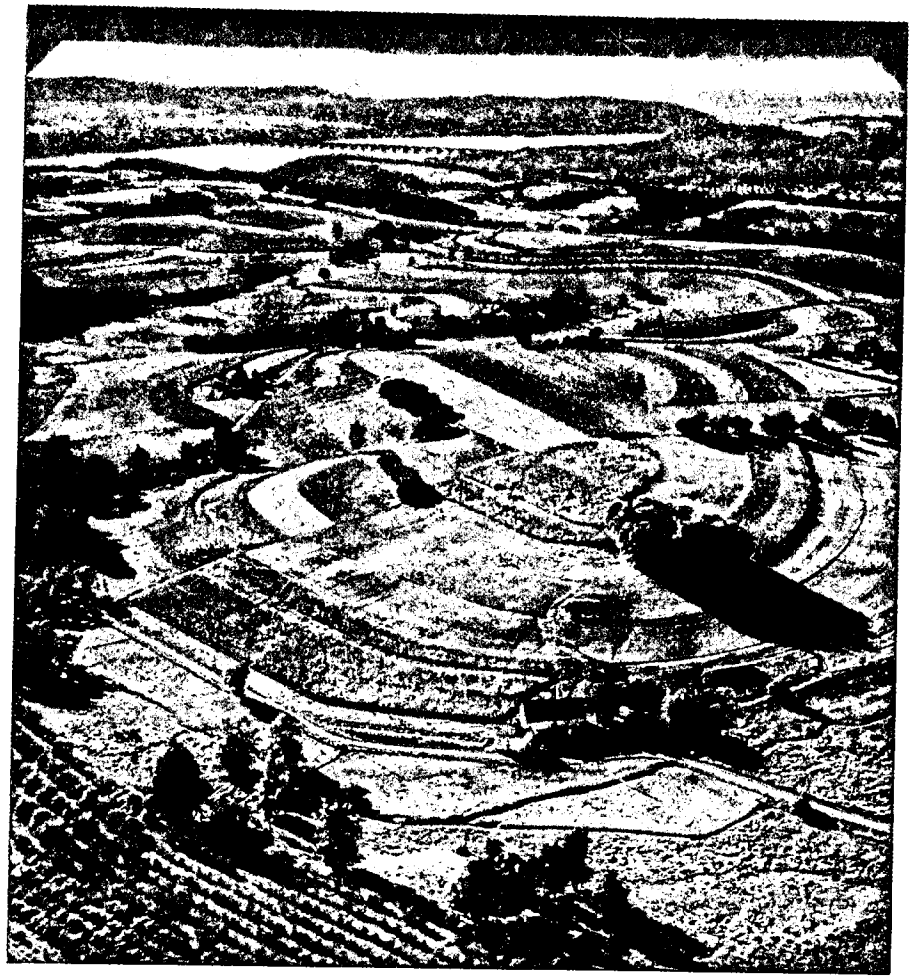
Another difference between the environment to be described and the world of physics is in the temporal scale of the process and events we choose to consider. The duration of processes at the level of the universe may be measured in millions of years, and the

duration of processes at the level of the atom may be measured in millionths of a second. But the duration of processes in the environment is measured only in years and seconds. The various life spans of the animals themselves fall within this range. The changes that are perceived, those on which acts of behavior depend, are neither

Figure 1.1

The structure of the terrestrial earth as seen from above.

In this aerial photograph only the large-scale features of the terrain are shown. (Photo by Grant Heilman)



extremely slow nor extremely rapid. Human observers cannot perceive the erosion of a mountain, but they can detect the fall of a rock. They can notice the displacement of a chair in a room but not the shift of an electron in an atom.

The same thing holds for frequencies as for durations. The very slow cycles of the world are imperceptible, and so are the very rapid cycles. But at the level of a mechanical clock, each motion of the pendulum can be seen and each click of the escapement can be heard. The rate of change, the transition, is within the limits of perceptibility.

In this book, emphasis will be placed on events, cycles, and changes at the terrestrial level of the physical world. The changes we shall study are those that occur in the environment. I shall talk about changes, events, and sequences of events but not about time as such. The flow of abstract empty time, however useful this concept may be to the physicist, has no reality for an animal. We perceive not time but processes, changes, sequences, or so I shall assume. The human awareness of clock-time, socialized time, is another matter.

Just as physical reality has structure at all levels of metric size, so it has structure at all levels of metric duration. Terrestrial processes occur at the intermediate level of duration. They are the natural units of sequential structure. And once more it is important to realize that smaller units are nested within larger units. There are events within events, as there are forms within forms, up to the yearly shift of the path of the sun across the sky and down to the breaking of a twig. And hence there are no elementary units of temporal structure. You can describe the events of the environment at various levels.

The acts of animals themselves, like the events of the environment they perceive, can be described at various levels, as subordinate and superordinate acts. And the duration of animal acts is comparable to the duration of environmental events. There are no elementary atomic responses.

The natural units of the terrestrial environment and the natural units of terrestrial events should not be confused with the *metrical* units of space and time. The latter are arbitrary and conventional. The former are unitary in one sense of the term, and the latter are unitary in a quite different sense. A single whole is not the same as a standard of measurement.

PERMANENCE AND CHANGE OF THE LAYOUT

Space and time will not often be referred to in this book, but a great deal will be said about permanence and change. Consider the shape of the terrestrial environment, or what may be called its *layout*. It will be assumed that the layout of the environment

is both permanent in some respects and changing in some other respects. A living room, for example, is relatively permanent with respect to the layout of floor, walls, and ceiling, but every now and then the arrangement of the furniture in the room is changed. The shape of a growing child is relatively permanent for some features and changing for others. An observer can recognize the same room on different occasions while perceiving the change of arrangement, or the same child at different ages while noticing her growth. The permanence underlies the change.

Permanence is relative, of course; that is, it depends on whether you mean persistence over a day, a year, or a millennium. Almost nothing is forever permanent; nothing is either immutable or mutable. So it is better to speak of *persistence* under change. The "permanent objects" of the world, which are of so much concern to psychologists and philosophers, are actually only objects that persist for a very long time.

The abstract notion of invariance and variance in mathematics is related to what is meant by persistence and change in the environment. There are variants and invariants in any transformation, constants and variables. Some properties are conserved and others not conserved. The same words are not used by all writers (for example, Piaget, 1969), but there is a common core of meaning in all such pairs of terms. The point to be noted is that for persistence and change, for invariant and variant, each term of the pair is reciprocal to the other.

PERSISTENCE IN THE ENVIRONMENT

The persistence of the geometrical layout of the environment depends in part on the kind of substance composing it and its rigidity or resistance to deformation. A solid substance is not readily changed in shape. A semisolid substance is more easily changed in shape. A liquid substance takes on whatever may be the shape of its solid container. The upper surface of a liquid substance tends to the ideal shape of a plane perpendicular to gravity, but this is easily disturbed, as when waves form. When we speak of the permanent layout of the environment, therefore, we refer mainly to the solid substances. The liquids of the world, the streams and oceans, are shaped by the solids, and as for the gaseous matter of the world, the air, it is not shaped at all. I will argue that the air is actually a *medium* for terrestrial animals.

When a solid substance with a constant shape melts, as a block of ice melts, we say that the object has ceased to exist. This way of speaking is ecological, not physical, for there is physical conservation of matter and mass despite the change from solid to liquid. The same would be true if a shaped object disintegrated, changing from solid to granular. The object does not persist, but the matter does. Ecology calls this a *nonpersistence*, a destruction of the object, whereas physics calls it a mere *change of*

state. Both assertions are correct, but the former is more relevant to the behavior of animals and children. Physics has sometimes been taken to imply that when a liquid mass has evaporated and the substance has been wholly dispersed in the air, or when an object has been consumed by fire, *nothing* has really gone out of existence. But this is an error. Even if terrestrial matter cannot be annihilated, a resistant light-reflecting surface can, and this is what counts for perception.

Going out of existence, cessation or destruction, is a kind of environmental event and one that is extremely important to perceive. When something is burned up, or dissolved, or shattered, it *disappears*. But it disappears in special ways that have recently been investigated at Cornell (Gibson, 1968*a*). It does not disappear in the way that a thing does when it becomes hidden or goes around a corner. Instead, the form of the object may be optically dispersed or dissipated, in the manner of smoke. The visual basis of this kind of perception will be further considered in Part II on ecological optics.

The environment normally manifests some things that persist and some that do not, some features that are invariant and some that are variant. A wholly invariant environment, unchanging in all parts and motionless, would be completely rigid and obviously would no longer be an environment. In fact, there would be neither animals nor plants. At the other extreme, an environment that was changing in all parts and was wholly variant, consisting only of swirling clouds of matter, would also not be an environment. In both extreme cases there would be space, time, matter, and energy, but there would be no habitat.

The fact of an environment that is mainly rigid but partly nonrigid, mainly motionless but partly movable, a world that is both changeless in many respects and changeable in others but is neither dead at one extreme nor chaotic at the other, is of great importance for our inquiry. This fact will become evident later when we talk about the geometry of the environment and its transformations.

On Persistence and Change

Our failure to understand the concurrence of persistence and change at the ecological level is probably connected with an old idea—the *atomic theory of persistence and change*, which asserts that what persists in the world are atoms and what changes in the world are the positions of atoms, or their arrangement. This is still an influential assumption in modern physics and chemistry, although it goes back to Democritus and the Greek thinkers who followed him. There will be more about the atomistic assumption in Chapter 6 on events and how they are perceived.

MOTION IN THE ENVIRONMENT

The motions of things in the environment are of a different order from the motions of bodies in space. The fundamental laws of motion hold for celestial mechanics, but events on earth do not have the elegant simplicity of the motions of planets. Events on earth begin and end abruptly instead of being continuous. Pure velocity and acceleration, either linear or angular, are rarely observable except in machines. And there are very few ideal elastic bodies except for billiard balls. The terrestrial world is mostly made of surfaces, not of bodies in space. And these surfaces often flow or undergo stretching, squeezing, bending, and breaking in ways of enormous mechanical complexity.

So different, in fact, are environmental motions from those studied by Isaac Newton that it is best to think of them as changes of structure rather than changes of position of elementary bodies, changes of form rather than of point locations, or changes in the layout rather than motions in the usual meaning of the term.

SUMMARY

The environment of animals and men is what they perceive. The environment is not the same as the physical world, if one means by that the world described by physics.

The observer and his environment are complementary. So are the set of observers and their common environment.

The components and events of the environment fall into natural units. These units are nested. They should not be confused with the metric units of space and time.

The environment persists in some respects and changes in other respects. The most radical change is going out of existence or coming into existence.

TWO

MEDIUM, SUBSTANCES, SURFACES

According to classical physics, the universe consists of bodies in space. We are tempted to assume, therefore, that we live in a physical world consisting of bodies in space and that what we *perceive* consists of objects in space. But this is very dubious. The terrestrial environment is better described in terms of a *medium, substances,* and the *surfaces* that separate them.

THE MEDIUM

Let us begin by noting that our planet consists mainly of earth, water, and air—a solid, a liquid, and a gas. The earth forms a substratum; the water is formed by the substratum into oceans, lakes, and streams; and the formless gases of the air make a layer of atmosphere above the earth and the water. The interface between any two of these three states of matter—solid, liquid, and gas—constitutes a surface. The earth-water interface at the bottom of a lake is one such, the water-air interface at the top is another, and the earth-air interface is a third—the most important of all surfaces for terrestrial animals. This is the *ground.* It is the ground of their perception and behavior, both literally and figuratively. It is their surface of support.

One characteristic of a gas or a liquid as contrasted with a solid is the fact that a detached solid body can move through it without resistance. Air is "insubstantial" and so is water, more or less. It thus affords locomotion to an animate body. A gas or a liquid, then, is a *medium* for animal locomotion. Air is a better medium for locomotion than water because it offers less resistance. It does not require the streamlined anatomy needed by a fish for rapid movements.

Another characteristic of a gas or liquid medium is that it is generally transparent, transmitting light, whereas a solid is generally opaque, absorbing or reflecting light. A homogeneous medium thus affords vision. The way in which it does so will be described in Part II. For the present it is sufficient to observe that a terrestrial medium is a region in which light not only is transmitted but also *reverberates,* that is, bounces back and forth between surfaces at enormous velocity and reaches a sort of steady state. The light has to be continually replenished from a source of illumination because some of it is absorbed by the substances of the environment, but the reverberating flux of light brings about the condition we call *illumination.* Illumination "fills" the medium in the sense that there is *ambient* light at any point, that is, light coming to the point from all directions. Ambient light, as we shall see, is not to be confused with radiant light.

A third characteristic of air or water is that it transmits vibrations or pressure waves outward from a mechanical event, a source of sound waves. It thus makes possible hearing what we call the sound; more exactly, it permits listening to the vibratory event. (The solid earth also transmits pressure waves, to be sure, but we do not ordinarily call them sound waves unless we are thinking in terms of physics. In physics a medium is any substance, including solids, that transmits waves.)

A fourth characteristic is the fact that a medium of air or water allows rapid chemical diffusion whereas the earth does not. Specifically, it permits molecules of a foreign substance to diffuse or dissolve outward from a source whenever it is volatile or soluble. In this way, the medium affords "smelling" of the source, by which I mean detecting of the substance at a distance.

Let us next observe that animal locomotion is not usually aimless but is guided or controlled—by light if the animal can see, by sound if the animal can hear, and by odor if the animal can smell. Because of illumination the animal can see things; because of sound it can hear things; because of diffusion it can smell things. The medium thus contains information about things that reflect light, vibrate, or are volatile. By detecting this information, the animal guides and controls locomotion.

If we understand the notion of medium, I suggest, we come to an entirely new way of thinking about perception and behavior. The medium in which animals can move about (and in which objects can *be* moved about) is at the same time the medium for light, sound, and odor coming from sources in the environment. An enclosed medium can be "filled" with light, with sound, and even with odor. Any point in the medium is a possible point of observation for any observer who can look, listen, or sniff. And these points of observation are continuously connected to one another by paths of possible locomotion. Instead of geometrical points and lines, then, we have points of observation and lines of locomotion. As the observer moves from point to point, the optical information, the acoustic information, and the chemical information change accordingly. Each potential point of observation in the medium is unique in this respect. The notion of a medium, therefore, is not the same as the concept of space inasmuch as the points in space are not unique but equivalent to one another.

All these facts about moving bodies and about the transmission of light, sound, and odor in a medium are *consistent* with physics, mechanics, optics, acoustics, and chemistry, but they are facts of higher order that have never been made explicit by

those sciences and have gone unrecognized. The science of the environment has its own facts.

Another important characteristic of a medium, it should now be noted, is that it contains oxygen and permits breathing. The principles of respiration are the same in the water as in the air; oxygen is absorbed and carbon dioxide is emitted after the burning of fuel in the tissues. This ceaseless chemical exchange of substance is truly the "flame of life." The animal must breathe, whether by gills or by lungs. It must breathe all the time and everywhere it goes. Thus, the medium needs to be relatively constant and relatively homogeneous.

Both the air and the water do afford breathing. The amount of oxygen in the air has not departed much from 21 percent in countless ages. The amount of dissolved oxygen in the water, although variable, tends to be sufficient. Animals have been able to rely on oxygen, and this is why evolution could proceed. Similarly, both the air and the water tend to be homogeneous, although fresh water differs from salt water. From place to place, the composition of air changes very little and the composition of water changes very gradually, for the temporary gradients that arise are dissipated by winds and currents. There are no sharp *transitions* in a medium, no boundaries between one volume and another, that is to say, no surfaces. This homogeneity is crucial. It is what permits light waves and sound waves to travel outward from a source in spherical wave fronts. Indeed, it is what makes a chemical emanation from a source foreign to the medium itself, and thus capable of being smelled.

Finally, a sixth characteristic of a medium for animal life is that it has an intrinsic polarity of up and down. Gravity pulls downward, not upward. Radiant light comes from above, not below, from the sky, not the substratum, and this is as true in the water as in the atmosphere. Because of gravity, water pressure and air pressure increase downward and decrease upward. The medium is not isotropic, as the physicist says, along this dimension. Hence it is that a medium has an *absolute* axis of reference, the vertical axis. Even the two horizontal axes of reference are not wholly arbitrary, for they depend on sunrise and sunset. This fact reveals another difference between medium and space, for in space the three reference axes are arbitrary and can be chosen at will.

THE PROPERTIES OF THE ATMOSPHERE

To sum up, the characteristics of an environmental medium are that it affords respiration or breathing; it permits locomotion; it can be filled with illumination so as to permit vision; it allows detection of vibrations and detection of diffusing emanations; it is homogeneous; and finally, it has an absolute axis of reference, up and down. All these offerings of nature, these possibilities or opportunities, these *affordances* as I will call them, are invariant. They have been strikingly constant throughout the whole evolution of animal life.

EVENTS IN THE ATMOSPHERE

The atmospheric medium, unlike the underwater medium, is subject to certain kinds of change that we call weather. Sometimes there are drops or droplets of water in the air, rain or fog. Annually, in some latitudes of the earth, the air becomes cold and the water turns to ice. Occasionally the air currents flow strongly, as in storms and hurricanes. Rain, wind, snow, and cold, the latter increasing toward the poles of the earth, prevent the air from being perfectly homogeneous, uniform, and unchanging. The changes are rarely so extreme as to kill off the animals, but they do necessitate various kinds of adaptation and all sorts of behavioral adjustments, such as hibernation, migration, shelter-building, and clothes-wearing.

SURFACES AND THE ECOLOGICAL LAWS OF SURFACES

For describing the environment, we have now established the triad of medium, substances, and surfaces, allowing for both persistence and change. The medium is separated from the substances of the environment by *surfaces*. Insofar as substances persist, their surfaces persist. All surfaces have a certain *layout*, as I will call it, and the layout also tends to persist. The persistence of the layout depends on the resistance of the substance to change. If a substance is changed into the gaseous state, it is no longer substantial and the surface together with its layout ceases to exist. These statements provide a new way of describing the environment.

For our purposes, this description is superior to the accepted description in terms of space, time, matter and material bodies, the forms of these bodies, and their motions. It is novel, but only in the sense that it has never been explicitly stated. Everything in the above paragraph has long been known implicitly by practical men—the surveyors of the earth, the builders, and the designers of the environment. It is *tacit* knowledge (Polanyi, 1966). This description is superior because it is appropriate to the study of the perception and behavior of animals and men as a function of what the environment affords, that is, to psychology.

The above description, to be complete, should include the reverberating flux of

light in the medium. The way in which light is absorbed and reflected at surfaces and the way this action depends on the composition of the substances should also be considered. At the ecological level of size, surfaces soak up or throw back the illumination falling upon them, although at the atomic level of size, matter and light energy are said to *interact*. Substances are substantial with respect to light as much as they are substantial with respect to force. They resist the penetration of light as they resist the penetration of a moving body. And substances differ among themselves in the former respect as much as they do in the latter.

In our concern with surfaces and their purely geometrical layout, we must not forget that the air is filled with sunlight during the day and that some illumination always remains, even during the night. This fact, too, is an invariant of nature. Light comes from the sky and becomes ambient in the air. This is what makes persisting surfaces potentially visible as well as potentially tangible. How they are actually seen by animals with eyes is the problem of this book (although admittedly we are arriving at the problem only by slow stages). A *potentially visible surface* is one that could be looked at from some place in the medium where an animal *might* be. Nothing is implied about the actual stimulation of an eye, not yet. And no slightest reference is made to sensations of vision.

No mention has yet been made of luminous surfaces such as very hot bodies that emit light, or of flat surfaces of transparent substances such as glass that transmit light with refraction, or of polished flat surfaces such as mirrors that reflect light "regularly." Emission, absorption, transmission, refraction, and diffraction refer to abstract laws of physical and geometrical optics. It may be possible to combine them in complex ways to explain the gross facts of illuminated terrestrial surfaces, but that possibility is something to be considered later.

Why, in the triad of medium, substances, and surfaces, are surfaces so important? The surface is where most of the action is. The surface is where light is reflected or absorbed, not the interior of the substance. The surface is what touches the animal, not the interior. The surface is where chemical reaction mostly takes place. The surface is where vaporization or diffusion of substances into the medium occurs. And the surface is where vibrations of the substances are transmitted into the medium.

A formulation of what might be called the *ecological laws of surfaces* would be useful. The following laws are proposed, without any claim of completeness. The list will serve, however, to focus the discussion, and it also provides an outline of what is to follow. The laws are not independent of one another and must be considered in combination.

1. All persisting substances have surfaces, and all surfaces have a layout.
2. Any surface has resistance to deformation, depending on the *viscosity* of the substance.

3. Any surface has resistance to disintegration, depending on the *cohesion* of the substance.
4. Any surface has a characteristic texture, depending on the *composition* of the substance. It generally has both a layout texture and a pigment texture.
5. Any surface has a characteristic shape, or large-scale layout.
6. A surface may be strongly or weakly illuminated, in light or in shade.
7. An illuminated surface may absorb either much or little of the illumination falling on it.
8. A surface has a characteristic reflectance, depending on the substance.
9. A surface has a characteristic distribution of the reflectance ratios of the different wavelengths of the light, depending on the substance. This property is what I will call its color, in the sense that different distributions constitute different colors.

SUBSTANCE, SURFACE, LAYOUT, AND PERSISTENCE

The first law above merely summarizes what has been emphasized repeatedly about the substantial persisting surfaces of the environment. Combined with the second law, it explains why the level terrestrial surface, the ground, offers support for animals. They can crawl on the earth as a lizard or a human infant does, or they can walk or run on it because it is solid. But the law of layout also applies to surfaces like walls and obstacles that are barriers to locomotion—surfaces with which they will collide unless they stop short. A surface can be laid out parallel to gravity as well as perpendicular to it, so that surfaces can surround them as well as support them. A surface can even be held up by walls so as to be above them, that is, there can be a roof over their heads as well as a floor under their feet. A medium can be more or less enclosed by surfaces, and a cave, or a burrow, or a house is such an enclosure.

RESISTANCE TO DEFORMATION

The second law allows for variation in the solidity of surfaces. It says that substances vary in the degree to which they resist deformation, from rigid to plastic to semisolid to liquid. When measured in terms of resistance to *flow*, this variable is called *viscosity*. The more fluid or flowing the substance, the more penetrable the surface, and the more changeable (less permanent) the layout. This law implies that the bog or swamp offers practically no support for standing or walking to heavy animals, and that the pond or lake offers no support. There will be more about the perception of a surface of support by terrestrial animals in Chapter 9.

With respect to obstacles, the second law implies that the surfaces of flexible substances are yielding or can be pushed aside, whereas the surfaces of rigid substances cannot. With respect to fluid substances, this law implies that fluid surfaces are polymorphic in the extreme; they can be poured, spilled, and splashed, and they can be smeared, painted, and dabbled in. The human infant explores these possibilities with great zest; the adult artisan has learned to perceive and take advantage of them.

RESISTANCE TO DISINTEGRATION

The third law allows for variation in the degree to which surfaces are breakable or go to pieces. The surface of a viscoelastic substance will stretch and remain continuous under the application of a force, whereas the surface of a rigid substance may be disrupted and become discontinuous. This distinction, incidentally, is fundamental to *topology*, the branch of mathematics sometimes called "rubber sheet geometry," in which it is assumed that a plane (actually a surface) can be bent or curved or stretched or compressed but cannot be torn.

The second and third laws explain why clay can be pressed into the shape of a pot, whereas flint has to be chipped into the shape of an axe. And they explain why the pot and the axe become useless when broken. These laws imply that a house of glass is a poor place to live and the person who lives in one should certainly not throw stones.

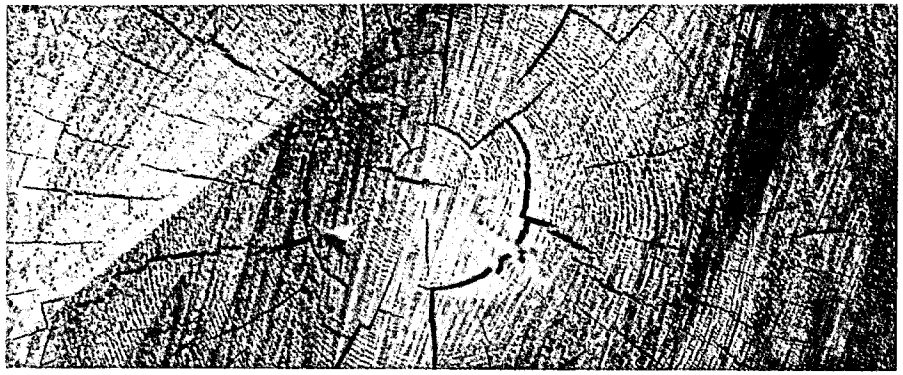
CHARACTERISTIC TEXTURE

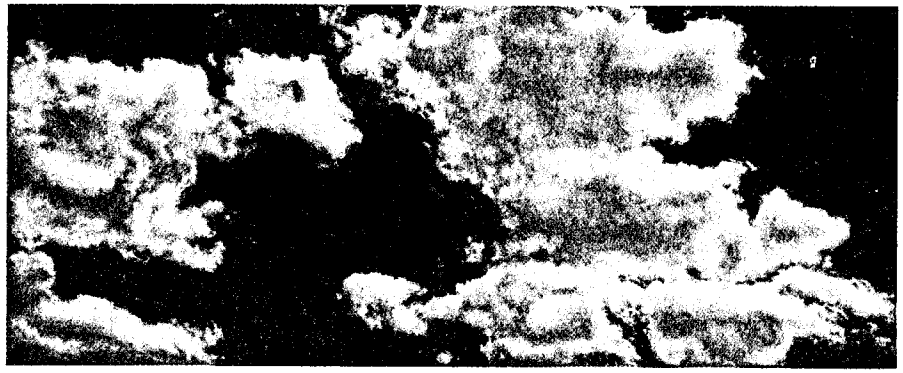
The fourth law concerns what I call *texture*, which might be thought of as the structure of a surface, as distinguished from the structure of the substance underlying the surface. We are talking about the relatively fine structure of the environment at the size-level around centimeters and millimeters. Surfaces of rock, or of plowed soil, or of grass are aggregated of different units—crystals, clumps, and grass blades, respectively—but these units are nested within larger units.

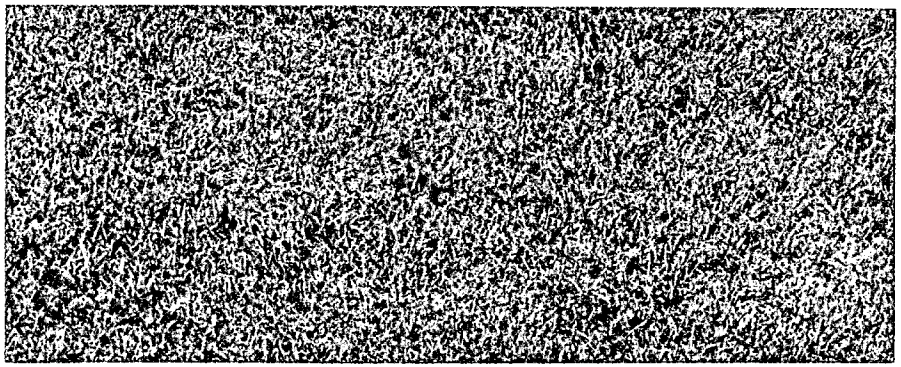
The texture of a surface arises from two main facts: first, a natural substance is seldom *homogeneous* but is more or less aggregated of different homogeneous substances; and second, it is seldom *amorphous* but is more or less aggregated of crystals and chunks and pieces of the same stuff. Hence, the surface of a natural substance is also neither homogeneous nor amorphous but has both a chemical and a physical texture; it is generally both conglomerated and corrugated. It has what I will call a *pigment texture* and a *layout texture*. It is generally both speckled and rough.

This says that a perfectly homogeneous and perfectly smooth surface is an abstract

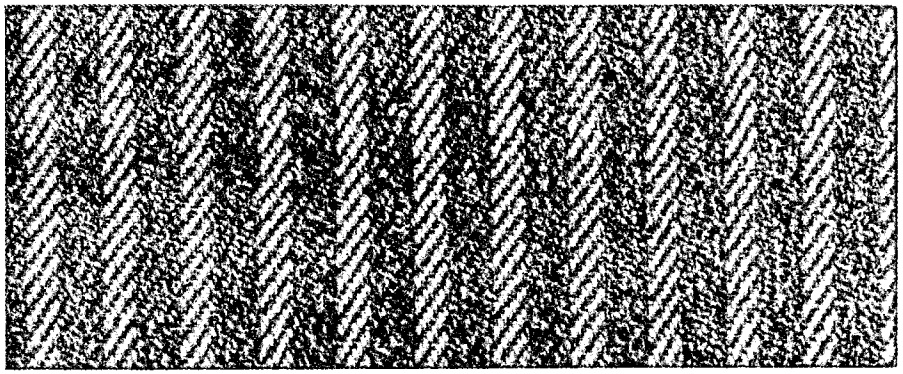
Figure 2.1
The characteristic textures of the surfaces of various substances.

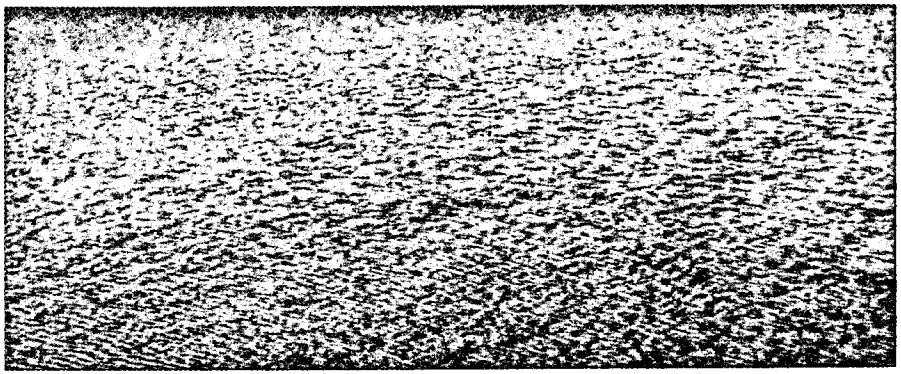


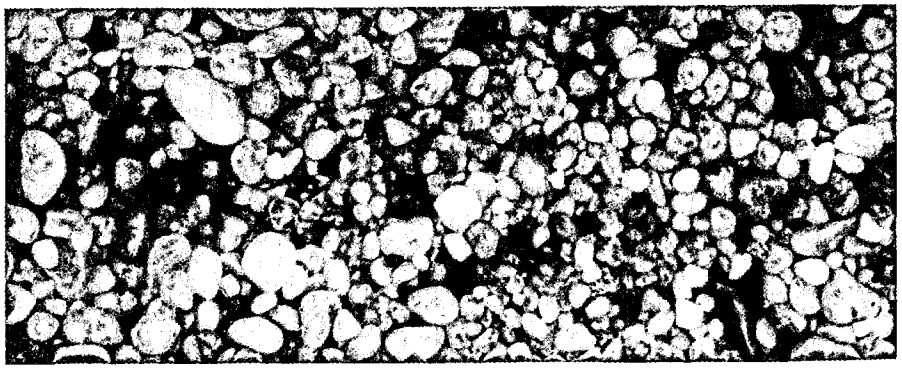




Grass, cloth, pebbles, water, clouds, and wood grain are shown. Can you identify them? (Photos by Phil Brodatz, "Textures" and "Wood and Woodgrains")







limiting case. A polished surface of glass approximates to it, but it has to be manufactured. Mirrors are rare in nature (although the still surface of the pool into which Narcissus gazed is a natural mirror).

When the chemical and geometrical units of a surface are relatively small, the texture is *fine*; when they are relatively large, the texture is *coarse*. If the units are sufficiently distinct to be counted, the *density* of the texture can be measured as the number of units in an arbitrary unit of area, a square centimeter or meter. But this is often very hard to do because units of texture are generally nested within one another at different levels of size. The texture of commercial sandpapaer can be graded from fine to coarse, but the textures of vegetation cannot. Moreover, the units of texture vary in form, and there are forms within forms, so that the "form" of a texture escapes measurement. The ideal pigment texture of a checkerboard and the ideal layout texture of a tessellated surface are rare.

The law says that rock, shale, soil, and humus have different textures and that mud, clay, sand, ice, and snow have different textures. It says that the bark and the leaf and the fruit of a tree are differently textured and that the surfaces of animals are differently textured, by fur, feathers, or skin. The surfaces of the substances from which primitive men fashioned tools have different textures—flint, clay, wood, bone, and fiber. The surfaces of the artificial environment—plywood, paper, fabric, plaster, brick—have different textures. The surfaces with which man is beginning almost to carpet the earth are differently textured—the pavements of concrete, asphalt, and other aggregates. The texture in each case specifies what the substance is, what the surface is made of, its composition. And that, as noted above, is something of great importance. The relations between the layout texture of a surface, the pigment texture, and the shadow texture are complex; they will be considered below and in Chapter 5.

It is important to understand the determinants of surface texture, so that we will later be able to understand what I call *optical texture* when this notion is introduced in Part II. The two are not at all the same thing. It is enough to observe now that surfaces are homogeneous only as a limiting case—for example, the plaster wall behind a stage setting that looks like the sky from a distance—and that surfaces are smooth only as a limiting case, such as a sheet of plate glass and a mirror. Under certain conditions a homogeneous, very smooth, flat, large surface is not visible to a person or animal with ordinary eyesight.

CHARACTERISTIC SHAPE

The fifth law has to do with the layout of the environment on a scale that is relatively *large*—its coarse structure or macrostructure. A surface can often be analyzed into facets, and a layout can often be analyzed into faces. This terminology refers to *facing*,

that is, facing or not facing the source of illumination and facing or not facing the point of observation. For the present, let us take a surface to mean a flat surface, a face, and a layout of adjoining surfaces to mean a set of faces meeting at dihedral angles, that is, edges and corners. These terms will be defined later.

The law has to do with surface layout at the size-level of environmental *enclosures* and environmental *objects*. It asserts that enclosures and objects have characteristic shapes. Enclosures differ in shape as, for example, a cave, a tunnel, and a room differ. Objects differ in shape as, for example, the polyhedrons of solid geometry differ (the tetrahedron, pyramid, cube, octahedron, and so on) and in all the ways that the irregular polyhedrons differ. These geometrical solids, so-called, progress toward enormous complexity, but they can all be analyzed in terms of three components called *faces*, *edges*, and *vertices*. These components have meaning for environmental objects because, for example, the edge is characteristic of a cutting tool and the vertex is characteristic of a piercing tool.

Obviously, differently shaped enclosures afford different possibilities of inhabiting them. And differently shaped solids afford different possibilities for behavior and manipulation. Man, the great manipulator, exploits these latter possibilities to the utmost degree.

HIGH AND LOW ILLUMINATION

The sixth law says that the light falling on a surface, the incident light, may be high or low, intense or dim, but that generally there is some illumination even at night. The completely dark room of the vision laboratory, like the deep interior of a cave, is a limiting case.

The amount of sunlight falling on a terrestrial surface depends on the condition of the atmosphere, clear or cloudy; but it also depends on two other factors that combine: the position of the sun in the sky and the orientation of the surface relative to the sky. It should be remembered that light comes from the whole sky as well as from the sun, and from other reflecting surfaces as well. Light reverberates between the sky and the earth and between surfaces. Direct illumination from a source is always mixed with indirect illumination. The incident light is never unidirectional, as it would be in empty space, but more or less omnidirectional. Nevertheless, there is always a "prevailing" illumination, a direction at which the incident light is strongest.

A surface facing the prevailing illumination will be more highly illuminated than a surface not facing it. This seems to be a general principle relating illumination to surface layout. This principle means that the different adjacent faces of the environment will be differently illuminated at any given time of day. But it also means that the faces under high illumination early in the day will be under low illumination late in the day

and vice versa because of the motion of the sun across the sky. This daily exchange between the lighted state and the shaded state of a given surface is an important but little noted fact about the environment. It will be further elaborated in Chapter 5.

HIGH AND LOW ABSORPTION OF LIGHT

The seventh law says that, of the illumination falling on a surface, more or less will be absorbed by it depending on the chemical composition of the substance. Certain substances like pure carbon absorb much, and others like chalk absorb little. This is why carbon is black and chalk is white.

In optics there are two alternatives to the absorption of light by a surface, transmission and reflection. For present purposes, only reflection will be emphasized, because most surfaces are not transparent like optical glass and pure water but are opaque. And in any case *no* substance is perfectly transmitting. Only the medium itself ever approximates to perfect transmission. A surface that transmitted all the light falling on it would not be a surface but would be the mere ghost of a surface, like the insubstantial fiction of a geometrical plane. Sheets of polished glass and surfaces of still water only transmit enough of the incident light to be called transparent.

CHARACTERISTIC REFLECTANCE

The eighth law is a corollary of the seventh. It says that the amount of light bounced back into the medium, instead of being soaked up by the surface, is a characteristic of the substance. That is, the ratio of light reflected to light incident is a constant for any given compound or any homogeneous mixture. This ratio is the *reflectance* of a surface.

Coal has a low reflectance (about 5 percent), and snow has a high reflectance (about 80 percent). When substances of this sort are conglomerated, the surface will have what I called a pigment texture; it will be speckled. Granite and marble are substances whose surfaces are mottled or variegated in this way.

CHARACTERISTIC SPECTRAL REFLECTANCE

The ninth law of ecological surfaces asserts that a surface has a characteristic distribution of the reflectance ratios of the different wavelengths of the incident light and that these

different distributions constitute different colors. The word *color* here means *hue*, or chromatic color as distinguished from achromatic color, the variation of black, gray, and white.

For animals and humans, the colors of surfaces as defined above are more important than the colors of sunsets, rainbows, and flames. They specify the ripeness or unripeness of fruit and distinguish the leaf from the flower. Along with the textures of those surfaces, the colors help to distinguish feathers and fur and skin. Surface color is inseparably connected with surface texture, for colors often go with textures, and colored objects are apt to be particolored. The color and texture of a surface together specify the *composition* of the substance, what it is made of, and this is important, as noted above.

THE QUALITIES OF SUBSTANTIAL SURFACES

A tentative classification of surfaces is now possible. First, there are *luminous* surfaces as distinguished from *illuminated* surfaces, those that emit light and those that do not. Second, there are *more illuminated* and *less illuminated* surfaces, those we call lighted and shaded. Third, there are the surfaces of *volumes* as distinguished from the surfaces of *sheets* and *films*. Fourth, there are *opaque* surfaces as distinguished from *semitransparent* and *translucent* surfaces; these forms of nonopaqueness will be further analyzed in Part II. Fifth, there are *smooth* surfaces and *rough* surfaces, the former being of two kinds, *glossy* and *matte*, and the latter having a great variety of forms of roughness. The distinction between smooth and rough is not as simple as it sounds but, in general, implies the mirror-reflecting of light at one extreme and the scatter-reflecting of light at the other. Sixth, there are *homogeneous* and *conglomerated* surfaces, the former being monocolored and the latter particolored; the "color" of a surface or of any bit of a surface refers to both its *overall reflectance* (black, gray, or white) and its *spectral reflectance* (hue). Finally, seventh, there are *hard*, *intermediate*, and *soft* surfaces, depending on the substance that underlies the surface.

These seven modes or qualities take the place of the so-called modes of appearance of color (Beck, 1972). And, when surface layout is also considered, they take the place of the so-called qualities of objects, color on the one hand and "form, size, position, solidity, duration, and motion" on the other. These latter are John Locke's "primary" qualities, those that were supposed to be "in the objects" instead of merely "in us." This distinction between primary and secondary qualities is quite unnecessary and is wholly rejected in the above description.

SUMMARY

We live in an environment consisting of substances that are more or less substantial; of a medium, the gaseous atmosphere; and of the surfaces that separate the substances from the medium. We do not live in "space."

The medium permits unimpeded locomotion from place to place, and it also permits the seeing, smelling, and hearing of the substances at all places. Locomotion and behavior are continually controlled by the activities of seeing, smelling, and hearing, together with touching.

The substances of the environment need to be distinguished. A powerful way of doing so is by seeing their surfaces.

A surface has characteristic properties that can persist or change, such as its layout, its texture, the property of being lighted or shaded, and the property of reflecting a certain fraction of the illumination falling on it.

THREE

THE MEANINGFUL ENVIRONMENT

The world of physical reality does not consist of meaningful things. The world of ecological reality, as I have been trying to describe it, does. If what we perceived were the entities of physics and mathematics, meanings would have to be imposed on them. But if what we perceive are the entities of environmental science, their meanings can be *discovered.*

SUMMARY: WHAT SHALL WE TAKE AS AN EVENT?

The foregoing classification is a kind of preliminary survey only. Ecological events are various and difficult to formalize. But when we attempt to reduce them to elementary physical events, they become impossibly complex, and physical complexity then blinds us to ecological simplicity. For there *are* regularities to be found at the higher level, regularities that cannot now be encompassed by the simple equations of mechanics and physics. The movements of animals, for example, are lawful in ways that cannot yet be derived from the laws of orthodox mechanics, and perhaps never can be. A too strict adherence to mechanics has hampered the study of terrestrial events.

Events as Primary Realities In the first place, the flow of ecological events is distinct from the abstract passage of time assumed in physics. The stream of events is heterogeneous and differentiated into parts, whereas the passage of time is supposed to be homogeneous and linear. Isaac Newton asserted that "absolute, true, and mathematical time, of itself and from its own nature, flows equably without relation to anything external." But this is a convenient myth. It assumes that events occur "in" time and that time is empty unless "filled." This habitual way of thinking puts the cart before the horse. We should begin thinking of events as the primary realities and of time as an abstraction from them—a concept derived mainly from regular repeating events, such as the ticking of clocks. Events are perceived, but time is not (Gibson, 1975).

It is the same with space as with time. Objects do not *fill* space, for there was no such thing as empty space to begin with. The persisting surfaces of the environment are what provide the framework of reality. The world was never a void. As for the medium, the region in which motion and locomotion can occur, where light can reverberate and surfaces can be illuminated, this might be called *room* but it is not *space*. Surfaces and their layout are perceived, but space is not, as I have long been arguing (Gibson, 1950).

It might be said, without going as far as I have done above, that time *consists* of the events filling it and that space *consists* of the objects filling it. But I will argue that this formula still perpetuates the fallacy. The metaphor of *filling* is wrong. Time and space are not empty receptacles to be filled; instead, they are simply the ghosts of events and surfaces.

Time is not another dimension of space, a fourth dimension, as modern physics assumes for reasons of mathematical convenience. The reality underlying the dimension of time is the sequential order of events, and the reality underlying the dimensions of space is the adjacent order of objects or surface parts. Sequential order is not comparable to adjacent order; it is not even *analogous* to adjacent order. For the order of events cannot be permuted, whereas the order of parts can. You can reshuffle the parts but not the events, as you can rearrange the furniture in a room but not the happenings that occur in it.

EIGHT

THE THEORY OF AFFORDANCES

I have described the environment as the surfaces that separate substances from the medium in which the animals live. But I have also described what the environment *affords* animals, mentioning the terrain, shelters, water, fire, objects, tools, other animals, and human displays. How do we go from surfaces to affordances? And if there is information in light for the perception of surfaces, is there information for the perception of what they afford? Perhaps the composition and layout of surfaces *constitute* what they afford. If so, to perceive them is to perceive what they afford. This is a radical hypothesis, for it implies that the "values" and "meanings" of things in the environment can be directly perceived. Moreover, it would explain the sense in which values and meanings are external to the perceiver.

The *affordances* of the environment are what it *offers* the animal, what it *provides* or *furnishes*, either for good or ill. The verb *to afford* is found in the dictionary, but the noun *affordance* is not. I have made it up. I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment. The antecedents of the term and the history of the concept will be treated later; for the present, let us consider examples of an affordance.

If a terrestrial surface is nearly horizontal (instead of slanted), nearly flat (instead of convex or concave), and sufficiently extended (relative to the size of the animal) and if its substance is rigid (relative to the weight of the animal), then the surface *affords support*. It is a surface of support, and we call it a substratum, ground, or floor. It is stand-on-able, permitting an upright posture for quadrupeds and bipeds. It is therefore walk-on-able and run-over-able. It is not sink-into-able like a surface of water or a swamp, that is, not for heavy terrestrial animals. Support for water bugs is different.

Note that the four properties listed—horizontal, flat, extended, and rigid—would be *physical* properties of a surface if they were measured with the scales and standard units used in physics. As an affordance of support for a species of animal, however, they have to be measured *relative to the animal*. They are unique for that animal. They are not just abstract physical properties. They have unity relative to the posture and

behavior of the animal being considered. So an affordance cannot be measured as we measure in physics.

Terrestrial surfaces, of course, are also climb-on-able or fall-off-able or get-underneath-able or bump-into-able relative to the animal. Different layouts afford different behaviors for different animals, and different mechanical encounters. The human species in some cultures has the habit of sitting as distinguished from kneeling or squatting. If a surface of support with the four properties is also knee-high above the ground, it affords sitting on. We call it a *seat* in general, or a stool, bench, chair, and so on, in particular. It may be natural like a ledge or artificial like a couch. It may have various shapes, as long as its functional layout is that of a seat. The color and texture of the surface are irrelevant. Knee-high for a child is not the same as knee-high for an adult, so the affordance is relative to the size of the individual. But if a surface is horizontal, flat, extended, rigid, and knee-high relative to a perceiver, it can in fact be sat upon. If it can be discriminated as having just these properties, it should *look* sit-on-able. If it does, the affordance is perceived visually. If the surface properties are seen relative to the body surfaces, the self, they constitute a seat and have meaning.

There could be other examples. The different substances of the environment have different affordances for nutrition and for manufacture. The different objects of the environment have different affordances for manipulation. The other animals afford, above all, a rich and complex set of interactions, sexual, predatory, nurturing, fighting, playing, cooperating, and communicating. What other persons afford, comprises the whole realm of social significance for human beings. We pay the closest attention to the optical and acoustic information that specifies what the other person is, invites, threatens, and does.

THE NICHES OF THE ENVIRONMENT

Ecologists have the concept of a *niche*. A species of animal is said to utilize or occupy a certain niche in the environment. This is not quite the same as the *habitat* of the species; a niche refers more to *how* an animal lives than to *where* it lives. I suggest that a niche is a set of affordances.

The natural environment offers many ways of life, and different animals have different ways of life. The niche implies a kind of animal, and the animal implies a kind of niche. Note the complementarity of the two. But note also that the environment as a whole with its unlimited possibilities existed prior to animals. The physical, chemical, meteorological, and geological conditions of the surface of the earth and the pre-existence of plant life are what make animal life possible. They had to be invariant for animals to evolve.

There are all kinds of nutrients in the world and all sorts of ways of getting food; all sorts of shelters or hiding places, such as holes, crevices, and caves; all sorts of materials for *making* shelters, nests, mounds, huts; all kinds of locomotion that the environment makes possible, such as swimming, crawling, walking, climbing, flying. These offerings have been taken advantage of; the niches have been occupied. But, for all we know, there may be many offerings of the environment that have *not* been taken advantage of, that is, niches not yet occupied.

In architecture a niche is a place that is suitable for a piece of statuary, a place into which the object fits. In ecology a niche is a setting of environmental features that are suitable for an animal, into which it fits metaphorically.

An important fact about the affordances of the environment is that they are in a sense objective, real, and physical, unlike values and meanings, which are often supposed to be subjective, phenomenal, and mental. But, actually, an affordance is neither an objective property nor a subjective property; or it is both if you like. An affordance cuts across the dichotomy of subjective-objective and helps us to understand its inadequacy. It is equally a fact of the environment and a fact of behavior. It is both physical and psychical, yet neither. An affordance points both ways, to the environment and to the observer.

The niche for a certain species should not be confused with what some animal psychologists have called the *phenomenal environment* of the species. This can be taken erroneously to be the "private world" in which the species is supposed to live, the "subjective world," or the world of "consciousness." The behavior of observers depends on their perception of the environment, surely enough, but this does not mean that their behavior depends on a so-called private or subjective or conscious environment. The organism depends on its environment for its life, but the environment does not depend on the organism for its existence.

MAN'S ALTERATION OF THE NATURAL ENVIRONMENT

In the last few thousand years, as everybody now realizes, the very face of the earth has been modified by man. The layout of surfaces has been changed, by cutting, clearing, leveling, paving, and building. Natural deserts and mountains, swamps and rivers, forests and plains still exist, but they are being encroached upon and reshaped by man-made layouts. Moreover, the *substances* of the environment have been partly converted from the natural materials of the earth into various kinds of artificial materials such as bronze, iron, concrete, and bread. Even the *medium* of the environment—the

air for us and the water for fish—is becoming slowly altered despite the restorative cycles that yielded a steady state for millions of years prior to man.

Why has man changed the shapes and substances of his environment? To change what it affords him. He has made more available what benefits him and less pressing what injures him. In making life easier for himself, of course, he has made life harder for most of the other animals. Over the millennia, he has made it easier for himself to get food, easier to keep warm, easier to see at night, easier to get about, and easier to train his offspring.

This is not a *new* environment—an artificial environment distinct from the natural environment—but the same old environment modified by man. It is a mistake to separate the natural from the artificial as if there were two environments; artifacts have to be manufactured from natural substances. It is also a mistake to separate the cultural environment from the natural environment, as if there were a world of mental products distinct from the world of material products. There is only one world, however diverse, and all animals live in it, although we human animals have altered it to suit ourselves. We have done so wastefully, thoughtlessly, and, if we do not mend our ways, fatally.

The fundamentals of the environment—the substances, the medium, and the surfaces—are the same for all animals. No matter how powerful men become they are not going to alter the fact of earth, air, and water—the lithosphere, the atmosphere, and the hydrosphere, together with the interfaces that separate them. For terrestrial animals like us, the earth and the sky are a basic structure on which all lesser structures depend. We cannot change it. We all fit into the substructures of the environment in our various ways, for we were all, in fact, formed by them. We were created by the world we live in.

SOME AFFORDANCES OF THE TERRESTRIAL ENVIRONMENT

Let us consider the affordances of the medium, of substances, of surfaces and their layout, of objects, of animals and persons, and finally a case of special interest for ecological optics, the affording of concealmeant by the occluding edges of the environment (Chapter 5).

THE MEDIUM

Air affords breathing, more exactly, respiration. It also affords unimpeded locomotion relative to the ground, which affords support. When illuminated and fog-free, it affords visual perception. It also affords the perception of vibratory events by means of sound fields and the perception of volatile sources by means of odor fields. The airspaces between obstacles and objects are the paths and the places where behavior occurs.

The optical information to specify air when it is clear and transparent is not obvious. The problem came up in Chapter 4, and the experimental evidence about the seeing of "nothing" will be described in the next chapter.

THE SUBSTANCES

Water is more substantial than air and always has a surface with air. It does not afford respiration for us. It affords drinking. Being fluid, it affords pouring from a container. Being a solvent, it affords washing and bathing. Its surface does not afford support for large animals with dense tissues. The optical information for water is well specified by the characteristics of its surface, especially the unique fluctuations caused by rippling (Chapter 5).

Solid substances, more substantial than water, have characteristic surfaces (Chapter 2). Depending on the animal species, some afford nutrition and some do not. A few are toxic. Fruits and berries, for example, have more food value when they are ripe, and this is specified by the color of the surface. But the food values of substances are often misperceived.

Solids also afford various kinds of manufacture, depending on the kind of solid state. Some, such as flint, can be chipped; others, such as clay, can be molded; still others recover their original shape after deformation; and some resist deformation strongly. Note that manufacture, as the term implies, was originally a form of manual behavior like manipulation. Things were fabricated *by hand*. To identify the substance in such cases is to perceive what can be done with it, what it is good for, its utility; and the hands are involved.

THE SURFACES AND THEIR LAYOUTS

I have already said that a horizontal, flat, extended, rigid surface affords support. It permits equilibrium and the maintaining of a posture with respect to gravity, this being a force perpendicular to the surface. The animal does not fall or slide as it would on a steep hillside. Equilibrium and posture are prerequisite to other behaviors, such as locomotion and manipulation. There will be more about this in Chapter 12, and more evidence about the perception of the ground in Chapter 9. The ground is quite literally the *basis* of the behavior of land animals. And it is also the basis of their visual

perception, their so-called space perception. Geometry began with the study of the earth as abstracted by Euclid, not with the study of the axes of empty space as abstracted by Descartes. The affording of support and the geometry of a horizontal plane are therefore not in different realms of discourse; they are not as separate as we have supposed.

The flat earth, of course, lies *beneath* the attached and detached objects on it. The earth has "furniture," or as I have said, it is cluttered. The solid, level, flat surface extends behind the clutter and, in fact, extends all the way out to the horizon. This is not, of course, the earth of Copernicus; it is the earth at the scale of the human animal, and on that scale it is flat, not round. Wherever one goes, the earth is separated from the sky by a horizon that, although it may be hidden by the clutter, is always there. There will be evidence to show that the horizon can always be seen, in the sense that it can be visualized, and that it can always be felt, in the sense that any surface one touches is experienced in relation to the horizontal plane.

Of course, a horizontal, flat, extended surface that is *nonrigid*, a stream or lake, does not afford support for standing, or for walking and running. There is no footing, as we say. It may afford floating or swimming, but you have to be equipped for that, by nature or by learning.

A *vertical*, flat, extended, and rigid surface such as a wall or a cliff face is a barrier to pedestrian locomotion. Slopes between vertical and horizontal afford walking, if easy, but only climbing, if steep, and in the latter case the surface cannot be flat; there must be "holds" for the hands and feet. Similarly, a slope downward affords falling if steep; the brink of a cliff is a falling-off place. It is dangerous and looks dangerous. The affordance of a certain layout is perceived if the layout is perceived.

Civilized people have altered the steep slopes of their habitat by building stairways so as to afford ascent and descent. What we call the steps afford stepping, up or down, relative to the size of the person's legs. We are still capable of getting around in an arboreal layout of surfaces, tree branches, and we have ladders that afford this kind of locomotion, but most of us leave that to our children.

A cliff face, a wall, a chasm, and a stream are barriers; they do not afford pedestrian locomotion unless there is a door, a gate, or a bridge. A tree or a rock is an obstacle. Ordinarily, there are paths between obstacles, and these openings are visible. The progress of locomotion is guided by the perception of barriers and obstacles, that is, by the act of steering into the openings and away from the surfaces that afford injury. I have tried to describe the optical information for the control of locomotion (Gibson, 1958), and it will be further elaborated in Chapter 13. The *imminence* of collision with a surface during locomotion is specified in a particularly simple way, by an explosive rate of magnification of the optical texture. This has been called *looming* (e.g., Schiff, 1965). It should not be confused, however, with the magnification of an opening

between obstacles, the opening up of a *vista* such as occurs in the approach to a doorway.

THE OBJECTS

The affordances of what we loosely call *objects* are extremely various. It will be recalled that my use of the terms is restricted and that I distinguish between *attached* objects and *detached* objects. We are not dealing with Newtonian objects in space, all of which are detached, but with the furniture of the earth, some items of which are attached to it and cannot be moved without breakage.

Detached objects must be comparable in size to the animal under consideration if they are to afford behavior. But those that are comparable afford an astonishing variety of behaviors, especially to animals with hands. Objects can be manufactured and manipulated. Some are portable in that they afford lifting and carrying, while others are not. Some are graspable and other not. To be graspable, an object must have opposite surfaces separated by a distance less than the span of the hand. A five-inch cube can be grasped, but a ten-inch cube cannot (Gibson, 1966*b*, p. 119). A large object needs a "handle" to afford grasping. Note that the size of an object that constitutes a graspable size is specified in the optic array. If this is true, it is *not* true that a tactual sensation of size has to become associated with the visual sensation of size in order for the affordance to be perceived.

Sheets, sticks, fibers, containers, clothing, and tools are detached objects that afford manipulation (Chapter 3). Additional examples are given below.

1. An elongated object of moderate size and weight affords wielding. If used to hit or strike, it is a *club* or *hammer*. If used by a chimpanzee behind bars to pull in a banana beyond its reach, it is a sort of *rake*. In either case, it is an extension of the arm. A rigid staff also affords leverage and in that use is a *lever*. A pointed elongated object affords piercing—if large it is is a *spear*, if small a *needle* or *awl*.

2. A rigid object with a sharp dihedral angle, an edge, affords cutting and scraping; it is a *knife*. It may be designed for both striking and cutting, and then it is an *axe*.

3. A graspable rigid object of moderate size and weight affords throwing. It may be a *missile* or only an object for play, a *ball*. The launching of missiles by supplementary tools other than the hands alone—the sling, the bow, the catapult, the gun, and so on—is one of the behaviors that makes the human animal a nasty, dangerous species.

4. An elongated elastic object, such as a *fiber*, *thread*, *thong*, or *rope*, affords knotting, binding, lashing, knitting, and weaving. These are kinds of behavior where manipulation leads to manufacture.

5. A hand-held tool of enormous importance is one that, when applied to a surface, leaves traces and thus affords *trace-making*. The tool may be a *stylus, brush, crayon, pen,* or *pencil,* but if it marks the surface it can be used to depict and to write, to represent scenes and to specify words.

We have thousands of names for such objects, and we classify them in many ways: pliers and wrenches are tools; pots and pans are utensils; swords and pistols are weapons. They can all be said to have properties or qualities: color, texture, composition, size, shape and features of shape, mass, elasticity, rigidity, and mobility. Orthodox psychology asserts that *we perceive these objects insofar as we discriminate their properties or qualities.* Psychologists carry out elegant experiments in the laboratory to find out how and how well these qualities are discriminated. The psychologists assume that objects are *composed* of their qualities. But I now suggest that what we perceive when we look at objects are their affordances, not their qualities. We can discriminate the dimensions of difference if required to do so in an experiment, but what the object affords us is what we normally pay attention to. The special combination of qualities into which an object can be analyzed is ordinarily not noticed.

If this is true for the adult, what about the young child? There is much evidence to show that the infant does not begin by first discriminating the qualities of objects and then learning the combinations of qualities that specify them. Phenomenal objects are *not* built up of qualities; it is the other way around. The affordance of an object is what the infant begins by noticing. The meaning is observed before the substance and surface, the color and form, are seen as such. An affordance is an invariant combination of variables, and one might guess that it is easier to perceive such an invariant unit

To Perceive an Affordance Is Not to Classify an Object

The fact that a stone is a missile does not imply that it cannot be other things as well. It can be a paperweight, a bookend, a hammer, or a pendulum bob. It can be piled on another rock to make a cairn or a stone wall. These affordances are all consistent with one another. The differences between them are not clear-cut, and the arbitrary names by which they are called do not count for perception. If you know what can be done with a graspable detached object, what it can be used for, you can call it whatever you please.

The theory of affordances rescues us from the philosophical muddle of assuming fixed classes of objects, each defined by its common features and then given a name. As Ludwig Wittgenstein knew, you *cannot* specify the necessary and sufficient features of the class of things to which a name is given. They have only a "family resemblance." But this does not mean you cannot learn how to use things and perceive their uses. You do not have to classify and label things in order to perceive what they afford.

than it is to perceive all the variables separately. It is never necessary to distinguish *all* the features of an object and, in fact, it would be impossible to do so. Perception is economical. "Those features of a thing are noticed which distinguish it from other things that it is not—but not *all* the features that distinguish it from *everything* that it is not" (Gibson, 1966*b*, p. 286).

OTHER PERSONS AND ANIMALS

The richest and most elaborate affordances of the environment are provided by other animals and, for us, other people. These are, of course, detached objects with topologically closed surfaces, but they change the shape of their surfaces while yet retaining the same fundamental shape. They move from place to place, changing the postures of their bodies, ingesting and emitting certain substances, and doing all this spontaneously, initiating their own movements, which is to say that their movements are *animate*. These bodies are subject to the laws of mechanics and yet *not* subject to the laws of mechanics, for they are not *governed* by these laws. They are so different from ordinary objects that infants learn almost immediately to distinguish them from plants and nonliving things. When touched they touch back, when struck they strike back; in short, they *interact* with the observer and with one another. Behavior affords behavior, and the whole subject matter of psychology and of the social sciences can be thought of as an elaboration of this basic fact. Sexual behavior, nurturing behavior, fighting behavior, cooperative behavior, economic behavior, political behavior—all depend on the perceiving of what another person or other persons afford, or sometimes on the misperceiving of it.

What the male affords the female is reciprocal to what the female affords the male; what the infant affords the mother is reciprocal to what the mother affords the infant; what the prey affords the predator goes along with what the predator affords the prey; what the buyer affords the seller cannot be separated from what the seller affords the buyer, and so on. The perceiving of these mutual affordances is enormously complex, but it is nonetheless lawful, and it is based on the pickup of the information in touch, sound, odor, taste, and ambient light. It is just as much based on stimulus information as is the simpler perception of the support that is offered by the ground under one's feet. For other animals and other persons can only give off information about themselves insofar as they are tangible, audible, odorous, tastable, or visible.

The other person, the generalized *other*, the *alter* as opposed to the *ego*, is an ecological object with a skin, even if clothed. It is an object, although it is not *merely* an object, and we do right to speak of *he* or *she* instead of *it*. But the other person has

a surface that reflects light, and the information to specify what he or she is, invites, promises, threatens, or does can be found in the light.

PLACES AND HIDING PLACES

The habitat of a given animal contains *places*. A place is not an object with definite boundaries but a region (Chapter 3). The different places of a habitat may have different affordances. Some are places where food is usually found and others where it is not. There are places of danger, such as the brink of a cliff and the regions where predators lurk. There are places of refuge from predators. Among these is the place where mate and young are, the home, which is usually a partial enclosure. Animals are skilled at what the psychologist calls place-learning. They can find their way to significant places.

An important kind of place, made intelligible by the ecological approach to visual perception, is a place that affords concealment, a *hiding place*. Note that it involves social perception and raises questions of epistemology. The concealing of oneself from other observers and the hiding of a detached object from other observers have different kinds of motivation. As every child discovers, a good hiding place for one's body is not necessarily a good hiding place for a treasure. A detached object can be concealed both from other observers and from the observer himself. The observer's body can be concealed from other observers but *not* from himself, as the last chapter emphasized. Animals as well as children hide themselves and also hide objects such as food.

One of the laws of the ambient optic array (Chapter 5) is that at any fixed point of observation some parts of the environment are revealed and the remaining parts are concealed. The reciprocal of this law is that the observer himself, his body considered as part of the environment, is revealed at some fixed points of observation and concealed at the remaining points. An observer can perceive not only that other observers are unhidden or hidden from him but also that he is hidden or unhidden from other observers. Surely, babies playing peek-a-boo and children playing hide-and-seek are practicing this kind of apprehension. To *hide* is to position one's body at a place that is concealed at the points of observation of other observers. A "good" hiding place is one that is concealed at nearly all points of observation.

All of these facts and many more depend on the principle of occluding edges at a point of observation, the law of reversible occlusion, and the facts of opaque and nonopaque substances. What we call privacy in the design of housing, for example, is the providing of opaque enclosures. A high degree of concealment is afforded by an enclosure, and complete concealment is afforded by a complete enclosure. But note that there are peepholes and screens that permit seeing without being seen. A transparent sheet of glass in a window transmits both illumination and information, whereas a *translucent* sheet transmits illumination but not information. There will be more of this in Chapter 11.

Note also that a glass wall affords seeing through but not walking through, whereas a cloth curtain affords going through but not seeing through. Architects and designers know such facts, but they lack a theory of affordances to encompass them in a system.

SUMMARY: POSITIVE AND NEGATIVE AFFORDANCES

The foregoing examples of the affordances of the environment are enough to show how general and powerful the concept is. Substances have biochemical offerings and afford manufacture. Surfaces afford posture, locomotion, collision, manipulation, and in general behavior. Special forms of layout afford shelter and concealment. Fires afford warming and burning. Detached objects—tools, utensils, weapons—afford special types of behavior to primates and humans. The other animal and the other person provide mutual and reciprocal affordances at extremely high levels of behavioral complexity. At the highest level, when vocalization becomes speech and manufactured displays become images, pictures, and writing, the affordances of human behavior are staggering. No more of that will be considered at this stage except to point out that speech, pictures, and writing still have to be perceived.

At all these levels, we can now observe that some offerings of the environment are beneficial and some are injurious. These are slippery terms that should only be used with great care, but if their meanings are pinned down to biological and behavioral facts the danger of confusion can be minimized. First, consider substances that afford ingestion. Some afford nutrition for a given animal, some afford poisoning, and some are neutral. As I pointed out before, these facts are quite distinct from the affording of pleasure and displeasure in eating, for the experiences do not necessarily correlate with the biological effects. Second, consider the brink of a cliff. On the one side it affords walking along, locomotion, whereas on the other it affords falling off, injury. Third, consider a detached object with a sharp edge, a knife. It affords cutting if manipulated in one manner, but it affords being cut if manipulated in another manner. Similarly, but at a different level of complexity, a middle-sized metallic object affords grasping, but if charged with current it affords electric shock. And fourth, consider the other person. The animate object can give caresses or blows, contact comfort or contact injury, reward or punishment, and it is not always easy to perceive which will be provided. Note that all these benefits and injuries, these safeties and dangers, these positive and negative affordances are properties of things *taken with reference to an observer* but not properties of the *experiences of the observer*. They are not subjective values; they are not feelings of pleasure or pain added to neutral perceptions.

There has been endless debate among philosophers and psychologists as to whether values are physical or phenomenal, in the world of matter or only in the world of mind. For affordances as distinguished from values, the debate does not apply. Affordances are neither in the one world or the other inasmuch as the theory of two worlds is rejected. There is only one environment, although it contains many observers with limitless opportunities for them to live in it.

THE ORIGIN OF THE CONCEPT OF AFFORDANCES: A RECENT HISTORY

The gestalt psychologists recognized that the meaning or the value of a thing seems to be perceived just as immediately as its color. The value is clear *on the face of it,* as we say, and thus it has a *physiognomic* quality in the way that the emotions of a man appear *on his face.* To quote from the *Principles of Gestalt Psychology* (Koffka, 1935), "Each thing says what it is. . . . a fruit says 'Eat me'; water says 'Drink me'; thunder says 'Fear me'; and woman says 'Love me' " (p. 7). These values are vivid and essential features of the experience itself. Koffka did not believe that a meaning of this sort could be explained as a pale context of memory images or an unconscious set of response tendencies. The postbox "invites" the mailing of a letter, the handle "wants to be grasped," and things "tell us what to do with them" (p. 353). Hence, they have what Koffka called "demand character."

Kurt Lewin coined the term *Aufforderungscharakter,* which has been translated as *invitation character* (by J. F. Brown in 1929) and as *valence* (by D. K. Adams in 1931; cf. Marrow, 1969, p. 56, for the history of these translations). The latter term came into general use. *Valences* for Lewin had corresponding *vectors,* which could be represented as arrows pushing the observer toward or away from the object. What explanation could be given for these valences, the characters of objects that invited or demanded behavior? No one, not even the gestalt theorists, could think of them as physical and, indeed, they do not fall within the province of ordinary physics. They must therefore be phenomenal, given the assumption of dualism. If there were *two* objects, and if the valence could not belong to the physical object, it must belong to the phenomenal object—to what Koffka called the "behavioral" object but not to the "geographical" object. The valence of an object was bestowed upon it in experience, and bestowed by a need of the observer. Thus, Koffka argued that the postbox has a demand character only when the observer needs to mail a letter. He is attracted to it when he has a letter to post, not otherwise. The value of something was assumed to change as the need of the observer changed.

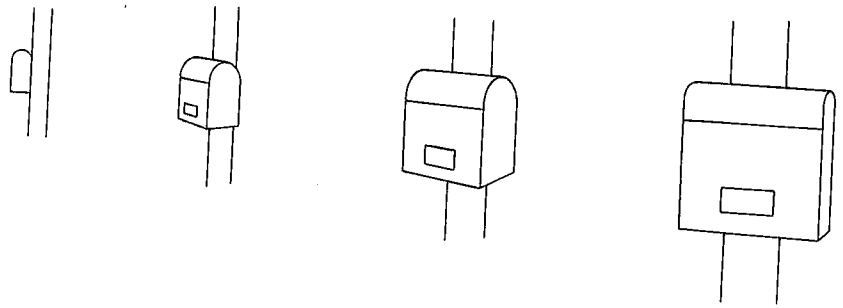
The concept of affordance is derived from these concepts of valence, invitation, and demand but with a crucial difference. The affordance of something does *not change* as the need of the observer changes. The observer may or may not perceive or attend to the affordance, according to his needs, but the affordance, being invariant, is always there to be perceived. An affordance is not bestowed upon an object by a need of an observer and his act of perceiving it. The object offers what it does because it is what it is. To be sure, we define *what it is* in terms of ecological physics instead of physical physics, and it therefore possesses meaning and value to begin with. But this is meaning and value of a new sort.

For Koffka it was the *phenomenal* postbox that invited letter-mailing, not the *physical* postbox. But this duality is pernicious. I prefer to say that the real postbox (the *only* one) affords letter-mailing to a letter-writing human in a community with a postal system. This fact is perceived when the postbox is identified as such, and it is apprehended whether the postbox is in sight or out of sight. To feel a special attraction to it when one has a letter to mail is not surprising, but the main fact is that it is perceived as part of the environment—as an item of the neighborhood in which we live. Everyone above the age of six knows what it is for and where the nearest one is. The perception of its affordance should therefore not be confused with the temporary special attraction it may have.

The gestalt psychologists explained the directness and immediacy of the experience of valences by postulating that the ego is an object in experience and that a "tension" may arise between a phenomenal object and the phenomenal ego. When the object is in "a dynamic relation with the ego" said Koffka, it has a demand character. Note that the "tension," the "relation," or the "vector" must arise in the "field," that is, in the field of phenomenal experience. Although many psychologists find this theory intelligible, I do not. There is an easier way of explaining why the values of things seem to

Figure 8.1

The changing perspective structure of a postbox during approach by an observer. As one reduces the distance to the object to one-third, the visual solid angle of the object increases three times. Actually this is only a detail near the center of an outflowing optic array. (From *The Perception of the Visual World* by James Jerome Gibson and used with the agreement of the reprint publisher, Greenwood Press, Inc.)



be perceived immediately and directly. It is because the affordances of things for an observer are specified in stimulus information. They *seem* to be perceived directly because they *are* perceived directly.

The accepted theories of perception, to which the gestalt theorists were objecting, implied that *no* experiences were direct except sensations and that sensations mediated all other kinds of experience. Bare sensations had to be clothed with meaning. The seeming directness of meaningful perception was therefore an embarrassment to the orthodox theories, and the Gestaltists did right to emphasize it. They began to undermine the sensation-based theories. But their own explanations of why it is that a fruit says "Eat me" and a woman says "Love me" are strained. The gestalt psychologists objected to the accepted theories of perception, but they never managed to go beyond them.

THE OPTICAL INFORMATION FOR PERCEIVING AFFORDANCES

The theory of affordances is a radical departure from existing theories of value and meaning. It begins with a new definition of what value and meaning *are*. The perceiving of an affordance is not a process of perceiving a value-free physical object to which meaning is somehow added in a way that no one has been able to agree upon; it is a process of perceiving a value-rich ecological object. Any substance, any surface, any layout has some affordance for benefit or injury to someone. Physics may be value-free, but ecology is not.

The central question for the theory of affordances is not whether they exist and are real but whether information is available in ambient light for perceiving them. The skeptic may now be convinced that there is information in light for some properties of a surface but not for such a property as being good to eat. The taste of a thing, he will say, is not specified in light; you can see its form and color and texture but not its palatability; you have to *taste* it for that. The skeptic understands the stimulus variables that specify the dimensions of visual sensation; he knows from psychophysics that brightness corresponds to intensity and color to wavelength of light. He may concede the invariants of structured stimulation that specify surfaces and how they are laid out and what they are made of. But he may boggle at invariant combinations of invariants that specify the affordances of the environment for an observer. The skeptic familiar with the experimental control of stimulus variables has enough trouble understanding the invariant variables I have been proposing without being asked to accept invariants of invariants.

Nevertheless, a unique combination of invariants, a *compound* invariant, is just another invariant. It is a unit, and the components do not *have* to be combined or associated. Only if percepts were combinations of sensations would they have to be associated. Even in the classical terminology, it could be argued that when a number of stimuli are completely covariant, when they *always* go together, they constitute a single "stimulus." If the visual system is capable of extracting invariants from a changing optic array, there is no reason why it should not extract invariants that seem to us highly complex.

The trouble with the assumption that high-order optical invariants specify high-order affordances is that experimenters, accustomed to working in the laboratory with low-order stimulus variables, cannot think of a way to *measure* them. How can they hope to isolate and control an invariant of optical structure so as to apply it to an observer if they cannot quantify it? The answer comes in two parts, I think. First, they should not hope to *apply* an invariant to an observer, only to make it available, for it is not a stimulus. And, second, they do not have to quantify an invariant, to apply numbers to it, but only to give it an exact mathematical description so that other experimenters can make it available to *their* observers. The virtue of the psychophysical experiment is simply that it is disciplined, not that it relates the psychical to the physical by a metric formula.

An affordance, as I said, points two ways, to the environment and to the observer. So does the information to specify an affordance. But this does not in the least imply separate realms of consciousness and matter, a psychophysical dualism. It says only that the information to specify the utilities of the environment is accompanied by information to specify the observer himself, his body, legs, hands, and mouth. This is only to reemphasize that exteroception is accompanied by proprioception—that to perceive the world is to coperceive oneself. This is wholly inconsistent with dualism in any form, either mind-matter dualism or mind-body dualism. The awareness of the world and of one's complementary relations to the world are not separable.

The child begins, no doubt, by perceiving the affordances of things for her, for her own personal behavior. She walks and sits and grasps relative to her own legs and body and hands. But she must learn to perceive the affordances of things for other observers as well as for herself. An affordance is often valid for all the animals of a species, as when it is part of a niche. I have described the invariants that enable a child to perceive the same solid shape at different points of observation and that likewise enable two or more children to perceive the same shape at different points of observation. These are the invariants that enable two children to perceive the common *affordance* of the solid shape despite the different perspectives, the affordance of a toy, for example. Only when each child perceives the values of things for others as well as for herself does she begin to be socialized.

MISINFORMATION FOR AFFORDANCES

If there is information in the ambient light for the affordances of things, can there also be misinformation? According to the thoery being developed, if information is picked up perception results; if misinformation is picked up misperception results.

The brink of a cliff affords falling off; it is in fact dangerous and it looks dangerous to us. It seems to look dangerous to many other terrestrial animals besides ourselves, including infant animals. Experimental studies have been made of this fact. If a sturdy sheet of plate glass is extended out over the edge it no longer affords falling and in fact is not dangerous, but it may still *look* dangerous. The optical information to specify depth-downward-at-an-edge is still present in the ambient light; for this reason the device was called a *visual cliff* by E. J. Gibson and R. D. Walk (1960). Haptic information was available to specify an adequate surface of support, but this was contradictory to the optical information. When human infants at the crawling stage of locomotion were tested with this apparatus, many of them would pat the glass with their hands but would not venture out on the surface. The babies misperceived the affordance of a transparent surface for support, and this result is not surprising.

Similarly, an adult can misperceive the affordance of a sheet of glass, by mistaking a closed glass door for an open doorway and attempting to walk through it. He then crashes into the barrier and is injured. The affordance of collision was not specified by the outflow of optical texture in the array, or it was insufficiently specified. He mistook glass for air. The occluding edges of the doorway were specified and the empty visual solid angle opened up symmetrically in the normal manner as he approached, so his behavior was properly controlled, but the imminence of collision was not noticed. A little dirt on the surface, or highlights, would have saved him.

These two cases are instructive. In the first a surface of support was mistaken for air because the optic array specified air. In the second case a *barrier* was mistaken for air for the same reason. Air downward affords falling and is dangerous. Air forward affords passage and is safe. The mistaken perceptions led to inappropriate actions.

Errors in the perception of the surface of support are serious for a terrestrial animal. If quicksand is mistaken for sand, the perceiver is in deep trouble. If a covered pitfall is taken for solid ground, the animal is trapped. A danger is sometimes hidden—

Things That Look like What They Are

If the affordances of a thing are perceived correctly, we say that it looks like what it *is*. But we must, of course, *learn* to see what things really are—for example, that the innocent-looking leaf is really a nettle or that the helpful-sounding politician is really a demagogue. And this can be very difficult.

the shark under the calm water and the electric shock in the radio cabinet. In the natural environment, poison ivy is frequently mistaken for ivy. In the artificial environment, acid can be mistaken for water.

A wildcat may be hard to distinguish from a cat, and a thief may look like an honest person. When Koffka asserted that "each thing says what it is," he failed to mention that it may lie. More exactly, a thing may not look like what it is.

Nevertheless, however true all this may be, the basic affordances of the environment are perceivable and are usually perceivable directly, without an excessive amount of learning. The basic properties of the environment that make an affordance are specified in the structure of ambient light, and hence the affordance itself is specified in ambient light. Moreover, an invariant variable *that is commensurate with the body of the observer himself* is more easily picked up than one not commensurate with his body.

SUMMARY

The medium, substances, surfaces, objects, places, and other animals have affordances for a given animal. They offer benefit or injury, life or death. This is why they need to be perceived.

The possibilities of the environment and the way of life of the animal go together inseparably. The environment constrains what the animal can do, and the concept of a niche in ecology reflects this fact. Within limits, the human animal can alter the affordances of the environment but is still the creature of his or her situation.

There is information in stimulation for the physical properties of things, and presumably there is information for the environmental properties. The doctrine that says we must distinguish among the variables of things before we can learn their meanings is questionable. Affordances are properties taken with reference to the observer. They are neither physical nor phenomenal.

The hypothesis of information in ambient light to specify affordances is the culmination of ecological optics. The notion of invariants that are related at one extreme to the motives and needs of an observer and at the other extreme to the substances and surfaces of a world provides a new approach to psychology.

FOURTEEN

THE THEORY OF INFORMATION PICKUP AND ITS CONSEQUENCES

In this book the traditional theories of perception have been abandoned. The perennial doctrine that two-dimensional images are restored to three-dimensional reality by a process called depth perception will not do. Neither will the doctrine that the images are transformed by the cues for distance and slant so as to yield constancy of size and shape in the perception of objects. The deep-seated notion of the retinal image as a still picture has been abandoned.

The simple assumption that perceptions of the world are caused by stimuli from the world will not do. The more sophisticated assumption that perceptions of the world are caused when sensations triggered by stimuli are supplemented by memories will not do either. Not even the assumption that a sequence of stimuli is converted into a phenomenal scene by memory will do. The very notion of stimulation as typically composed of discrete stimuli has been abandoned.

The established theory that exteroception and proprioception arise when exteroceptors and proprioceptors are stimulated will not do. The doctrine of special channels of sensation corresponding to specific nerve bundles has been abandoned.

The belief of empiricists that the perceived meanings and values of things are supplied from the past experience of the observer will not do. But even worse is the belief of nativists that meanings and values are supplied from the past experience of the race by way of innate ideas. The theory that meaning is attached to experience or imposed on it has been abandoned.

Not even the current theory that the inputs of the sensory channels are subject to "cognitive processing" will do. The inputs are described in terms of information theory, but the processes are described in terms of old-fashioned mental acts: recognition, interpretation, inference, concepts, ideas, and storage and retrieval of ideas. These are still the operations of the mind upon the deliverances of the senses, and there are too many perplexities entailed in this theory. It will not do, and the approach should be abandoned.

What sort of theory, then, will explain perception? Nothing less than one based on the pickup of information. To this theory, even in its undeveloped state, we should now turn.

Let us remember once again that it is the perception of the environment that we wish to explain. If we were content to explain only the perception of forms or pictures on a surface, of nonsense figures to which meanings must be attached, of discrete stimuli imposed on an observer willy-nilly, in short, the items most often presented to an observer in the laboratory, the traditional theories might prove to be adequate and would not have to be abandoned. But we should not be content with that limited aim. It leaves out of account the eventful world and the perceiver's awareness of being in the world. The laboratory does not have to be limited to simple stimuli, so-called. The experiments reported in Chapters 9 and 10 showed that information can be displayed.

WHAT IS NEW ABOUT THE PICKUP OF INFORMATION?

The theory of information pickup differs radically from the traditional theories of perception. First, it involves a new notion of perception, not just a new theory of the process. Second, it involves a new assumption about what there is to be perceived. Third, it involves a new conception of the information for perception, with two kinds always available, one about the environment and another about the self. Fourth, it requires the new assumption of perceptual systems with overlapping functions, each having outputs to adjustable organs as well as inputs from organs. We are especially concerned with vision, but none of the systems, listening, touching, smelling, or tasting, is a channel of sense. Finally, fifth, optical information pickup entails an activity of the system not heretofore imagined by any visual scientist, the concurrent registering of both persistence and change in the flow of structured stimulation. This is the crux of the theory but the hardest part to explicate, because it can be phrased in different ways and a terminology has to be invented.

Consider these five novelties in order, ending with the problem of detecting variants and invariants or change and nonchange.

A REDEFINITION OF PERCEPTION

Perceiving is an achievement of the individual, not an appearance in the theater of his consciousness. It is a keeping-in-touch with the world, an experiencing of things rather than a having of experiences. It involves awareness-of instead of just awareness. It may be awareness of something in the environment or something in the observer or both at once, but there is no content of awareness independent of that of which one is aware. This is close to the act psychology of the nineteenth century except that perception is

not a mental act. Neither is it a bodily act. Perceiving is a psychosomatic act, not of the mind or of the body but of a living observer.

The act of picking up information, moreover, is a continuous act, an activity that is ceaseless and unbroken. The sea of energy in which we live flows and changes without sharp breaks. Even the tiny fraction of this energy that affects the receptors in the eyes, ears, nose, mouth, and skin is a flux, not a sequence. The exploring, orienting, and adjusting of these organs sink to a minimum during sleep but do not stop dead. Hence, perceiving is a stream, and William James's description of the stream of consciousness (1890, Ch. 9) applies to it. Discrete percepts, like discrete ideas, are "as mythical as the Jack of Spades."

The continuous act of perceiving involves the coperceiving of the self. At least, that is one way to put it. The very term *perception* must be redefined to allow for this fact, and the word *proprioception* must be given a different meaning than it was given by Sherrington.

A NEW ASSERTION ABOUT WHAT IS PERCEIVED

My description of the environment (Chapters 1–3) and of the changes that can occur in it (Chapter 6) implies that places, attached objects, objects, and substances are what are mainly perceived, together with events, which are changes of these things. To see these things is to perceive what they afford. This is very different from the accepted categories of what there is to perceive as described in the textbooks. Color, form, location, space, time, and motion—these are the chapter headings that have been handed down through the centuries, but they are not what is perceived.

Places A *place* is one of many adjacent places that make up the habitat and, beyond that, the whole environment. But smaller places are nested within larger places. They do not have boundaries, unless artificial boundaries are imposed by surveyors (my piece of land, my town, my country, my state). A place at one level is what you can see from here or hereabouts, and locomotion consists of going from place to place in this sense (Chapter 11). A very important kind of learning for animals and children is place-learning—learning the affordances of places and learning to distinguish among them—and way-finding, which culminate in the state of being oriented to the whole habitat and knowing where one is in the environment.

A place persists in some respects and changes in others. In one respect, it cannot be changed at all—in its location relative to other places. A place cannot be *displaced* like an object. That is, the adjacent order of places cannot be permuted; they cannot be shuffled. The sleeping places, eating places, meeting places, hiding places, and

falling-off places of the habitat are immobile. Place-learning is therefore different from other kinds.

Attached Objects I defined an *object* in Chapter 3 as a substance partially or wholly surrounded by the medium. An object attached to a place is only partly surrounded. It is a protuberance. It cannot be displaced without becoming detached. Nevertheless, it has a surface and enough of a natural boundary to constitute a unit. Attached objects can thus be counted. Animals and children learn what such objects are good for and how to distinguish them. But they cannot be separated from the places where they are found.

Detached Objects A fully detached object can be displaced or, in some cases, can displace itself. Learning to perceive it thus has a different character from learning to perceive places and attached objects. Its affordances are different. It can be put side by side with another object and compared. It can therefore be grouped or classed by the manipulation of sorting. Such objects when grouped can be rearranged, that is, permuted. And this means not only that they can be counted but that an abstract number can be assigned to the group.

It is probably harder for a child to perceive "same object in a different place" than it is to perceive "same object in the same place." The former requires that the information for persistence-despite-displacement should have been noticed, whereas the latter does not.

Inanimate detached objects, rigid or nonrigid, natural or manufactured, can be said to have features that distinguish them. The features are probably not denumerable, unlike the objects themselves. But if they are compounded to specify affordances, as I argued they must be, only the relevant compounds need to be distinguished. So when it comes to the natural, nonrigid, animate objects of the world whose dimensions of difference are overwhelmingly rich and complex, we pay attention only to what the animal or person affords (Chapter 8).

Persisting Substances A *substance* is that of which places and objects are composed. It can be vaporous, liquid, plastic, viscous, or rigid, that is, increasingly "substantial." A substance, together with what it affords, is fairly well specified by the color and texture of its surface. Smoke, milk, clay, bread, and wood are polymorphic in layout but invariant in color-texture. Substances, of course, can be smelled and tasted and palpated as well as seen.

The animal or child who begins to perceive substances, therefore, does so in a different way than one who begins to perceive places, attached objects, and detached objects. Substances are formless and cannot be counted. The number of substances,

natural compositions, or mixtures is not fixed. (The number of chemical elements is fixed, but that is a different matter.) We discriminate among surface colors and textures, but we cannot group them as we do detached objects and we cannot order them as we do places.

We also, of course, perceive changes in otherwise persisting substances, the ripening of fruit, and the results of boiling and baking, or of mixing and hardening. But these are a kind of event.

Events As I used the term, an *event* is any change of a substance, place, or object, chemical, mechanical, or biophysical. The change may be slow or fast, reversible or nonreversible, repeating or nonrepeating. Events include what happens to objects in general, plus what the animate objects *make* happen. Events are nested within superordinate events. The motion of a detached object is not the prototype of an event that we have been led to think it was. Events of different sorts are perceived as such and are not, surely, reducible to elementary motions.

THE INFORMATION FOR PERCEPTION

Information, as the term is used in this book (but not in other books), refers to specification of the observer's environment, not to specification of the observer's receptors or sense organs. The qualities of objects are specified by information; the qualities of the receptors and nerves are specified by sensations. Information about the world cuts right across the qualities of sense.

The term *information* cannot have its familiar dictionary meaning of *knowledge communicated to a receiver*. This is unfortunate, and I would use another term if I could. The only recourse is to ask the reader to remember that picking up information is not to be thought of as a case of communicating. The world does not speak to the observer. Animals and humans communicate with cries, gestures, speech, pictures, writing, and television, but we cannot hope to understand perception in terms of these channels; it is quite the other way around. Words and pictures convey information, carry it, or transmit it, but the information in the sea of energy around each of us, luminous or mechanical or chemical energy, is not conveyed. It is simply there. The assumption that information can be transmitted and the assumption that it can be stored are appropriate for the theory of communication, not for the theory of perception.

The vast area of speculation about the so-called media of communication had a certain discipline imposed on it some years ago by a mathematical theory of communication (Shannon and Weaver, 1949). A useful measure of information transmitted was formulated, in terms of "bits." A sender and receiver, a channel, and a finite number of possible signals were assumed. The result was a genuine discipline of communications

engineering. But, although psychologists promptly tried to apply it to the senses and neuropsychologists began thinking of nerve impulses in terms of bits and the brain in terms of a computer, the applications did not work. Shannon's concept of information applies to telephone hookups and radio broadcasting in elegant ways but not, I think, to the firsthand perception of being in-the-world, to what the baby gets when first it opens its eyes. The information for perception, unhappily, cannot be defined and measured as Claude Shannon's information can be.

The information in ambient light, along with sound, odor, touches, and natural chemicals, is inexhaustible. A perceiver can keep on noticing facts about the world she lives in to the end of her life without ever reaching a limit. There is no threshold for information comparable to a stimulus threshold. Information is not lost to the environment when gained by the individual; it is not conserved like energy.

Information is not specific to the banks of photoreceptors, mechanoreceptors, and chemoreceptors that lie within the sense organs. Sensations are specific to receptors and thus, normally, to the kinds of stimulus energy that touch them off. But information is not energy-specific. Stimuli are not always imposed on a passive subject. In life one *obtains* stimulation in order to extract the information (Gibson, 1966*b*, Ch. 2). The information can be the same, despite a radical change in the stimulation obtained.

Finally, a concept of information is required that admits of the possibility of illusion. Illusions are a theoretical perplexity in any approach to the study of perception. Is information always valid and illusion simply a failure to pick it up? Or is the information picked up sometimes impoverished, masked, ambiguous, equivocal, contradictory, even false? The puzzle is especially critical in vision.

In Chapter 14 of *The Senses Considered as Perceptual Systems* (Gibson, 1966*b*) and again in this book I have tried to come to terms with the problem of misperception. I am only sure of this: it is not one problem but a complex of different problems. Consider, first, the mirage of palm trees in the desert sky, or the straight stick that looks bent because it is partly immersed in water. These illusions, together with the illusion of Narcissus, arise from the regular reflection or refraction of light, that is, from exceptions to the ecological optics of the scatter-reflecting surface and the perfectly homogeneous medium. Then consider, second, the misperception in the case of the shark under the calm water or the electric shock hidden in the radio cabinet. Failure to perceive the danger is not then blamed on the perceiver. Consider, third, the sheet of glass mistaken for an open doorway or the horizontal sheet of glass (the optical cliff) mistaken for a void. A fourth case is the room composed of trapezoidal surfaces or the trapezoidal window, which look normally rectangular so long as the observer does not open both eyes and walk around. Optical misinformation enters into each of these cases in a different way. But in the last analysis, *are* they explained by misinformation? Or is it a matter of failure to pick up *all* the available information, the inexhaustible reservoir that lies open to further scrutiny?

The misperceiving of affordances is a serious matter. As I noted in Chapter 8, a wildcat may look like a cat. (But *does* he look just like a cat?) A malevolent man may act like a benevolent one. (But *does* he exactly?) The line between the pickup of misinformation and the failure to pick up information is hard to draw.

Consider the human habit of picture-making, which I take to be the devising and displaying of optical information for perception by others. It is thus a means of communication, giving rise to mediated apprehension, but it is more like direct pickup than word-making is. Depiction and its consequences are deferred until later, but it can be pointed out here that picture-makers have been experimenting on us for centuries with artificial displays of information in a special form. They enrich or impoverish it, mask or clarify it, ambiguate or disambiguate it. They often try to produce a discrepancy of information, an equivocation or contradiction, in the same display. Painters invented the cues for depth in the first place, and psychologists looked at their paintings and began to talk about cues. The notions of counterbalanced cues, of figure-ground reversals, of equivocal perspectives, of different perspectives on the same object, of "impossible" objects—all these come from artists who were simply experimenting with frozen optical information.

An important fact to be noted about any pictorial display of optical information is that, in contrast with the inexhaustible reservoir of information in an illuminated medium, it cannot be looked at close up. Information to specify the display as such, the canvas, the surface, the screen, can always be picked up by an observer who walks around and looks closely.

THE CONCEPT OF A PERCEPTUAL SYSTEM

The theory of information pickup requires perceptual systems, not senses. Some years ago I tried to prove that a perceptual system was radically different from a sense (Gibson, 1966*b*), the one being active and the other passive. People said, "Well, what I mean by a sense is an *active* sense." But it turned out that they still meant the passive inputs of a sensory nerve, the activity being what occurs in the brain when the inputs get there. That was not what I meant by a perceptual system. I meant the activities of looking, listening, touching, tasting, or sniffing. People then said, "Well, but those are responses to sights, sounds, touches, tastes, or smells, that is, motor acts resulting from sensory inputs. What you call a perceptual system is nothing but a case of feedback." I was discouraged. People did not understand.

I shall here make another attempt to show that the senses considered as special senses cannot be reconciled with the senses considered as perceptual systems. The five perceptual systems correspond to five modes of overt attention. They have overlapping

functions, and they are all more or less subordinated to an overall orienting system. A system has organs, whereas a sense has receptors. A system can orient, explore, investigate, adjust, optimize, resonate, extract, and come to an equilibrium, whereas a sense cannot. The characteristic activities of the visual system have been described in Chapter 12 of this book. The characteristic activities of the auditory system, the haptic system, and the two related parts of what I called the "chemical value system" were described in Chapters 5–8 of my earlier book (Gibson, 1966*b*). Five fundamental differences between a sense and a perceptual system are given below.

1. A special sense is defined by a bank of receptors or receptive units that are connected with a so-called projection center in the brain. Local stimuli at the sensory surface will cause local firing of neurons in the center. The adjustments of the organ in which the receptors are incorporated are not included within the definition of a sense.

A perceptual system is defined by an organ and its adjustments at a given level of functioning, subordinate or superordinate. At any level, the incoming and outgoing nerve fibers are considered together so as to make a continuous loop.

The organs of the visual system, for example, from lower to higher are roughly as follows. First, the lens, pupil, chamber, and retina comprise an organ. Second, the eye with its muscles in the orbit comprise an organ that is both stabilized and mobile. Third, the two eyes in the head comprise a binocular organ. Fourth, the eyes in a mobile head that can turn comprise an organ for the pickup of ambient information. Fifth, the eyes in a head on a body constitute a superordinate organ for information pickup over paths of locomotion. The adjustments of accommodation, intensity modulation, and dark adaptation go with the first level. The movements of compensation, fixation, and scanning go with the second level. The movements of vergence and the pickup of disparity go with the third level. The movements of the head, and of the body as a whole, go with the fourth and fifth levels. All of them serve the pickup of information.

2. In the case of a special sense, the receptors can only receive stimuli, passively, whereas in the case of a perceptual system the input-output loop can be supposed to obtain information, actively. Even when the theory of the special senses is liberalized by the modern hypothesis of receptive units, the latter are supposed to be triggered by complex stimuli or modulated in some passive fashion.

3. The inputs of a special sense constitute a repertory of innate sensations, whereas the achievements of a perceptual system are susceptible to maturation and learning. Sensations of one modality can be combined with those of another in accordance with the laws of association; they can be organized or fused or supplemented or selected, but *no new sensations can be learned.* The information that is picked up, on the other hand, becomes more and more subtle, elaborate, and precise with practice. One can keep on learning to perceive as long as life goes on.

4. The inputs of the special senses have the qualities of the receptors being stimulated, whereas the achievements of the perceptual systems are specific to the qualities of things in the world, especially their affordances. The recognition of this limitation of the senses was forced upon us by Johannes Müller with his doctrine of specific "nerve energies." He understood clearly, if reluctantly, the implication that, because we can never know the external causes of our sensations, we cannot know the outer world. Strenuous efforts have to be made if one is to avoid this shocking conclusion. Helmholtz argued that we must deduce the causes of our sensations because we cannot detect them. The hypothesis that sensations provide clues or cues for perception of the world is similar. The popular formula that we can interpret sensory signals is a variant of it. But it seems to me that all such arguments come down to this: we can perceive the world only if we already know what there is to be perceived. And that, of course, is circular. I shall come back to this point again.

The alternative is to assume that sensations triggered by light, sound, pressure, and chemicals are merely incidental, that information is available to a perceptual system, and that the qualities of the world in relation to the needs of the observer are experienced directly.

5. In the case of a special sense the process of attention occurs at centers within the nervous system, whereas in the case of a perceptual system attention pervades the whole input-output loop. In the first case attention is a consciousness that can be focused; in the second case it is a skill that can be educated. In the first case physiological metaphors are used, such as the filtering of nervous impulses or the switching of impulses from one path to another. In the second case the metaphors used can be terms such as *resonating, extracting, optimizing,* or *symmetricalizing* and such acts as orienting, exploring, investigating, or adjusting.

I suggested in Chapter 12 that a normal act of visual attention consists of scanning a whole feature of the ambient array, not of fixating a single detail of the array. We are tempted to think of attention as strictly a narrowing-down and holding-still, but actually this is rare. The invariants of structure in an optic array that constitute information are more likely to be gradients than small details, and they are scanned over wide angles.

THE REGISTERING OF BOTH PERSISTENCE AND CHANGE

The theory of information pickup requires that the visual system be able to detect both persistence and change—the persistence of places, objects, and substances along with whatever changes they undergo. Everything in the world persists in some respects and changes in some respects. So also does the observer himself. And some things persist for long intervals, others for short.

The perceiving of persistence and change (instead of color, form, space, time, and motion) can be stated in various ways. We can say that the perceiver *separates* the change from the nonchange, *notices* what stays the same and what does not, or *sees* the continuing identity of things along with the events in which they participate. The question, of course, is how he does so. What is the information for persistence and change? The answer must be of this sort: The perceiver extracts the invariants of structure from the flux of stimulation while still noticing the flux. For the visual system in particular, he tunes in on the invariant structure of the ambient optic array that underlies the changing perspective structure caused by his movements.

The hypothesis that invariance under optical transformation constitutes information for the perception of a rigid persisting object goes back to the moving-shadow experiment (Gibson and Gibson, 1957). The outcome of that experiment was paradoxical; it seemed at the time that a changing form elicited the perception of a constant form with a changing slant. The solution was to postulate invariants of optical structure for the persisting object, "formless" invariants, and a particular disturbance of optical structure for the motion of the object, a perspective transformation. Separate terms needed to be devised for physical motions and for the optical motions that specified them, for events in the world and for events in the array, for geometry did not provide the terms. Similarly, different terms need to be invented to describe invariants of the changing world and invariants of the changing array; the geometrical word *form* will not do. Perhaps the best policy is to use the terms *persistence* and *change* to refer to the environment but *preservation* and *disturbance* of structure to refer to the optic array.

The stimulus-sequence theory of perception, based on a succession of discrete eye fixations, can assume only that the way to apprehend persistence is by an act of comparison and judgment. The perception of what-it-is-now is compared with the memory of what-it-was-then, and they are judged *same*. The continuous pickup theory of perception can assume that the apprehension of persistence is a simple act of invariance detection. Similarly, the snapshot theory must assume that the way to apprehend change is to compare what-it-is-now with what-it-was-then and judge *different*, whereas the pickup theory can assume an awareness of transformation. The congruence of the array with itself or the disparity of the array with itself, as the case may be, is picked up.

The perception of the persisting identity of things is fundamental to other kinds of perception. Consider an example, the persisting identity of another person. How does a child come to apprehend the identity of the mother? You might say that when the mother-figure, or the face, is continually fixated by the child the persistence of the

sensation is supported by the continuing stimulus. So it is when the child clings to the mother. But what if the mother-figure is scanned? What if the figure leaves and returns to the field of view? What if the figure goes away and comes back? What is perceived when it emerges from the distance or from darkness, when its back is turned, when its clothing is changed, when its emotional state is altered, when it comes back into sight after a long interval? In short, how is it that the phenomenal identity of a person agrees so well with the biological identity, despite all the vicissitudes of the figure in the optic array and all the events in which the person participates?

The same questions can be asked about inanimate objects, attached objects, places, and substances. The features of a person are invariant to a considerable degree (the eyes, nose, mouth, style of gesture, and voice). But so are the analogous features of other things, the child's blanket, the kitchen stove, the bedroom, and the bread on the table. All have to be identified as continuing, as persisting, as maintaining existence. And this is not explained by the constructing of a concept for each.

We are accustomed to assuming that successive stimuli from the same entity, sensory encounters with it, are united by an act of recognition. We have assumed that perception ceases and memory takes over when sensation stops. Hence, every fresh glimpse of anything requires the act of linking it up with the memories of that thing instead of some other thing. The judgment, "I have seen this before," is required for the apprehension of "same thing," even when the observer has only turned away, or

The Effect of Persisting Stimulation on Perception

We have assumed that perception stops when sensation stops and that sensation stops when stimulation stops, or very soon thereafter. Hence, a persisting stimulus is required for the perception of a persisting object. The fact is, however, that a truly persisting stimulus on the retina or the skin specifies only that the observer does not or cannot move his eye or his limb, and the sense perception soon fades out by sensory adaptation (Chapter 4). The persistence of an object is specified by invariants of structure, not by the persistence of stimulation.

The seeing of persistence considered as the picking up of invariants under change resolves an old puzzle: the phenomenal identity of the spots of a retinal pattern when the image is transposed over the retina stroboscopically. The experiments of Josef Ternus first made this puzzle evident. See Gibson (1950, p. 56 ff.) for a discussion and references.

I used to think that the aftereffects of persisting stimulation of the retina obtained by the prolonged fixation of a display could be very revealing. Besides ordinary afterimages there are all sorts of perceptual aftereffects, some of which I discovered. But I no longer believe that experiments on so-called perceptual adaptation are revealing, and I have given up theorizing about them. The aftereffects of prolonged scrutiny are of many sorts. Until we know more about information pickup, this field of investigation will be incoherent.

has only glanced away for an instant. The classical theory of sense perception is reduced to an absurdity by this requirement. The alternative is to accept the theory of invariance detection.

The quality of familiarity that can go with the perception of a place, object, or person, as distinguished from the quality of unfamiliarity, is a fact of experience. But is familiarity a result of the percept making contact with the traces of past percepts of the same thing? Is unfamiliarity a result of not making such contact? I think not. There is a circularity in the reasoning, and it is a bad theory. The quality of familiarity simply accompanies the perception of persistence.

The perception of the persisting identity of places and objects is more fundamental than the perception of the differences among them. We are told that to perceive something is to categorize it, to distinguish it from the other types of things that it might have been. The essence of perceiving is discriminating. Things differ among themselves, along dimensions of difference. But this leaves out of account the simple fact that the substance, place, object, person, or whatever has to last long enough to be distinguished from other substances, places, objects, or persons. The detecting of the invariant features of a persisting thing should not be confused with the detecting of the invariant features that make different things similar. Invariants over time and invariants over entities are not grasped in the same way.

In the case of the persisting thing, I suggest, the perceptual system simply extracts the invariants from the flowing array; it *resonates* to the invariant structure or is *attuned* to it. In the case of substantially distinct things, I venture, the perceptual system must *abstract* the invariants. The former process seems to be simpler than the latter, more nearly automatic. The latter process has been interpreted to imply an intellectual act of lifting out something that is mental from a collection of objects that are physical, of forming an abstract concept from concrete percepts, but that is very dubious. Abstraction is invariance detection across objects. But the invariant is only a similarity, not a persistence.

SUMMARY OF THE THEORY OF PICKUP

According to the theory being proposed, *perceiving* is a registering of certain definite dimensions of invariance in the stimulus flux together with definite parameters of disturbance. The invariants are invariants of structure, and the disturbances are disturbances of structure. The structure, for vision, is that of the ambient optic array.

The invariants specify the persistence of the environment and of oneself. The disturbances specify the changes in the environment and of oneself. A perceiver is aware of her existence in a persisting environment and is also aware of her movements

relative to the environment, along with the motions of objects and nonrigid surfaces relative to the environment. The term *awareness* is used to imply a direct pickup of the information, not necessarily to imply consciousness.

There are many dimensions of invariance in an ambient optic array over time, that is, for paths of observation. One invariant, for example, is caused by the occluding edge of the nose, and it specifies the self. Another is the gradient of optical texture caused by the material texture of the substratum, and it specifies the basic environment. Equally, there are many parameters of disturbance of an ambient optic array. One, for example, is caused by the sweeping of the nose over the ambient optic array, and it specifies head turning. Another is the deletion and accretion of texture at the edges of a form in the array, and it specifies the motion of an object over the ground.

For different kinds of events in the world there are different parameters of optical disturbance, not only accretion-deletion but also polar outflow-inflow, compression, transformation, substitution, and others. Hence, the same object can be seen undergoing different events, and different objects can be seen undergoing the same event. For example, an apple may ripen, fall, collide, roll, or be eaten, and eating may happen to an apple, carrot, egg, biscuit, or lamb chop. If the parameter of optical disturbance is distinguished, the event will be perceived. Note how radically different this is from saying that if stimulus-event *A* is invariably followed by stimulus-event *B* we will come to expect *B* whenever we experience *A*. The latter is classical association theory (or conditioning theory, or expectancy theory). It rests on the stimulus-sequence doctrine. It implies that falling, colliding, rolling, or eating are not units but sequences. It implies, with David Hume, that even if *B* has followed *A* a thousand times there is no certainty that it will follow *A* in the future. An event is only known by a conjunction of atomic sensations, a contingency. If this recurrent sequence is experienced again and again, the observer will begin to anticipate, or have faith, or learn by induction, but that is the best he can do.

The process of pickup is postulated to depend on the input-output loop of a perceptual system. For this reason, the information that is picked up cannot be the familiar kind that is transmitted from one person to another and that can be stored. According to pickup theory, information does not have to be stored in memory because it is always available.

The process of pickup is postulated to be very susceptible to development and learning. The opportunities for educating attention, for exploring and adjusting, for extracting and abstracting are unlimited. The increasing capacity of a perceptual system to pick up information, however, does not in itself constitute information. The ability to perceive does not imply, necessarily, the having of an idea of what can be perceived. The having of ideas is a fact, but it is not a prerequisite of perceiving. Perhaps it is a kind of extended perceiving.

THE TRADITIONAL THEORIES OF PERCEPTION: INPUT PROCESSING

The theory of information pickup purports to be an alternative to the traditional theories of perception. It differs from all of them, I venture to suggest, in rejecting the assumption that perception is the processing of inputs. *Inputs* mean sensory or afferent nerve impulses to the brain.

Adherents to the traditional theories of perception have recently been making the claim that what they assume is the processing of information in a modern sense of the term, not sensations, and that therefor they are not bound by the traditional theories of perception. But it seems to me that all they are doing is climbing on the latest bandwagon, the computer bandwagon, without reappraising the traditional assumption that perceiving is the processing of inputs. I refuse to let them pre-empt the term *information*. As I use the term, it is not something that has to be processed. The inputs of the receptors have to be processed, of course, because they in themselves do not specify anything more than the anatomical units that are triggered.

All kinds of metaphors have been suggested to describe the ways in which sensory inputs are processed to yield perceptions. It is supposed that sensation occurs first, perception occurs next, and knowledge occurs last, a progression from the lower to the higher mental processes. One process is the filtering of sensory inputs. Another is the organizing of sensory inputs, the grouping of elements into a spatial pattern. The integrating of elements into a temporal pattern may or may not be included in the organizing process. After that, the processes become highly speculative. Some theorists propose mental operations. Others argue for semilogical processes or problem-solving. Many theorists are in favor of a process analogous to the decoding of signals. All theorists seem to agree that past experience is brought to bear on the sensory inputs, which means that memories are somehow applied to them. Apart from filtering and organizing, the processes suggested are cognitive. Consider some of them.

Mental Operations on the Sensory Inputs

The a priori categories of understanding possessed by the perceived, according to Kant

The perceiver's presuppositions about what is being perceived

Innate ideas about the world

Semilogical Operations on the Sensory Inputs

Unconscious inferences about the outer causes of the sensory inputs, according to Helmholtz (the outer world is deduced)

Estimates of the probable character of the "distant" objects based on the "proximal" stimuli, according to Egon Brunswik (1956), said to be a quasirational, not a fully rational, process

Decoding Operations on the Sensory Inputs

The interpreting of the inputs considered as signals (a very popular analogy with many variants)

The decoding of sensory messages

The utilizing of sensory cues

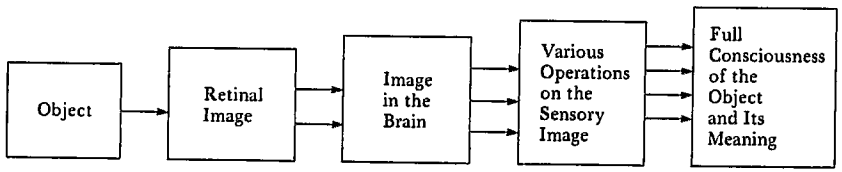
The understanding of signs, or indicators, or even *clues*, in the manner of a police detective

The Application of Memories to the Sensory Inputs

The "accrual" of a context of memory images and feelings to the core of sensations, according to E. B. Titchener's theory of perception (1924)

This last hypothetical process is perhaps the most widely accepted of all, and the most elaborated. Perceptual learning is supposed to be a matter of enriching the input, not of differentiating the information (Gibson and Gibson, 1955). But the process of combining memories with inputs turns out to be not at all simple when analyzed. The appropriate memories have to be retrieved from storage, that is, aroused or summoned; an image does not simply accrue. The sensory input must fuse in some fashion with the stored images; or the sensory input is assimilated to a composite memory image, or, if this will not do, it is said to be assimilated to a class, a type, a schema, or a concept. Each new sensory input must be categorized—assigned to its class, matched to its type, fitted to its schema, and so on. Note that categories cannot become established until enough items have been classified but that items cannot be classified until categories have been established. It is this difficulty, for one, that

Figure 14.1
The commonly supposed sequence of stages in the visual perceiving of an object.



compels some theorists to suppose that classification is a priori and that people and animals have innate or instinctive knowledge of the world.

The error lies, it seems to me, in assuming that either innate ideas or acquired ideas must be applied to bare sensory inputs for perceiving to occur. The fallacy is to assume that because inputs convey no knowledge they can somehow be made to yield knowledge by "processing" them. Knowledge of the world must come from somewhere; the debate is over whether it comes from stored knowledge, from innate knowledge, or from reason. But all three doctrines beg the question. Knowledge of the world cannot be explained by supposing that knowledge of the world already exists. All forms of cognitive processing imply cognition so as to account for cognition.

All this should be treated as ancient history. Knowledge of the environment, surely, develops as perception develops, extends as the observers travel, gets finer as they learn to scrutinize, gets longer as they apprehend more events, gets fuller as they see more objects, and gets richer as they notice more affordances. Knowledge of this sort does not "come from" anywhere; it is got by looking, along with listening, feeling, smelling, and tasting. The child also, of course, begins to acquire knowledge that comes from parents, teachers, pictures, and books. But this is a different kind of knowledge.

THE FALSE DICHOTOMY BETWEEN PRESENT AND PAST EXPERIENCE

The division between present experience and past experience may seem to be self-evident. How could anyone deny it? Yet it is denied in supposing that we can experience both change and nonchange. The difference between present and past blurs, and the clarity of the distinction slips away. The stream of experience does not consist of an instantaneous present and a linear past receding into the distance; it is not a "traveling razor's edge" dividing the past from the future. Perhaps the present has a certain duration. If so, it should be possible to find out when perceiving stops and remembering begins. But it has not been possible. There are attempts to talk about a "conscious" present, or a "specious" present, or a "span" of present perception, or a span of "immediate memory," but they all founder on the simple fact that there is no dividing line between the present and the past, between perceiving and remembering. A special sense impression clearly ceases when the sensory excitation ends, but a perception does not. It does not become a memory after a certain length of time. A perception, in fact, does not *have* an end. Perceiving goes on.

Perhaps the force of the dichotomy between present and past experience comes from language, where we are not allowed to say anything intermediate between "I see

you" and "I saw you" or "I am seeing you" and "I was seeing you." Verbs can take the present tense or the past tense. We have no words to describe my continuing awareness of you, whether you are in sight or out of sight. Language is categorical. Because we are led to separate the present from the past, we find ourselves involved in what I have called the "muddle of memory" (Gibson, 1966*a*). We think that the past ceases to exist unless it is "preserved" in memory. We assume that memory is the bridge between the past and the present. We assume that memories accumulate and are stored somewhere; that they are images, or pictures, or representations of the past; or that memory is actually physiological, not mental, consisting of engrams or traces; or that it actually consists of neural connections, not engrams; that memory is the basis of all learning; that memory is the basis of habit; that memories live on in the unconscious; that heredity is a form of memory; that cultural heredity is another form of memory; that any effect of the past on the present is memory, including hysteresis. If we cannot do any better than this, we should stop using the word.

The traditional theories of perception take it for granted that what we see *now*, present experience, is the sensory basis of our perception of the environment and that what we have seen *up to now*, past experience, is added to it. We can only understand the present in terms of the past. But what we see *now* (when it is carefully analyzed) turns out to be at most a peculiar set of surfaces that happen to come within the field of view and face the point of observation (Chapter 11). It does not comprise what we see. It could not possibly be the basis of our perception of the environment. What we see *now* refers to the self, not the environment. The perspective appearance of the world at a given moment of time is simply what specifies to the observer where he is at that moment. The perceptual process does not begin with this peculiar projection, this momentary pattern. The perceiving of the world begins with the pickup of invariants.

Evidently the theory of information pickup does not need memory. It does not have to have as a basic postulate the effect of past experience on present experience by way of memory. It needs to explain learning, that is, the improvement of perceiving with practice and the education of attention, but not by an appeal to the catch-all of past experience or to the muddle of memory.

The state of a perceptual system is altered when it is attuned to information of a certain sort. The system has become sensitized. Differences are noticed that were previously not noticed. Features become distinctive that were formerly vague. But this altered state need not be thought of as depending on a memory, an image, an engram, or a trace. An image of the past, if experienced at all, would be only an incidental symptom of the altered state.

This is not to deny that reminiscence, expectation, imagination, fantasy, and dreaming actually occur. It is only to deny that they have an essential role to play in

perceiving. They are kinds of visual awareness other than perceptual. Let us now consider them in their own right.

A NEW APPROACH TO NONPERCEPTUAL AWARENESS

The redefinition of *perception* implies a redefinition of the so-called higher mental processes. In the old mentalistic psychology, they stood above the lower mental processes, the sensory and reflex processes, which could be understood in terms of the physiology of receptors and nerves. These higher processes were vaguely supposed to be intellectual processes, inasmuch as the intellect was contrasted with the senses. They occurred in the brain. They were operations of the mind. No list of them was ever agreed upon, but *remembering, thinking, conceiving, inferring, judging, expecting*, and, above all, *knowing* were the words used. *Imagining, dreaming, rationalizing*, and *wishful thinking* were also recognized, but it was not clear that they were higher processes in the intellectual sense. I am convinced that none of them can ever be understood as an operation of the mind. They will never be understood as reactions of the body, either. But perhaps if they are reconsidered in relation to ecological perceiving they will begin to sort themselves out in a new and reasonable way that fits with the evidence.

To perceive is to be aware of the surfaces of the environment and of oneself in it. The interchange between hidden and unhidden surfaces is essential to this awareness. These are existing surfaces; they are specified at some points of observation. Perceiving gets wider and finer and longer and richer and fuller as the observer explores the environment. The full awareness of surfaces includes their layout, their substances, their events, and their affordances. Note how this definition includes within perception a part of memory, expectation, knowledge, and meaning—some part but not all of those mental processes in each case.

One kind of remembering, then, would be an awareness of surfaces that have ceased to exist or events that will not recur, such as items in the story of one's own life. There is no point of observation at which such an item will come into sight.

To expect, anticipate, plan, or imagine creatively is to be aware of surfaces that do not exist or events that do not occur but that could arise or be fabricated within what we call the limits of possibility.

To daydream, dream, or imagine wishfully (or fearfully) is to be aware of surfaces or events that do not exist or occur and that are outside the limits of possibility.

These three kinds of nonperceptual awareness are not explained, I think, by the traditional hypothesis of mental imagery. They are better explained by some such hypothesis as this: a perceptual system that has become sensitized to certain invariants and can extract them from the stimulus flux can also operate without the constraints of the stimulus flux. Information becomes further detached from stimulation. The adjustment loops for looking around, looking at, scanning, and focusing are then inoperative. The visual system visualizes. But this is still an activity of the system, not an appearance in the theater of consciousness.

Besides these, other kinds of cognitive awareness occur that are not strictly perceptual. Before considering them, however, I must clarify what I mean by *imaginary* or *unreal*.

THE RELATIONSHIP BETWEEN IMAGINING AND PERCEIVING

I assume that a normal observer is well aware of the difference between surfaces that exist and surfaces that do not. (Those that do not have ceased to exist, or have not begun to, or have not and will not.) How can this be so? What is the information for existence? What are the criteria? It is widely believed that young children are not aware of the differences, and neither are adults suffering from hallucinations. They do not distinguish between what is "real" and what is "imaginary" because perception and mental imagery cannot be separated. This doctrine rests on the assumption that, because a percept and an image both occur in the brain, the one can pass over into the other by gradual steps. The only "tests for reality" are intellectual. A percept cannot validate itself.

We have been told ever since John Locke that an image is a "faint copy" of a percept. We are told by Titchener (1924) that an image is "easily confused with a sensation" (p. 198). His devoted student, C. W. Perky, managed to show that a faint optical picture secretly projected from behind on a translucent screen is sometimes not identified as such when an observer is imagining an object of the same sort on the screen (Perky, 1910). We are told by a famous neurosurgeon that electrical stimulation of the surface of the brain in a conscious patient "has the force" of an actual perception (Penfield, 1958). It is said that when a feeling of reality accompanies a content of consciousness it is marked as a percept and when it does not it is marked as an image. All these assertions are extremely dubious.

I suggest that perfectly reliable and automatic tests for reality are involved in the working of a perceptual system. They do not have to be intellectual. A surface is seen

with more or less definition as the accommodation of the lens changes; an image is not. A surface becomes clearer when fixated; an image does not. A surface can be scanned; an image cannot. When the eyes converge on an object in the world, the sensation of crossed diplopia disappears, and when the eyes diverge, the "double image" reappears; this does not happen for an image in the space of the mind. An object can be scrutinized with the whole repertory of optimizing adjustments described in Chapter 11. No image can be scrutinized—not an afterimage, not a so-called eidetic image, not the image in a dream, and not even a hallucination. An imaginary object can undergo an *imaginary* scrutiny, no doubt, but you are not going to discover a new and surprising feature of the object this way. For it is the very features of the object that your perceptual system has already picked up that constitute your ability to visualize it. The most decisive test for reality is whether you can discover new features and details by the act of scrutiny. Can you obtain new stimulation and extract new information from it? Is the information inexhaustible? Is there more to be seen? The imaginary scrutiny of an imaginary entity cannot pass this test.

A related criterion for the existence of a thing is reversible occlusion. Whatever goes out of sight as you move your head and comes into sight as you move back is a *persisting* surface. Whatever comes into sight when you move your head is a *preexisting* surface. That is to say, it exists. The present, past, or future tense of the verb *see* is irrelevant; the fact is perceived without words. Hence, a criterion for *real* versus *imaginary* is what happens when you turn and move. When the infant turns her head and creeps about and brings her hands in and out of her field of view, she perceives what is real. The assumption that children cannot tell the difference between what is real and what is imaginary until the intellect develops is mentalistic nonsense. As the child grows up, she apprehends more reality as she visits more places of her habitat.

Nevertheless, it is argued that dreams sometimes have the "feeling" of reality, that some drugs can induce hallucinations, and that a true hallucination in psychosis is proof that a mental image can be the same as a percept, for the patient acts as if he were perceiving and thinks he is perceiving. I remain dubious (Gibson, 1970). The dreamer is asleep and cannot make the ordinary tests for reality. The drug-taker is hoping for a vision and does not want to make tests for reality. There are many possible reasons why the hallucinating patient does not scrutinize what he says he sees, does not walk around it or take another look at it or test it.

There is a popular fallacy to the effect that if you can touch what you see it is real. The sense of touch is supposed to be more trustworthy than the sense of sight, and Bishop Berkeley's theory of vision was based on this idea. But it is surely wrong. Tactual hallucinations can occur as well as visual. And if the senses are actually perceptual systems, the haptic system as I described it (Gibson, 1966*b*) has its own exploratory adjustments and its own automatic tests for reality. One perceptual system

does not *validate* another. Seeing and touching are two ways of getting much the same information about the world.

A NEW APPROACH TO KNOWING

The theory of information pickup makes a clear-cut separation between perception and fantasy, but it closes the supposed gap between perception and knowledge. The extracting and abstracting of invariants are what happens in both perceiving and knowing. To perceive the environment and to conceive it are different in degree but not in kind. One is continuous with the other. Our reasons for supposing that seeing something is quite unlike knowing something come from the old doctrine that seeing is having temporary sensations one after another at the passing moment of present time, whereas knowing is having permanent concepts stored in memory. It should now be clear that perceptual seeing is an awareness of persisting structure.

Knowing is an *extension* of perceiving. The child becomes aware of the world by looking around and looking at, by listening, feeling, smelling, and tasting, but then she begins to be *made* aware of the world as well. She is shown things, and told things, and given models and pictures of things, and then instruments and tools and books, and finally rules and short cuts for finding out more things. Toys, pictures, and words are aids to perceiving, provided by parents and teachers. They transmit to the next generation the tricks of the human trade. The labors of the first perceivers are spared their descendants. The extracting and abstracting of the invariants that specify the environment are made vastly easier with these aids to comprehension. But they are not in themselves knowledge, as we are tempted to think. All they can do is facilitate knowing by the young.

These extended or aided modes of apprehension are all cases of information pickup from a stimulus flux. The learner has to hear the speech in order to pick up the message; to see the model, the picture, or the writing; to manipulate the instrument in order to extract the information. But the information itself is largely independent of the stimulus flux.

What are the kinds of culturally transmitted knowledge? I am uncertain, for they have not been considered at this level of description. Present-day discussions of the "media of communication" seem to me glib and superficial. I suspect that there are many kinds merging into one another, of great complexity. But I can think of three obvious ways to facilitate knowing, to aid perceiving, or to extend the limits of comprehension: the use of instruments, the use of verbal descriptions, and the use of pictures. Words and pictures work in a different way than do instruments, for the information is obtained at second hand. Consider them separately.

Surfaces and events that are too small or too far away cannot be perceived. You can of course increase the visual solid angle if you approach the item and put your eye close to it, but that procedure has its limits. You cannot approach the moon by walking, and you cannot get your eye close enough to a drop of pond water to see the little animals swimming in it. What can be done is to *enlarge* the visual solid angle from the moon or the water drop. You can convert a tiny sample of the ambient optic array at a point of observation into a magnified sample by means of a telescope or a microscope. The structure of the sample is only a little distorted. The surfaces perceived when the eye is placed at the eyepiece are "virtual" instead of "real," but only in the special sense that they are very much closer to the observer. The invariants of structure are nearly the same when a visual angle with its nested components is magnified. This description of magnification comes from ecological optics. For designing the lens system of the instrument, a different optics is needed.

The discovery of these instruments in the seventeenth century enabled men to know much more about very large bodies and very small bodies than they had before. But this new knowledge was almost like seeing. The mountains of the moon and the motions of a living cell could be observed with adjustments of the instrument not unlike those of the head and eyes. The guarantees of reality were similar. You did not have to take another person's word for what he had seen. You might have to learn to use the instrument, but you did not have to learn to interpret the information. Nor did you have to judge whether or not the other person was telling the truth. With a telescope or a microscope you could look for yourself.

The Unaided Perceiving of Objects in the Sky

Objects in the sky are very different from objects on the ground. The heavenly bodies do not come to rest on the ground as ordinary objects do. The rainbow and the clouds are transient, forming and dissipating like mists on earth. But the sun, the moon, the planets, and the stars seem permanent, appearing to revolve around the stationary earth in perfect cycles and continuing to exist while out of sight. They are immortal and mysterious. They cannot be scrutinized.

Optical information for direct perception of these bodies with the unaided eye is lacking. Their size and distance are indeterminate except that they rise and set from behind the distant horizon and are thus very far away. Their motions are very different from those of ordinary objects. The character of their surfaces is indefinite, and of what substances they are composed is not clear. The sun is fiery by day, and the others are fiery at night, unlike the textured reflecting surfaces of most terrestrial objects. What they afford is not visible to the eye. Lights in the sky used to look like gods. Nowadays they look like flying saucers.

All sorts of instruments have been devised for mediating apprehension. Some optical instruments merely enhance the information that vision is ready to pick up; others—a spectroscope, for example—require some inference; still others, like the Wilson cloud chamber, demand a complex chain of inferences.

Some measuring instruments are closer to perception than others. The measuring stick for counting units of distance, the gravity balance for counting units of mass, and the hourglass for time are easy to understand. But the complex magnitudes of physical science are another matter. The voltmeters, accelerometers, and photometers are hard to understand. The child can see the pointer and the scale well enough but has to learn to "read" the instrument, as we say. The direct perception of a distance is in terms of whether one can jump it. The direct perception of a mass is in terms of whether one can lift it. Indirect knowledge of the metric dimensions of the world is a far extreme from direct perception of the affordance dimensions of the environment. Nevertheless, they are both cut from the same cloth.

KNOWING MEDIATED BY DESCRIPTIONS: EXPLICIT KNOWLEDGE

The principal way in which we save our children the trouble of finding out everything for themselves is by describing things for them. We transmit information and convey knowledge. Wisdom is handed down. Parents and teachers and books give the children knowledge of the world at second hand. Instead of having to be extracted by the child from the stimulus flux, this knowledge is communicated to the child.

It is surely true that speech and language convey information of a certain sort from person to person and from parent to child. Written language can even be stored so that it accumulates in libraries. But we should never forget that this is information that has been put into words. It is not the limitless information available in a flowing stimulus array.

Knowledge that has been put into words can be said to be *explicit* instead of *tacit*. The human observer can verbalize his awareness, and the result is to make it communicable. But my hypothesis is that there has to be an awareness of the world before it can be put into words. You have to see it before you can say it. Perceiving precedes predicating.

In the course of development the young child first hears talk about what she is perceiving. Then she begins herself to talk about what she perceives. Then she begins to talk to herself about what she knows—when she is alone in her crib, for example. And, finally, her verbal system probably begins to verbalize silently, in much the same way that the visual system begins to visualize, without the constraints of stimulation or

muscular action but within the limits of the invariants to which the system is attuned. But no matter how much the child puts knowledge into words all of it cannot be put into words. However skilled an explicator one may become one will always, I believe, see more than one can say.

Consider an adult, a philosopher, for example, who sees the cat on the mat. He knows *that* the cat is on the mat and believes the proposition and can say it, but all the time he plainly sees all sorts of wordless facts—the mat extending without interruption behind the cat, the far side of the cat, the cat hiding part of the mat, the edges of the cat, the cat being supported by the mat, or resting on it, the horizontal rigidity of the floor under the mat, and so on. The so-called concepts of extension, of far and near, gravity, rigidity, horizontal, and so on, are nothing but partial abstractions from a rich but unitary perception of *cat-on-mat*. The parts of it he can name are called concepts, but they are not all of what he can see.

FACT AND FICTION IN WORDS AND PICTURES

Information about the environment that has been put into words has this disadvantage: The reality testing that accompanies the pickup of natural information is missing. Descriptions, spoken or written, do not permit the flowing stimulus array to be scrutinized. The invariants have already been extracted. You have to trust the original perceiver; you must "take his word for it," as we say. What he presents may be fact, or it may be fiction. The same is true of a depiction as of a description.

The child, as I argued above, has no difficulty in contrasting real and imaginary, and the two do not merge. But the factual and the fictional may do so. In storytelling, adults do not always distinguish between true stories and fairy stories. The child herself does not always separate the giving of an account from the telling of a story. Tigers and dragons are both fascinating beasts, and the child will not learn the difference until she perceives that the zoo contains the former but not the latter.

Fictions are not necessarily fantasies. They do not automatically lead one astray, as hallucinations do. They can promote creative plans. They can permit vicarious learning when the child identifies with a fictional character who solves problems and makes errors. The "comic" characters of childhood, the funny and the foolish, the strong and the weak, the clever and the stupid, occupy a great part of children's cognitive awareness, but this does not interfere in the least with their realism when it comes to perceiving.

The difference between the real and the imaginary is specified by two different modes of operation of a perceptual system. But the difference between the factual and the fictional depends on the social system of communication and brings in complicated

questions. Verbal descriptions can be true or false as predications. Visual depictions can be correct or incorrect in a wholly different way. A picture cannot be true in the sense that a proposition is true, but it may or may not be true to life.

KNOWING AND IMAGINING MEDIATED BY PICTURES

Perceiving, knowing, recalling, expecting, and imagining can all be induced by pictures, perhaps even more readily than by words. Picture-making and picture-perceiving have been going on for twenty or thirty thousand years of human life, and this achievement, like language, is ours alone. The image makers can arouse in us an awareness of what they have seen, of what they have noticed, of what they recall, expect, or imagine, and they do so *without converting the information into a different mode.* The description puts the optical invariants into words. The depiction, however, captures and displays them in an optic array, where they are more or less the same as they would be in the case of direct perception. So I will argue, at least. The justification of this theory is obviously not a simple matter, and it is deferred to the last chapters of this book, Part IV.

The reality-testing that accompanies unmediated perceiving and that is partly retained in perceiving with instruments is obviously lost in the kind of perceiving that is mediated by pictures. Nevertheless, pictures give us a kind of grasp on the rich complexities of the natural environment that words could never do. Pictures do not stereotype our experience in the same way and to the same degree. We can learn from pictures with less effort than it takes to learn from words. It is not like perceiving at first hand, but it is *more* like perceiving than any verbal description can be.

The child who has learned to talk about things and events can, metaphorically, talk to himself silently about things and events, so it is supposed. He is said to have "internalized" his speech, whatever that might mean. By analogy with this theory, a child who has learned to draw might be supposed to picture to himself things and events without movement of his hands, to have "internalized" his picturemaking. A theory of internal language and internal images might be based on this theory. But it seems to me very dubious. Whether or not it is plausible is best decided after we have considered picturemaking in its own right.

SUMMARY

When vision is thought of as a perceptual system instead of as a channel for inputs to the brain, a new theory of perception considered as information pickup becomes possible. Information is conceived as available in the ambient energy flux, not as signals in a bundle of nerve fibers. It is information about both the persisting and the changing features of the environment together. Moreover, information about the observer and his movements is available, so that self-awareness accompanies perceptual awareness.

The qualities of visual experience that are specific to the receptors stimulated are not relevant to information pickup but incidental to it. Excitation and transmission are facts of physiology at the cellular level.

The process of pickup involves not only overt movements that can be measured, such as orienting, exploring, and adjusting, but also more general activities, such as optimizing, resonating, and extracting invariants, that cannot so easily be measured.

The ecological theory of direct perception cannot stand by itself. It implies a new theory of cognition in general. In turn, that implies a new theory of noncognitive kinds of awareness—fictions, fantasies, dreams, and hallucinations.

Perceiving is the simplest and best kind of knowing. But there are other kinds, of which three were suggested. Knowing by means of instruments extends perceiving into the realm of the very distant and the very small; it also allows of metric knowledge. Knowing by means of language makes knowing explicit instead of tacit. Language permits descriptions and pools the accumulated observations of our ancestors. Knowing by means of pictures also extends perceiving and consolidates the gains of perceiving.

The awareness of imaginary entities and events might be ascribed to the operation of the perceptual system with a suspension of reality-testing. Imagination, as well as knowledge and perception, can be aroused by another person who uses language or makes pictures.

These tentative proposals are offered as a substitute for the outworn theory of past experience, memory, and mental images.