

The Boundaries of Human Knowledge

A Phenomenological Epistemology

or

Waking Up in a Strange Place

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Chapter 1

What Do We Know?

Waking Up in a Strange Place

Our personal experience of this world is something like the experience of waking up in a strange place and momentarily not knowing where we are, or how we got here, or perhaps even who we are. Except that in life, it takes decades to piece together what takes only seconds in awakening. Furthermore, during the mental awakening in our infancy, we do not have the guidance of memory to make sense of the world around us. As we begin to piece together a coherent picture of the world around us in our early childhood, we quickly forget the initial confusion of the first stages of awareness. For we discover through experience that the world in which we live is a stable structured place, in that the places we explore have an existential permanence. If we leave one place and go to another, we find that we can always return, because the places we leave behind seem to continue to exist even in our absence. And when we observe changes in this world, they always seem to have reasonable causes. We no longer experience the unaccountable appearances and disappearances that were common in the magical world of our infancy. We begin to trust that the sun will rise again every new day just as it has every day before, and that the world will continue to run according to the causal laws that it has always seemed to follow. For although we cannot always predict the exact course of events in the future, we can usually piece together how and why things occurred after the fact, which can sometimes give us a fair guess as to how events might unfold in the future. But as our mental picture of the world around us comes into sharper, more stable focus, we experience a progressive amnesia for those decades of bewildered confusion that marked our initial entrance into this world.

Knowledge is a structured affair, individual facts and observations fit neatly into place amongst other facts and observations. The sky above arches over the earth underfoot, and our personal environment is nestled between the two. The road to the center of town runs this way, and the road to school runs that way. Then we discover that we can travel from downtown straight to school, without having to come back home first, because town, school, and home maintain a structured existence in our map of the world. As our knowledge expands into a scientific understanding of the world, we learn that the earth underfoot is a sphere of enormous dimensions, and that the blue sky extends only some few miles overhead under the boundless black void of outer space. We build up our understanding of the world from the center outwards, gradually expanding the world of our immediate experience between earth and sky, into a much larger space of the globe of the world suspended in the void of space. And the expansion of knowledge occurs also inwards, from the large to the small, as we learn of the microscopic world of germs and viruses, and the sub-microscopic world of molecules, atoms, and sub-atomic particles, all the way to the quantum fluctuations of space-time. Science seems to offer an impartial objective view of the world, unlike the egocentric perspective of our infantile experience. We begin

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to develop the impression that the world revealed by science is a world of objective reality that represents a kind of absolute truth. The physical world revealed by science is what is *real*.

Trouble in the World of Knowledge

But there is trouble in the world of knowledge. For although our factual understanding of the world hangs together as an integrated whole, with our knowledge of physics and astronomy and geography each taking their appointed place in the structured tree of knowledge, the tree itself hangs unsupported by anything substantial. Although we know that empty space extends upward and outward in all directions, exactly what it is that exists beyond the farthest stars and galaxies, nobody can really say. Modern cosmology offers glib reassurances of the concept of a finite but boundless universe, like the surface of a sphere, which can be traversed endlessly in any direction without ever leaving the finite surface. In a three-dimensional space with this property we could set out in any direction, and if we travel far enough in a straight line, we would eventually arrive back at our initial starting point from the opposite direction. This explanation seems far more satisfactory than the idea of an infinite universe, a mental image that simply doesn't seem to fit into our head, or the idea of a finite and bounded universe, which begs the question of what might be beyond the boundary. But the idea of a finite but boundless universe is also somewhat unsatisfactory, because it is difficult to make a mental image of the absolute nothingness that supposedly surrounds the finite universe. The best I can picture nothingness, i.e. the absence even of empty space, is when it is surrounded by somethingness. For example there is nothing between my thumb and forefinger when I pinch them together tightly. But what kind of nothingness can it be that surrounds the four-dimensional sphere of the finite boundless universe? The best we can do with this kind of mystery is to attach some kind of label to the quandary, and file it for future reference, to be dealt with later, preferably by someone else, who can perhaps couch the solution in enough obfuscatory mathematical formalism as to convince us of its veracity.

But the limits of our knowledge of the outer universe is not the only problem of this nature. We have exactly the same kind of fundamental problem at the other end of the size spectrum, in the realm of the very small. Mathematicians comfort us with the notion of space as a continuum, like the line that represents real numbers, any interval of which is infinitely divisible into still smaller intervals. But can we have any confidence that there is any kind of ultimate truth to this as a property of space itself? As far as we know, the quantum fluctuations of space-time are about the smallest thing we know about (what little we can know about such things). But is it at all meaningful to say that distance itself exists to much smaller scales than that? Is there any such thing as distance below a certain ultra-tiny scale? For my part, I can say that it hurts my brain just as much to think about "infinitessimality" as it does to think of infinity. And yet the alternative concept, of a minimum scale to reality below which distance is no longer divisible, seems as absurd as the finite but bounded universe at the other end of the size spectrum. Again, this is a problem to be filed for future reference, or to be papered over with an official-sounding label to indicate that we have been there, and pondered that, and marked it as another well known frontier of the *terra incognita* that surrounds our

knowledge of the world.

The boundaries of our knowledge pertain not only to the universe's spatial extent, but also to its essence. What *is* space, or time, or space-time? Or, as philosophers like to phrase it, what is the *ontology* (*is-ness*, ultimate nature) of space-time? Ontology is one of those comforting words that we use to paste over ultimate mysteries to shield us from their frightening glare. What *kind* of explanation could possibly be satisfactory to account for the ultimate nature of space and time? And a similar ontological quandary hangs over the ultimate nature of matter, and energy. In physics we describe these things with mathematical equations and formulae that predict how matter and energy behave. But matter and energy are more than just equations, they have material existence, and extendedness in space and time, something that an equation does not have. As for time, astronomers assure us that it has a finite beginning at the moment of the big bang, which they assure us, has been reconstructed to the minutest fraction of a second after its spontaneous coming into existence. But as to what, if anything, occurred before the big bang, or whether it is even meaningful to think of anything occurring then, or what the ultimate fate of the universe might be at the other end of the time line, these too are mysteries too great to be grasped in any meaningful way, so we label them neatly and file them for future reference.

What Do We Know?

With all this profound mystery suffused throughout our world of knowledge, we might well ask what it is that we really know with any kind of confidence? What do we know with any certainty to actually be true? The answer to that question can only be found back at the trunk, or the heart of our tree of knowledge, the ultimate basis on which all of our observations of the world are founded, and that is our own conscious experience. Consciousness is known to be somewhat unreliable as a representation of external reality, because we are easily fooled by illusions, and occasionally by outright hallucinations. But when the subject of our scrutiny is conscious experience itself, our knowledge of that particular entity is the most certain truth that we can ever possibly know. So although I see a table before me, I cannot be absolutely certain that it is not a hallucination, there may or may not be a real table present before me. But I do know for a fact the properties of that spatial experience, that it is a volumetric spatial structure bounded by a colored surface. I see a table, so I am certain that a table has appeared in my consciousness.

Descartes argued that the epistemological tree is rooted on the deduction "I think therefore I am". It is hard to argue with that logic. But there is something that we know with equal certainty as the knowledge of our existence, and that is our sensory experience. Whether in the form of perception or hallucination, we know for a fact when we are experiencing something. In fact, experience is more basic and primal than abstract cogitation, and therefore raw experience has a stronger claim to the root of knowledge, because thought and cognition are themselves based on experience. It is hard to have a thought of any significance and information content without that thought referring directly or indirectly to some kind of experience. Experience, on the other hand, requires no cogitation, as is demonstrated by the practice of meditation, whose objective is to experience the

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raw experience of being, in the absence of any explicit cogitation. It is more correct therefore for the foundational statement of epistemology to be “I experience, therefore I am.” or perhaps, “There exists an experience” (in my awareness) whether or not there is a ‘me’ or ‘I’ to observe that experience.

In his book *Perception*, H. H. Price (1933, p. 3) presents an insightful analysis of the relation between knowledge and experience.

“When I see a tomato there is much I can doubt. I can doubt whether it is a tomato that I am seeing, and not a cleverly painted piece of wax. I can doubt whether there is any material thing there at all. Perhaps what I took for a tomato was really a reflection, perhaps I am even the victim of some hallucination. One thing however I cannot doubt; that there exists a red patch of a round and somewhat bulgy shape, standing out from a background of other color patches, and having a certain visual depth, and that this whole field of colour is directly present to my consciousness.”

The Critical Realist movement in philosophy (Sellars 1916, Russell 1921, Broad 1925, Drake et al. 1920) made a significant advance in addressing the epistemological question with the introduction of the notion of *sense data*, or *sensa*. The sense data are the raw material of experience before cognition has stepped in to analyze and interpret that experience. In the case of the tomato, the sense data are exactly that red patch of round and bulgy shape. It is the aspect of experience of which we can be absolutely certain that it exists, at least in the form of an experience. It is the sense data, therefore, that are the real foundation of all of human knowledge, both of the individual and of humanity at large, so it is with the sense data of experience that we must begin the investigation of what we can know.

Knowledge and Experience

All sensory experience is knowledge, although it is direct knowledge only of the internal state of our own mind, and only indirect knowledge of the world beyond mind. We cannot in principle distinguish between the world and our experience of it with any real certainty, because the only way we can see the external world at all is by its effects on the phenomenal world. Nevertheless, like the wiggly picture we see of the bottom of a swimming pool through its surface waves, we can tell that experience is composed of a wiggly wobbly picture of an enduring unchanging pattern seen through the disturbance. The unchanging or invariant feature is likely to be a manifestation of objective external reality seen through our ever-changing and unstable perceptual representation of it. The perceptual representation sets the limits on the possible range of experience, while the configuration of that representation, the state that it is in at any one time, carries the information content of the experience. Like an alphabet of 26 letters, or a color gamut composed of 256 color values, the brain speaks a language of representation that is spelled out in a finite alphabet of experiential tokens. But the code of perceptual experience is analogical, an explicitly spatial language of representation. We see the world as a colored spatial structure, embedded in a quasi-spherical space we experience to surround us. The spatial configuration of solid volumes with colored surfaces that we perceive embedded in the sphere of our spatial experience is the knowledge that we have of our perceptual experience, and indirectly, we

commonly assume it to also be knowledge of our local environment. We learn to recognize the telltale signs of illusions or hallucinations masquerading as external objects. When perceived objects appear or disappear suddenly and unaccountably, or exhibit other unusual behavior such as floating away or changing shape or color, we quickly learn to question their reality as objectively real external objects. Invariance is the key characteristic of the objectively real seen through the transient unreal.

There is more to perception therefore than the mere recording of sensory experience. There is also a spatial understanding, an extraction of deeper knowledge from the sensory scene. Sensation presents configurations of colored surfaces, while perception presents whole objects with characteristic properties. There is a great deal of interpolation and extrapolation that takes place in the perceptual process. Although we only experience the visible front face of the tomato directly, unless we have specific information to the contrary, we generally suppose the tomato to be a whole fruit, whose hidden rear surfaces are presumed to be similar to the visible front face of the fruit that we see. If we have actually seen that hidden surface recently, for example if we handle the fruit, turning it over in our hand before putting it down before us, then our knowledge of its hidden surfaces becomes much more certain. But in any case our experience of the fruit always has this dual character, split between a visible front surface, the red and bulgy sensation, and our perceptual experience of the whole fruit as a solid volumetric object. We can almost “see” its hidden rear face, in the sense that we “know” with a fairly high degree of certainty the exact shape and spatial extent of the fruit as a quasi-spherical object. And if we have any experience with tomatoes, we can even imagine its internal structure, the thin outer membrane backed by a fleshy crust, and a soft wet core of seeds embedded in a greenish gelatinous mass. This knowledge takes the form of a spatial picture that we experience, like an engineering drawing of a building, or a ship, or an airplane, with semi-transparent walls that reveal its internal structures. In fact, the engineering drawing is a pretty good depiction of our spatial understanding when viewing an object like a building, or a ship, or an airplane, even when we see only its exterior. That is why engineers find this style of presentation so useful for communicating spatial ideas. Michotte (1967, 1991) has named this dichotomy between the sensory experience of visible colored surfaces, and the invisible spatial structures that are inferred by perceptual processes. Sensory experience is always expressed in some specific sensory modality, whether it be color, brightness, motion, or binocular disparity, and this experience is therefore known as *modal* perception. The invisible spatial structure inferred from this experience on the other hand is known as *amodal* perception, because it is not expressed in any particular sensory modality.

Now of course not all knowledge appears in the form of a transparent mental picture. For example the knowledge of the price of a tomato, or where it can be obtained, or how this particular tomato came to be where we now find it, these are knowledge of a higher more abstract form which does not appear in the transparent pictorial way that we experience an object’s hidden structure. There is however a continuum between that kind of abstract symbolic knowledge and the transparent spatial structure presented by the amodal spatial experience, which in turn is intimately coupled to the spatial experience of the modal surfaces from

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which that structure is inferred. All knowledge is ultimately founded on direct sensory experience, or at least on a memory or imagination of such an experience, and therefore our investigation of what we can know must begin with an analysis of our experience.

Quantifying Knowledge and Experience

How are we to quantify something as vague and all-encompassing as the concept of experience? What is the appropriate level of analysis? Experience ranges from the low level sensory qualia, the raw material of sensory experience, to the more abstract but still vividly sensory experience of colored surfaces on volumetric objects, to the still more abstracted experience of the objects themselves as volumetric structures, to the still more abstract concept of the identity of those objects, and the hierarchy of categories to which different objects belong. All of these are aspects of experience, ranging from lower, more immediate sensory experience, to higher, more abstracted, non-sensory or cognitive experience. What is the appropriate level of description, and what are the fundamental units?

As in physics, I propose that we begin from the bottom upwards, beginning with a description of the most immediate modal experience, its dimensions of variability, and information content. The units are those of the artist: color, space, and light, with properties as we perceive them to have. So, for example, the experience of a table is defined as a table-shaped volumetric region of phenomenal space that is “painted” in the color that the table is perceived to have. Actually, only the nearer exposed surfaces of the table are experienced with modal color, the hidden rear surfaces, and sometimes the volumetric interior are generally assumed to be of the same color, although that color is not part of the modal experience of the table. The purpose of this almost tautological quantification of the structure of experience is to highlight an aspect of that experience which is often overlooked, that is, its vividly spatial nature. Whatever the neurophysiological coding scheme by which that experience might be implemented in the brain, the experience that is generated by the brain, the product of all that perceptual processing, is an explicitly spatial structure in experience.

There is a curious split, or schism, running right through the perceived object, that splits it into sensory stimulus versus perceptual interpretation; given evidence and inferred conclusions; the vivid modal sensation, and the invisible, amodal, knowledge. Although we generally consider knowledge to be an abstracted non-spatial kind of affair, at this lowest-level sensory interface, knowledge reveals itself to be a vivid spatial structure, even if it is only an amodal one. We see the world as volumetric objects. And those volumetric objects are inferred from their visible exposed surfaces by a process of symmetry completion or spatial extrapolation/interpolation. The mechanism by which the brain extracts epistemic knowledge from sensory experience involves the same kind of symmetry detection and completion process that is used by the artist, sculptor, poet, and composer, to flesh out the rich symmetrical and periodic patterns of the world as they appear in the exaggerated and cartoonized world of aesthetic synthesis. The processes of artistic creation, musical composition, and mathematical analysis, involve very similar principles of pattern recognition and completion, analysis and synthesis, abstraction and reification, that shed light on the fundamental principles behind

perceptual knowledge. These issues are discussed in chapter 8.

Models of conscious experience often go astray by defining experience in such vague or abstracted terms that the explanation is no clearer than the aspect of consciousness that it supposedly explains. I intend to ground my discussion of consciousness by beginning at the lowest, most concrete level, the part of experience that is probably very similar across individuals, and even across related species. I further ground my speculations by expressing them in terms that could actually be implemented, at least in principle, in some physical machine, although the kinds of machines I propose are very different than those generally favored for computation today. In effect what I describe is the functional architecture, or how the perceptual system operates functionally, based on its observed properties in experience. I do not have a complete answer to how perception completes volumetric forms, but I do establish that this is what perception is doing, as a computation. In Chapter 7 and 8 I explore the basic laws of perceptual processing based on an introspective analysis of perceptual completion as I experience it in everyday vision, and in Chapter 9 I propose a neurophysiological theory of how the brain computes these spatial symmetries, by way of harmonic resonance, or patterns of standing waves in the neural substrate to express the spatial structures of our experience.

But first we begin with an analysis of the dimensions of visual experience, its capacities and limitations. In Chapter 3 I discuss the distinction between the experience of self and of non-self, where the boundaries of our self really are. In chapters 4 and 5 I discuss the historical debate between realism and idealism, and show that much of the confusion has been due to lack of clarity on the central epistemological issue, of what in our experience is “inside” our self, and what is “outside”. The realist is right, that we can observe the external world (as if) directly. The idealist is also right, that all we can ever experience is the inside of our own head. These two apparently contradictory views, each of which can be shown to be true, and to be false, can both be true simultaneously within the larger framework of *representationalism*; our experience of the world is indeed indirect, so we cannot ever experience external reality directly, which is consistent with the idealist claim. At the same time however, certain aspects of our internal experience do correlate reliably with certain essential aspects of our environment, such that we can get reliable information about the configuration of the world around us, as the realist claims, although that information is acquired indirectly, through the medium of the sense data, which are themselves properties of experience. But the *qualia* of conscious experience, the raw colors and feelings with which it is painted, the interface between our brain and its experience, are themselves intrinsic properties of the brain, at the same time as being part of our experience. The internal mechanism of the physical brain, or certain very special parts of it, are the only physical entity which we can experience directly. We know what it is like to “be” the patterns of electrochemical activity in our own physical brain. But by the very fact that our mind is conscious of its own spatial structure, and given that our mind is a physical process taking place in the physical mechanism of our brain, that is already direct and incontrovertible evidence that a physical process can, under certain circumstances, become conscious of its own spatial structure. This insight has profound implications for the place of science and physical knowledge with respect to conscious experience. In fact, this insight

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inverts the traditional relationship between science and experience, because it shows that experience is a primary and foundational aspect of all physical matter, and therefore consciousness is not some mysterious entity that serves no functional purpose and leaves no detectable mark in physical reality, as many philosophers propose, but rather, consciousness is a fundamental aspect of all physical existence, of which human consciousness is only a tiny subset. Consciousness is what it feels like for physical matter to exist, and human consciousness is what it feels like to be a certain physical process in a living human brain. It turns out that this one epistemological inversion resolves a number of the profound paradoxes that have plagued discussion of consciousness for centuries.

Chapter 2

How Is Your Experience?

The Dimensions of Conscious Experience

Let us begin our investigation of the basis of human knowledge by an examination of the dimensions of conscious experience. Whether or not our experience is representative of something real or external to our self will not concern us here. That issue will be addressed later, once we have established the observed properties of the experience itself, that thing of which we can be absolutely certain without a shadow of doubt. The most vivid and impressive of our modes of experience is the visual modality, so we will begin with visual experience.

The visual world appears in consciousness as solid volumes, bounded by colored surfaces, embedded in a spatial void. Every point on every visible surface is perceived at an explicit spatial location in the volume of our experienced space, and all of the visible points on a perceived object, like a cube or a sphere, or this page, are perceived simultaneously in the form of continuous surfaces in depth. And the spatial void within which we perceive objects to be embedded is also perceived as a volumetric spatial structure, albeit one that is composed of nothing but empty space. But the experience of empty space is distinct from the experience of no space at all. I can conceptualize any point in the empty space around me to as high a resolution as a point on a visible surface. All of the points in the volume of that empty space are experienced simultaneously in parallel as a spatial void, a potential holder of volumetric objects that can appear in that space. Intermediate between the experience of solid objects and empty space is the experience of transparent objects, like the water in a swimming pool, or semi-transparent objects like a glass of red wine. In the latter case, the red color is perceived not only on the exposed surfaces of the wine, but it is perceived to pervade the entire volumetric space occupied by the wine, as a three-dimensional structure located in a specific volume of space.

In the days before science, as in our infancy, it was commonly assumed that our world of experience was identically equal to the world represented by that experience. That the properties of volume and color were the properties of the world itself, experienced directly where they lie in the world around us. But as science advanced our understanding of the physical world, it has become ever more clear that there are profound differences between the world we know in experience, and the objective external world known to science. This in turn gives us a greater appreciation for the fundamental limits of human experience, and the vast gulf between experience and the world it represents. When Anton Van Leeuwenhoek first opened the world of the microscopic to scientific scrutiny, people were astounded to discover how fantastically tiny things could be.

Big fleas have little fleas on their backs to bite 'em

And little fleas have lesser fleas, and so on ad infinitum

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Van Leeuwenhoek's microscope forever smashed the notion that the tiniest scale of the world is anywhere near the scale of the tiniest motes of dust that we can barely perceive. But that was only the beginning. The science of the microscopic went on plunging to the unimaginably tiny scales of the molecule, the atom, the nucleus, and beyond, that positively defy our imagination to fully comprehend at their true scale. In fact the size of an atom is so many orders of magnitude smaller than the smallest perceivable mote of dust, as to be beyond real human comprehension. The only way I can picture an atom is by imagining a scaled-up model of an atom, like a figure in a physics or chemistry text. I am incapable of perceiving or even imagining something as tiny as an atom at its true, practically infinitesimal size. And the same is true at the other end of the size scale, where the size of the earth, and the distance to the moon, the sun, the planets, and the stars, are so unimaginably immense that they dwarf by orders and orders of magnitude the size of the largest thing that we can perceive, which is the dome of the night sky.

The book *Powers of Ten* (Morrison & Morrison, 1982; inspired by Boeke, 1957) illustrates the vast gulf of the true range of scales, from the size of the universe at the big end, to the size of quantum fluctuations at the small end. And at the same time, it illustrates the discrete series of small gulps of mental imagery with which we mentally span the immense range of scale known to science. Each of the frames of the *Powers of Ten* captures a small window of the spectrum of size scale in the physical universe. Like the tiny window of visible light compared to the vast range of the electromagnetic spectrum, the tiny range of scale of our conscious experience shrinks to near insignificance in comparison to the vast range of scales of the cosmos itself.

Limits of Perceptual Complexity

Our world of visual experience is also limited to a finite level of complexity. Our visual system is completely overwhelmed by the detail in a single tree with all its leaves, twigs, and branches, let alone a forest of trees all waving and dancing chaotically in a stiff breeze. An artist trying to depict a tree with photographic accuracy cannot simply glance at the tree and then record his experience on the page, but rather, the artist must record one tiny piece of the picture at a time, and connect those pieces laboriously on the page to produce the full picture. The artist demonstrates the capacity of his short term memory for visual detail in the amount of detail he carries to the page with each glance. We tend to blithely assume that the world around us is as complex as it appears in our experience, and yet the true complexity of the world known to science is immeasurably greater than that of the world of experience.

Consider for example a tiny featureless patch of white paper between the letters printed on this page. We know from physics that every tiny shred of paper from this book is composed of millions and millions of molecules of matter. Each molecule is made up of numerous atoms, hundreds or thousands of them form organic molecules like those of the wood pulp, arrayed in fantastically improbable geometric configurations, and interacting wildly with each other, bouncing, twisting and jerking in a crazy blur of Brownian motion. And every atom of those molecules is composed of protons and neutrons locked together by immense forces and

surrounded by clouds of electrons spinning in complex shells and orbitals. If we could really see all the action in the tiniest shred of paper of this page our mind would be completely overwhelmed by the fantastic galaxies of crazy patterns and wild motions. And yet all that we observe is a white surface remarkable only by its uniformity of color and absence of texture.

Consider also the fantastic pulses of radiation that science tells us are cascading through this book every second, reflecting or refracting, jiggling the electrons in their orbits on their way through the body of the book. There are radio waves of all frequencies, coded with sounds and images of all the channels in your listening area. Infrared, ultra-violet, x-rays and cosmic rays arriving from space, radiating from the earth, or even glowing from the book's own atoms. Streams of sub-atomic particles and neutrinos course through the solid structure of the book knocking atoms out of place or passing harmlessly between them. On a different scale the bleached and desiccated fibers of wood pulp that are intertwined in a tangled mat are also invisible to us, as are the crystals of various chemicals trapped between the strands, grains of sand and dust, patches of oil left by your fingers, and the multitudes of micro-organisms that have made a home among the fibers. In fact, our experience of the book is restricted to the tiny set of patterns that can filter through the biological sensors with which the human body is equipped. In the words of William Blake:

If the doors of perception were cleansed, everything would appear to man as it is, *infinite*.

Science tells us much about the vast and immensely complex universe that we inhabit. It is by stark contrast with the incredible vastness and complexity of the real universe revealed by science that we can begin to appreciate the relative simplicity of the internal universe of our experience.

The Dimensions of Color Experience

The limits of visual experience extend also into our perception of color. Initially, color was presumed to be a property of light, or of surfaces that reflect light. Later, when light was identified as electromagnetic radiation, color was attributed to the wavelength of light. But it soon became clear that the relationship between wavelength and experienced color was not at all straightforward. Although longer wavelengths appear near the red end of the spectrum, while shorter wavelengths appear more blue, the opposite ends of the spectrum are joined in perceptual experience through a range of 'non-spectral hues', shades of purple that do not correspond to any single wavelength of light, and thus do not appear in the spectrum of light, but must be manufactured by mixing red and blue light in various proportions. Although the physical spectrum is linear, ranging from shorter to longer wavelengths of light, the perceptual spectrum is circular, as seen in the artist's color circle, where the light of the most dissimilar wavelengths, long wave red and short wave blue, appear similar perceptually, blending through non-spectral purple. Mixing two or more samples of pure light of different wavelengths does not produce a compound color experience, as for example when mixing two or more musical tones in a chord, but rather it produces an experience of intermediate colors. For example red and yellow make orange, even though the light produced by this mixing contains no light of the wavelength of orange as

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found on the spectrum. It was then discovered that three lights of pure colors, such as red, green, and blue, (RGB) can be mixed in various proportions to produce the full gamut of colors between them in RGB color space. That is how color television produces the whole range of colors that appear on your TV using just three primary colors of phosphor dots at each point on the screen. The only reason this works is because we cannot perceive colors as they really are, but our color experience is detected by red, green, and blue sensitive photoreceptors on our retina, as in a color television camera. If our eye had four primary colors instead of three, then our color television system would also have to use four primary colors to fool us into seeing the full gamut of colors. In other words, our color experience is three-dimensional, meaning that any color experience can be uniquely defined by just three color values.

In color television colors are expressed in an RGB triplet, with one value for each of the primary colors. In perception it is more natural to express color in the phenomenal variables of hue, intensity, and saturation. Hue is the technical word for what in common usage is meant by the word color; red, green, and blue are different hues. Intensity corresponds to the experienced brightness of the colored light. For example dimming a light illuminating a scene changes the brightness of all of the colors of that scene without changing their hue. Saturation refers to the purity of the color. Fully saturated colors are pure colors, like the colors on the spectrum, each of which reflects the hue of a single unmixed wavelength of light. De-saturated or impure colors appear as if mixed with some white, for example pink and sky blue are de-saturated versions of the pure colors red and blue respectively. A simple mathematical formula converts an RGB triplet into the corresponding Hue, Intensity, and Saturation (HIS) triplet of phenomenal color experience. Any color experience can therefore be expressed as three values, one each for hue, intensity, and saturation, or equivalently, red, green, and blue. Physical light is not restricted to these three dimensions however. The spectrum of a typical sample of colored light contains a separate and distinct magnitude for every spectral frequency of the light. If the spectrum were quantized into 256 discrete wavelengths, for example, then that spectrum would define a 256-dimensional space, which is considerably greater in information content than the three dimensions of phenomenal color that we experience. But since the spectrum of light defines a continuum of different wavelengths, this actually corresponds to an infinite-dimensional space. In other words, as in the case of spatial experience, the dimensions of color experience are immeasurably smaller than the range of variability in the wavelengths of a typical sample of colored light. As in spatial experience, our experience of color is very much simpler than the physical chromaticity of light itself.

The Reliability of Introspection

It might be appropriate at this point to say a word about phenomenological observation, or introspection: the observation of one's own mental states. Introspection is often criticized for being too subjective, impossible to verify. The logical positivist Gilbert Ryle (Ryle 1949) argued that thoughts, perceptions, and mental imagery, are so private that they are not meaningfully reportable in scientific discourse. This is why modern psychology has turned to psychophysical experiments, where subjects are presented with a series of stimuli, often on a

computer monitor, and required to press a key indicating some aspect of their experience of the stimulus. This is supposedly a more objective procedure because the scientist is observing experience “from the outside” in a manner that is repeatable, and the results are averaged over many subjects to compensate for individual variations in experience. The trouble with psychophysics is that there is only so much you can communicate through a keypress response. How would you determine psychophysically whether the subject experienced the world as a spatial structure? Can we just ask “Does your experience of the world appear as a spatial structure?” Does his observation become objectively valid if he presses a “Yes” key, along with a statistically significant number of other subjects? Or is it simply absurd to ask such a question psychophysically? This is where phenomenology is preferable to psychophysics, because instead of the subject with a key to press, I ask the *reader* to examine their *own* subjective experience and to verify for themselves if they experience the same thing that I experience, that is, a rich spatial structure as I describe it. If they don’t see it, they can go ahead and reject my observation and the conclusions I draw from it, but if they do see what I do (and most everybody does!) then they can follow me to the implications of that experience. Excessive rigor in psychology, sometimes called “physics envy”, is sometimes liable to fog the issues rather than to clear them up. There are times when it is best to just open your eyes and report on what you see. In fact, introspection, or phenomenology, is *at least* as rigorous and certain as are psychophysical data gathered by observation of the subject from the outside. The only difference is that in introspection, the reader or researcher is also playing the role of the subject, observing the experience first hand, and thus they can observe a much greater depth of rich information than could ever be communicated through a keypress response.

A Quantified Phenomenology

We have described visual experience as a volumetric space, parts of which are occupied by solid volumetric objects with colored surfaces, each color being defined by a triplet of color values. The information content of a visual experience is therefore similar to that of a museum diorama, or theatre set. We can quantify the information content of spatial experience therefore by defining experience as a three-dimensional spatial manifold, every point of which can encode either an experience of transparency, as in the spatial void that we perceive to surround solid objects, or an experience of a color at that point in perceived space, encoded by the three values of HIS at that point, as suggested in Fig. 2.1. Mathematically, the space in a three-dimensional manifold is a continuum, that is, every interval in that space is infinitely divisible into ever smaller intervals. That is not true of perception however which has a limited spatial resolution, so our model of visual experience should also be defined only to a certain finite resolution. While this model does not capture all of the information content of visual experience, it does provide a starting point that encodes the most primal and basic aspects of that experience which we can elaborate on as we discuss other aspects of the experience.

We will defer for the moment the question of what the structure of experience is made of and where it is located, whether it is in our own brain or out in the world, as well as the question of whether the structure of our visual experience requires

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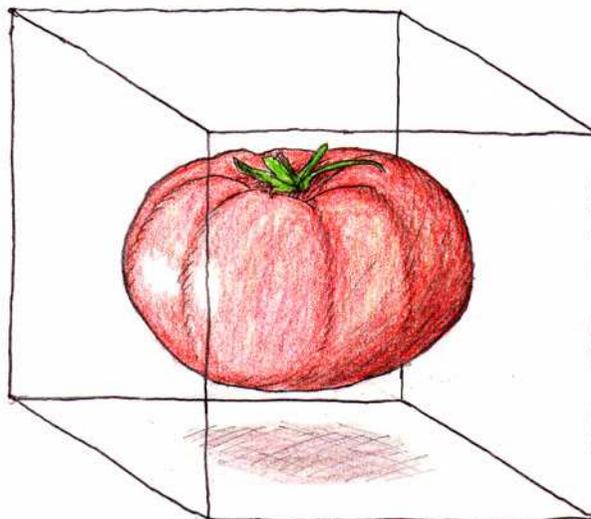


Fig. 2.1 The information content of the experience of a tomato, expressed as a volumetric object embedded in a volumetric space, whose bounding surfaces encode the perceived color of those surfaces, like a painted model in a museum diorama.

a viewer of that experience, or whether it simply experiences itself. These questions will be discussed in chapters 3 to 5. For now, let us state the foundational epistemological fact of visual experience, which is that experience reveals the existence a spatial structure of which we are somehow aware, and that structure has these particular properties, that is, three spatial dimensions, and three color dimensions at every point in that space. This model therefore quantifies the form, or *information content* of the knowledge of which we are most certain.

We can now add to our quantified model of spatial experience the experience of amodal perception, discussed in chapter 1. When we view a solid object, such as a tomato, we do not experience the whole tomato exclusively as a modal colored experience. We experience its visible faces that are exposed to our view as a modal colored surface, like a veneer, or visual facade, as if painted on the exposed surface of the fruit. But we also experience its hidden structure as an amodal spatial experience. We can add the amodal component of perception to our quantified model of experience by defining another state that the representational manifold can take, which is the experience of an amodal volumetric structure located at some point in visual space. In other words, the modal experience of the visible surface of the tomato is expressed in our model as a curved colored surface, and within that surface the representational manifold is in the modal red color state. The amodal component of our experience of the tomato is expressed as a tomato-shaped volume which is in a state representing amodally perceived solid matter. The relationship between the modal and amodal components of the experience of a tomato is depicted in Fig. 2.2.

The amodal component of experience is less certain and less vivid than the visible modal surfaces, because we cannot be sure that the red bulgy surface is really a tomato instead of a visual facade, although the certainty increases if we have an opportunity to view the hidden rear faces. Nevertheless, even with access to its

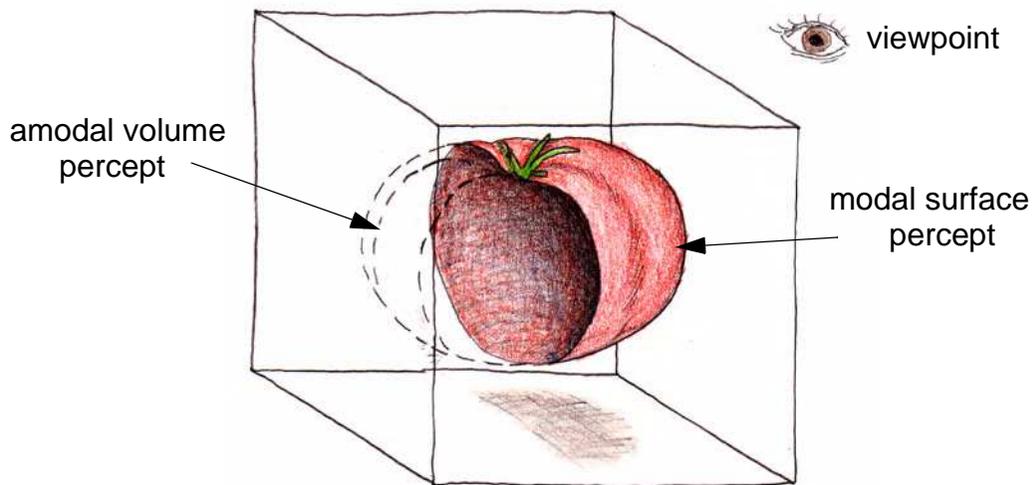


Fig. 2.2 The subjective experience of a tomato, factored into the modal surface percept on the side exposed to the viewer, and the amodal volume percept of the tomato as a volumetric object of a particular size and shape.

hidden rear side, we only see one aspect of the tomato at any one time, the amodal structure being merely an inference based on the direct modal experience, and that uncertainty is expressed in perception as a less vivid, more ghostly, almost transparent or 'invisible' quality to the amodal percept.

Although the amodal component of experience is not perceived as a vivid colored structure, it is perceived to have color, because we can 'see' the color of the inside of the tomato even if only in a ghostly uncertain semi-transparent manner. We would be truly surprised if, on cutting open the tomato we found its insides to be any other color than that which we expected from the view of its external aspect. So, in our quantified model of experience, the state of perception corresponding to amodal experience must also encode the color triplet of HIS at every volumetric point within the amodal percept. Amodal and modal perception therefore together define a seven-dimensional space, consisting of three spatial dimensions, any point of which can express three dimensions of HIS color, and one additional variable to express the modal/amodal distinction, brings the total to seven dimensions.

The amodal percept is also distinguished from the modal experience by the fact that it appears to be a volumetric structure, i.e. the color that we imagine for the interior of the tomato is a color that pervades the volumetric form, as opposed to the modal experience of visible color that resides exclusively in the skin, or outer surface of the tomato. But this is not always the case. When viewing a plastic object, like a Lego block or other plastic toy, we often assume its surface color to pervade the volume of the object continuously with the color observed at its surface. Furthermore, modal color experience can also be volumetric as when viewing a semi-transparent object like a glass of red wine. In that case the red color is perceived modally, as an immediate vivid experience, whose red color pervades the entire volume of the wine simultaneously.

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Physicalist versus Phenomenalist Perspective

The dichotomy between the modal and amodal aspects of perceptual experience is mirrored by a similar schizophrenic split between a *physicalist* and a *phenomenalist* view of reality. Physicalism is the belief that what is most 'real' and certain in the world is the physical world known to science. That world is populated by invisible entities such as atoms, molecules, and a whole array of invisible electromagnetic radiation. In other words, the physicalist sees the 'real' world of truth as corresponding to the invisible amodal component of perception, and the level of detail and specificity of the amodal percept is directly related to the level of scientific knowledge of the perceiver. A young infant on viewing a tomato might assume its surface color to pervade the interior of the fruit uniformly, as would be the case for a solid plastic model of a tomato, whereas a child that has seen tomatoes being sliced, might perceive the interior of an unsliced tomato more correctly as an outer red crust with a greenish slimy core. A botanist would see even more detail amodally, knowing the pattern of arrangement of the seeds in the core, and the botanist would picture the flesh of the tomato as a matrix of living cells, as it appears under the microscope. But even the botanist need not fill in their tomato perceptually to this level of detail every time they look at one. When a botanist is engaged in merely picking up a tomato to put it away in the refrigerator, he may well momentarily perceive it as uniformly red within, like the experience of the young infant. In other words the amodal component of the percept is very much under cognitive control, and can be made to appear in greater or lesser detail, depending on the knowledge and experience of the perceiver, and on the requirements of the moment. In this sense, the amodal percept is less stable, and more shifting and variable, depending as it does to a greater degree on the mental state of the percipient. After all, the amodal component is merely an inference based on the appearance of the outside of the tomato, and an inference is a voluntary thought whose content is dictated by the needs of the moment.

Phenomenalism is the belief that the most certain and reliable knowledge is to be found in immediate conscious experience, which corresponds to the modal component of perception. Epistemologically speaking this view is more correct, since the modal experience is the foundation or basis for the amodal inferences drawn from it. But it is also clear why the physicalist shuns the modal experience, because experience is often erroneous or illusory. For example a wax replica of a tomato presents an external face identical to that of a real tomato, and can thus deceive the percipient about its true internal nature. The error however occurs not in the modal experience, which is perceived veridically as a red and bulgy shape, but the error occurs in the amodal inference drawn from that experience, on the assumption that the experience is of a tomato.

The truth of physicalism arises from the fact that the amodal percept penetrates deeper into the true nature of things than their mere external appearance, and that deeper knowledge, when not erroneous or illusory, offers a more solid and reliable picture of the 'real' world of truth. As an infant we begin with an experience that is almost exclusively modal; we believe what we see to be true. As we grow to adulthood, our world of experience becomes ever more heavily weighted toward the amodal component of experience, so much so that an adult tends to ignore the modal component altogether, and focus more on the 'real' objects and events

around them as they are experienced in amodal inference. It takes special training and practice for an artist to learn to ignore the amodal, cognitive knowledge of the world, and to focus again on the modal experience of color and light as it presents itself to immediate consciousness.

There is a certain tension in the philosophical literature between the phenomenological and the physicalist view of conscious experience, as if they were mutually exclusive. As long as one maintains that physical entities such as matter and energy are entirely devoid of any trace of self-consciousness or experience of their own existence, the existence of our own conscious experience must forever remain a profound mystery. As Chalmers (1995) explains, everything in physical theory is consistent with a complete absence of consciousness. In chapter 5 I will show that this is not necessarily the case, that in fact an expanded physicalist view can be devised that makes room for conscious experience as an essential component of our scientific description of the world (as Chalmers himself proposes). I will use the term *pure physicalism* to denote the conventional notion of a physical world entirely devoid of experience, because the *expanded physicalist* view remains within the definition of physicalism, that what is most 'real' and certain is the world known to science, because now experience is part of science.

Spatial versus Symbolic Knowledge

The close relationship between scientific knowledge and amodal perception reveals an important aspect of knowledge that is often overlooked. That is that scientific knowledge often is, or at least can be a spatial structure, i.e. it is knowledge that can be expressed as a volumetric three-dimensional model within which various volumes and structures are 'painted' in amodal color. Why should this be so surprising? Throughout our scientific and mathematical training we are urged to take a complex spatial problem, for example calculating how many tiles are required to tile a bathroom wall, and convert it to an abstract symbolic form that can be solved by manipulation of abstract mathematical symbols. Nobody ever needs to be taught to see or imagine the bathroom wall, or to understand how tiles line up in rows and columns. That is knowledge we acquired wordlessly in our infantile observations of the world, and everyone is assumed to have this knowledge as a prerequisite to learning science and math in school. When learning about electric current and voltage, we are taught the analogy to current and pressure in water pipes, but nobody has to teach us about pressure and flow of water, that is something that we discover in the bathtub as children as we squirt water from various toys, or in the garden as we try to block the flow of water from the hose with our thumb. The entire focus of the scientific education is on the abstract symbolic expression and solution to problems, very little attention is given to the spatial knowledge of mental imagery which is so essential to a real scientific understanding. This gives the budding scientist a distorted picture of the world of knowledge as something that is purely abstract and symbolic. The analogical spatial component of scientific thinking is not generally considered to be part of science at all, because it is something that is neither explicitly taught nor tested for in the typical scientific education. Consequently, the spatial structure of amodal experience seen in the hidden volumes and surfaces behind modal experience are often mis-identified by the scientist as reality itself, the 'real' tomato that is

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present before our eyes, while our scientific knowledge of tomatoes involves a mass of abstract non-spatial facts, such as equations for calculating surface area or center of mass, etc. This leads to endless confusion when the scientifically-minded tackle the issue of consciousness, because it fosters the naive realist illusion that the spatially structured world of our amodal experience is the world itself where it lies in the surrounding world, as opposed to a spatial knowledge structure that is actually built by perceptual and cognitive processes within our own mind on the basis of modal experience.

It should be mentioned at this point that our model of knowledge as developed so far is missing an essential component that goes beyond a mere spatial structure. When we experience a spatial structure in our conscious experience, for example a sphere or a cube hanging in space, there is more to our understanding of what we are experiencing than the mere presence of that spatial structure in our experience, whether modal or amodal. There has to be something different that occurs in our head when we see a cube instead of a sphere, something corresponding to a recognition of the cubical shape as distinct from the spherical shape. This is the difference between *sensory* and *epistemic* perception. Sensory perception is the mere experience of certain shapes and colors in the world, in the absence of an acknowledgement or understanding of the meaning of that experience. It is like the visual experience of a man so preoccupied with other concerns as to be paying no attention to what he is seeing. The shapes and colors appear in his mind, but they penetrate no deeper than just raw experience. That is the kind of experience that we have modeled with our seven-dimensional colored manifold. Epistemic perception involves an understanding of what it is that we are perceiving. In fact, amodal completion of the hidden rear surfaces of a perceived sphere or cube requires a familiarity with the geometrical concepts of sphere and cube, whether that familiarity comes from a formal education in geometry, or from simple childhood experience with the regularity of balls and blocks. The round surface experienced modally must be recognized as part of a sphere to complete it correctly as a full sphere, and that completion follows different rules than the amodal completion of the cube. There are two complementary aspects to this epistemic knowledge, *abstraction* and *reification*. Abstraction involves the reduction of the spatial pattern of the experience to a symbolic label such as 'sphere' or 'cube'. This is the aspect of knowledge that is emphasized in a typical scientific or mathematical education. The other component, reification, is the process of perceptual filling-in, a constructive, or generative function of perception that is manifest in amodal perception. Abstraction concerns knowledge of the abstract rules that govern all spheres and cubes whatever their location, orientation, or spatial scale, whereas reification concerns knowledge of how those abstract rules apply to this particular sphere or cube, with respect to its actual location, orientation, and spatial scale. It is this constructive reification component of knowledge that receives so little attention in scientific circles, because it is so easily confused with a detection of structures out in the world where they lie, as opposed to a construction of those structures on the basis of their visible surfaces as they are computed by amodal perceptual processes. The issue of sensory and epistemic perception will be discussed at greater length in chapter 7.

Other Sensory Modalities

We began the analysis of conscious experience with a discussion of visual experience, because vision provides the most vividly structured example of spatial experience. It turns out however that almost every other sensory modality is also spatially structured at least to some extent, and that spatial structure is essential to the practical function of those sensory modalities. Perhaps the most primal spatial experience is found in the somatosensory and tactile experience of the world we feel with eyes closed or in pitch darkness. No matter where we are, we always feel ourselves to be in a space, and we are conscious of our body in that space, even without having to look down and see our body. In fact, we can feel the posture and configuration of our body automatically and instantaneously, even if we lie passively while somebody else moves our arms and legs into different postures. The sensory awareness of our own body posture is known in psychology as *proprioception*, and it is one of the most primal components of our experience of the world.

Besides the proprioceptive sense, we also feel a tactile sensation of the pressure of the earth on our feet when standing, or of the chair or bed on our body as we sit or lie. There are a number of different modalities that can be distinguished in the somatosensory world, for example we can feel pressure, texture, heat or cold, each as distinct sensory modalities that 'color' the world of our sensory experience in much the same way that color and brightness paint the picture of our visual experience. As in the case of color, the experience of these other modalities is not felt so much on the sensory surface, even when the perceived surface is pressing against the sensory surface of our skin. Rather, we tend to assign the sensation to the surface that is causing that sensation. When I lie on a rough ground, it is the ground that feels rough, not my body that is in contact with it. There is a general representational principle apparent in these various modes of sensory experience, which is that our mind always attempts to interpret the sensory input as a property of the world around us, and it does so by constructing a three-dimensional spatial image of the world we believe to be the source of that sensory input. Our experience of the world is an experience of that three-dimensional spatially structured construct, 'painted' with the various sensory modalities that we experience through the sensory nerves in our skin. That is the same representational principle that is apparent also in visual experience.

Although the sensory organs of the tactile sense are located in the skin, they too produce a perceptual experience of solid volumes, bounded by textured surfaces, embedded in a spatial void. When, with eyes closed, I roll a small stone between thumb and forefinger, or manipulate a rock in my hand, the experience of spatial structure is every bit as vivid as the amodal percept due to a view of those objects seen visually. And when I explore a space in pitch darkness, or with eyes closed, I feel the various walls, floor, and obstacles where I perceive them to lie in the world. When my hand encounters a wall as I explore in the dark, that single contact point generates a percept of a whole wall expanding outward from the point of contact with my hand, although the perceptual certainty of that experience diminishes with distance from that point. As I encounter other walls and obstacles in the dark room, I gradually build up a picture of the whole room as a volumetric spatial structure that is larger than my body, and I perceive my body as a dynamic

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spatial structure moving through that larger space. The assignment of tactile sensation to specific locations in a structural model of the external world is the most fundamental aspect of tactile perception, without which tactile experience would be virtually useless as a window to the world. Perception of all sensory modalities is as much a matter of active construction as it is of passive reception.

Sensory Confluence in the Amodal Percept

Finally, there is one more general principle apparent in all sensory experience. The sensory input, whether it be visual color or brightness, tactile texture, pressure, heat or cold, is experienced as if painted on the spatial structure of the world we perceive amodally. Furthermore, we do not perceive different amodal structures for each sensory modality separately, but rather all of the different sensory modalities share the same amodal structural framework. When we hold a baseball in our hand, the tactile texture of the ball sensed through the skin of our palm is experienced on the very same spherical surface as is the color and brightness that we perceive visually. The hardness or irregularity of the ground that we feel underfoot are experienced as properties of the very same amodally perceived ground that carries the color and brightness that we perceive visually. In other words, the spatial structure that is our amodal experience of the world is the common ground, or *lingua franca*, that unites all sensory experience in a modality-independent structural representation of the world, and that amodal structure represents our perceptual and cognitive understanding of the world. It is this unifying property of the amodal percept that is responsible for the compellingly vivid illusion that the amodal framework is the actual world itself as revealed by our senses, as assumed by the pure physicalist, rather than a structure in our mind constructed on the basis of sensory input, as understood by the phenomenologist.

The same basic principle applies also to the auditory modality, and to a lesser extent, also to the olfactory sense. When we hear a sound, we do not experience it as located inside our ear, except perhaps when listening through headphones. When we hear the squeak of chalk on a blackboard, or the clink of glass when we raise a toast, we hear those sounds located at the chalk where it meets the blackboard, or at the point of contact between the clashing glasses. And when we ourselves are writing on the blackboard, or clinking our glass in a toast, we feel, as much as hear the sound of the squeak or clink, by a vibration through our fingertips, but experienced at the location of its source in the chalk or glass. The amodal vibration is experienced simultaneously through the tactile and auditory modalities, each reinforcing the other to produce a vivid picture of events that we perceive to occur out in the world, not at the sensory surface.

Even olfactory experience, perhaps the least spatial of the five senses, produces a spatially structured experience. Although we smell odors with our nose, we do not experience those odors in our nose, but rather we assign the odor to the object that we are smelling. When we sniff a tomato close to our nose, it is the tomato, not our nose, that we perceive to be odoriferous, and we perceive that odor as a kind of spatial halo surrounding the tomato, becoming more intense with proximity to the tomato, even if our sampling of that odor occurs by approaching it from one direction only. Even an odor that cannot be localized, like a smell of

smoke in the air, is perceived as a property of the surrounding air rather than a sensation in our nose. The construction of the amodal structure of perception based on the various sensory modalities is the most fundamental aspect of experience, without which the various sensations would remain a blooming buzzing confusion.

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Chapter 3

The Experience of Self and Non-Self

The Epistemological Quest

When a newborn infant first opens its eyes on to the world, its first visual experience must be one of a massive confusion of disorganized color, brightness, and form. At that point the infant has no idea who or what it is, and most likely it cannot even distinguish between self and non-self. This is the very beginning of the individual's epistemological quest, where the infant's experience is confined to its direct sensory experiences. At this point a tomato would probably appear to the infant as a pair of fuzzy red patches of constantly changing character. Fuzzy, because it has not yet learned to focus its eyes to the appropriate distance; a pair of patches, because the infant cannot yet bring its eyes into binocular fusion, and therefore the tomato would register as a double image, as seen also by an adult who is profoundly drunk. And the experience is constantly changing, even if the tomato were standing still, because the infant's eyes are constantly changing their focus, and because the infant has not yet learned that the erratic gyrations of its visual experience are due to its own frantic gyrations of its eyes, head, and body relative to the external world. It is doubtful whether the experience of a tomato would even be round and bulgy to the infant, and the amodal percept of the tomato as an oblate spheroid would almost certainly be absent. At this point, even if the infant were neurologically capable of forming long term memories, its experience of the world must be so chaotic and confused that there would be no definable structure of its experiences to be committed to memory, just a senseless confusion of color and form in constant chaotic motion.

Although it is difficult for an adult to imagine the experience of a new born infant, a hint of what it might be like can be experienced under the influence of large doses of hallucinogenic substances such as LSD or Mescaline. A common feature reported in such deep states of intoxication is a loss of the distinction between self and non-self. At first when the drug begins to take effect, one sees small errors in the visual picture of the world. Edges become fuzzy or doubled, colors become unnaturally vivid, and peculiar artifacts appear in the picture in a shifting unstable manner. As the effects of the drug become more pronounced, everything becomes even more shifty and unstable, and there is ever more visual confusion, making it difficult to make out what it is that one is looking at. In the most profound states of intoxication the whole image becomes a senseless confusion, presumably similar in some respects to the experience of the new born infant. It is at this point that the tripper sometimes loses the distinction between self and non-self, because the image of his own body is so chaotic and confused that it merges seamlessly with the visual confusion of the surrounding environment, giving the impression that his normal "self" has simply disappeared.

Even under the normal state of sober consciousness we can imagine this dissolution of the self in a thought experiment. I can imagine what it would be like to have no legs, and no arms, and in my imagination I can even picture myself without a trunk. But what of my head? Can I imagine myself without a head?

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Setting aside the fact that without a head I would have no experiences at all, I can easily picture my experience of the world in the complete absence of an experience of my own head or body at the center of my world. It would be like the view of the world by a disembodied spirit--everything would appear exactly as it normally does, except without an experience of my body. I would see a world around me in the absence of a "me" to observe the observation.

D. E. Harding (1961, p. 1-2) writes eloquently on the subjective experience of the self, from which I quote:

"The best day of my life- my rebirthday, so to speak- was when I found I had no head....

It was when I was thirty-three that I made the discovery. Though it certainly came out of the blue, it did so in response to an urgent inquiry; I had for several months been absorbed in the question: WHAT AM I? The fact that I happened to be walking in the Himalayas at the time probably had little to do with it; though in that country unusual states of mind are said to come more easily....

What actually happened was something absurdly simple and unspectacular: just for the moment I stopped thinking. Reason and imagination and all mental chatter died down. For once, words really failed me. I forgot my name, my humanness, my thingness, all that could be called me or mine. Past and future dropped away. It was as if I had been born that instant, brand new, mindless, innocent of all memories. There existed only the Now, that present moment and what was clearly given in it. To look was enough. And what I found was khaki trouser legs terminating downwards in a pair of brown shoes, khaki sleeves terminating sideways in a pair of pink hands, and a khaki shirtfront terminating upwards in - absolutely nothing whatever! Certainly not in a head.

It took me no time at all to notice that this nothing, this hole where a head should have been, was no ordinary vacancy, no mere nothing. On the contrary, it was very much occupied. It was a vast emptiness vastly filled, a nothing that found room for everything - room for grass, trees, shadowy distant hills, and far above them snow-peaks like a row of angular clouds riding the blue sky. I had lost a head and gained a world."

Is it really true, as Harding contends, that we see nothing whatsoever of our own head in experience? In my experience I do perceive my own head, although it is experienced as if viewed from the inside, as if my head were a hollow shell, filled with a murky redish-brown emptiness. I feel as if I am peering out at the world through my eyes, like through two open windows, and I can even see the frame of those windows, as a fuzzy out-of-focus pinkish rim at the edges of my visual field. But this raises the question of who it is who is doing the peering. I can easily triangulate my egocentric point by pointing two index fingers back at myself, so as to view both fingers exactly end-on. Where the linear extensions of those two fingers intersect inside the hollow volume of my head is the exact location of my egocentric point. But what is it that is located at that unique singular point? In my experience there is absolutely *nothing* located there! The "I" that is doing the viewing is an empty void, exactly as Harding describes. So we do not have to

imagine what it is like to be a disembodied spirit, for our experience of the world is exactly that, except that our invisible “spirit” seems to be trapped inside a surrounding head and body, like a ghost chained to the castle that it is condemned to haunt. The internal mechanisms of my perceptual apparatus, my retinae, optic nerves, and visual cortex, are completely invisible to my experience, they are seen as just an empty nothingness through which I view the world. I propose that this aspect of visual experience is exactly what has inspired the traditional religious or spiritual belief shared by so many different cultures throughout history, of the self as an immaterial spirit whose existence is independent of the material body in which it is temporarily housed.

There is an alternative, more conventional definition of the self, that is to define the self as the body that we experience to surround our egocentric point. I experience my body as a spatial structure, whose spatial configuration I can “feel” even without looking. This aspect of perception, *proprioception*, is so natural and intuitive a part of our every day experience that we tend to simply take it for granted, hardly aware of it as a sensory experience at all, but rather we tend to consider our proprioception as a directly experienced fact. There exists however a rare neurological condition, described most eloquently by Oliver Sacks (1970 p. 43: *The Disembodied Lady*) where the patient loses her proprioceptive sense, and can no longer feel the posture of her own body without looking down at it. Epistemologically speaking the message of proprioception is something like: “There exists a spatial structure (my body) that is shaped like *this*, (two arms, two legs, and a head, attached to a trunk) and that structure is currently in *this* spatial configuration (whatever it happens to be).” Add to that the more basic epistemological fact discovered already by the newborn infant, that “There exists a spatial world of form, color, and motion, and that world is currently in *this* configuration (whatever it happens to be).” and you have the foundational basis of our knowledge of our self in the world in normal everyday experience.

But the apparently solid factual experience of our self in the world is by no means as solid and stable as we normally assume it to be. One of the curious aspects of all sensory experience is that it is often much more sensitive to change than to static conditions. We feel our body most vividly proprioceptively when it is in active volitional motion. Of course our body is constantly in motion, even when we are sitting quietly reading a book. Our feet and legs are constantly shifting, our head and eyes are constantly darting back and forth, and we constantly shift our weight and alter our posture in the chair. The practice of hypnosis employs a technique of total relaxation to produce an experience of disembodiment, a floating free of the spirit from the anchor of the body. To experience hypnotic trance, just lay down on a comfortable couch or bed with eyes closed, and concentrate on relaxing your whole body. It is helpful to begin with your feet and ankles, then progress up slowly to your legs and knees, and so on finishing finally at your head, at each point making sure that each body part is completely relaxed and tranquil. If you remain completely motionless for long enough, you gradually lose touch with your proprioceptive sense, and you will no longer experience the presence of your body as vividly as in normal experience. A professional hypnotist might encourage the disembodied state with directives to imagine yourself floating free of your body and drifting off into space, like the proverbial “near death experience” reported by patients in certain states of anaesthesia.

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Zen meditation produces a similar disembodied mental state, although usually performed sitting erect, perhaps cross-legged (if that posture is not too uncomfortable), with eyes open but staring forward relaxed, with minimal motion of the eyeballs. In meditation one also endeavors to banish all verbal or logical thought; to shut down the stream-of-consciousness running narrative that normally accompanies our waking experience. I suspect that the experience produced by this practice is similar to the experience of our animal ancestors, who see the world around them in the absence of a verbal narrative. If you have never tried this kind of meditation, I highly recommend it as a path to self-knowledge, although it takes some practice to successfully achieve, because the beginner will discover that words pop into consciousness incessantly and persistently. There are a few techniques available to help the beginner. One is to endlessly repeat a mantra, which can be any word, its actual meaning being irrelevant, because its meaning is quickly lost through the endless repetition. Another technique is to put your verbal mind into an infinite feedback loop by thinking again any verbal thoughts that come involuntarily to mind. For example you might think something like: "Ok, I'll try that technique. I just thought 'Ok, I'll try that technique.' I just thought that I just thought 'Ok, I'll try that technique'..." and so forth, and if that circle of thought gets interrupted by a different uninvited thought, continue repeating the new interrupting thought until it too loses its meaning through endless repetition. But the most important advice is not to fight it, so much as to learn to ignore your verbal stream of thoughts, allowing it to ramble on meaninglessly, and eventually after much practice the chatter will die away altogether, resulting in a state of serene mental silence. The purpose of all this effort is to learn to experience a new and different form of wordless consciousness, a consciousness of pure being. Or as D. E. Harding put it, "There existed only the Now, that present moment and what was clearly given in it." From a phenomenological perspective what is interesting in this practice is that by shutting down the verbal stream of thought, all of the mental energy normally devoted to that process gets redirected to the other, pure existence aspect of consciousness. In fact, many people have never noticed this aspect of consciousness as consciousness at all, but associate the concept of consciousness exclusively with the verbal stream of thought. By shutting down that endless chattering stream we become aware perhaps for the first time (since infant hood) of the very existence of that other form of consciousness, and we realize that it has been working away quietly in the background throughout our whole lives, unnoticed, due to the overwhelming predominance of that left-brained verbal stream.

And when we finally direct our attention to that alternative, right-brained pure existence component of experience, we begin to notice features of it that we may never have noticed before. We notice for instance that our vision is only sharp and clear in the direction of our fixed and glassy stare. Peripheral regions of our visual field are very much more fuzzy and uncertain. By putting a stop to the natural inclination to jump visually from one object to the next in inquisitive, exploratory search, we begin to see the picture as a whole, as a surrounding world of pure experience that simply *is*. We see with the eyes of an artist, who perceives shapes and colors and forms, as opposed to trees and clouds and mountains. In other

words we see the raw sense data of our conscious experience, unsullied by the verbal and linguistic interpretations that we instinctively impose on it. This is the raw data of epistemology, the one thing that we can be certain to actually exist.

It is perfectly clear why the Buddha found enlightenment in this practice. As in the case of hypnotic trance, holding the eyes immobile causes the visual world to fade, and sometimes disappear. For in vision too, we see best when our eyes are darting intently from one thing to another. When we hold our eyes relaxed in a fixed glassy stare, we see much more of the noise and error in our visual system. In fact, the experience is somewhat similar to that observed under hallucinogenic intoxication; edges become fuzzy or doubled, colors become unnaturally vivid, and peculiar artifacts appear in the picture in a shifting unstable manner.

Why should seeing the imperfections of our visual system be associated with any kind of enlightenment? It leads to enlightenment because this kind of meditation gives us a new realization of the true nature of self. We know that the sky and earth around us are solid and stable structures, as they appear under normal viewing. The shifting, unstable scintillation of that world that we observe in the meditative state therefore is not a twittering scintillation of the world itself, but in fact that experience is a shifting unstable picture in a very imperfect visual representation of the solid stable and enduring world that must underlie that shifting experience. The profound insight that the Buddha discovered was essentially the same insight that was rediscovered by D. E. Harding: that the self is not confined to the limits of the physical body that we inhabit, but that the self extends outward to encompass everything that we experience. We, as a self, are very much larger and more complex than naive perception would seem to indicate. That is about as profound an insight as the human mind is capable of having.

Is Experience Viewed from a Point?

Visual experience appears in the form of a spatial structure with colored surfaces embedded in a space. That much we can know with absolute certainty. But does the experience of that structure necessarily involve the experience of viewing from a point or perspective? Is it possible in principle to have an experience of a structure without the experience of viewing that structure from a particular viewpoint or direction? What is it that makes our experience of the structure of the visual world appear as if viewed from a point? The answer to these questions can be found by contrasting the observed properties of amodal and modal experience.

Fig. 2.2 depicted a compound experience of an amodal volumetric tomato superimposed on a modal colored surface experienced on one side of it. In Fig. 3.1 this compound experience has been factored into modal (Fig. 3.1A) and amodal (Fig. 3.1B) components. Since both models represent the same tomato in the same location, they are by definition still superimposed, but separated here conceptually to allow us to study their properties individually. The modal experience by its very nature implies a viewer viewing from a specific direction, even in the absence of an experience of a body at that location, the minimal viewer being no more real or substantial than our own egocentric point in the middle of our head. The amodal experience on the other hand has no such implicit

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viewer, because it is a volumetric model that can essentially be viewed from any direction, because the information content of that structured experience does not depend on a viewer or a viewpoint.

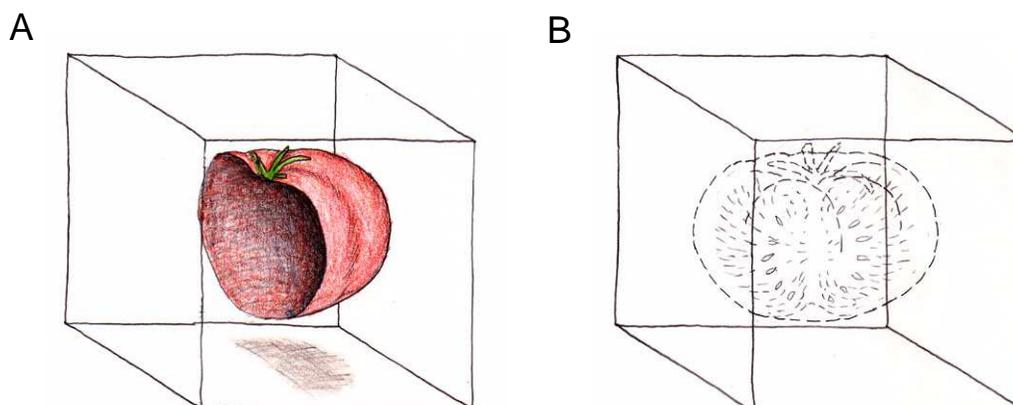


Fig. 3.1 The experience of a tomato factored into A: the modal surface percept, and B: the amodal volume percept.

I do not propose that all amodal perception is entirely devoid of the experience of a viewpoint. I propose only that there exists a component, or aspect of amodal perception that is indeed independent of a viewpoint, and it is exactly its viewpoint-independence that makes it so useful as a representation of external reality. This issue can be explored with a little thought experiment. When you imagine a tomato a few inches in front of your face, your mental image is an amodal experience, similar to the amodal component of the percept of a tomato actually present. And yet at the same time the mental image is also modal, in that you tend to imagine the tomato with an outer skin that appears red and smooth and tight on its exposed face, in contrast to the hidden volume and rear surfaces of the imagined tomato that are seen in a purely amodal fashion. In other words, the mental image, like a normal perceptual experience, is also composed of modal and amodal components, even though the modal aspect of a mental image is still invisible or transparent, and very much less vivid than a normal modal experience. Like the modal surfaces of perception, the modal component of a mental image also implies a viewpoint, and is thus not viewpoint-independent. But the remaining *purely amodal* component of the mental image is in fact viewpoint-independent.

The reason why the purely amodal experience is viewpoint independent is because the near surface is no more vividly opaque and colored than the internal structures that it no longer occludes. My experience of the rear face of the amodal tomato is just as red (in an amodal sense) as the purely amodal component of its exposed front face. The knowledge or information embodied in the amodal image of the tomato is equal to the information inherent in a three-dimensional colored model of the tomato, accurate not only in its external appearance, but also in its internal anatomical details, even if those internal structures are not visible to external inspection. In the purely amodal experience however the hidden configuration of a solid object is in fact visible in the mental image, like the internal details of a semi-transparent engineering sketch.

Now the mental image of a tomato in front of me includes an image of myself back here viewing that imagined fruit. But as we showed in an earlier thought experiment, it is possible to imagine the image of a tomato in the absence of an image of my self back here viewing it. In imagination anything is possible, even the experience of a disembodied spirit. But when the image of my self as a body is banished from my mental image of the tomato, there remains the ghostly self as an egocentric point at the former location of the center of my perceived head, as in our previous thought experiment. I am still viewing the imagined tomato from the location where my bodily self used to be, and thus it might seem that my amodal experience is still experienced as being viewed from a point, albeit a disembodied egocentric point. But that point is no longer special in any way whatsoever, it becomes a point like any other in the volume of my imagined experience. And since there is no longer a special viewpoint, the amodal component of experience becomes completely independent of any view direction, and becomes instead a volumetric representation of spatial data, like the volumetric images used in medical imagery that simply register the location of different anatomical parts as different color or shading in different locations in the volumetric image.

To be clear, I am not claiming that mental imagery or amodal perception as we normally experience them are entirely devoid of the experience of a viewpoint. We can never entirely banish from consciousness the proprioceptive experience of our body where we feel it to exist, or the memory of the experience of our body in its usual location, or the knowledge and memory of our modal experience and its implications for the location of our 'self as a viewer'. What I am saying is that there exists a component of amodal experience that is indeed viewpoint independent, and that component demonstrates that the experience as if viewing from a point is not a necessary and inevitable concomitant to the experience of a spatial structure, but that it is possible in principle to have a structured experience in the absence of an experience of viewing it from a particular viewpoint or perspective. In fact, it is this objective 'God's eye view' aspect of the amodal experience which makes it so useful as a representation of the reality underlying modal or sensory experience. This idea will become clear with a few more thought-experimental manipulations.

The Displaced Self

While viewing the mental image of a tomato, I can picture my head shifted from its usual location to a new location off to the left of the tomato, seen as if in profile view, as shown in Fig. 3.2. I can imagine having full control of my facial expression, the blinking of my eyes, and the tilting of my head in its new displaced location, like the face I see in the mirror when I shave, except that in this case the proprioceptive experience of my body at the original location has been banished, promoting the impression that it is really *me* that is displaced to the new location, not just a duplicate replica or reflection of me. If I feel a pain from a headache or if I cut myself shaving, that pain is also displaced to the new location of my head. To complete the displacement, I should not imagine the near side of my displaced head as a modally perceived surface, as it would appear if viewed from the outside, but rather the exterior of my displaced head should be transparent and invisible, or purely amodal, just as our face is in our normal experience. Likewise, since the displaced self is viewing the tomato from the left, only the left side of the

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tomato should be imagined to appear in modal color, the right side being hidden from my new displaced location to the left. If this mental image is made sufficiently vivid and complete (which is admittedly difficult to do, although clearly possible in principle) then there really is nothing of significance located at my former egocentric point, all of the important functional properties of my perception of me as a viewer have been displaced to the new leftward position. That is where I experience a surrounding body over which I have full control, and that is the direction in which all modal surfaces of the scene are oriented, suggesting a viewer of the experience located at that spot. If we were born with this kind of displaced experience, it would not take very long to learn to recognize that displaced point as the center of our experienced self. I propose that the location of our egocentric self is just as arbitrary as the displaced self.



Fig. 3.2 The displaced self. A thought experiment in which you imagine your self displaced to one side, viewing a tomato a few inches in front of you. Your own face appears only in amodal form, as when it is in its usual location, and the tomato appears in modal form only on the side exposed to the displaced self.

Is there one more residual aspect of this mental image that refuses to shift to the new configuration? What if, instead of a tomato, the object I was viewing in my mental imagination was a cylinder lying on its side. From my original egocentric point we view the cylinder end-on, where it presents a circular aspect to us from that original viewpoint, but from the new displaced location it is seen from the side, thus presenting a rectangular aspect from that direction. Is it not true to say that even with the new displaced viewpoint, our experience of the central object is seen as projecting a circular, rather than a rectangular aspect? If so, then there is something remaining of the experience of viewing from that direction.

But this impression is due only to a failure to form a truly amodal mental image. The purely amodal representation is a volumetric model whose structure appears to us in our experience as a volumetric whole. It is no more true to say that we view a mental image from a point behind our eyes, than to say that we view it from our belly, or from our big toe, which are also parts of our body, and thus parts of our 'self'. This is seen more clearly in the experience of a blind man, or a man in pitch darkness whose structured experience of the world is built up by tactile feel.

When feeling a cylinder suspended in front of him, it is no more true to say that the blind man feels its volumetric form from the near side than the far side. Although it is true that he feels different surfaces from different directions as he explores the cylinder with his palms, the spatial shapes and volumetric structures appear to his experience where they are found in three-dimensional space, they are no more viewed from the location of his head or hand than they are from his knee, or his big toe. The experience is of a volumetric cylindrical form that projects a circular aspect in this direction and a rectangular aspect in that, without need for any kind of viewer in either of those directions to have the experience of those projections. In this kind of representation our former egocentric point is no different from any other point in imagined space, because that space implicitly encodes all viewpoints around it simultaneously, without committing to any one of them over any other.

The Modal Viewpoint

In contrast to the amodal experience, the modal experience is by its nature a surface representation, because a modally experienced surface is opaque to any further modal experience beyond it, making it impossible to experience the solid volume of an opaque object modally. This is not a limitation in principle, one can imagine a modal experience of a solid object including a modal experience of colored volume, all we have to do is imagine an image like the amodal experience of the volumetric object except that it is modal. We come close to the experience of a modally perceived volume when viewing a glass of red wine, whose colored volume is experienced simultaneously and in parallel throughout its liquid volume. It is however an observational fact that we never seem to experience modal volumes behind opaque modal front surfaces, and this property of modal experience as vivid colored surfaces as if painted only on the near sides of opaque objects is the property that gives modal perception the illusion of being viewed from a point. This principle is demonstrated in Fig. 3.3, where all of the perceived spheres in the volumetric representation present modal surfaces only in the directions that are exposed to a central egocentric point, implying that those spheres are being viewed from that central perspective, even though there is no viewer as such at that location. That one-sided aspect of modal perception is the primary factor responsible for visual experience giving the impression of being viewed from a point. But why should modal experience have this one-sided nature?

The sense of viewing from a point is also seen in a radar image of a scene. A radar dish gets strong radar reflections back only from surfaces that are exposed to the central radar dish, as seen in Fig. 3.4. The visual impression of the radar image is similar to a birds-eye view of a dark landscape illuminated from a point light source at the center. All reflecting surfaces on the radar image point back towards the center of the screen, implying that the scene on the radar screen is being viewed, or at least illuminated from that central point. Note how as in visual experience, foreground objects in the radar image occlude more distant background objects in a manner exactly analogous to the amodal 'shadows' cast by foreground objects on more distant modal surfaces that they occlude, as seen in Fig. 3.4. For example the nearer shoreline to the upper-left of the center of the scope (bearing about 270 - 330 on the scope) blocks radar returns from the

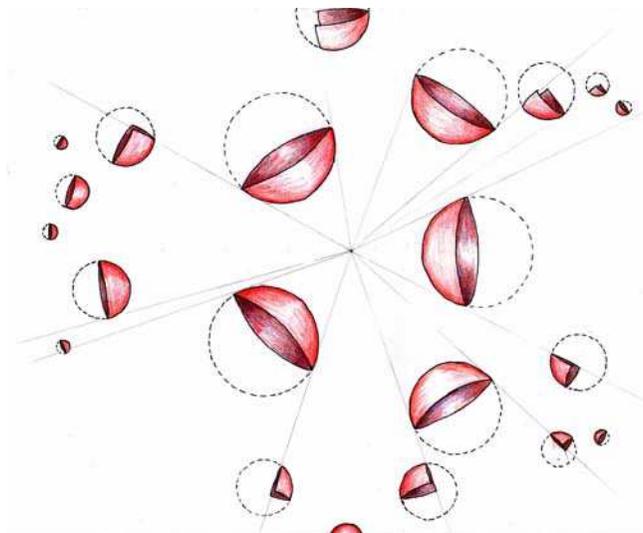


Fig. 3.3 A number of spheres floating in space, expressed as modal front surfaces and amodal volumes. If all of the modal surfaces point back towards a single viewpoint, that configuration of modal surfaces itself implies the presence of that viewpoint.

landscape beyond, which suggests that this shoreline must be higher ground, or perhaps tall buildings of a city, that block the view to the landscape beyond. Returns are however received from farther away along the channel both below (bearing about 190 - 250) and above (bearing 360, straight up), due to the clear line of sight through the channel. The long range returns from the right side of the scope (bearing 20 - 180) suggest that the landscape in that direction must be fairly flat, allowing sight lines out toward the horizon. In other words the highlighted regions denote objects that would be visible on a clear day from the location of the radar transceiver. A narrow dark 'shadow' is observed stretching from the center of the scope, downwards (bearing 173 degrees on the scope) this time stretching out all the way from the center to the rim of the scope. This 'shadow' is therefore due to an occluding object very close to the radar dish, perhaps the smoke stack of the ship from which this radar image was recorded. This is analogous to the missing sector of the visual world behind us occluded by our own head.

Is the special viewpoint apparent in the radar image real or illusory? It is real in the external world, where radar signals are transmitted from a particular location, and therefore the echoes from those signals replicate that veridical pattern of central illumination. In the internal world of the radar scope on the other hand there is nothing special going on at the center of the glass screen, except for the fact that that point happens to represent the position of the radar dish itself in the external world. But the center of the scope does not "view" the rest of the pattern on the screen, the center of the scope is merely part of the space represented by the screen, and is expressed in that representation in the same manner as every other part of the represented space. In exactly analogous manner, we observe a special point in phenomenal space towards which all modal surfaces in the world are oriented, and that is a veridical manifestation of the true external situation where the surrounding world is indeed viewed from a particular viewpoint by our eyes. But in the phenomenal world, the world of our visual experience, there is nothing special at all about the center of that space. The egocentric point is not



Fig. 3.4 Radar scope image taken from a ship, located at the center of the scope, in a harbor (dark patch through the center) surrounded by land (bright returns). Radar reflections are received only from objects exposed to the central radar dish. Parts of the image occluded by nearer objects show no radar reflections. The thin vertical shadow extending downward from the center is probably due to some obstacle, like the ship's own smoke stack, blocking the radar signal in that direction.

the viewer of the rest of the scene around it, but rather the egocentric point is the point in perceived space that represents the perceived location of the ego, which serves as the origin of the spherically-symmetric world of perceptual experience.

The illusion of viewing our experience from an egocentric point was already dispelled by the Buddhist realization that the world of experience that appears to surround us is actually part and parcel of our own self. Despite appearances to the contrary, we do not view the dome of the blue sky 'out there' *from* this central location 'in here', but rather the experience of the sky is a spatial structure that appears in our experience at the location where we experience it to be located. It simply exists out there as part of our experience. The only reason why it disappears from its experienced location when we lower our eyelids like a curtain between the blue sky and our egocentric point, is not because the egocentric point is looking outward at the perceived sky through the windows of our eyes, as it appears naively, but because the phenomenal experience of vision reflects the causal structure of the real external situation, where our physical eyes do indeed view the physical world through our physical eyes. Significantly, mental images, dreams, and hallucinations can occur with eyes closed, and when they do so, they appear in the volumetric space beyond the closed lids unhindered by the blockage posed by those lids. So the illusion of viewing our experience from a particular point is both real and illusory; it is real in the external world of reality of which our experience is an imperfect replica, but it is illusory in the internal representation itself where experience is painted or plotted at the location where the corresponding external objects and surfaces are perceived to be located.

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We see that the self is a far more complex entity than it may first appear. The perceived self is an illusion, and that illusion is composed of several components. The first is the directionality of modal experience that always 'points back' to an egocentric point. This reverse tracing of modal surfaces is itself what defines the egocentric point, thus in the absence of modal experience there is no longer a defined egocentric point. Another component of the illusion is the proprioceptive experience of one's own body perceived to surround the egocentric point. Many sensory modalities contribute to the solid spatial experience of one's own body, the most direct of which is the proprioceptive sense, the vivid presence of a body in a distinct posture or configuration. This experience is so primal, it is usually the last one to blink out in states of intoxication or partial consciousness. There is one more component to the illusion of viewing our experience from a point, and that is the phenomenon of perspective, that issue will be discussed in chapter 6 as one of the prominent distortions of perceptual experience. But first let us address the epistemological implications of the observed properties of experience and the properties of our observed self, or what they can tell us about that which we can know with any certainty.

Chapter 4

Epistemological Considerations

Realism versus Idealism

The history of philosophy has seen an endless back and forth between two opposing paradigms of epistemology, *realism* versus *idealism*. Realism, also known as *naive realism* or *direct realism*, is the natural intuitive understanding of experience that we accept without question from the earliest days of childhood, that the world we see around us in conscious experience is the real world itself. Our belief in the reality of our perceived world is continually reaffirmed by the stability and permanence of objects we perceive in the world. But there are deep logical problems with the direct realist view that cannot be ignored if we are ever to understand the true nature of perceptual processing.

The first chink in the armor of naive realism was revealed by Descartes. As an anatomist, Descartes observed that the brain is connected to sensory organs such as the eye by way of nervous pathways like the optic nerve. Since Kepler had already demonstrated that the eye works like a camera, using the lens to focus an image on the retina, the obvious conclusion was that the eye transmits the image from the retina up the optic nerve to the brain. When viewed from the outside, this explanation seems completely consistent and un-problematic. The problem arises when considering conscious experience phenomenologically, i.e. as experienced from the 'inside'. If Descartes' conclusion were correct, then the world we see around us cannot be the real world itself, but must be the image sent by the eye to the brain. But even Descartes could not accept the obvious implications of his neuroanatomical observations. Descartes was rescued from this profound philosophical quandary by his belief in God and in the immaterial soul. He proposed that as the soul receives the sensory signals from the optic nerve, it instantaneously becomes aware of the external objects which are the ultimate source of the sensory signals. To follow the causal chain of vision from Descartes' viewpoint, light from the world enters the eye, where it is transduced to an electrochemical signal which is sent from the eye to the brain which is the seat of the soul. As the soul receives this electrochemical signal, awareness jumps back out of the head again to make direct contact with the external world. Literally anything is possible as long as one maintains a belief in supernatural entities such as the immaterial soul. Nevertheless, this aspect of Descartes theory was immediately recognized as being problematic, because it leaves the role of the sensory organs in a peculiar kind of limbo. If the soul can see the world directly, then why does it need the eye and optic nerve at all? If, on the other hand, it cannot see the world directly but only through the mediation of the eye and optic nerve, then why would we not experience the image sent to the brain from the eye, instead of the external world as it appears naively? In order to rationalize this bizarre twist of logic, Descartes endowed the magical soul with supernatural properties that disqualify this concept as a scientific hypothesis.

But whatever the problems with Descartes' explanation as a scientific theory of perception, it does have the powerful advantage of being an accurate account of

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the *experience* of visual consciousness. Descartes was an astute observer of phenomenal experience, because it does indeed appear as if we view the world directly, out where it lies beyond our skull rather than as a picture inside our head, and yet it is also clear that visual experience is dependent on the eye, because the visual world goes dark whenever we close our eyes. The bizarre contradiction built into Descartes' theory of vision is a bizarre contradiction directly observable in visual experience itself, and that explains why belief in an immaterial soul remains so popular as a belief system among so many different cultures.

Subsequent explanations of the epistemological question were equally confused and self-contradictory. Malebranche (1674) proposed that sensory qualities, such as color, taste, and sounds, are not part of the external object but are internal phenomenal properties. The mind "becomes colored" when we view a colored object, although the object on which that color is perceived is not an internal replica, but is seen directly in the world where it lies. A perceived object therefore is partially an internal and partially an external phenomenon, with shape and volume existing out in the external world itself, but the color clothing the object being something in the mind. Again, as absurd as this theory might sound, it is a very good description of our phenomenal experience, and relates to the dichotomy between modal and amodal experience.

John Locke took the implications of Descartes' neuroanatomical observation to their obvious conclusion, and stated that the world we see around us is the product of the brain, based on the sensory input provided by the eye. Human knowledge therefore is necessarily confined to a knowledge of 'ideas', which in Locke's usage included sensations and perceptions. We cannot in principle have direct awareness of things out in the world beyond the mind. This is the *representationalist* thesis, that our experience is a re-presentation, or internal replica of something more remote and external.

Varieties of Idealism

Berkeley objected to the representationalist view that if our experience is really shut in to the confines of our own brain, then there is no way in principle for us to know anything at all about the external world. Berkeley concluded therefore that mind is all that exists, (or all that can be reasonably concluded to exist) which is the philosophy of *idealism*. There is a subtle but critical distinction between idealism and *solipsism*, the idea that our experience in this world is a kind of dream or hallucination that is going on in *my* mind, and that nothing else exists beyond my mind. Only a mad man can possibly believe something so absurd, although logically speaking this alternative can never be disproved. But a solipsist should not care about proving anything to anybody else, because in his view other minds don't exist as independent entities, but only as figments of his own mind, so it does not matter what those other minds do or do not believe. Idealism differs from solipsism in one of two critical ways. In Berkeley's view other minds do exist as independent entities, and we share an objective external environment with those other minds. That external world is what connects and synchronizes the experiences in different individual minds. But the external world that is common to our individual experiences is not a physical world, it too is a world of mind, although it is the mind of God, and thus still objectively real and external to our

selves.

Idealism of this sort comes in different flavors, depending on one's conception of God. If God is thought of as an intelligent personality with moral rules and higher objectives for this world of His creation, then we get the traditional spiritual belief in God as the intelligent controller of the universe, and our role is to recognize His majesty and obey His laws. If on the other hand God is thought of as the universe itself with all its laws, the kind of God that Einstein believed in, then God has no real personhood as such, and therefore He cannot possibly care about our individual fates and fortunes, but just exists as the All in which we find ourselves embedded. By this view the laws of God are identically equal to the laws of physics. With this kind of God, idealism reduces to the belief that there is only one kind of 'stuff' of which the universe is composed, and that 'stuff' is one and the same substance as the 'substance' of our own mind.

There is another somewhat different form of idealism whereby the world external to our minds is acknowledged to exist as an objective independent entity, but that there is nothing whatsoever that we can possibly know about its true nature, and that therefore it is meaningless to even discuss that world or any of its properties beyond the bare fact that it exists. To some extent this is also undeniably true. Once we abandon the naive notion that we can see the world and its true nature directly in perception, and we acknowledge that all we can know is the contents of our own mind, that in turn suggests that the world beyond our mind is fundamentally un-knowable. This is the kind of idealism found in most Buddhist philosophies. This was also the principal thesis of Immanuel Kant, who identified the two worlds of reality as the internal *phenomenal* world, and the external *noumenal* world. Kant declared that the only way we can know anything about the noumenal world is by its effects on the phenomenal world.

Is External Reality Knowable?

There are two counter-arguments to the un-knowability of the external world. First of all, one of the most significant (to us) entities that exist in the noumenal world are other minds, which are similar in principle to our own. Since we know our own mind (as well as we can know anything), then we also know about other minds, at least to the extent that they are similar to our own. We all experience a three-dimensional world of color and light, mysteriously embedded in a fourth dimension of time. Whether the noumenal world is also confined to three spatial dimensions and time, we cannot ever know with any real certainty. But the dimensions of other people's experiences are in fact knowable by us at least on the assumption that they are similar to those of our own mind, and those other minds are part of the noumenal world, having their own existence independent of our own phenomenal world. Therefore not all of the noumenal world is completely un-knowable, we know of other islands of color and light in the consciousness of other people, floating in the inky sea of black nothingness which is all we can know of the rest of the world.

Secondly, in every other sphere of human knowledge, from business and finance, engineering and construction, military combat, transportation, politics, and industry, in all other realms of human endeavor the realist assumption that the phenomenal world is a veridical replica of the objective noumenal world is so

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successful and accurate as a working hypothesis, that surely there must be some essential aspects of the noumenal world that are accurately captured in the properties of the phenomenal world. In fact, it would be impossible to get anything done in this world without beginning with the assumption that the world is as it appears to be, having three spatial dimensions and time, and, just about everything of any value that has ever been accomplished by man, has been accomplished on the basis of that realist premise.

Idealism held sway in philosophical circles throughout the centuries following Kant, as professional philosophers almost universally denied the possibility of any knowledge whatsoever of external reality. But this prominent violation of common sense eventually triggered a backlash by the American realist, or *neo-realist* philosophers, (Holt et al., 1912) who pointed out what is so plainly manifest to the common man, that the world *is* knowable through our experience of it. The neo-realists claimed that even the secondary qualities of experience such as color, smell, and taste, are objective properties of the external objects themselves, and are observed directly out in the external world, superimposed on the external objects to which they belong. So the epistemological debate had gone full circle, back to the naive realism familiar to the common man. But a naive realist philosophy cannot survive long against the obvious objections, and once again the same progression was replayed as one by one, ever more of the properties of the external world of perception were attributed instead to processes internal to the brain and body.

A more sophisticated epistemology was offered by the *critical realist* movement (Sellars 1916, Russell 1921, Broad 1925, Drake *et al.* 1920) who, like Malebranche, claimed that some aspects of the perceived object, such as its color, are in fact subjective and inhere in the mind, while other aspects, such as its shape, are properties of the objects themselves, and are observed directly out in the world on the objects themselves. But this explanation led to the same kind of confusions as its earlier incarnation under Malebranche. For the perceived shape and perceived color appear superimposed in the same apparently external space, although one is supposedly a property of the mind which is presumably in the brain, whereas the other is a property of the external world which is outside the brain.

There seems to be a profound paradox inherent in the question of the knowability of external reality, that it is both knowable, as is plainly manifest to the common man, and at the same time it is fundamentally un-knowable, as explained by Kant. A compelling case can be made for both of these opposing views, and both views can also be convincingly refuted. The truth must lie somewhere in between; that the external world is both knowable and un-knowable.

The Paradox of Time

The nature of the knowability and un-knowability of the noumenal world is most easily understood by taking a specific example. Consider our perception of time. It has long been recognized that physical time is very different than the time of our experience. In phenomenal time there is a past, present, and future, and we have the experience of our self as flowing through time, from past, through present, towards the future, although at the same time we are also permanently fixed in the

present moment. It is always “now”. In physics there is no such distinction, any instant of time can be set arbitrarily as the origin $t = 0$, but in fact that particular moment in time is no different in principle than any other moment in past or future. In physics, time is a dimension, much like space, and in modern physics space and time are combined in the notion of spacetime. Let us suppose, hypothetically speaking, that physics is right, and that there is no flow of time, every moment is like every other. We can imagine a series of events as a length of a movie strip, whose individual frames can be viewed in succession through a movie projector, but that the succession is actually illusory, and that real time underlying the illusion is the movie strip itself, as if laid out on a table, with past towards the left and future towards the right. This results in a deterministic view of reality in which the final outcome is pre-determined, and there is no longer anything like ‘free will’ as we normally conceive it. And yet the characters recorded in the movie strip behave exactly as if they do have free will. At one point one character decides to take this action instead of that, and every time we go back to that point in the movie we see that same character exercising his free will again by making the same choice. The free choice is frozen in time when viewed externally, outside of time, but to the character there is nevertheless a free choice that he experiences as occurring at that point in time, as when viewing the film strip in sequence through a projector. Every frame in the movie sequence is perceived as the present moment, framed between leftward past and rightward future events, and yet as in physics, this perception is illusory, because in fact every instant is equal to every other, the past and future directions being merely relative.

A persistent believer in free will might object that there are potential branch points along the stream of time, at which one choice would result in one sequence of consequences, while a different choice would result in a completely different sequence. In our movie strip analogy this would appear as forks, or branch points where, like a train at a fork in the tracks, events choose to follow one path or the other. Free will, in this analogy, is the switch that determines the final path only at the time that the train arrives at that point. But when the train actually gets to a fork, it does actually take one path instead of the other, whether it does so by ‘free will’ or by random chance. And if in the end the train does choose one path over another, then the other paths do not really exist in the time line of *real* events that actually occur, but only as *potential* events that never actually occurred, and therefore they do not really exist in the final time line of reality, which again reverts to a single linear sequence. Alternatively, one might argue that the train splits at each fork, and in some sense takes both paths simultaneously. In that case our memory is of only one path from our past, every branch point of which leads to our present moment of existence, but the future of our own fate remains undetermined until we reach the future branchpoints. But if both alternatives are actually taken as real events that actually occur, then there must be other selves on all of the other parallel branches of the time line that experience themselves as having taken all of those different paths. The linear movie strip has been transformed into a branching tree-like pattern of parallel time lines, all of which are equally real, and free will is again frozen to a meaningless static concept.

As in our perception of external space, our perception of time embodies a fundamental paradox that reveals a profound limitation in our ability to ever get to the real essence of things. The paradox of time was already recognized by the

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ancient Greeks, as embodied in their legend of the oracle of Delphi. If the oracle reliably predicts the future, then it is pointless to try to resist that inevitable outcome, because if that were possible, then the oracle would have predicted the different outcome in the first place. By extension, if there is an eventual outcome, whether it is predicted by an oracle or not, then it is pointless to try to fight that outcome, we might just as well go with the flow and see where it takes us. Immanuel Kant identified a number of these self-contradictory paradoxes inherent in our conceptions of space and time and causality, which he called the *antinomies*. Kant argued that these paradoxes cannot be inherent in the real nature of things. The universe follows its own inscrutable logic, even if that logic remains beyond the scope of human comprehension, so the antinomies provide evidence not of contradictions in the true nature of things, but rather they reveal paradoxical contradictions in our own perception and understanding of things.

If time were a frozen dimension as proposed above, that would do considerable violence to our everyday notions of causality, and thereby radically alter our view of all causal explanations. For example the first, most basic feature of causality is that matter that exists has a tendency to continue to exist. (unless it happens to decay into energy, which then also continues to exist) In frozen space-time, this means that particles of matter no longer appear as points moving through empty space, but they become long spaghetti strands extending continuously through the time dimension. The causal property of persistence has thereby been transformed into a geometrical or structural feature in frozen spacetime, something like the logic of static structures, whereby a block will never be found hanging unsupported in space, but must always be supported by other blocks that rest on still other blocks all the way down to the supporting ground. Likewise, the explanation for the logic of evolution is dramatically altered when viewed in frozen spacetime. It can no longer be said that if an organism adapts to its environment it will continue to propagate, otherwise it will go extinct. Instead, we would have to say that there are many parallel and branching threads of life from the first living thing stretching on toward the future, together with countless side-branches of life that peter out because they don't stretch forward in time toward the future, but break up into disorganized lifeless matter. The conventional causal explanation becomes as tautological in frozen spacetime as saying that the only branches of a tree that grow to great heights are those that grow upward, otherwise they never grow to great heights. A causal law has been transformed into a structural feature of the time-line of life.

I do not propose that the static formulation of frozen space-time is necessarily more correct or veridical than the conventional flowing time explanation, but rather that there is no way in principle for us to comprehend something as fundamental as time, and the frozen time explanation may well be just as far from the 'truth' as the conventional flowing time explanation. The point is that there can be alternative explanations of reality that are as profoundly different in their assumptions and their manner of explaining that reality as are the flowing and frozen time explanations, and yet they are also in some sense equivalent, because the structural laws of the frozen time explanation correspond exactly to the causal law of the flowing time explanation, although expressed in a completely different form. So it may be that the realist explanation of the world in terms of flowing time and causality is both an accurate reflection of the causal laws of the

noumenal world, while at the same time being as fundamentally different and thus 'wrong' in its expression of those laws as the difference between the flowing-time and the frozen-time explanations of reality. Thus the realist and the idealist are both right, our perception of the dimensions of reality are both an accurate reflection of the world as it really is, as must necessarily be the case for perception to be evolutionarily adaptive, and at the same time there is truly nothing we can know about the true nature of the noumenal world as it really is, it may be as different from our phenomenal experience as is the frozen spacetime world to the flowing-time causal world.

In answer to the idealist's objection therefore that there is nothing we can possibly know about the external world, we must admit that this is true, and yet the very best model of that unknowable reality available for human understanding is the realist interpretation, that the noumenal world has the familiar three spatial dimensions and time, with the conventional view of causality. Whatever its ultimate un-knowability might be, this view is as good a working hypothesis as any that can be fathomed by the mind of man. So in the absence of a better alternative, that model is the very closest we can come to knowing an external world which is in principle unknowable.

The paradoxical cracks or seams in our world of experience offer solid clues to the disparity between that experience and the ultimate reality that it attempts to replicate in effigy, in the same way that the discrete phosphor dots on our television screen, and the flickering shadows seen when we wave our hand in front of it, reveal the television picture to be an indirect replica of the world it depicts, rather than a direct window onto that world. Kant (1781/1993 pp. 317-340, A424/B352 - A460/B488) identified a number of additional antinomies, some of which were discussed in chapter 1. The world must have a beginning in time because if it has always existed, then up to any given moment in time an eternity must have elapsed. But an eternity can never have an end, so it is impossible for an eternity to ever have elapsed. Alternatively, if the world did begin at a certain point in time, then there must have been an empty time before that point in which the world did not exist. But in an empty time nothing can begin to happen because no part of such a time contains a distinctive condition of being in preference to that of non-being, whether the supposed thing originated by itself, or by means of some other cause. Similarly, the world cannot be infinite in spatial extent because the world as a whole is the sum of its parts, but the finite parts of an infinite entity can never be fully tallied; they are, by definition, endless in number. However, neither can the world be finite in extent, because if the world were bounded by nothing, then there are no boundaries to the world, which is to say that it is unbounded, and thus infinite. Again, these antinomies do not highlight the inconsistencies in the external world itself, but merely the limitations of our conceptualizations of that world.

Representationalism

Neither realism nor idealism can fully account for our direct and indirect knowledge of reality. Idealism accounts well for the phenomenal world, and the unknowable nature of whatever lies beyond it, while realism accounts well for the nature of external reality, as well as the human mind can grasp something so

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fundamentally un-knowable. But there is a third alternative that takes account of both of those aspects of reality equally, and that is the theory of *representationalism*, as introduced by Locke, and clearly elaborated by Immanuel Kant. Kant proclaimed that there are two worlds of reality, the internal phenomenal world, and the external noumenal world. The only way we can know the noumenal world is by its effects on the phenomenal world. The dimensions of conscious experience, the three spatial dimensions and time, are properties of the internal phenomenal world, and have no objective reality in and of themselves, except as a representation of something external. We have no idea whether the external world has three dimensions and time; for all we know it may have a multitude of additional dimensions as suggested by some modern cosmological theories, and they may be organized in a manner that bears no similarity to their phenomenal counterparts, like the relation between phenomenal flowing time model and its noumenal frozen time counterpart. Unlike idealism, representationalism recognizes the reality of a world beyond mind as the most reasonable explanation for the observed properties of the phenomenal world. And although that noumenal world is un-knowable, as suggested by idealism, to a first approximation sufficient for practical action in the world we can consider the external world to be of three spatial dimensions and time, as it appears to us in experience. Representationalism therefore offers the most coherent view of reality that is consistent with both idealism and realism, and most importantly, it is fully consistent with our scientific understanding of the world. The theory of representationalism is also sometimes called *epistemological dualism*, because it suggests a fundamental dualism in our epistemology, with a phenomenal world that is known to us directly and immediately, and a noumenal world that is known only indirectly by its effects on the phenomenal world. (As a technical aside, Kant was paradoxically both a representationalist and an idealist. Like Berkeley he supposed the noumenal world to be the mind of God, which is the idealist aspect of Kant's philosophy, but that the configuration of the phenomenal world is an imperfect and finite reflection of that infinite unknowable external reality, the representationalist aspect of Kant's philosophy. The epistemological debate therefore did not really begin in earnest until the French materialist philosophers had finally banished God and spirits from our explanations of reality.)

The Buddhist insight that everything that we experience as a surrounding world is nothing other than our own mind and self, must therefore be modified by the realism of modern science, that mind is the functioning of the physical brain, and that therefore mind is necessarily contained within the physical brain. In other words, beyond the world of experience is an unimaginably immense external world of which the images in our mind are merely an imperfect replica. The world beyond mind is fundamentally un-knowable, and yet at the same time it is also knowable through our internal replica of it. Although mind is all that we can know directly, we can have knowledge of the world beyond mind through mind, just as we can see the world beyond our television screen through the image glowing on its surface. Mind is a re-presentation of external reality, so although the substance of mind is entirely internal, the configuration of that experience, the shapes and colors that we see in normal perception are representative of objects and surfaces beyond the mind.

Chapter 5

Ontological Considerations

Monism versus Dualism

The theory of representationalism reveals a dualist epistemology, that our world of knowledge is cloven into two fundamentally different parts: that which we can know directly, which is our own mind, and that which we can know only indirectly, which is the world beyond our mind. We will never come to grips with the true nature of the world and our place in it without first acknowledging this profound dualism in our sources of knowledge. This schism in turn raises a deeper question, which is whether the dualism is restricted to our sources of knowledge of the world, or whether the epistemological dualism is symptomatic of a more profound ontological dualism. That is the question whether mind and matter are made of essentially the same, or fundamentally different 'substance'. Is mind composed of nothing other than the ordinary matter of the physical universe? Or is mind, as it appears in raw experience, ontologically distinct from the physical brain that sustains it? This is the choice between *monism* as opposed to *dualism* of mind and matter, an ontological as opposed to epistemological dualism.

In scientific theory the preference is always for a monistic ontology, i.e. that there is a single set of laws that account for all of the apparent dichotomies in the observed world. Historically, science has already dispelled a number of apparent dualisms observed in our world. Science has discovered, for example, that the earth below and the heavens above are not made of different substance or follow different laws, as was proposed by Plato, but the sun and the planets are composed of the same material substance as the earth. Spectroscopy has revealed that even distant stars are composed of the same elements as our own sun, although in different proportions. The dualism between living and non-living matter has also been dispelled by modern biology, there is no 'vital essence' that inheres exclusively in living things, as proposed by the *vitalists* at the turn of the last century, but in fact life is nothing other than a more complex organization of the same material substance as inanimate matter. Even matter and energy have been shown to be transformable from one to another. Modern cosmological theories continue to strive towards a grand unified theory that will hopefully explain everything in the universe with a single set of laws. Dichotomies are necessary in science where they reflect real dichotomies in the world, such as the distinction between positive and negative electrical charge, or male and female, plant and animal, living and non-living, and so forth. But whenever possible, science attempts to eliminate fundamental dichotomies, or at least to discover an underlying unity that connects them.

It was a quest for monistic unity of explanation that motivated the idealism of Berkeley and Kant, and that leads realists and pure physicalists to deny the existence of a separate and distinct 'mind stuff' of which experience is composed. Is this striving for unity justified? Are mind and matter composed of the same or of distinct kinds of substance? In the absence of compelling evidence to the contrary, the most parsimonious explanation is the monistic one, that mind is

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nothing other than the functioning of the physical brain. But the evidence for a profound duality between mind and matter is pretty compelling. In fact, the experiential component of mind is knowledge that is arrived at by such a different route compared to our knowledge of external reality, that it seems impossible in principle to ever account for the experiential component of consciousness with scientific models in the same way that we can account for everything else in the observed universe.

The Hard Problem of Consciousness

David Chalmers (1995) highlighted this profound dichotomy with his distinction between the 'easy' and the 'hard' problems of consciousness. The so-called 'easy' problems of consciousness are themselves about as challenging as any problem that science has encountered, and are thus only 'easy' relative to the one remaining 'hard' problem of consciousness, which is hard because it appears to involve a fundamental paradox. The 'easy' problems concern the functional aspects of conscious experience: the ability to discriminate, categorize, and respond to environmental stimuli; the integration of sensory information by a cognitive system; the ability of a system to access its own internal states, and so forth. These are the kinds of problems that can be addressed by computational models that perform the functionality in question: discriminating between stimuli, integrating information from different sensors, accessing the values of its own internal states, etc. In other words, these are the functional aspects of experience as it is observed from the outside, they concern the function of consciousness, not its ontology.

The 'hard' problem of consciousness is the problem of *experience*, and why we have it when our brain performs certain computational tasks. Why is it that when our perceptual systems engage in visual or auditory processing that we have visual or auditory experiences? It is widely agreed that experience arises from a physical basis, but we have no good explanation of why and how it arises. Why should physical processing give rise to a rich inner life? It seems objectively unreasonable that it should, and yet it is an observational fact that it does. It seems as if the experiential component of perceptual processing is in principle beyond scientific scrutiny. Our physical explanations of the brain are complete in themselves without any kind of experience being involved, and it appears to be impossible in principle to devise a scientific explanation of this experiential aspect of perceptual processing, because, as Chalmers observes, everything in physical theory is compatible with the complete absence of consciousness. It is the fundamental unobservability of experience by scientific means that leads many scientists to simply ignore conscious experience as if it had no objective existence in the physical world known to science.

Contents and Qualia

Whether or not experience has a place in scientific theory, we know for an observational fact that experience exists and is therefore real. In fact, epistemologically speaking we can be more certain of the existence of experience than we can of anything else in the world, because the entire edifice of science is merely an elaborate inference based on experience. A science that excludes this

most primary fact of reality is a science that excludes the very pedestal on which it stands, the foundation on which it is built. It turns out however that there is a hard link between the structure of experience and the world known to science, and that link is to be found through information theory.

Philosophers draw a distinction between the contents of consciousness, i.e. that which we are conscious *of*, and the experiential *qualia* by which that content is expressed in experience. For example the longer wavelengths of light are represented in experience by the red *quale*, the raw experience of redness, while the shorter wavelengths are expressed by a blue quale. The experiential aspect of these raw dimensions of experience have nothing whatsoever to do with the physical properties that they represent. Qualia are the very essence of the hard problem of consciousness.

In information theoretic terms, qualia are the *carriers* of the information experienced in perception (Rosenberg, 1999) just as electromagnetic waves are the carriers of radio and television signals. Information is defined independent of the physical medium by which it is carried, whether it be electromagnetic radiation, electrical voltages on a wire, or characters on a printed page, or whatever. However, in every case there must be some physical medium to carry that information, for it is impossible for information to exist without a physical carrier of some kind. A similar principle holds on the subjective side of the mind/brain barrier, where the information encoded in perceptual experience is carried by modulations of some subjective quale, whether it be variations of hue, intensity, saturation, pitch, heat or cold, pleasure or pain, and so on.

This view of qualia as the carriers of the information in conscious experience casts a new light on the concept of primary and secondary qualities of perception. Although all of conscious experience is necessarily 'secondary' in Locke's sense, there are nevertheless certain aspects of conscious experience that are a primary manifestation of the actual configuration of external reality, such as the spatial structures in conscious experience, at least when perception is veridical, that is, non-illusory. Other aspects of phenomenal experience are entirely 'secondary,' such as the qualia for color, pleasure, or pain, in the sense that they represent an arbitrary mapping that has no direct correspondence to external reality. By analogy, the position of a glowing phosphor 'blip' on a radar scope is a 'primary' manifestation of the location of a radar reflecting surface in external space, although expressed in a distorted miniature representation, whereas the green color and fuzzy shape of that blip are entirely secondary qualities of this representation, corresponding to the actual mechanism of the representation, rather than to any property of the external world. This suggests that the 'secondary qualities' of perception are a direct manifestation of the actual mechanism of our own brain, as viewed 'from the inside'. The phenomenal quale of the color red, for example, is not a quality of some ethereal 'mind stuff', but rather it is an observed state of the actual mechanism of the physical brain, used to represent light of longer wavelengths detected in the world.

This insight has a profound impact on the ontology of the representationalist thesis. For the most part perception is indirect; we view the world through the medium of conscious experience. But there is one, and only one external entity that we do experience directly, and that is the representational mechanism itself,

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the inside of our own brain. In the words of Schopenhauer (1966, p. 195):

We shall never get beyond the representation, i.e. the phenomenon. We shall therefore remain at the outside of things; we shall never be able to penetrate into their inner nature, and investigate what they are in themselves... So far I agree with Kant. But now, as the counterpoise to this truth, I have stressed that other truth that we are not merely the *knowing subject*, but that *we ourselves* are also among those realities or entities we require to know, that *we ourselves are the thing-in-itself*. Consequently, a way *from within* stands open to us as to that real inner nature of things to which we cannot penetrate *from without*. It is, so to speak, a subterranean passage, a secret alliance, which, as if by treachery, places us all at once in the fortress that could not be taken by attack from without.

The idea that the qualia of conscious experience are not only states of our subjective mind, but at the same time are identically equal to physical states of our physical brain, is known in philosophical circles as mind-brain *identity theory*. (Russell 1927, Feigl 1958) This theory finally offers a way to fuse the mind/brain dualism revealed by Chalmers' 'hard problem' of consciousness into an ontological monism that provides the final intimate link between mind and brain.

Space and Time are Qualia Too

One of the principal sources of confusion throughout the epistemological debate has been the natural assumption that space and time are properties of the external world rather than of the phenomenal world. That is why Malebranch's experienced colors which are part of the mind and thus internal, were supposed to pervade external structures where they are perceived out in the world. That is why the critical realists acknowledged the subjective nature of color experience, but insisted that the perceived structures on which those colors appeared were perceived out in the world where they lie. The source of this persistent confusion can be traced to the duality in experience whereby objects are perceived as both modal exposed surfaces, and as amodal volumetric objects filling out those surfaces. The naive realist or pure physicalist interpretation of this bimodal experience is that the modal surface is recognized as a raw visual sensation, whereas the amodal volume is normally assumed to be the actual object itself, an external rather than an internal entity. That the perceptual inference of the amodal structure is an act of discovering something that exists out there, as opposed to the construction of something internal within the mind. This however is an illusion, because in fact the space within which colored objects are perceived is also an internal representational dimension.

This concept becomes clear by analogy with the image on a radar scope. A radar signal is actually a temporal signal, a time trace of the echoes of a pulse of radar energy transmitted in one direction. Multiple traces of echoes picked up from different directions are used to 'paint' a radar image on the scope, sweeping the transceiver dish around the horizon while at the same time sweeping the time trace of the returning echo around the circle of the scope in synchrony with the rotating antenna dish. The two-dimensional space of the radar image is a space of the representational mechanism itself, rather than of external space, although that internal space is meaningful only because it accurately reproduces certain aspects of the external world that it replicates in effigy.

In every case perception involves a representation, and a representation has a pre-ordained dimensionality. For example the retina is a representation, and it has two dimensions, so it is impossible for the retina itself to record a three-dimensional image. The cortex is also a representation, but it too is limited, this time to representing three spatial dimensions (and time). Even if there were four-dimensional objects to be found in our world, we would never be able to perceive them as four-dimensional, all we would ever see is the peculiar morphing of a three-dimensional projection of that four-dimensional shape. This is not to deny that the external world also has (at least) three spatial dimensions, as it must to accommodate the representation in our brain. But those dimensions would be completely invisible to us were we not also equipped with a three-dimensional perceptual representation. Kant was right therefore, that the dimensionality of the phenomenal world is a property first and foremost of the representational mechanism of the brain, and only in secondary fashion is it also representative of some of the dimensions of external reality. The spatial extendedness of perceptual experience is therefore a quale, not so different in principle from the color qualia that allow any point in phenomenal space to appear through a range of different possible colors, except that the modulation of spatial experience is a modulation of color and brightness across space rather than color.

Once we recognize the space of our experience as being a space of the representational mechanism in our brain, we can see by direct inspection that that representation is expressed in three spatial dimensions and time. From our observations of the dimensionality of phenomenal space therefore we can conclude that the noumenal world has at least three spatial dimensions, otherwise there would be no room in the representation in our brain to encode the three spatial dimensions of our experience, just as the radar scope requires at least two dimensions of glass and phosphor to accommodate the two-dimensional map of its spatial representation. Through the secret alliance of Schopenhauer's subterranean passageway we can get a peek at a tiny portion of the noumenal world located somewhere in our brain. This tiny portion of external reality is therefore not entirely un-knowable, but can be known through raw experience. The tiny fragment of noumenal reality that is the only portion of objective reality we can ever know directly, presents itself as a world of space, light, and color, a world of sound, sensation, and feeling. If the tiny corner of the noumenal world that is the only external reality we can ever observe directly is a world full of raw sensory experience, then why should we assume sensory experience to be unique to the corner of the world that is our experience?

This modified view of the scope of science turns the whole of our knowledge inside-out. The first and most reliable information we have about the external physical world is that it has (at least) three dimensions, and that it has experiences of color and shape and sound. These can now be acknowledged to be physical properties of the physical world, although our experience is confined to one tiny corner of that world inside our brain. So it is not science, or the external world itself that is so devoid of the qualia of sensory experience, as suggested by the pure physicalist, but rather our amodal conceptualization or abstraction of that raw data of the material world that appears devoid of color and light. These amodal abstractions are a construct of our mind, the raw sensory experience on which those abstractions are based are a direct manifestation of the physical

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reality within our physical brain. This inverted epistemology now places raw sensory experience within the scope of science, not outside of it. It is the first thing that we know with certainty about the true nature of being. Experience is a fundamental property of the material world as we observe it, as Chalmers also concluded, and this places the qualia of experience firmly within the bounds of science, and thus science finally includes the very pedestal upon which it stands.

As a technical aside to pure physicalists, a note about the experience of pure structure. Consider a mental image of a cube of the geometrical variety, that is, devoid of color and substance, expressed entirely in the Euclidean elements of perfect lines that meet at infinitesimal points, and yet vividly visualized before you, for example at a specific location in the world you see around you. Modern philosophers of consciousness generally deny that this kind of pure concept is an experience at all. And yet, how could it not be? It is a spatial structure, and it is experienced, so how could this experience not be an experience? The reason for this common confusion is that the pure physicalist assumes amodal structures to be objective and external structures, as in the case of amodal perception. But a mental image cannot be an external structure, it can only be an internal construct. The very experience of space, therefore, “colored” by the colorless amodal lines and planes that define the imagined cube, are themselves a kind of modality that expresses a modulation of experience. Space and time are qualia too, and so is the invisible amodal state that modulates the experience of space in the amodally perceived structure; it is “painted” in a kind of colorless transparent color that is invisible, but experienced nonetheless as a spatial structure located in a space.

Is Experience Universal?

Once we absorb raw experience into the ontology of the scientific world view, the next question is whether experience is unique to the physical mechanism of the human brain, or of living brains above a certain level of complexity, or is it something more fundamental? Does experience blink out of existence and revert to a dark insensate state as soon as its essential computational functionality is disrupted? Or does experience merely disassemble itself into a more primal disorganized form when living brains die? Although this is a question whose answer can never be determined with absolute certainty, one alternative leads back to a profound dualism between mind and matter, while the other shows the way to a new monism that finally unites the world of mind with the physical matter of which it is composed.

If we accept the materialist view that mind is a physical process taking place in the physical mechanism of the brain, and since we know that mind is conscious, then that already is direct and incontrovertible evidence that a physical process taking place in a physical mechanism can under certain conditions be conscious. Now it is true that the brain is a very special kind of mechanism. But what makes the brain so special is not its substance, for it is made of the ordinary substance of matter and energy. What sets the brain apart from normal matter is its complex organization. The most likely explanation therefore is that what makes our consciousness special is not its substance, but its complex organization. The fundamental “stuff” of which our consciousness is composed, i.e. the basic qualia of color and space, are apparently common with the qualia of children, as far back

as I can remember, although I also remember a less complex organization of my experiences as a child. It is also likely that animals have some kind of conscious qualia on logical grounds, because the information of their perceptual experience cannot exist without some kind of carrier to express that information in their internal picture of the world. Whether the subjective qualia of different species, or even different individuals of our own species, are necessarily the same as ours experientially, is a question that is difficult or maybe impossible in principle to answer definitively. But the simplest, most parsimonious explanation is that our own conscious qualia evolved from those of our animal ancestors, and differ from those earlier forms more in its level of complex organization rather than in its fundamental nature. And that same argument applies equally all the way down the evolutionary chain and beyond.

The natural reluctance that we all feel to extending consciousness to our animal ancestors, and even more so to plants, or to inanimate matter, is a stubborn legacy of our anthropocentric past. But the history of scientific discovery has been characterized by a regular progression of *anthrodecentralization*, demoting humans from the central position in the universe under the personal supervision of God, to lost creatures on the surface of a tiny blip of matter orbiting a very unremarkable star, among countless billions of stars in an unremarkable galaxy amongst countless billions of other galaxies as far as the telescopic eye can see. Modern biology has discovered that there is no vital force in living things, but only a complex organization of the ordinary matter of the universe, following the ordinary laws of that universe. There is no reason on earth why consciousness should not also be considered to be a manifestation of the ordinary matter of the universe following the ordinary laws of that universe, although expressed in a complex organization in the case of the human brain. A claim to the contrary would necessarily fall under the category of an extraordinary claim, which, as Carl Sagan pointed out, would require extraordinary evidence for it to be accepted by reasonable men.

Chalmers' discussion of the hard problem of consciousness brings this issue into stark focus. Chalmers observed that everything in physical theory is consistent with a complete absence of consciousness. It is as if consciousness existed in an orthogonal dimension to that occupied by the world revealed by science. As far as science is concerned, consciousness does not exist as a scientific entity. And yet the existence of conscious experience is the most certain knowledge that we can possibly have. How can this most certain fact of existence be entirely absent from our scientific knowledge of the world? How can science, which is so centrally concerned with the attempt to establish certainty, leave out this most certain of things?

But this pure physicalist view of science ignores the more basic fact that science itself comes to us through experience, and without experience there could be no science. Experience, both of the veridical perceptual sort, and in the form of mental imagery and imagination, are the very foundation of all of science, as they are required to make empirical observations of events in the world, and theoretical models of the hidden processes that underlie those observed events. After all, experience is knowledge, although simple modal experience offers only low level knowledge of colors, volumes, and surfaces. The reason why pure physicalists

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have tended to ignore the experiential aspect of scientific observation is because the very first stage of abstraction on the road to scientific understanding is the abstraction performed by amodal perceptual experience, an experience that is characterized by a prominent paucity of sensory qualia relative to raw modal experience. As long as we confuse the amodal percept with the external object, our view of external reality is of a world devoid of sensory qualia. As soon as we recognize the amodal percept as an internal rather than an external entity, we see that our most direct and reliable observation of the substance of the noumenal world (inside our brain) is painted in the bright colors of sensory qualia. Once we absorb experiential qualia into the ontology of science, and recognize that our mind, a physical process, is painted in the colors of sensory qualia, there would have to be compelling evidence to the contrary to deny the possibility of qualia existing in other matter beyond that of our own brain. In our new inclusive scope of science, it is no longer true that everything in physical theory is compatible with the absence of consciousness, because sensory qualia are themselves an observed property of our own physical brain, as observed through the science of phenomenology, so our science would be incomplete if it did not acknowledge this most fundamental of scientific observations. In fact, science itself would be fundamentally impossible in the absence of the qualia of space and time and color. The new expanded science is built upon a solid foundation whose pedestal is painted in the bright colors of sensory qualia.

The next question is what kind of experience could we possibly imagine for simple animals like lizards and insects? Is it even meaningful to discuss consciousness for creatures simpler than that, for example the multi-celled hydra with its decentralized network nervous system? Or the single-celled amoeba that has no nervous system at all? Does consciousness extend beyond life into inanimate matter and beyond? Or does the meaning of the word evaporate into meaninglessness when it is so broadly applied? First of all, it is important to separate the semantic question from the ontological one. Even if it were true that there is a simple primal kind of consciousness that inheres in all living things and beyond, to even call something so primitive 'consciousness' is indeed to dilute the word into meaninglessness. Chalmers proposes the term *pan-experientialism* to distinguish this kind of primal *proto-consciousness* from the complex and elaborate kind of consciousness observed in human experience. The question therefore is whether something so simple can even be called experience, or whether the term is meaningless in the absence of the complex features that we observe in our experience? I address this question with another thought experiment, travelling up and down the ladder of complexity both in the phenomenal world of experience, and in the physical world known to science, to see if it is possible to establish a correspondence between them.

Jacob's Ladder: A Thought Experiment

Let us begin with visual experience, that appears to us as spatial structures bounded by colored surfaces in a spatial void of finite size surrounding our central self. Can we imagine an experience that is simpler while still remaining an experience? Of course! We can begin by removing the self from the center of our visual world, as in our earlier thought experiment, resulting in a spatially structured experience in the absence of a self 'having' that experience. The structure is

simply aware of its own spatial structure. We can simplify further, for example eliminating the variation in experienced color across the space, resulting in a spatial structure that is painted exclusively one hue, for instance in the blue quale of brighter and darker shades. We can reduce the experience further by reducing its spatial resolution. Instead of the intricately articulated world of our own experience, we can imagine a fuzzy out-of-focus blur in which anything smaller than a coffee cup can no longer be experienced. From an information-theoretic perspective this is no different than reducing the size of the representation, because the structure of experience has no objective size as such, its size is defined in relative terms only, or by its potential information content. The dome of the sky at the outer boundary in this reduced world would appear barely farther than arm's reach away (except that no arms are experienced in this disembodied space). We can reduce the spatial resolution and information content even further, all the way down to a single point of blue experience, encoding essentially one pixel's worth of blue color. The question is not whether this kind of reduced experience is possible for any creature to have, but rather at this point the question is only: if such a reduced experience were possible, would it still qualify as an experience, or at least a proto-experience? The answer is by definition in the affirmative, because the item we began with was a pure experience, so when that experience is reduced to a single point, it remains a point *of* experience, although this experience is so different from our normal conception of that word, that it is more appropriate to call it a proto-experience. I can imagine the experience of a single point of blue, not so different than a tiny piece of my experience of the blue sky, except that that point appears in isolation from the rest of the sky and the rest of the experienced world. I can imagine this primal experience in the complete absence of a sense of self, of memories or aspirations, just blue, right here, right now, as an eternal timeless experience. Leibnitz coined the term *monad* to express this concept of a pinpoint of raw experience. If this experience were reduced any more, it would simply blink out of existence. This is the simplest conceivable form of experience, although similar primal experiences can be imagined of different colors, or painted in different qualia, like the qualia of pain and pleasure, warmth or cold, or musical pitch. Just as we can distinguish different qualia within our globally structured experience, so too can we imagine any one of those qualia in isolation from the rest, not necessarily as a physical possibility in a real organism, but as an entity which, if it *could* exist, would be considered to be an experience, albeit a simple one. In other words, the concept of experience does not require complex articulation, nor a self as an apparent viewer of that experience to be considered an experience.

Now, at the very bottom of the ladder of experienced complexity, we can pose the question: is it possible that a point of matter, an atom say, has anything like this kind of primal point-like experience? The pure physicalist's answer is "of course not! An atom is just an atom, it cannot possibly have any experience!" But now let us ascend back up the ladder again, this time on the insensate side of the boundary of mind and matter. If one atom has no experience, then neither does a molecule composed of atoms. And neither does an organic molecule composed of hundreds or thousands of atoms. Neither does an organic membrane like the cell wall, self-assembled from countless organic molecules, have any sort of experience. And the same argument propagates all the way back up to the top of

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the ladder of complexity to a human brain. The point is, as Chalmers explains, that if we do not endow atoms and molecules of physical matter with that tiny spark of proto-consciousness, then *no amount* of complex structuring of those elemental components could *ever* conjure into existence any kind of larger consciousness from that insensate matter! As Chalmers explained, everything in physical theory is compatible with the absence of consciousness. There is only one thing wrong with that statement, and that is that at the very top of the ladder of complexity we *do* in fact have an experience of colored spatial structures in our own brain, and if the phenomenon of our own conscious experience is totally absent from science, then there is something very fundamental that is missing from our science.

Functionalist Explanations of Consciousness

There have been numerous attempts to account for consciousness in functional terms, defining consciousness as some process or function that the brain performs. For example Crick and Koch (1990; see also Crick 1994) propose that synchronous oscillations in the brain are the physical correlate of conscious experience, because the oscillations seem to be correlated with awareness in certain modalities, and also because synchronous oscillations perform a binding between the information represented in different cortical areas. This theory might eventually lead to a general account of how perceived information is bound and stored in memory, but it could never tell us anything about why the relevant contents are *experienced*. Crick and Koch suggest that these oscillations are the neural *correlates* of experience. But even if this is accepted, the *explanatory* question remains: Why do the oscillations give rise to experience? The only basis for an explanatory connection is the role they play in binding and storage, but the question of why binding and storage should themselves be accompanied by experience is never addressed. Furthermore, if synchronous oscillations in the brain were somehow conscious, then synchronous oscillations in other inanimate systems would also have to possess some primal form of consciousness. Another proposal for the basis of consciousness is Bernard Baars' (1988) global workspace theory of consciousness. According to this theory, the contents of consciousness are contained in a *global workspace*, a central processor used to mediate communication between a host of specialized nonconscious processors. Baars uses this model to address many aspects of human cognition, and to explain a number of contrasts between conscious and unconscious cognitive functioning. Ultimately, however, it is a theory of *cognitive accessibility*, explaining how it is that certain information contents are widely accessible within a system, as well as a theory of informational integration and reportability. The theory shows promise as a theory of the global availability of sensory information, but it cannot in principle address the more fundamental question of why globally accessible information should suddenly be conscious of itself. Chalmers observes that almost all work taking a cognitive or neuroscientific approach to consciousness in recent years could be subjected to a similar critique. The "Neural Darwinism" model of Edelman (1989), for instance, addresses questions about perceptual awareness and the self-concept, but says nothing about why there should also be experience. The "multiple drafts" model of Dennett (1991) is largely directed at explaining the reportability of certain mental contents. The "intermediate level" theory of Jackendoff (1987) provides an account of some computational

processes that underlie consciousness, but Jackendoff stresses that the question of how these “project” into conscious experience remains mysterious. At the end of the day, the same criticism applies to *any* purely physical account of consciousness. For any physical process we specify there will be an unanswered question: Why should this process give rise to experience?

What is missing from physical theory is not a function or a mechanism, but something more fundamental. We need to add something to the ontology of science to account for the otherwise unaccountable phenomenon of conscious experience. For example we could propose that a single atom has a basic primal consciousness. Nothing elaborate, but rather an experience as simple as the atom itself; something like the pinpoint monad of blue experience described above. If matter, even at this primal level, were to possess a tiny spark of experience as a necessary part of its very essence, then it would no longer be so implausible to assume that a molecule made up of multiple atoms should possess an experience that is slightly more complex than that of an atom. Still mind-numbingly simple compared to our own structured experience, but as much more complex than the monad as is the molecule compared to the atom. Ascending the ladder of complexity through organic membranes, simple creatures, and animal brains, we arrive again at the top of the ladder at the human brain, whose conscious experience of itself is no longer profoundly mysterious. This is the only alternative that eliminates the profound dualism in the ontology of mind and brain, and thus provides a ‘grand unified theory’ of mind and brain, both under the umbrella of scientific knowledge. It is an observational fact that consciousness exists at least in the human brain, and this observation is more certain and reliable than any other observation made by science. The time has come to take full account of Darwin’s theory of evolution and to finally recognize that we are not external observers of the physical universe, we ourselves are part of that universe, and our experience is a tiny fragment of the experience of the larger universe around us, although expressed in a very much more complex form in the human brain. This way of describing consciousness is the only true monism, that really equates mind with the functioning of physical matter, without recourse to nomological danglers and spiritual mumbo-jumbo. Otherwise consciousness must forever remain as many suppose it to be, a profound mystery forever beyond human comprehension, and science must remain forever incapable of explaining that which is of the greatest significance to us as sentient beings.

Parts and wholes

There is one more piece of the puzzle required to complete our pan-experientialist picture of the universe, and that is the mereological question of how the parts relate to the whole. In my consciousness I experience no trace whatsoever of the component atoms or molecules of my brain; nor do I experience my own neurons, or cortical structures of my brain. In fact, there are large portions of my ‘unconscious mind’ of which I am not directly aware. If all of the matter of which I am composed has a primal proto-consciousness, then why is a large portion of that experience inaccessible to my familiar global narrative consciousness? The answer to this question can be found by expanding on Rosenberg’s hypothesis (2002) that consciousness is a direct manifestation of forces and energy, or energetic wrinkles in space-time, or what Rosenberg calls manifestations of

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causality in the physical world.

Let us consider by comparison to human mental function the functioning of an autopilot in control of an airplane in flight. Like the human brain, the autopilot receives input from a variety of sensors connected to altimeters, gyroscopes, and 'proprioceptive' sensors that record the current deflection of each of the various control surfaces of the airplane. If the human mind is conscious, then this autopilot should also have some kind of primal consciousness. (To minimize cumbersome verbiage I will leave off the 'proto-' prefix where its application is obvious) But is the autopilot conscious of every component of its own structure? If we associate consciousness with causal connection, then the answer is no. The autopilot is carefully insulated from irrelevant signals and extraneous noise. The wires of its electrical functions, and the pipes and hoses of its hydraulic and pneumatic functions are carefully sealed from external influences so as to respond only to the electrical voltages or hydraulic pressures which are directly relevant to its own computational function. The autopilot does not feel the air flowing over the control surfaces of the airplane, but only the position of the control rods or electrical signals that inform it of the position of those surfaces. Although the autopilot is sensitive to the orientation of its directional gyro, it does not feel the spinning of the internal rotor of that gyro, any more than a pilot flying by reference to a directional gyro on the instrument panel feels the internal rotation of the gyro on its bearings, but only the global rotation of the gyro as a whole that indicates the current heading of the airplane. Now the gyro itself has its own component causal structures that relate to each other in specific ways. The spinning gyro rotor feels centrifugal force trying to pull it apart against the cohesion of the steel of which it is milled, and the rotor also feels gyroscope torque effects which are the forces that enable its direction-sensing function. But the gyro rotor does not feel the individual rotations of the multiple ball bearings that make its own low-friction rotation possible. It does feel the collective action of all of the ball bearings jointly, and the forces they exert to confine the gyro's rotation to the locus allowed by the gyro design. The individual ball bearings on the other hand do each feel their own centrifugal rotation pulling them outward against their inward cohesion, and each ball bearing also feels the forces exerted on it by the bearing race, the ever-changing surface of contact through which the balls communicate with the shaft of the gyro rotor by the language of push and pull.

In other words we can build up a picture of conscious experience as the causal forces that impinge on each other in the computational mechanism. If an object is isolated from external influences, then its conscious awareness is confined to its own internal structure, whereas objects that are causally connected have a larger interconnected experience. By the same token, human consciousness is confined to the one system of electrochemical waves of activation that the brain uses to represent external reality. Those patterns of activation are carefully insulated from external influences, and that includes the influences due to the neurons, cell bodies, molecules and atoms of the brain, just as in the autopilot. This suggests however that our true physical self embodies a whole host of separate conscious causal structures, for example those that reflect the pressure in our blood vessels, the forces in our digestive gut, the physical stresses borne by our bones, sinews, and muscles, etc. each of which would have its own separate experience of its own internal causal processes.

This concept of causal consciousness allows us to build up larger conscious entities by emergence from smaller isolated entities exactly as science builds up larger physical entities by emergence from smaller isolated entities. Beginning at the lowest end of the ladder of complexity, we can say that an atomic nucleus feels its own spatial structure as the powerful attraction and repulsion of its component protons and neutrons and quarks. But does the nucleus have any awareness of the electrons that form its surrounding electron orbitals? Does it make any difference to the nucleus whether it is alone, as are the atoms in a plasma (like the fiery hot gas of which the sun is composed) or whether it has its full or partial complement of orbiting electrons to balance its positive charge, as in a gas at normal temperatures? By the causal theory the answer to that question converts simply to a physical question: does the presence of electrons surrounding the nucleus have any effect on the configuration of the causal forces between the component quarks of that nucleus? The answer is no. The nucleus is far too small relative to even the innermost electron shell, and its nuclear forces are far too strong to be influenced significantly by the configuration of the electrons in their orbitals. But the electrons in their orbits do influence each other deeply. Each electron feels a powerful attraction to the nucleus at the core of the atom, as well as a repulsion to any other electrons in orbit around that nucleus. If there are only two electrons in an atomic orbital, those electrons will always remain at opposite poles of the atom while both orbiting. In fact the force of attraction to the nucleus and repulsion from other electrons defines a new emergent causal structure in the form of the atomic orbitals, that are best described as a cloud-like spatial field that appears around the nucleus. By themselves the nucleus and each electron have no orientation, they are spherical-symmetric, with no coordinates besides nearer or farther. But when electrons enter into their complex dance around the atomic nucleus, they create a characteristic spatial structure that has a very definite orientation. For example a carbon atom has four electrons in its outer shell, and those electrons repel each other and thereby remain as far away from each other as they can without leaving the nucleus. This creates four electrically negative bonds that stick out of the nucleus like four toothpicks stuck into an olive. Out of circular-symmetric elemental components emerges a structured field of causal forces with a definite spatial structure, a structure that appears 'out of nowhere' by the causal connectivity of its parts, and has an emergent consciousness of its own spatial structure that is independent of the elements of which it is composed.

By extension, atoms assemble themselves into mass matter by powerful electrostatic or electrovalent forces. A droplet of water that condenses out of a cloud defines an emergent quasi-spherical entity that is very much more than the sum of its water-molecular parts. There is this wobbly bobbly quasi-spherical blob as a larger emergent force-field that hangs together as an integrated whole, with the inward force of surface tension balanced against the outward force of the incompressible liquid. This spherical energy structure bears no direct relation to the configuration of its component molecular parts. It is conscious of its own causal structure in an integrated holistic manner, because it responds to forces acting on that wobbly droplet somewhat like an amoeba. It has a characteristic dance as it wobbles and bobbles in response to passing gusts of wind, that is not choreographed by the properties of its component molecules, but by the mass,

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inertia, and surface tension of the bulk blob acting as an emergent whole. When a raindrop lands on a window pane, it feels a powerful urge to progress downward in response to gravity, although it is held back by patches of oily film on the surface of the glass. As more water from other raindrops feed into it, the droplet grows, and thus builds up its desire to continue downward towards the earth, eventually overcoming the resistance of the oily obstacles, lunging downward in fits and starts. The 'decision making' process of the water droplet is similar to that of an amoeba. It picks a path of least resistance in its quest to consummate its love for Mother Earth, jerking this way and that, with pauses to gather its strength, before expending itself in brief dashes down the glass that drain it of its essence. When the droplet makes it to a puddle at the bottom of the window, it plunges in, and thereby surrenders its individuality to the larger mass of the water in the puddle as a whole. But that larger puddle also behaves somewhat like a living amoeba-like organism, sending out feelers in different directions in search of the path of least resistance to further downward progress. Seen in this light, the mass of water from a rainstorm that pools together as a flood, can be seen as a powerful animate entity with a powerful will of its own. Like an angry monster it bursts through dikes and levees, overflowing or undermining, creeping with countless tentacles seeking out a weak point, which once breached, releases a monstrous torrent that carries away everything unfortunate enough to be in its path.

I have described the behavior of inanimate matter in an anthropomorphic manner, generally a no-no in serious scientific circles. But I do not mean to suggest by that anthropomorphic description that the water droplet has any sense of its self, beyond its own wobbly-bobbly dynamic balance of spherical forces. It has neither memories nor aspirations, beyond a powerful urge to push downward toward the larger earth. But unless we endow bulk matter with a primal awareness of its own spatial structure, consciousness in the bulk matter of the human brain must remain forever profoundly inexplicable. My anthropomorphizing of the little water droplet is not intended to suggest that it has any more properties than those revealed by a physical analysis of its internal forces. All I am saying is that those causal forces must themselves possess a primal proto-consciousness, otherwise there would be no raw material available from which human and animal consciousness could have been assembled by evolution. Experience is simply the subjective aspect of the very forces and structures of nature revealed by science. We have yet to establish which aspect of experience correspond to which states of matter or energy. But unless we invoke mystical concepts of disembodied experience, experience simply must be a direct manifestation of electrochemical patterns in the brain.

If you consider the forces in a simple droplet, devoid of any sense of self, any memory of past, or aspirations for the future, to be so far removed from real human or animal consciousness as to not even deserve the label *proto-consciousness*, I can hardly disagree. I do not claim for the water droplet anything more nor less than what physics tells us of its physical properties. All I am saying is that whatever you might call it, this same simple causal interaction of physical matter, when organized in the complex pattern of a living human brain, does indeed necessarily become what we call true human consciousness; that there is no abrupt threshold or boundary where consciousness suddenly comes into existence, but rather consciousness is nothing other than a more complex

organization of the primal matter of which brains are composed. This is the only true monism that finally unites the world of matter known to science with the world of mind known to experience in a single unified ontology required of a true physicalist explanation of mind and matter.

In his profoundly moving and enlightened book *Skeptics and True Believers*, Chet Raymo (1998, p. 194-196) writes:

To admit that we are matter and mechanism is to ground our selves in the wholeness of the cosmos. In the new physics, self coalesces from the stuff of the stars, exists briefly,... then flows back into wholeness. Such a concept of self can be ennobling, cosmic, ecological—more so than the ghostly spirit soul I encountered in freshman theology.... To understand that we are structurally no different from the rest of the cosmos is to let ourselves expand into infinity.

Chapter 6

Something Wrong with My Picture!

The Phenomenon of Perspective

In chapter 2 we discussed a number of limitations of perceptual experience that reflect a limited resolution of the representation with respect to the world that it represents. There are limits to the maximum size of our experience, as seen most clearly when we expose ourselves to the boundless void of the night sky, and there are limits to the minimum size, the size of the smallest perceivable mote of dust. There are limitations in the complexity or information content of our experience, including the limits of color experience. In each of those cases the limiting factor is one of resolution, information of the external world that is missing in the representation due to the fact that reality is infinite, but the human mind is finite. But there are other aspects of perceptual experience that represent not just an absence of information, but an outright distortion, or misrepresentation of external reality. These errors or inconsistencies in our picture of the world offer the clearest evidence for the indirect nature of our experience.

There is perhaps nothing quite as strange in the world of experience as the phenomenon of perspective, a prominent warp observed in our experience of space itself. And just as strange as the warp in our phenomenal space is the fact that this warp passes completely unnoticed in our everyday experience of the world. The warp of perspective can be seen most clearly when standing on a long straight road or railway track that stretches to the horizon in a straight line in opposite directions. The sides of the road appear to converge to a point up ahead and back behind, but while converging, they are also perceived to pass to either side of the percipient, and at the same time, the road is perceived to be straight and parallel throughout its length. This property of perceived space is so familiar in everyday experience as to seem totally unremarkable. And yet this prominent violation of Euclidean geometry offers clear evidence for the non-Euclidean nature of perceived space. For the two sides of the road must therefore in some sense be perceived as being bowed, and yet while bowed, they are also perceived as being straight. This can only mean that the space within which we perceive the road to be embedded must itself be curved.

What does it mean for a space to be curved? If it is the space itself that is curved, rather than just the objects within that space, then it is the definition of straightness itself that is curved in that space. In other words, if the space were filled with a set of grid lines marking straight lines with uniform spacing, those lines themselves would be curved rather than straight, as they are in Euclidean space. However, the curvature would not be apparent to creatures who live in that curved space, because the curves that are followed by those grid lines are the very definition of straightness in that space. In other words, a curved object in that curved space would be defined as perfectly straight, as long as the curvature of the object exactly matched the curvature of the space it was in. If you are having difficulty picturing this paradoxical concept, and suspect that it embodies a contradiction in terms, just look at phenomenal perspective, which has exactly

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that paradoxical property. Phenomenal perspective embodies that same contradiction in terms, with parallel lines meeting at two points while passing to either side of the percipient, and while being at the same time straight and parallel and equidistant throughout their length. This absurd contradiction is clearly not a property of the physical world, which is measurably Euclidean, at least at the familiar scale of our everyday environment. Therefore that curvature must be a property of perceived space, thereby confirming that perceived space is not the same as the external space of which it is an imperfect replica.

The distortion of perceived space is suggested in Fig. 6.1, which depicts the perceptual representation for a man walking down a road. The phenomenon of perspective is by definition a transformation from a three-dimensional world through a focal point to a two-dimensional surface. The appearance of perspective on the retinal surface therefore is no mystery, and is similar in principle to the image formed by the lens in a camera. What is remarkable in perception is the perspective that is observed not on a two-dimensional surface, but somehow embedded in the three-dimensional space of our perceptual world. Nowhere in the objective world of external reality is there anything that is remotely similar to the phenomenon of perspective as we experience it phenomenologically, where a perspective foreshortening is observed not on a two-dimensional image, but in three dimensions on a solid volumetric object. The appearance of perspective in the three-dimensional world we perceive around us is perhaps the strongest evidence for the internal nature of the world of experience, for it shows that the world that appears to be the source of the light that enters our eye must actually be downstream of the retina, because it exhibits the traces of perspective distortion imposed by the lens of the eye, although in a completely different form.

This view of perspective offers an explanation for another otherwise paradoxical but familiar property of perceived space whereby more distant objects are perceived to be smaller, and yet at the same time are perceived as undiminished in size. This corresponds to the difference in subject's reports depending on whether they are given *objective* versus *projective* instruction (Coren et al., 1994, p. 500) in how to report their observations, showing that both types of information are available perceptually. This duality in size perception is often described as a cognitive compensation for the foreshortening of perspective, as if the perceptual representation of more distant objects is indeed smaller, but is somehow labeled with the correct size as some kind of symbolic tag representing objective size attached to each object in perception. However, this kind of explanation is misleading, for the objective measure of size is not a discrete quantity attached to individual objects, but is more of a continuum, or gradient of difference between objective and projective size, that varies monotonically as a function of distance from the egocentric point. In other words, this phenomenon is best described as a warping of the space itself within which the objects are represented, so that objects that are warped coherently along with the space in which they are embedded appear undistorted perceptually.

Size Constancy

The warp in perceived space can be measured directly by holding a foot-ruler



Fig. 6.1 The experience of a man walking down a street appears in the form of a spatial structure that is experienced to surround the self. The scale of that experience is observed to vary as a function of radial distance from the center, that is, farther things are represented at a smaller scale. The experience is modal in the direction of gaze, and amodal, or experienced as a vague sense of volumetric space, in the region outside the visual field, suggested by the dashed lines in the figure. The body image is also mostly an amodal experience, except for those portions of the body, like the arm and the leg, that happen to enter the visual field.

horizontally in front of you, and moving it inward and outward in depth. The ruler appears smaller when it is farther, and yet at the same time it remains exactly one foot long. What is curious about this experience is that as an adult, this bizarre shrinking of the ruler remains almost completely unnoticed, to the point that one would swear that there is no shrinking at all in the experience, even though the ruler shrinks to about half of its original length just at arm's length! This can be verified by holding two rulers simultaneously, one nearer and the other farther, thus revealing the invisible shrinkage due to perspective. Although this shrinking of perceived objects is almost invisible to an adult, it must be perfectly apparent to a young infant, who must see its own hands swelling and shrinking in this mysterious way as it waves them about in front of its face, before it learns to

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compensate for this effect perceptually. How does this perceptual compensation work? What is the secret behind size constancy in perception?

The secret behind size constancy is the use of a *variable representational scale*. Perception involves a representation, and a representation necessarily has a scale, which is the ratio of the length of an object in the representation relative to the length of the external object that it represents. In visual perception that ratio is observed to vary as a function of distance from the center of the space, the egocentric point, as is clearly evident in the observed behavior of the foot-ruler. In other words, the perceptual representation appears in the form of a museum diorama, as shown in Fig. 6.2A, in which nearer objects are represented larger, and farther objects are represented smaller, exactly as we experience them visually. When we view a diorama, we interpret it in much the same way as the world of experience, in that we mentally superimpose on the scene a warped reference grid, as shown in Fig. 6.2B, that shrinks with distance at a rate that matches the shrinking of the objects in the diorama. The grid represents our understanding of the 'true' or 'objective' scale of the world of our experience, and the construction of this invisible mental grid superimposed on our world of experience is exactly the computation of size constancy.

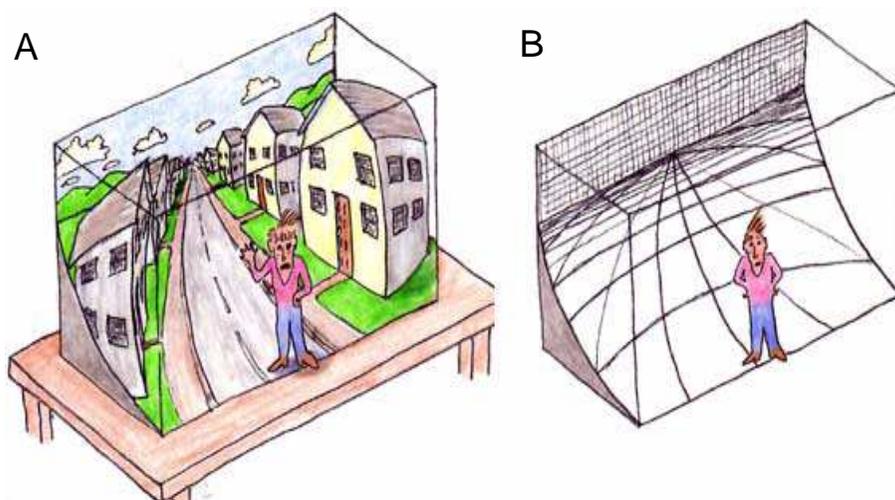


Fig. 6.2 A: A museum diorama, and a theatre set, both represent spatial depth the same way as observed in experience, that is, the spatial scale of the representation falls off as a function of radial distance from the center. B: The grid lines indicate a grid of identical squares, marking off equal distances of represented space by unequal distances in the representational space.

The compensation of size constancy occurs in stages as the child matures. The infant's world probably begins with a Euclidean mapping, as suggested in Fig. 6.3A, in which its own hand unaccountably balloons up and down in perceived size as it moves that hand closer and farther from its face. With enough experience the infant learns to expect this unaccountable behavior by developing a shrinking representational scale that presents its hand at constant size when moved in and out to arm's length, as shown in Fig. 6.3B. The hand is still perceived to balloon up and down in size, but now it does so coherently, in synch with its position in space, with a constant size as measured in objective coordinates. The hand has achieved size-invariance. But at a larger scale the infant may still see its mother balloon up from a tiny figure in the doorway to a

giant all-encompassing form as she approaches to pick it up in an embrace, as suggested in Fig. 6.3C. But with experience the infant learns constancy at that larger scale too, that is, it develops a steeper gradient to the warp of its perceptual reference grid, as suggested in figure 6.3D. But later, when the child first looks out at the vastly larger scale of the world out the window, it sees at first a miniature diorama with tiny insect-sized people crawling around on tiny streets and sidewalks apparently just beyond reach.

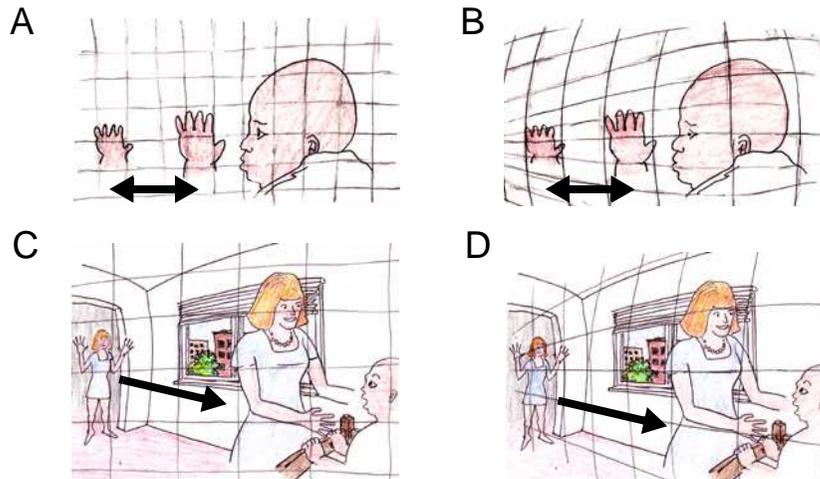


Fig. 6.3 A: At first, an infant sees its own hand balloon up to double its size whenever its hand approaches its face. B: Eventually the infant re-maps the scale of its experienced space, allowing the hand to zoom up in sensory size while remaining constant in perceived size. C: But the infant still sees its mother balloon up from a tiny figure in the distance to an all-encompassing form, until D: it learns to re-map even that more distant space to maintain a constant perceived size, although the world outside the window continues to appear as a miniature scale model.

In my own infant hood all this occurred before my first memories, so I have no recollection of this early stage of development. I do however recall the later stages that occurred by exactly the same principle. I remember climbing the hill across the street from my house and looking down at a miniature house in a miniature world. An adult standing on the same hillside would see no such distortion. But even an adult experiences a similar phenomenon the first time they go up in an airplane. I remember very vividly when I took my first flights in airplanes, how the world dropped away rapidly just after take-off, as might be expected. But as we continued to climb at a steady rate, the earth below receded downward ever more slowly, and began instead to shrink to ever smaller scale. I remember the very vivid impression of looking down in wonder and amazement on a miniature model world crawling with miniature cars on miniature streets. Later in life, when I first learned to fly, I remember an occasion when, starting a descent from 3000 to 1000 feet altitude, I had to suppress a momentary fear of colliding with the miniature world that appeared to be almost immediately below the landing gear. Later, as a flight instructor I had the opportunity to observe this shrinking and re-expansion of the landscape so many times that it too became familiar enough to be mapped in the warped scale of my constancy perception. But on my much less frequent flights as a passenger of an airliner I again experienced the perceptual shrinking of the world below as soon as the airplane climbed beyond the familiar altitudes of my light airplane experience, which was restricted to below about 10,000 feet.

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This shrinking of the world must be invisible to the airline pilot who is familiar with flights up to 30,000 feet and beyond, but it happens again to the astronaut the first time he launches out of the atmosphere altogether and sees the world for the first time as a ball.

The effect of this perceptual compensation is more than just a visual remapping; it is a remapping of the very scale of reality, as we experience it. An experienced pilot understands not only the true distance to the shrunken world below, but also understands the extraordinary mass of air that occupies that vast apparently empty space. When a pilot pushes the nose over into a really steep “Oh-my-God” dive, the plane drops rapidly at first, as expected. But as it picks up speed you hear the rising crescendo of a furious blast of air and the airframe shakes and shudders in protest. The airspeed increases rapidly at the beginning of the dive, but its rate of increase gets slower and slower as the plane ploughs violently into the enormous volume of air, giving the pilot a deeper understanding of the sheer mass and magnitude of that invisible fluid. In other words, an experienced pilot looking down at the miniature world below perceives the invisible atmosphere below as a dense fluid, more like water than the thin nothingness of air at the familiar scale. Similarly, a young child looking out a second-story window for the first time might expect a ball thrown out the window to hit the roof of the house across the street, and therefore be surprised to see it instead dropping steeply downward and landing back in his own yard almost vertically under the window. An adult can have the same kind of surprise when dropping a ball for the first time from a tall tower.

A Bounded Representation

The perceptual compensation of size constancy is never complete. Although an experienced pilot understands the vastness of the space below his airplane, he still sees the world below in miniature rather than at its true size, and his understanding of the vastness of the ocean of air below is expressed in the form of an image of air at greater density, because it is effectively squeezed into a smaller-scale volume of perceived space. The reason why the perceptual representation employs a variable representational scale is in order to fit an infinite external world into a finite internal representation. The nonlinear compression of the depth dimension observed in phenomenal space can be modeled mathematically with a vergence measure, which maps the infinity of Euclidean distance into a finite bounded range, as suggested in Fig. 6.4A. This produces a representation reminiscent of museum dioramas, like the one depicted in Fig. 6.4B, where objects in the foreground are represented in full depth, but the depth dimension gets increasingly compressed with distance from the viewer, eventually collapsing into a flat plane corresponding to the background. This vergence measure is presented here merely as a nonlinear compression of depth in a monocular spatial representation, as opposed to a real vergence value measured in a binocular system, although this system could of course serve both purposes in biological vision. Assuming unit separation between the eyes in a binocular system, this compression is defined by the equation

$$v = 2 \operatorname{atan}(1/2r)$$

where v is the vergence measure of depth, and r is the Euclidean range, or distance in depth. Actually, since vergence is large at short range and smaller at long range, it is actually the “ π -compliment” vergence measure ρ that is used in the representation, where $\rho = (\pi - v)$, and ρ ranges from 0 at $r = 0$, to π at $r = \infty$.

object at infinity, zero vergence

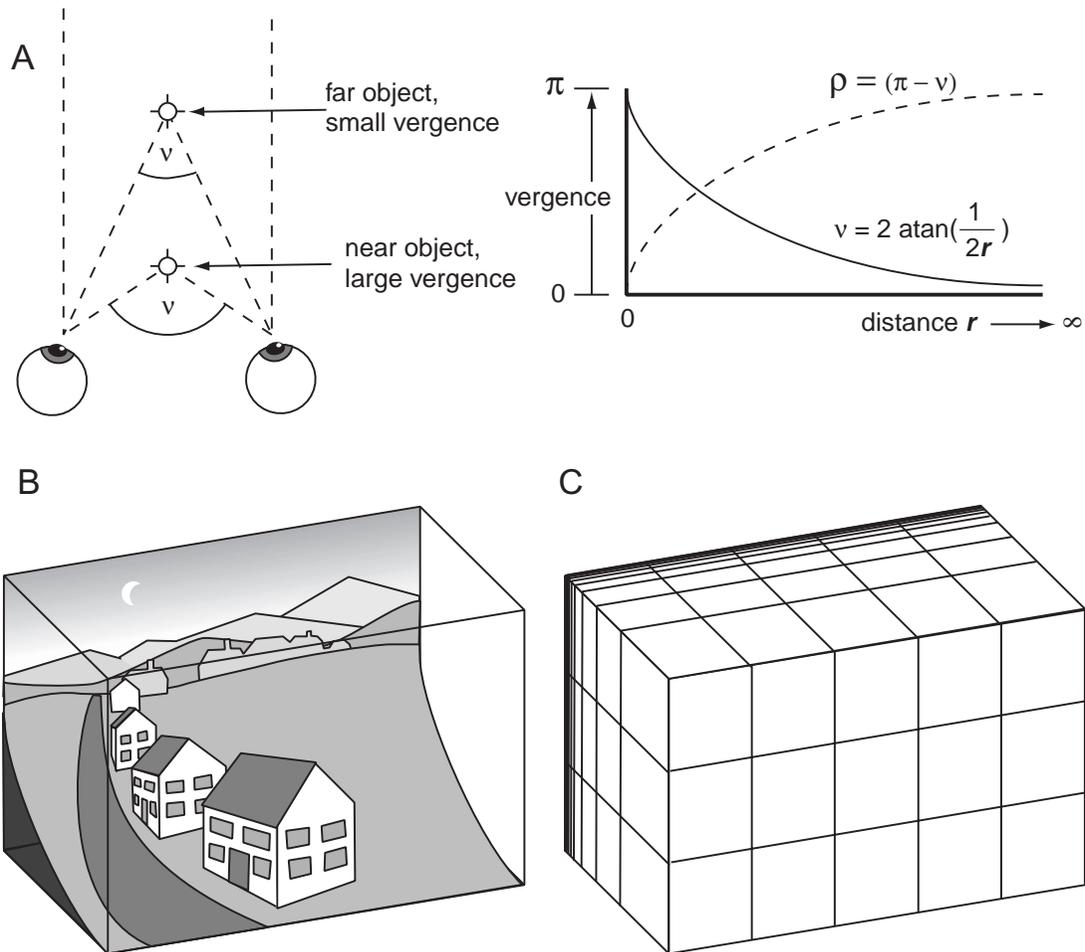


Fig. 6.4 (A) A vergence representation maps infinite distance into a finite range. (B) This produces a mapping reminiscent of a museum diorama. (C) The compressed reference grid in this compressed space defines intervals that are perceived to be of uniform size.

What does this kind of compression mean in an isomorphic representation? If the perceptual frame of reference is compressed along with the objects in that space, then the compression need not be perceptually apparent. Fig. 6.4C depicts this kind of compressed reference grid. The unequal intervals between adjacent grid lines in depth define intervals that are perceived to be of equal length, so the flattened cubes defined by the distorted grid would appear perceptually as regular cubes, of equal height, breadth, and depth. This compression of the reference grid to match the compression of space would, in a mathematical system with infinite resolution, completely conceal the compression from the percipient. In a real physical implementation there are two effects of this compression that would remain apparent perceptually, due to the fact that the spatial matrix itself would have to have a finite perceptual resolution. The resolution of depth within this space is reduced as a function of depth, and beyond a certain limiting depth, all

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objects are perceived to be flattened into two dimensions, with zero extent in depth. This phenomenon is observed perceptually, where the sun, moon, and distant mountains appear as if they are pasted against the flat dome of the sky.

The other two dimensions of space can also be bounded by converting the x and y of Euclidean space into azimuth and elevation angles, α and β , producing an angle/angle/vergence representation, as shown in Fig. 6.5A. Mathematically this transformation converts the point $P(\alpha, \beta, r)$ in polar coordinates to point $Q(\alpha, \beta, \rho)$ in this bounded spherical representation. In other words, azimuth and elevation angles are preserved by this transformation, and the radial distance in depth r is compressed to the vergence representation ρ as already described. This spherical coordinate system has the ecological advantage that the space near the body is represented at the highest spatial resolution, whereas the less important, more distant parts of space are represented at lower resolution. All depths beyond a certain radial distance are mapped to the surface of the representation which corresponds to perceptual infinity.

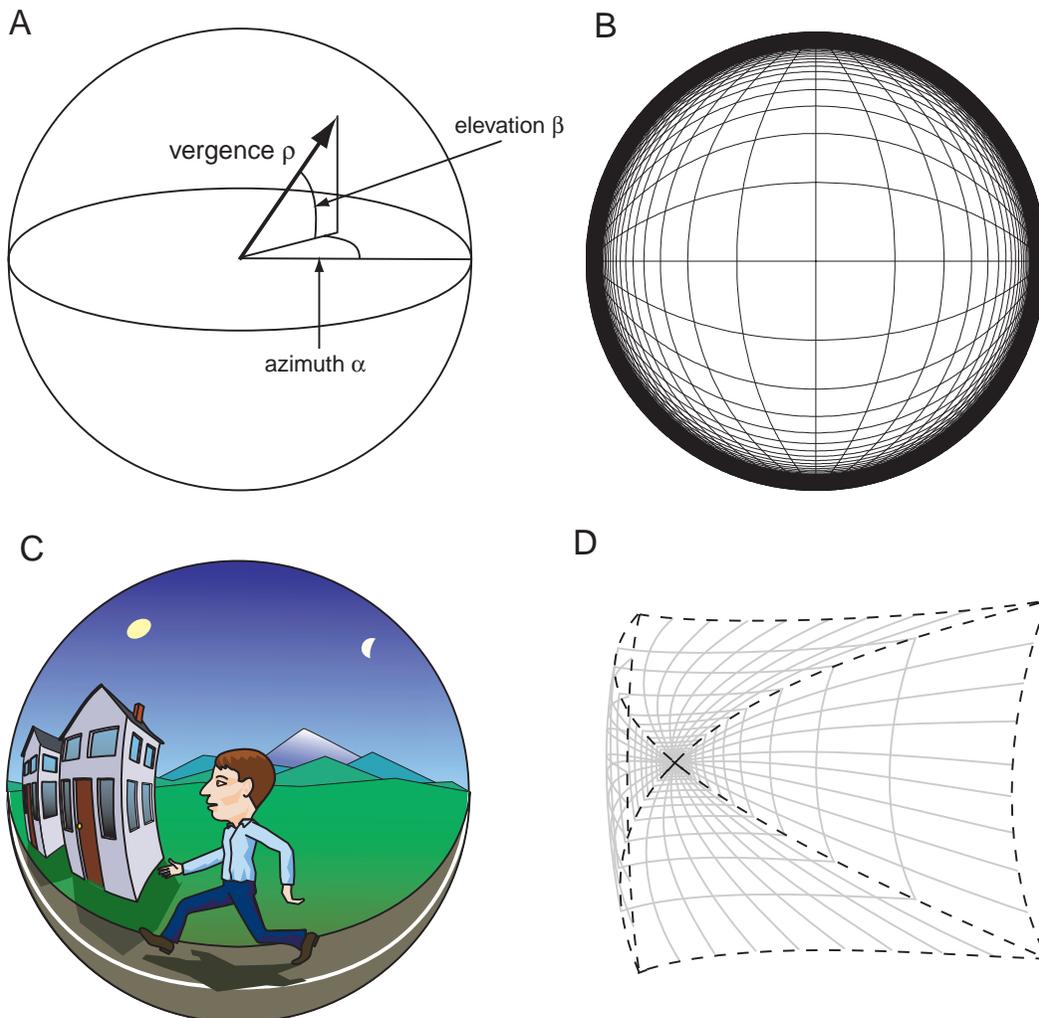


Fig. 6.5 (A) An azimuth/elevation/vergence representation maps the infinity of three-dimensional Euclidean space into a finite perceptual space. (B) The deformation of the infinite Cartesian grid caused by the perspective transformation of the azimuth/elevation/vergence representation. (C) A view of a man walking down a road represented in the perspective distorted space. (D) A section of the spherical space depicted in the same format as the perspective distorted space shown in Fig. 4.7.

The mathematical form of this distortion is depicted in Fig. 6.5B, where the distorted grid depicts the perceptual representation of an infinite Cartesian grid with horizontal and vertical grid lines spaced at equal intervals. This geometrical transformation from the infinite Cartesian grid actually represents a unique kind of perspective transformation on the Cartesian grid. In other words, the transformed space looks like a perspective view of a Cartesian grid when viewed from inside, with all parallel lines converging to a point in opposite directions. The significance of this observation is that by mapping space into a perspective-distorted grid, the distortion of perspective is removed, in the same way that plotting log data on a log plot removes the logarithmic component of the data. Fig. 6.5C shows how this space would represent the perceptual experience of a man walking down a road. If the distorted reference grid of Fig. 6.5B is used to measure lines and distances in Fig. 6.5C, the bowed line of the road on which the man is walking is aligned with the bowed reference grid and is therefore perceived to be straight. Therefore, the distortion of straight lines into curves in the perceptual representation is not immediately apparent to the percipient, because the lines are perceived to be straight. Similarly, the walls of the two houses shown in Fig. 6.5C which bow outward from the observer, conform to the distortion of the reference grid and are therefore perceived to be straight and vertical. Likewise, the nearer and farther houses are perceived to be of approximately equal height and depth in objective size, because they span the same number of grid lines in the perspective distorted grid, and yet at the same time the farther house is also perceived to be smaller in projective size, as observed also in perception. However, in a global sense there are peculiar distortions that are apparent to the percipient, caused by this deformation of Euclidean space: Although the sides of the road are perceived to be parallel, they are also perceived to meet at a point on the horizon. The fact that two lines can be perceived to be both straight and parallel and yet to converge to a point both in front of and behind the percipient indicates that our internal representation itself must be curved. Likewise, the vertical walls of the houses in Fig. 6.6C bow outward away from the observer, but in doing so they follow the curvature of the reference lines in the grid of Fig. 6.5B and are therefore perceived as being both straight and vertical.

The bizarrely warped space of subjective experience has another interesting property, which is that the two-dimensional projection of this warped representational space, projected radially from the center, is identical to the two-dimensional perspective projection of the corresponding Euclidean world that it represents, as suggested in Fig. 6.7. In other words, a photograph taken from the center of this distorted model world would be identical to a photograph taken from the corresponding point in the external world. This makes this particular representation a convenient format for what is, after all, the primary function of visual perception, which is to reconstruct a full three-dimensional model of the external world based on its two-dimensional retinal projection.

There is something telling that occurs at the very boundary of this spherical representational space, where the infinite measure of distance in internal phenomenal space meets the finite boundary of the representation. There are an *infinite* number of grid lines captured within this finite bounded space, and at the bounding surface of this space we see those infinite lines all piled up on top of each other—an infinity of phenomenal space packed into a singular boundary

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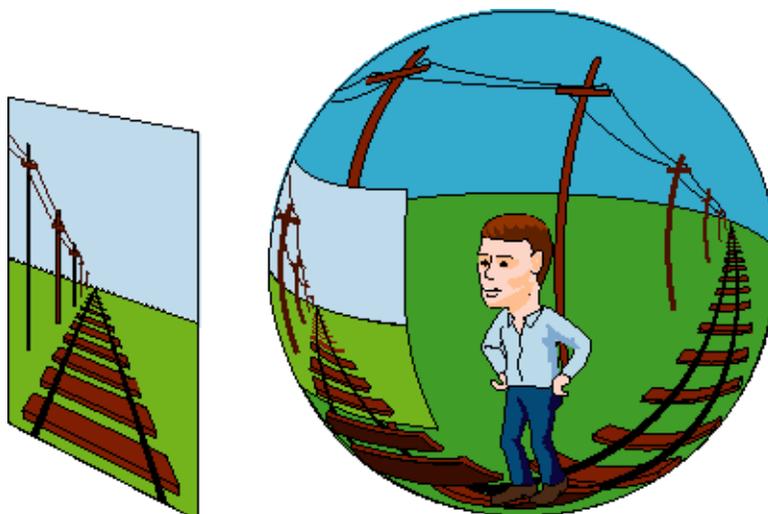


Fig. 6.6 A peculiar property of the warped representation is that its two-dimensional projection, projected radially outward from the central point, is identical to the two-dimensional perspective projection of the corresponding Euclidean space that it represents.

surface. This representation is a direct and literal expression of Kant's spatial antinomy discussed in chapter 4. Things that are impossible in the real world, such as a full tally of an infinite quantity, are suddenly possible in this warped space, because the representation embodies the paradoxical contradictions in the properties of the representation itself in a very literal form. In this space the world is both infinite and boundless, and yet at the same time it is both finite and bounded. And this trick is achieved by the introduction of an impossible notion, the notion of infinity as a finite concept.

Other Visual Glitches and Anomalies

There are a great number of other peculiar errors and glitches in our experience that alert us to the duality of our epistemology, that what we are seeing is a picture of reality, not reality itself. There are retinal after-images as seen for example after looking at a bright light or camera flash. These artifacts are not experienced at the location of our retina, but they appear out in the world beyond the retina. Even to the ancients, who were ignorant of retinal physiology, it must have been obvious at some level that our view of the world is indirect. Another clear indication of the indirect nature of perception is the phenomenon of *eigenlicht*, or *ideoretinal light*, (Schilder 1942 p. 7), innumerable small points of light that twinkle and scintillate rapidly on a dark-gray or brownish background, seen across the whole visual field in pitch darkness or with eyes closed. The term 'eigenlicht' refers to the fact that this visual scintillation can be seen in pitch darkness, and thus shines by its "own light". The specular scintillation of *eigenlicht* can also be seen however with eyes open, especially against a featureless expanse like a white page, or the blue sky. When viewed as a textured scintillation superimposed on a perceived scene, the phenomenon might more accurately be described as *specular scintillation*. This is clearly a case of noise in the visual system, an endogenous phenomenon that is nevertheless seen superimposed on the external world, along with a host of other phenomena such as the the branching dendritic pattern of one's own retinal veins,

known as the *Purkinje tree*, seen when looking into darkness near a bright offset light source. And the peculiar pattern of moving rings seen endlessly receding to a central focal point centered the fovea, seen most clearly against a bright blue sky. This is known as the *flying corpuscles* phenomenon because it is due to the shadows of individual blood corpuscles moving one by one through the capillaries of the fovea. And there are *floaters*, (*muscae volitantes* - 'flying flies') dark flecks that float around the visual field but remain anchored in one general location like a ship swinging to her anchor cable. These are due to small chunks of tissue or clusters of dead cells that have torn loose from the retina but remain anchored to it by a thin filament. I suspect that a young infant's first visual experience is flooded with these peculiar anomalies, overwhelming the image that is seen through it. It is only with practice and experience that the infant gradually learns to ignore these visual artifacts, and pay attention to the visual image of the world beyond them. A woman I know told me how she complained to her father when she was maybe three years old, of a disturbing sense of feeling separated from reality by some kind of film, or membrane, interposed between herself and the world, and that she felt that she could never touch the world itself, but was forever trapped inside her personal bubble, isolated from the world at large. Wisdom sometimes cometh out of the mouths of babes.

Dizziness

Another prominent perceptual glitch that should give pause to the naive realist in us is the phenomenon of dizziness, experienced after spinning rapidly around. It is not too surprising that the world goes blurry and unstable as we rotate, although even that much gives evidence for the indirectness of perception. But there is something even more strange and shocking about the fact that the world continues to spin after we stop. In fact, the dizzy sensation gets worse when we abruptly stop spinning, as we feel the solid earth underfoot rocking like the deck of a ship in a storm. And the visual world continues spinning even though it is no longer rotating, a stark contradiction of perceptual fact that resolves itself as a series of abrupt jerks, that repeatedly return the world to its real orientation to correct for a persistent drifting rotation in the opposite direction. This shocking violation of the solid reality of the surrounding world is clearly apparent to the young child when it first discovers this crazy phenomenon, as evidenced by the sheer delight and astonishment that the sensation evokes. It is clear that there is something fundamentally wrong with the world as we know it. But once the child has spun often enough for the sensation to become familiar, it loses interest, because the effect is no longer surprising or unexpected. As in the case of perspective, the perceptual error remains even after our mental compensation. Distant things still appear smaller, and the world still spins when we are dizzy. But as adults, these initially puzzling aspects of experience are hardly even noticed any more, unless they are raised to new heights, as when viewing the world from the unfamiliar height of an airplane, and the childish thrill of dizziness is revived when an adult first experiences an amusement park ride, or a steep turn in an airplane. I still remember my first steep turn as a student pilot. It seemed to me that the airplane remained level, but the world tilted up on its axis turning the horizon to vertical, and the vertical horizon rushed straight downward lengthwise past the nose of the plane in a dizzying blur as I pulled back on the stick. And if

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you look to the side beyond the wing tip towards the ground vertically below, the earth's surface appears vertical instead of horizontal, like a vertical cliff face, and the vertical disk of the earth rotates slowly around one central point just past your wing tip that is the point on the earth vertically below the airplane. Even as a licensed pilot I was fascinated for a long time by the sensation of a steep turn, until I had done so many of them that the world no longer tilted up on its axis for me, but remained flat and horizontal, as I learned to perceive that it was my airplane that was tilted, not the earth. I suspect a young infant has a similar sensation when it first learns to roll itself over from lying on its back to its belly, or vice-versa. The first few times it must seem as if it is the world that is turning rather than the self, because the self is the original reference to orientation, and it is only later that we learn of the stability and permanence of the horizontal plane of the earth.

Sleep and Dreams

Perhaps the most profound anomalous glitch of human experience is the phenomenon of sleep, and of dreams. Imagine how profoundly shocking it would be for an alien intelligence who is incapable of sleep to experience unconsciousness for the first time as an adult. It is one thing to close ones eyes and hear the world continuing to exist unseen, but it is quite another for the world to apparently stop happening altogether, as if it had abruptly ceased to exist, only to come back into existence again after some timeless interval of black non-existence. But when the world returns, it behaves exactly as if it had continued to exist for a specific interval of time during the unconscious episode. It must cause a profound shift in an infant's understanding of reality when it first realizes that the world continues to exist even while it sleeps, an unmistakable clue to the ultimate unreality of experience. And if that is not enough to stir us from our comfortable naive realism, then surely the phenomenon of dreams must. For in dreaming, we experience a parallel universe that contains a self and a body in a world, exactly as we see in normal waking experience, except that the dream world is less vivid, more shadowy, and full of irrational non-sequiturs and logical contradictions. The dream world is like the shifting pattern of waves on the surface of a swimming pool in the absence of a view of the fixed, unchanging bottom of the pool.

There are two possible explanations for the experience of sleep and dreams. Either the waking world is real, and dreams an illusion, or it is the waking world that is the illusion, and dreams reveal a hidden world of spiritual reality that is somehow more real and significant than our waking world of experience. I propose that the experience of sleep and dreaming, along with the disembodied experience of the egocentric point discussed in chapter 3, are the ultimate basis for a wide range of spiritual and religious beliefs held across a great variety of different cultures throughout history. The fact that our consciousness transfers effortlessly between the waking and the dream worlds suggests a self in the form of a disembodied spirit that is only temporarily anchored to a physical body when awake. Many of the paranormal properties often proposed in religious and spiritual beliefs, such as levitation, telepathy, astral projection, psychokinesis, miracles, etc. are commonly observed properties of the dream world.

The Missing Hemifield Phenomenon

Scott McCloud, author of the insightful and entertaining book *Understanding Comics*, (McCloud 1993) recalls a childhood memory of his own that reveals another prominent gap in our visual experience, shown in Fig. 6.7. As adults we



Fig. 6.7 Young Scott McCloud discovers the missing hemifield phenomenon.

have to think hard to see what is at all unusual about this familiar aspect of everyday experience. It seems perfectly natural that we cannot see behind our

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heads, given that our eyes are facing forward, and therefore that part of the world is naturally occluded from view by our head. What is less well recognized however is that this explanation only makes sense from an indirect realist perspective. It is conclusive proof that the world that we see around us in visual experience is not the world itself, as we might naively assume, but is an image inside our head. The only way to make sense of the missing hemifield phenomenon from a naive realist perspective is to propose a theory like Descartes' immaterial soul that can see the world directly out in the world where it lies, although strangely, it does so only when the eyes are open, and only in the direction that the eyes are pointed. But if the soul can see the world as if bypassing the eyes, then why should its view of the that world be restricted by the field of view of the eyes? There is a peculiar twist in the logic of naive realism that simply does not stand up to closer scrutiny. As Bertrand Russell explains, (Russell 1927, 1954 p. 320)

Whoever accepts the causal theory of perception is compelled to conclude that percepts are in our heads, for they come at the end of a causal chain of physical events leading, spatially, from the object to the brain of the percipient. We cannot suppose that, at the end of this process, the last effect suddenly jumps back to the starting point, like a stretched rope when it snaps.

In retrospect, this evidence should have been perfectly clear to the ancients even in their ignorance of modern neurophysiology, as it is clearly evident to the young child before it learns to rationalize the phenomenon as a pseudoproblem, as if it were no problem at all. It is no wonder that Empedocles (fifth century BC) proposed that our eyes project light outward from the eyes. Like Descartes' theory, this is an accurate description of the phenomenology of vision, except that it offers no explanation for the fact that in darkness we see nothing. In fact the missing hemifield phenomenon is no different in principle than the radar image shown in Fig. 3.4, where the smokestack of the ship blocks radar reception in one direction, blanking out a whole sector of the radar image.

Retinal Phenomena

The missing hemifield phenomenon is related to another phenomenon known since ancient times, which is the drop-off of resolution in our peripheral vision, or, the fact that we see most clearly and at the highest resolution in our central foveal vision. This can be easily demonstrated phenomenologically by fixating at some point and observing the visual experience of objects in the periphery. Television offers an ideal object for phenomenological exploration of peripheral vision due to the constant motion and ever-changing scenes typical of television shows. Again, this phenomenon provides direct evidence for the properties of our retina, which have since been corroborated histologically, that is that the retina is endowed with a much higher density of photoreceptors at the center than at the periphery. Other inhomogeneities of the retina can also be observed phenomenologically. Peripheral vision is more sensitive to motion than to geometrical form, which makes it difficult to recognize static features in the periphery. For example it is hard to count how many fingers someone is holding up in your peripheral vision, but much easier when they move their hand or wiggle those fingers. There is also a noticeable drop-off in the sensitivity to the color red in the far periphery, about 90 degrees eccentric from the foveal direction, although blue and green can be seen

out to the edge of the visual field. Another artifact of retinal origin is the fact that color vision only works in bright light. In low light conditions at dawn or dusk the world appears in shades of gray, as was noticed already by Purkinje long before the cellular basis of this phenomenon was confirmed histologically. It turns out that retinal photoreceptors come in two different varieties, rods and cones. The rods are insensitive to color, but are extremely sensitive to low light levels, whereas the cones come in three color varieties, and are responsible for our color vision, but they only work at higher light levels. The fovea is populated exclusively by rods, giving us excellent color perception in central vision. At night however the fovea becomes a blind spot, because it has no rods sensitive to low light levels. That is why one can see a dim star in the sky more clearly by looking off to one side of it, rather than directly at it. Another blind spot due to retinal architecture is seen at the point where the optic nerve passes through the wall of the eyeball, forming a circular region on the retina devoid of retinal photoreceptors of any kind. The remarkable property of the blind spot is its invisibility, most people are completely unaware of the existence of this feature, since the brain fills in the missing piece of the picture so efficiently that only careful tests can reveal it phenomenologically. All of these properties of phenomenal experience were observed and reported on in great detail by Goethe and Purkinje long before they were confirmed by anatomical studies of the retina, which demonstrates how much can be learned about our sensory systems based entirely on phenomenological observation.

Is Experience Unitary or Fragmentary?

One of the most prominent and puzzling aspects of experience is its fundamental unity. There is only one sky, and one earth, and the sky arches over the earth. Objects in between are each experienced to be located at specific locations within that unitary experience. This unity poses a profound challenge to theories of brain function, because neurophysiology reveals a fragmented architecture built up out of elements such as neurons, axonal pathways, and cortical areas. The question of how such a fragmentary architecture could lead to a unified experience is perhaps the single most challenging paradox facing neuroscience today. But experience is not entirely unified; there are fragmentary aspects of experience that occur within a larger framework of a unified experience overall. For example as we glance around a scene, our eyes jump from one feature to the next, building up a global picture out of fragmentary local views. In fact, many theorists seek to 'solve' the unity problem by denying that experience has any unity at all, citing the fragmentary nature of *some* experience. But although experience is not entirely unified, it is undeniable that some components of experience *are* unified. In fact, visual experience is composed of both *focal* and *global* components. We do not experience each visual saccade as a separate disconnected experience, like successive scenes showing on a television screen, but rather the local experience due to each saccade is experienced at the location that it is perceived to occupy in the global framework of perceived space. Fig. 6.8 depicts the experience of four individual saccades while glancing around a cluttered bookcase, showing how each glance produces a high resolution experience centered at some focal location, with considerably reduced resolution in peripheral regions surrounding that focal point, although there remains a global experience of the bookcase as a whole in which the individual focal views are experienced to be located.

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Fig. 6.8 The subjective experience of glancing around a book case is of a spatial structure, one part of which is perceived at higher detail and resolution, and that high resolution point shifts with visual fixation.

Parallel Streams of Consciousness

There are other fragmentary aspects of conscious experience that suggest an even more fragmented representation involving parallel streams of consciousness that can be disconnected from the global narrative consciousness that we normally consider to be 'our' experience. For example we have all had the experience of driving down a familiar road, only to find after the fact that we do not recall anything at all of that experience. Philosophers often point to this phenomenon as evidence that consciousness is not really necessary for behavior, because behavior can occur in the complete absence of consciousness. But it is at least equally likely *prima facie* that the behavior was experienced at the time it was happening, but was subsequently forgotten, and thus remains unreportable after the fact. In fact this is by far the more likely explanation given that whenever somebody is interrupted in the process of any behavior, even routine mindless behavior such as driving down a familiar road, people always report that they are conscious at that time. It is only in retrospect after the fact that the experienced behavior becomes unreportable, and even then, only if nothing of significance occurred during that behavior. Whenever something remarkable or noteworthy occurs while we are driving then we recall that experience perfectly clearly after the fact. It is far more likely therefore that the apparently unconscious behavior was consciously experienced at the time of the behavior, but that our memory has a filter that only records actions or events that are significant or interesting, ones that evoke an emotional response.

There is nevertheless a kind of fragmentation of experience while performing a familiar 'overlearned' behavior like driving, that frees our central narrative consciousness to wander to topics that are completely unrelated to our present situation, such as worrying about our work or family situation, or making plans for the near or distant future. A student driver first learning to drive does not have this freedom to daydream, but must focus his entire attention on the task at hand, resulting in a more unified consciousness locked on to the immediate here and now. But even the student driver's experience is fragmentary in some sense, as he directs his attention in sequence to individual tasks like checking the mirror, or glancing at the speedometer, etc. that highlight focal aspects of the global experience one at a time. The experienced driver on a familiar road therefore has a deeper level of fragmentation of consciousness, with their central narrative consciousness absorbed in contemplation of matters which are entirely unrelated to the present situation. A driver in this state is considered to be 'absent minded', his mind being absent from present circumstances, as if the person doing the driving is a mindless zombie or autopilot. In a very real sense the self is split into two separate persons on such occasions, one busy driving while the other is engaged in contemplation. I suspect that this ability to split the mind into two parallel streams is unique to humans, or at least higher primates, and reflects our ability to abstract a situation to a synthetic reality in a mental image where it can be manipulated and analyzed independently, in order to test various mental hypotheses by simulation.

The reason we don't usually consider this experience to be of two separate consciousnesses is because the two can be fused back together again instantaneously whenever something of significance suddenly occurs. For example if brake lights appear suddenly up ahead, and the car we are following looms alarmingly, the zombie autopilot part of the mind knows enough to apply the brakes immediately, but as it does so, it wakes up the other half of the mind to urge it to start paying attention to help figure out what to do next. In an instant the two separate consciousnesses slam back together again, and the fragmentary experience is immediately forgotten. As the higher cognitive consciousness returns to focus on the immediate environment, the zombie autopilot plays back its short-term memory of recent events in a rapid flashback similar to the experience of waking up in a strange place. "I was driving along perfectly normally, and then suddenly something flashed from left to right, and the car ahead hit the brakes hard!" This immediate flashback of recent events demonstrates that the zombie autopilot is equipped with a short-term memory for events, and those events, as they are recalled, appear in the same volumetric shapes and colors as normal conscious experience. But it seems that the zombie consciousness is not able to lay down long-term memories, but must wake up and recruit the central narrative consciousness whenever noteworthy or memorable events are observed. And when this occurs, we also notice that our absent-minded reverie is interrupted, showing that only one long-term memory trace can be recorded at a time. It is only at this higher narrative level that we cannot "walk and chew gum at the same time." If nothing noteworthy occurs during the familiar drive, we will not remember the drive itself, but we may well recall what we had been thinking about in our absent-minded reverie. This suggests that both aspects of our mind have a conscious experience, and they can experience different things at the same time,

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in a very real sense like two separate individuals.

The reason why the central narrative consciousness is necessary in emergency situations is that it has access to long term memories and cognitive knowledge that may apply to the situation at hand. The zombie can slam on the brakes, but the narrative consciousness knows to ease off on the brakes again if the car begins to skid (unless equipped with anti-lock brakes), or to turn into the skid if the car begins to slide sideways, or to steer aside if it looks like you can't stop in time to avoid a collision. An experienced racing driver would have trained his zombie consciousness to perform even these tasks automatically, leaving the narrative consciousness free to focus on still higher aspects of the problem, such as how to win the race, whereas the student driver needs his narrative consciousness even to slam on the brakes.

The amount of memory playback required to make sense of an emergency situation depends on the seriousness of the situation at hand. If the student driver panics at the flash of brake lights ahead, his narrative consciousness need only recall recent incidents of brake lights flashing to know that the problem requires application of the brakes, and no more. If the brakes have already been applied but the car ahead continues to loom alarmingly, this requires a deeper search of earlier memories to recall the last experiences of your car in an uncontrolled skid, to know that what is required is to ease up on the brakes and turn into the skid. What about when something really drastic and absolutely unique occurs? For example if the car goes out of control, breaks through a guard rail and noses over a cliff, the driver, looking straight down at his impending doom, flashes back through his memory to try to find an appropriate response to this drastic situation. Since no such event has ever occurred before, this results in the often reported experience of "seeing your life flash before your eyes." When your memory flashes all the way back to your childhood without finding an appropriate match to the present circumstances, it is then that you realize that you are faced with a unique life-changing event for which you are totally unprepared to respond.

Sequential Logical Thought

The sequential character of logical thought processes represents another fragmentary aspect of consciousness, because the mind changes abruptly from one state to the next as different steps of the logic chain are contemplated in sequence. At the highest, most abstract level, these logical sequences are totally abstracted into verbal or symbolic steps. IF the car skids, THEN ease off on the brakes. IF the car turns sideways, THEN steer into the turn. But this sequential logical thought can also occur at a lower pre-verbal level of mental imagery. We picture the image of our car skidding, and the next frame we 'see' in our mind's eye is of our foot easing off the brake, and the car coming back under control. This two frame mental image sequence is itself a logical sectioning of the problem into discrete steps, to help us make sense of a situation too complex for us to swallow in one bite. When a chimpanzee sees a banana beyond reach outside of its cage, it feels a wordless desire to close the distance between itself and the banana. When that desire is frustrated, either by a failed attempt to reach the banana by hand, or by a mental image of that failed attempt, the chimp feels first frustration, then it sees another mental image of itself retrieving the banana by using a stick,

followed by a mental image of a happy union between itself and the banana. That sweet reward in its mental image of the situation motivates it to pick up the stick and retrieve the banana. What might occur in one flash of unified thought for a human in a similar situation, must be broken down to a sequence of steps for the chimp, each step of which creates a distinct mental state, fragmented from the unitary here-and-now experience. The distinction between parallel and sequential representational strategies of the mind can be observed phenomenologically in the practice of Zen meditation, whose focus is explicitly on the parallel here-and-now, while the sequential logical aspect of thought is suppressed.

Dichotic Listening

Evidence for separate parallel streams of consciousness is also seen in dichotic listening tasks, (Cherry, 1953) where a subject is fitted with earphones that project different messages into different ears. When subjects are instructed to 'shadow' the message in one ear, that is, to repeat each item immediately after it is heard, while ignoring the input to the other ear, after the fact they recall words heard through the attended ear, but cannot recall words that came in to the unattended ear. It has been shown however that although the subject cannot recall the message sent to the unattended ear, that message must get through nevertheless, because it has a measurable effect on the subject's subsequent responses. For example if the word 'taxi' is presented in the unattended ear, the subject will not be able to recall consciously whether that word had been presented, and yet when it had, the subject is more likely to spell the homophone *fare/fair* as 'fare' because of the unconscious association with taxi (Murphy and Zajonc, 1993; Westen, 1999). Also, in the dichotic listening task, subjects will notice if the gender of the speaker suddenly changes, or if they hear their own name in the unattended ear. The latter phenomenon has been dubbed the "cocktail party effect", because of the familiar experience of attending to one conversation in a crowded room, and suddenly hearing one's own name spoken in a different conversation to which one was not paying attention. These phenomena are often interpreted as evidence that sensory processing of an auditory stimulus can occur in the absence of conscious experience of that processing, which in turn supports the possibility that conscious experience is neither a necessary prerequisite, nor an inevitable concomitant to sensory processing. It is at least equally likely however that all sensory processing is necessarily conscious at some level, but that consciousness need not be connected to the central narrative consciousness, but that individual conscious processes can sometimes operate independently, and thus be not available to be reported or recalled after the fact. The so-called "unconscious mind" may not in fact be unconscious at all, but may simply be independently conscious and disconnected from our central narrative consciousness. In fact that is by far the more parsimonious explanation because the alternative raises the profoundly paradoxical question of why one part of our brain is conscious of its own function while other parts of our brain, nervous system, and body, are not.

Binocular Scission

Another familiar example of semi-independent parallel streams of consciousness

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can be seen in the experience of *binocular scission*, when the binocular fusion of the two eyes breaks down, as occurs spontaneously when one is profoundly drunk. The condition can sometimes be achieved by simply relaxing the eyes and staring blankly at a page, or induced artificially by placing an angled mirror in front of one eye, thus sending two completely different uncorrelated images into the two eyes. The subjective experience of this ocular mismatch is a double visual experience—one sees two spatial images simultaneously, partially quasi-superimposed. The superposition is partial because there is a strong tendency for one image to dominate over the other, resulting in a strange experience of two parallel consciousnesses, one of which is experienced explicitly, while the other somehow lurks in the background, as if it too is being experienced, but not by “me”, but almost as if it were an independent conscious entity that is experiencing itself in my absence. The superposition is *quasi* because the two images are not really superimposed like two transparencies which are overlaid, but rather they are experienced as two images in two separate spaces which are only vaguely related to each other spatially. They tend to shift unstably relative to each other, and their apparent superposition seems somehow incidental and inconsequential, like the reflections in a glass window superimposed on the world seen through the glass. One tends to see one or the other, and it is only with a little effort that one can even relate the two images to each other spatially. This is the most clear and vivid example of the experience of disunified consciousness, every bit as paradoxical and significant as the phenomenon of the so-called “split brain” (collosectomy) patients resulting from surgical severing of their *corpus callosum*, except that the experience of binocular scission is available to normals with intact brains. It is no wonder that the collosectomy patients don’t seem to notice their mental scission, given that even normals seem totally unaware of their binocular scission until this bizarre feature of normal consciousness is pointed out to them.

Just as interesting as binocular scission is the remarkable phenomenon of *binocular fusion*, when the left and right eye images “find” each other and abruptly snap into place, resulting in an immediate fusion of the double experience into a single integrated and vividly three-dimensional experience. It is no longer even possible to identify which part of the experience is due to which eye, even when the images differ in certain details. For example sometimes one eye catches a specular reflection that is absent in the image from the other eye, or one eye sees a feature that is occluded in the view of the other eye, by the phenomenon known as *Da Vinci stereopsis*. In these cases it is often difficult (although not impossible) to determine which eye is seeing what without closing one eye, then the other in turn, although the feature that is detected by only one eye can seem somehow dazzling and magical, as if set apart from the rest of the experience, so as to be more easily either noticed or ignored. For example if you mark the back of one playing card with a tiny spot that is almost impossible to locate visually, due to the rich and complex pattern typically printed on the backs of playing cards exactly to conceal such blemishes from notice, that tiny blemish can be spotted almost instantly by laying it down next to another card from the same pack, and fusing the two as if they were a binocular pair (for those who have practiced the ability to “free fuse” binocular image pairs, or you can view them through a binocular viewer, for those who have not). This will immediately bring out all of the tiniest differences between the two patterns, and those differences seem to shimmer and

glint in a magical mystical manner, blinking alternately in and out of experience as if trying to decide whether they exist or not. (Incidentally, this is a good way to check for “trick” cards that use a hidden pattern on the backs of the cards for cheaters to identify the face value from the view of their backs.)

A similar phenomenon is observed in perceptual fusion across different sensory modalities. We are generally oblivious to the myriad tiny noises in our environment, from the creaking of pipes when the thermostat clicks on, to the sound of rain on the window, or the quiet ticking of a clock, etc., so much so that we would be inclined to report, if asked, that we were hearing “nothing”. And yet we are exquisitely sensitive to the tiniest sound that is inconsistent with our expectations, such as the tiny sounds due to a person quietly sneaking up on us from behind, or the sound of a mouse scuttling quietly above the ceiling. The anomalous sound stands out from the ambient noise, and catches our instant attention, like the blemish on the fused pair of cards. The secret behind the principle of binocular fusion is exactly the secret behind the unity of conscious experience, or how the patterns of activation in the many diverse cortical areas fuse to form a single coherent integrated experience.

The Nose On Your Face

Another example of binocular scission plain as the nose on our face is seen in the appearance of our own nose at the center of our visual field. How does your own nose appear to you in your phenomenal experience? It took me a long time of patient observation before I could answer that question for myself. Being so close, the image of your nose is permanently blurred, a fuzzy pinkish blob. But the experience is further complicated by the fact that your nose is so close as to be outside of “Panum’s fusional area”, that is, it cannot be fused binocularly into a single three-dimensional object, but appears as two separate and independent artifacts to the two separate eyes. To my left eye, my nose appears toward the right side of my visual field, seen almost in profile, pointing leftward, as shown in Fig. 6.9A, whereas to my right eye it appears on the left, pointing right wards, as shown in Fig. 6.9B. Curiously, the background viewed by both eyes is fused into a single continuous percept, while the nose remains split as a double experience. (The full monocular/binocular effect can be seen by fusing Fig. 6.9A and Fig. 6.9B as a left/right eye stereo pair.) There is also a strange shift in the location of my egocentric point as I view my nose from one eye or the other. When viewing the left eye view of my nose, as in Fig. 6.9A, I feel my egocentric point to be located behind my left eyeball, even while I am viewing the portion of the world visible only to the right eye, as if the bridge of my nose were transparent inside my head, allowing me to look with my left eye through my skull and out through the window of my right eye. Switching alternately between left and right eye views gives the impression that my egocentric point is moving back and forth across my head to look out of first one eye then the other, which makes my nose appear to waggle from side to side like a swinging door. I remember as a child in first grade, how my head appeared to me like the interior of the cockpit of an airplane, with the windshield divided by a central post, but allowing me to look out either side of the windshield.

The egocentric point can be returned to the center by looking straight ahead in the

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distance, in binocular fusion. This creates the experience of a single world in the distance, although the image of my nose remains split between two monocular views at the center of my visual field, as suggested in Fig 6.9C. The experience of my nose is rivalrous, that is, I tend to see one eye's view or the other in sequence, although at the same time my nose also appears semi-transparent in each view, as the portion of the world occluded by my nose is filled-in with the image from the other eye. Like a dirty windshield, I tend to see right "through" my nose as if it were not there, and it requires special attention to even see it at all. I can however make myself see both views at the same time, in which case the two profiles appear as two separate objects at different angles, like the dihedral formed by the wings of a butterfly sitting in the middle of my face. This is another example of a duality or scission of the unitary conscious experience into two parallel loosely-coupled conscious experiences, this time with the interesting property that the scission only occurs at very close distances, with fusion farther out.

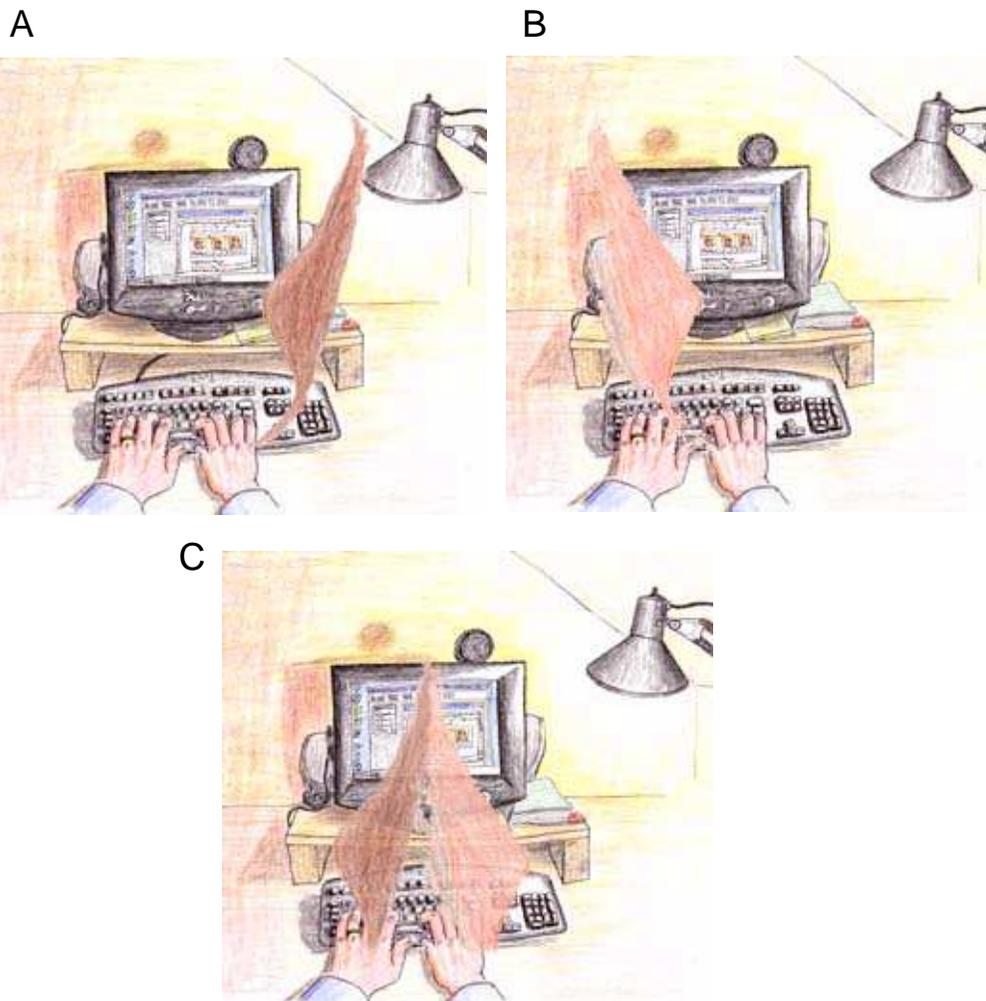


Fig. 6.9 The subjective experience of the nose on your face appears A: as a semi-transparent shaded structure on the right, when from your left eye, and B: a semi-transparent lighted structure on the left, when viewed from your right eye. C: When viewed with both eyes simultaneously, your nose projects a double aspect like the wings of a butterfly, in a vague, semi-transparent and rivalrous manner so as to be almost invisible to normal perception.

Signal and Noise

There is yet another kind of fragmentation in visual experience that has significant implications for the question of the unity of consciousness. In normal conscious experience I am completely unaware of the visual artifacts such as the specular scintillation, floaters, retinal after-images, and other visual artifacts described earlier, as if they were completely absent from my experience. If asked, I would tend to report a blue sky, or a white page, as a perfectly smooth homogeneous continuum. And yet whenever I choose, I can also focus my attention on any of these visual artifacts (once I have learned to see them at all) and again see them as part of my visual experience. The profound question raised by these observations is whether these phenomena are really invisible whenever they are not consciously experienced, or whether they are consciously experienced but normally being ignored. I suspect that the newborn infant, on first opening its eyes to the world, is flooded with a barrage of these imperfections of vision caused by the rather crude and noisy optical apparatus of the human eye, so much so that the infant probably has great difficulty seeing anything of the external world at all through this mass of visual confusion. The first weeks and months of the infant's experience must therefore be devoted to learning to ignore these disturbing patterns of visual experience, and to focus instead on the more interesting and significant features that reveal a stable structured world beyond immediate experience. So what of the visual noise that we sometimes observe? Is it a part of our consciousness when we are not conscious of it?

I propose that there is only one coherent explanation for these aspects of sometimes-conscious experience. By their nature we can determine with certainty that they are not part of the external world, but are artifacts of the imperfections of our own visual mechanism. It is most unlikely therefore that they can ever really cease to exist, even when we ignore them. After-images are an artifact of the depletion of the retinal photo pigment with exposure to bright light. The depletion is a neurophysiological process, and therefore it cannot have simply ceased to occur. I propose that the experience only disappears from our narrative consciousness because it has split off to become a separate parallel conscious entity that is no longer considered part of "my" experience, but somehow experiences itself independently. The principle of this disappearance is much the same as peering at the road through a dirty mud-streaked windshield. Normally we see right through a dirty windshield so as to be barely aware of its presence at all. In some sense we still "see" it as a separate layer of reality, but our attention is so focused on the world beyond the windshield that it no longer has any effect on our behavior. When the dirt gets so thick that we can no longer ignore it, we can shift our focus of attention onto the windshield long enough to deploy our washer and wipers, during which time the dirty windshield again becomes part of our narrative consciousness. The ability to ignore the dirty windshield requires an ability to segment the image of the windshield from that of the road beyond it, to see them as two separate planes of experience. We can then assign to the zombie autopilot part of our mind the task of keeping an eye on the state of that windshield, with instructions to wake up our narrative consciousness whenever the windshield gets so dirty as to require another wash and wipe.

So too with the visual artifacts that are endogenous to our visual system. To the

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newborn infant these artifacts are initially indistinguishable from the stable world viewed through them. As soon as these errors of vision have been recognized and sufficiently characterized so as to be distinguishable from the world beyond the eye, we can not only push them into a separate plane of experience, but we can even cut off that plane of experience from our central narrative consciousness so as to be no longer directly aware of their existence, even though they continue to exist as an experience in their own right. Our conscious experience therefore is not entirely unified, but consists of multiple parallel streams, most of which operate independently to monitor things like our bodily posture, acoustical environment, visual artifacts, dirty windshields, and so forth, each with a kind of zombie awareness devoid of long-term memory, so as to be unreportable as an experience too long after the fact, but each equipped with a zombie autopilot awareness ready to wake up the global narrative consciousness if conditions should warrant closer attention. But these parallel independent processes are still conscious, rather than unconscious, as evidenced by the fact that they each possess a short-term memory as an experience that can be accessed on demand by simply coupling them to the central narrative consciousness.

The brain must also possess a cleaning-up and filling-in function that corrects for these many visual artifacts, to produce the clean and clear image of the world which is the experience that we normally attend to. For example if a streak of mud on our windshield sweeps a brown arc over a portion of the blue sky, our brain must not only segment that muddy streak and pull it into the foreground, but it must also paint in the patch of the sky occluded by that brown streak, and paint it a pure clean homogeneous blue again, even if only in amodal color. To do this the brain must be able to guess what the sky should look like in the absence of the occluding muddy streak. So too with all of the other visual artifacts that plague our vision. The image of the world beyond all that visual chaos and noise can only appear as clear and sharp as we experience it to be because our brain has recognized, quantified, and finally nullified, or compensated for each different type of artifact, in order to recreate an experience of the crystal clear world that our narrative consciousness usually believes itself to be seeing.

Chapter 7

Sensory v.s. Epistemic Perception

Epistemic Perception

In chapter 2 I presented a quantified phenomenology in the form of a three-dimensional representational space, like a diorama, containing solid volumes bounded by colored surfaces. This spatial manifold is a model of the sensory component of perceptual experience, the actual shapes and colors experienced when viewing a scene. But there is more to perception than merely registering the shape and colors of perceived objects. As mentioned briefly in chapter 2, there is also an epistemic component to perception that involves an *understanding* of what it is that we are experiencing. What does it mean to understand what is seen? How can we quantify the principle behind understanding in a computational model of perceptual experience? The answer to this question is intimately connected with the amodal component of perception.

In neural network models recognition is most often modeled by the lighting up of specialized feature detection nodes, that become active in the presence of a particular feature in the visual field, and remain inactive in the absence of that feature. Neurophysiological studies of the activation of single cells in the visual cortex are also most often interpreted in these terms. But while it is true that our brain is in different states depending on the pattern we recognize to be present visually, there is more to recognition and understanding than merely the registration of this one bit of information. When we view the visible front face of an object, our perceptual apparatus automatically and involuntarily completes the whole object including its solid volume and hidden rear surfaces. I propose that true understanding is intimately connected with this reconstruction or reification function of perception. We understand a seen object when our amodal image of the object is sufficiently complete that we can form a mental image of the whole object as a volumetric structure, independent of the particular viewpoint from which we happen to view it at any one time. Understanding is intimately connected with the ability of our mind to generate volumetric simulations of external reality in amodal perception and mental imagery.

There are different levels of understanding of an object in perception. The zeroth level is no understanding at all; an object can be present in our experience, but that presence is being totally ignored, it is having no effect on any other part of our mental function or experience beyond the bare presence of its replica in our representational manifold. A representation by itself has no more understanding than the pattern of ripples on a pond, that simply exist in the state in which they exist. This is raw immediate experience, similar to the experience of a man so profoundly intoxicated that he lying incapacitated, with no perception of the external world, his experience being limited to whirling patterns in his own mind, patterns that are as quickly forgotten as they are replaced by new patterns in an endless and meaningless stream. The first level of recognition is that of a 'thing', a generalized nondescript object, a 'Gestalt'. We are aware of the presence of an object but our model of that object is developed no further. The effect of the object

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on our behavior is independent of the identity of that object, our response would be the same whatever that object turned out to be. For example when we become aware of an object blocking our vision, we attempt to sweep it aside with a generic sweeping motion of our hand. Our amodal image of the object remains fuzzy and non-specific, restricted to its general location and approximate size. But despite this generality, the perceived object has (or tends to have) permanence of existence; we are not convinced that we have cleared a visual obstruction unless we feel it come away in our hand, or feel or hear it drop as we sweep it aside. In other words, even if the obstacle disappears, we suspect that it continues to exist somewhere, and that suspicion corresponds to our recognition that there is something there. A higher level of understanding comes from seeing the object as a blob, clod, tuft, chunk, crumb, puff, or wisp. There is now some character attached to the otherwise nondescript object, something to help us recognize it next time we see it, or another one like it, even if we remain ignorant as to what it was a blob or clod *of*. The next higher level of recognition places the represented object in a general category; for example that it is a bug, or some kind of fiber fluff, and this additional general knowledge can have an influence on our behavior in response to the object. A wisp of fluff is perceived as something passive and innocuous, whereas an insect is perceived as an active and possibly malevolent agent, and thus it triggers a higher, more urgent level of behavioral response. Finally, the highest understanding comes from a full identification of the object as something specific, a house fly, for example, or a downy feather. Whether or not we use the same generic sweeping motion to clear away the house fly or the downy feather, our deeper recognition opens the *potential* for different responses if we deem them necessary. But we can only choose to respond differently if we have registered that difference in our amodal representation of the object in question. This is the basis of true understanding or recognition of what we are seeing.

There is no end to the depth of understanding that is possible for an object. A young infant might understand a tomato in the simplest possible way, as a red bulgy shape whose interior is presumed to be a homogeneous and featureless continuation of the red color that pervades its external surface. Children who have had experience with the interiors of tomatoes might have a more complete mental image of a fleshy cortex and a slimy core, whereas a botanist would have a still deeper understanding of the invisible cellular structure and living function of the tomato, knowledge that ranges beyond perceptual and into cognitive function.

And in the realm of cognitive function our knowledge tends to break into focal glimpses of parts of that knowledge disconnected from the whole, the image tends to lose its integrity with in-depth knowledge. For example the botanist's understanding of the cellular structure of the tomato does not render the entire tomato at microscopically high resolution with myriad microscopic cells seen at high resolution throughout the mental image, but rather, the botanist can home in on one small part of the mental image and zoom it up from microscopic size, revealing a tiny cameo of a microscopic scene in one small part of the whole tomato at a time. Our knowledge of the origin of the tomato, when we give it any thought, comes as a jerky sequence of disconnected images of seeds and plants and harvests, the exact sequence being different every time we contemplate the concept. The cognitive concept is far more complex and unstable than the

perceptual image, and it makes contact with that most fragmented and abstracted world of language. But our interest at this point is in the perceptual level of understanding, the preattentive and unconscious spatial inference of the configuration of the hidden portions of the object as suggested most literally by its visible features. This most basic form of understanding offers an avenue of investigation into the nature of understanding in general, and how it can be quantified in a computational model of the process, and thus eventually replicated in an artificial intelligence.

Completion by Symmetry

The computational principle behind amodal completion is a completion by *symmetry*, as seen in the case of the cube and the sphere, whose hidden geometry is extrapolated or interpolated from the configuration of the modal exposed surfaces. This is symmetry in the most general meaning of that word, that is, '*sym-metry*', or *of the same measure*. Wherever the visual system detects a pattern of symmetry in modal surfaces, the regularity in the stimulus-driven modal surfaces suggests an extrapolation and/or interpolation of that regularity into the amodal volumetric model of the object. This is the principle evident in the perceptual completion of a cube or sphere. But before we discuss recognition of whole forms, let us begin with the recognition of the elements such as volumes and surfaces and corners of which those geometrical forms are perceived to be constructed, because those too are aspects of symmetry, although symmetry of a lower, more primal order. Like Euclid, I propose to start with the point, line, and plane, because these concepts are not only the foundational axioms of geometry, they are related to the foundational axioms of our visual representation, and their use in geometry was surely inherited from their more primal role in perceptual representation.

The foundational axioms of visual representation are reified or filled-in renditions of the abstract Euclidean concepts of point, line, and plane. The perceptual variant of the plane is the surface. The surface shares with the plane its planar geometry. But a surface has more; it has a polarity: substance on one side and void on the other. A surface also has color, brightness, texture, or pattern. The colored surface is the basic building block of modal experience, and the solid volume that it delimits within its surface is the building block of amodal experience. The perceptual variant of the Euclidean line is the edge, an abrupt discontinuity of surface properties across the edge. An edge can mark a change of surface color, like the painted edges between white and black squares on a chessboard, or it can mark a discontinuity of surface configuration, like the corner-edges of a cube along which its plane facets meet. A trihedral corner marked by the intersection of three surfaces in space, as at the corners of a cube, is the perceptual variant of the Euclidean point. The concepts of surface, edge, and corner have a polarity, white/black, substance/void, which their abstracted Euclidean counterparts have abandoned. But one thing they share with the Euclidean line and plane is their geometrical regularity, or symmetry, whereby one sample of the edge or surface suggests a longer edge or larger surface of the same properties. This regularity is exploited by the visual system to make spatial inferences about missing or occluded portions of the scene, and this extrapolation is the first, most basic step of recognition or understanding of the scene.

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Fig. 7.1A shows a local portion of a surface viewed through a circular aperture. The surface seen through the aperture is not perceived as an isolated patch, but rather as a visible portion of a larger surface, the rest of which is perceived amodally behind the occluding screen. Furthermore, phenomenological examination of this amodal percept suggests that the hidden portions of that surface are perceived to be similar to the visible portion, with the same color and texture, although the confidence of this percept seems to diminish somewhat with distance from the visible portion of the surface. This kind of deduction is commonly assumed to be a cognitive process. However, whether it is labeled as cognitive or amodal-perceptual, the deduction can be described as a spatial image or fieldlike data structure extrapolated outward from the visible portion of the surface by a process that can be modeled by a spatial diffusion. The structural or spatial nature of this inference becomes more evident in the example shown in Fig. 7.1B, where the contrast edge is perceived amodally to continue beyond the aperture in both directions by extrapolation of the visual edge out into the occluded portions of the scene, in conjunction with the diffusion process that fills in the dark and bright surfaces on either side of the extrapolated edge. This type of collinear extrapolation can therefore be modeled by a *directed diffusion* process, as proposed by Lehar (1994), that projects the visual edge outward as a linear extension in both directions, and the confidence of this extension fades with distance like a spatial probability field. When contrast reversals are encountered across a visual edge, as seen in Fig. 7.1C, the edge is still inferred to continue into the occluded region, but this time like an edge in an outline drawing, with a linear form but without a specific contrast polarity. However, if the contrast reversals are periodic, as shown in this example, then this periodicity itself reflects a regularity in the visual stimulus that can be used in the construction of the spatial inference. Similarly, the Gestalt principle of closure would tend to complete the form in Fig. 7.1D, whereas symmetry would suggest the completion of Fig. 7.2E. These intuitive insights into the structure of the amodal percept can be easily tested psychophysically by asking subjects viewing images like those in Fig. 7.1 to guess the brightness values at various sample points on the hidden surfaces, in a manner similar to the procedure used by Attneave (1954).

Even longer range completion is observed with perceptual interpolation between regions of spatial information, as shown in Fig. 7.2. This interpolation appears to be of the same nature as the interpolation observed in modal illusory phenomena such as the Kanizsa figure, with the sole difference that the interpolated structures are amodal rather than modal in nature. The extrapolation and interpolation observed in Figs. 7.1 and 7.2 are therefore examples of perceptual reification, revealing the generative or constructive aspect of perception. However, this reification must presuppose a certain abstraction also, because the reification must conform to the patterns of regularity detected in the visible portions of the scene. There is a general principle evident in this manifestation of perceptual processing: that the visual system attempts to complete spatial structure into unseen portions of the scene based on the implicit assumption that the visible portion is a *representative sample* of the hidden parts of the scene.

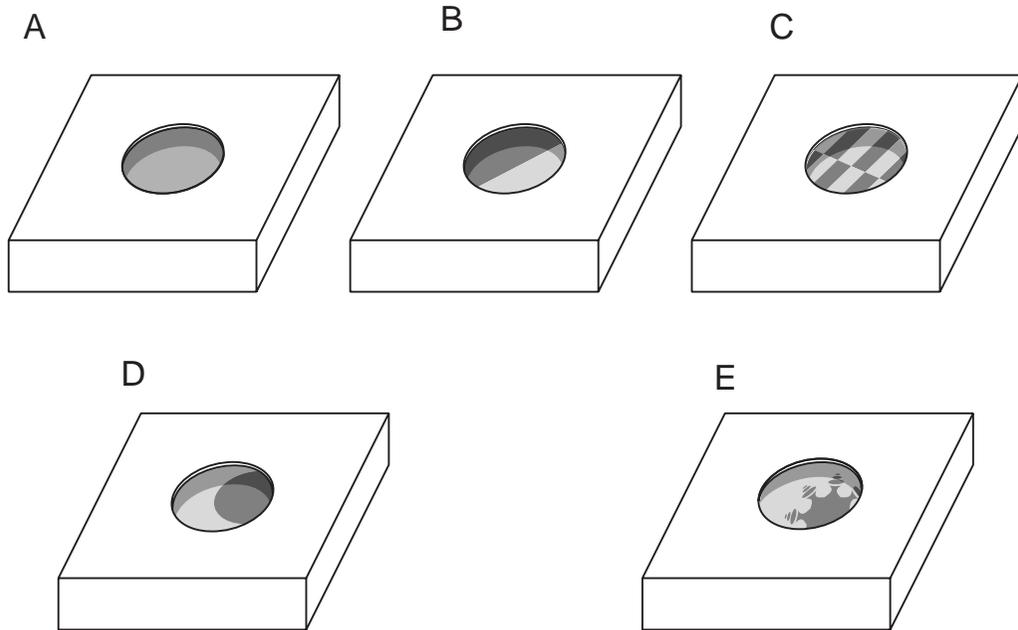


Fig. 7.1 (A) A local portion of a surface viewed through an aperture creates an amodal percept of a continuous surface extending outward from the visible portion. (B) If the visible portion contains a visual edge, that edge is perceived amodally to extend outward in both directions. (C) If the edge has no defined contrast polarity, then the amodally completed edge also has no defined contrast polarity, unless, as in this case, the contrast reversals are periodic, in which case the pattern is perceived to complete with the same periodicity. (D) Amodal completion also respects the Gestalt principle of closure and (E) the Gestalt principle of symmetry in the completion of the amodal percept.

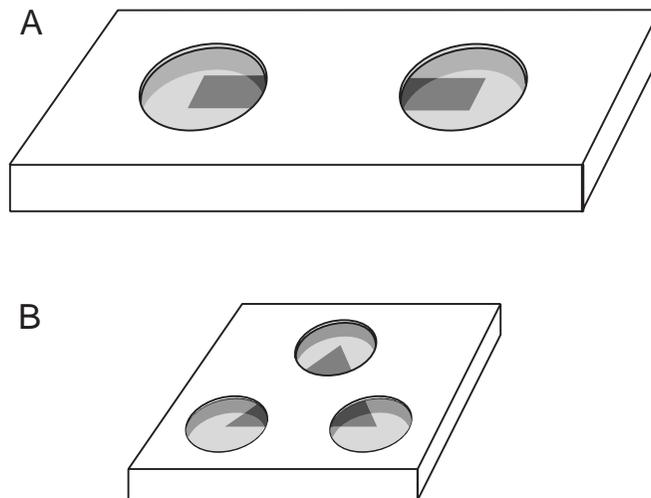


Fig. 7.2 Amodal completion produces an even more stable perceptual completion across longer distances by interpolation inward between visible portions of the scene than by extrapolation outward.

Pattern Completion in Three Dimensions

The *representative sample principle* holds also in the perception of the hidden portions of three-dimensional objects, such as the shapes shown in Fig. 7.3, which are experienced phenomenally as enclosed volumes in three dimensions, complete with an amodal percept of their hidden rear faces, constructed by completion of the regular pattern observed on their visible front faces. In the case

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of more regular shapes, such as Fig. 7.3A through 7.3C, the amodal percept could in theory be quite precise mathematically, although there is still a probabilistic component to the amodal percept because there is no guarantee that the regularity must necessarily hold through the hidden portions of the figure. The perceptual experience of the rear face of these objects is no more than a likely assumption in the absence of contradictory evidence, but a spatial assumption, nonetheless, that can be described as a three-dimensional spatial probability field. The resolution of the amodal percept also appears to be less than the resolution of the modal front face; for example, it is difficult to precisely locate individual spikes on the amodal side of the percept of Fig. 7.3D, even though that surface is perceived nevertheless as studded with spikes of a specific size and average spacing. The amodal completion of the shapes in Fig. 7.3E and Fig. 7.3F are even more probabilistic in nature, due to the irregularity of the visible front surface. However, these amodal percepts are also spatial structures, because it would be possible to measure a three-dimensional probability field defined by the likelihood that a subject would guess any point in three-dimensional space as being inside or outside of the three-dimensional figure from the view of its visible front face. The structure of the amodal percept is therefore lawfully related to the shape of the visible front surface, as constructed by perceptual processes.

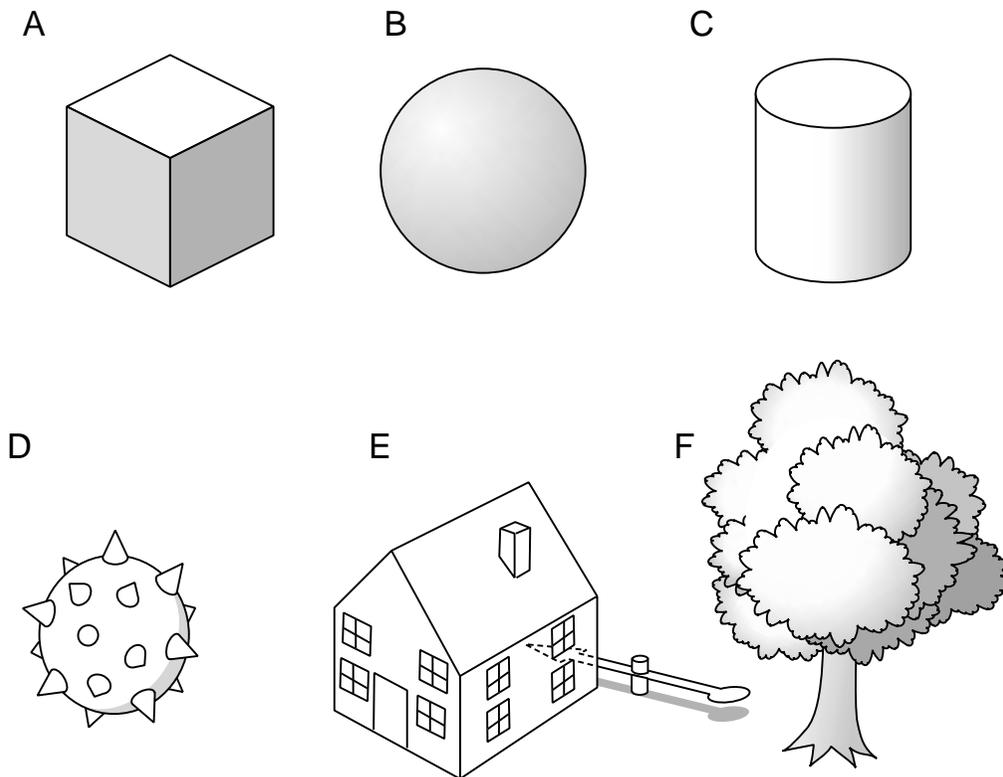


Fig. 7.3 A view of the front face of different objects generates an amodal percept of their hidden rear faces. This percept is like a spatial field, in that if a subject were given full three-dimensional models of these objects built as hollow facades with the rear faces missing, the subjects could easily indicate with their hand the perceived spatial extent of those hidden rear surfaces, like a three-dimensional probability field whose shape is determined by the perceived shape of the visible front faces.

Completion Behind the Head

The same kind of pattern completion can also be applied to the spatial percept of the world behind the head, based on the same general principle that the world within the visual field is a representative sample of the world all around. Therefore in the absence of contradictory evidence, this assumption is a useful working hypothesis until proven otherwise. For example, a view of the internal corner of a room seen in the visual field suggests a possible configuration for the rest of the room, as suggested in Fig. 7.4A, by the very same principle as that used with a view of a cube from the outside, as in Fig. 7.3A. Of course, there is no guarantee that a room should be necessarily square, or that the perceiver is necessarily located at its center, and therefore the amodal percept of the room behind the head would often be more vaguely specified than suggested in Fig. 7.4A. However, in a real situation the extent and aspect ratio of the room would have been observed when first entering it, and those proportions would be generally preserved to some level of accuracy in the amodal percept as the person walks about in the room and turns in different directions. This can be demonstrated by entering an unfamiliar room, and after a brief initial glance, it is possible to turn around and walk backward, and indicate with your palms the approximate location and surface orientation of various walls behind you at various sample points while viewing only the world in front of you, although you are likely to stumble over smaller obstacles like furniture, indicating that these are not mapped with great precision, but are experienced as a vague probability field. In the case of an outdoor space the same principle can also be applied. For example, a view of a forest, as suggested in Fig. 7.4B would suggest, in the absence of contradictory evidence, that the forest is expected to continue in similar fashion with a similar periodicity of trees, although the irregular spacing of the trees within the visual field and the variation among individual trees would not allow a precise prediction of the exact location of the trees outside the visual field. Nevertheless, the information about the approximate tree size, shape, and spacing seen up ahead would be very helpful in making sense of the visual stimulus if the man were to turn around suddenly and look at the world behind him, for the only information he would then need to encode from that view is the difference between what he sees and what he expected to see.

Abstraction as Derivative, Reification as Integral

The principles of information theory would suggest that the spatial information of the world can be encoded in most compressed form by encoding the points of transition, or places where the regularity of the pattern of the visual world is broken, in order to avoid redundancy in the representational code. In the case of a solid cube embedded in empty space, the transition from the solid substance of the cube to the empty space around it occurs at the surface of the cube, and therefore the volumetric percept of the cube can be encoded by that three-dimensional surface alone. This obviates the need to explicitly encode the solid volumes of either the object or the space around it. The surface of the cube in turn

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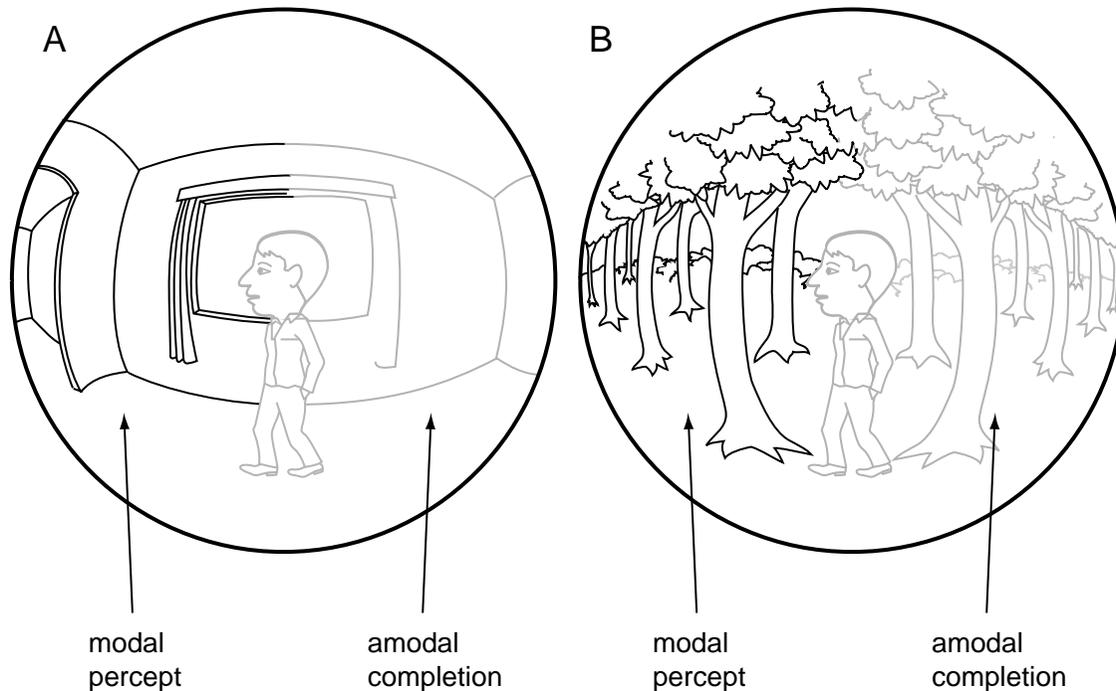


Fig. 7.4 The amodal completion of the hidden half of objects applies also to the hidden half of the world behind the head, which is also completed perceptually by an assumption of similarity with the visible front half, exactly as in the case of the hidden rear faces of objects.

is defined by plane faces, within which the pattern of the surface is regular, and therefore those faces need not be explicitly encoded point for point, but can be abbreviated to the three-dimensional corner-edges where the different facets of the cube meet, defining a three-dimensional wire frame like a Necker cube. The corner-edges themselves contain further redundancy, and therefore they too can be expressed more compactly terms of their two endpoints. The entire cube can therefore be encoded by the three-dimensional location of the eight corners of the cube. But those eight corners themselves define a regular pattern when viewed from the special location of the center of the cube, from which point the corners can be defined by eight identical vectors pointing outward from the center, as suggested in Fig. 7.5.

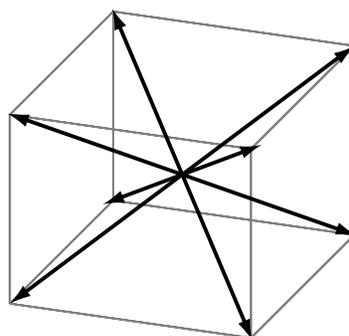


Fig. 7.5 A cube can be abstracted to its plane faces that bound the volume of the cube. Those faces can be further abstracted to the straight corner-edges that bound them. The lines can also be abstracted to the pair of points that bound their endpoints at the vertices of the cube, and finally the pattern of vertices can be abstracted to an eightfold pattern of vertices about a center of symmetry. That eightfold symmetry encodes the cubical form.

The reduction of the cube to this minimal representation is the process of abstraction in perception corresponding to compression in information theory. A complementary process of reification represents the inverse of abstraction, which, like a decompression algorithm in information theory, serves to reconstruct the perceptual image of the cube from the abstracted information. Given the compact information of the cube as an angular solid with an eightfold symmetry at a particular location and orientation in space, eight identical vectors can be constructed equally spaced in solid angle around the central point located somewhere in perceptual space. Each of these vectors defines the endpoints of the 12 linear corners of the cube, and these corner-edges in turn define the bounds of the flat surfaces of the cube, and those surfaces in turn separate the volumes of space that are inside versus outside of the cube.

I propose that the principle behind the perceptual transformation is a simultaneous and continuous process of abstraction and reification. The visible front faces of objects in the world are first reified from the visual stimulus. As these hollow shells, or visual facades, emerge in the volume of perceptual space, a symmetry detection mechanism marks any centers of symmetry in the volumetric matrix, and that compressed encoding in turn serves to regenerate the hidden portions of those facades to match their visible front faces, resulting in a solid three-dimensional amodal core with a hollow modal face on the visible side.

For example, the presence of a section of a spherical shell in the modal representation would produce a symmetry response at the spherical center of that surface, as suggested in Fig. 7.6A, and that response in turn would stimulate an amodal percept of the rest of the spherical shape, as suggested in dashed lines in that figure. Similarly, a portion of a cylindrical surface would promote the amodal completion of the rest of the cylindrical form, as suggested in Fig. 7.6B, and that cylinder would also tend to propagate outward along its cylindrical axis in both directions, as suggested in Fig. 7.6C, extrapolating the detected pattern of symmetry. A section of a planar surface would tend to propagate in planar fashion, as suggested in Fig. 7.6D. Angular shapes such as cubes, pyramids, tetrahedrons, dodecahedrons, and so on would also find simple expression in a symmetry-based descriptor, which would explain the perceptual significance of the Platonic solids, as recognized already in ancient Greek science. Fig. 7.6E shows schematically how a simple scene would be reified in perception, with the modal front faces of the foreground objects stimulating an amodal completion of their hidden rear surfaces. Notice how these foreground objects cast amodal "shadows" across the space that they occlude, which requires amodal completion to complete those background surfaces based on their visible portions. Given that the sensory stimulus of the experience of colored surfaces, begins with the flat two-dimensional image in Fig. 7.6E, the fact that the color component of this experience is projected onto the corresponding surface in the three-dimensional percept, explains why the hidden rear portions of objects can never appear as modal, because the two-dimensional stimulus only projects to the nearest surface that it encounters as it projects back into the depth dimension, except in the case of transparency, where part of the color projects to a nearer depth, and the rest projects to a farther depth.

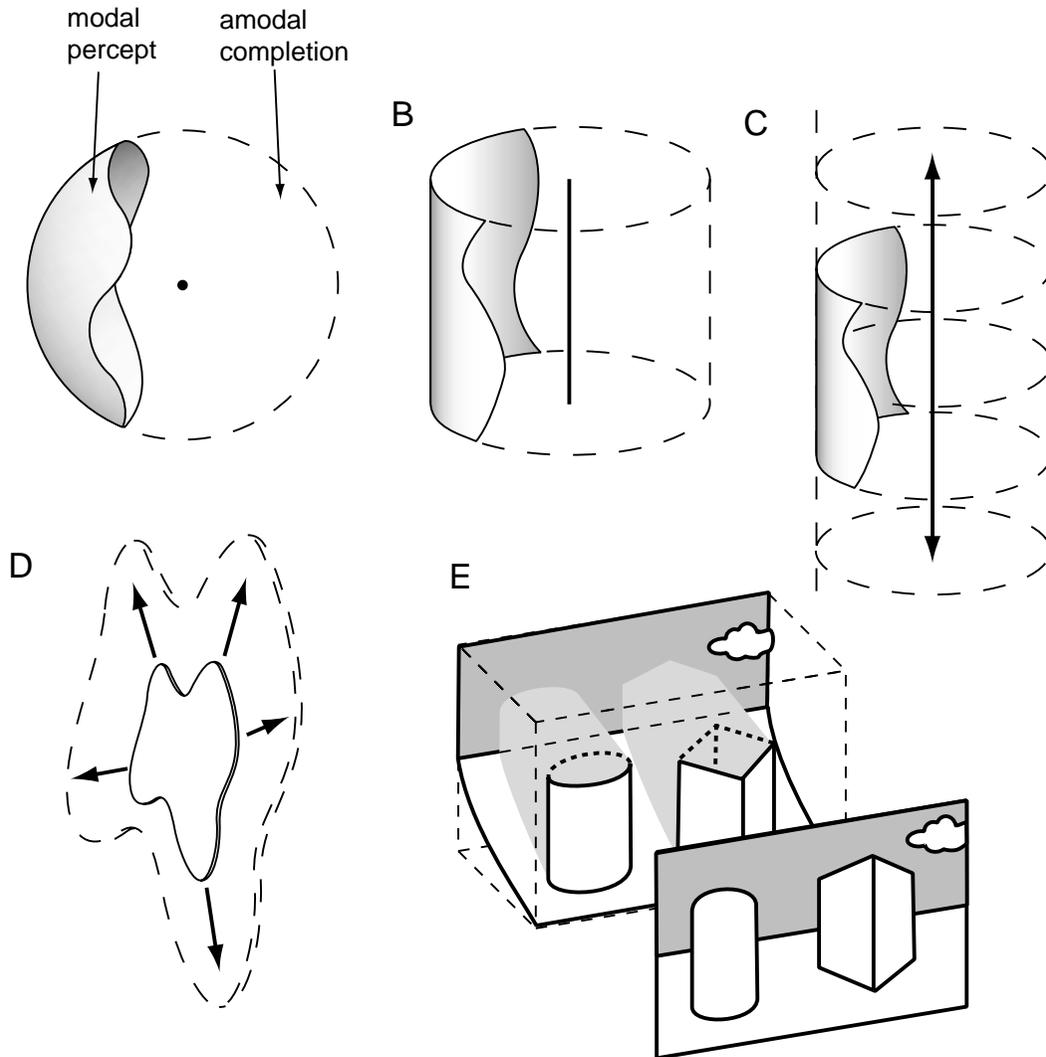


Fig. 7.6 The basic function of perception can be described as a simultaneous abstraction of perceived forms to their axis of central symmetry, together with a reification of that pattern of symmetry to construct an amodal completion of the percept based on the perceived regularity. A spherical surface (A) is completed as a whole sphere; a cylindrical surface (B) is completed to a full cylinder; and that cylinder is extrapolated (C) along its axis in both directions. (D) A planar surface is extrapolated outward in the plane. (E) Perceptual reification of a simple scene, showing amodal completion of hidden rear surfaces. Notice the amodal “shadows” cast by foreground objects, which require background surfaces to be completed through the occlusion from their visible portions.

General Function of Perception

The most general function of perception can thus be described somewhat as follows. Our most basic conscious experience is of a self within a world, the self and its world being defined as volumetric spatial structures. The spatial structure of the experienced self, if it is to serve any useful purpose, must be a veridical copy of the external body of which the experienced self is an internal replica. We experience our body to be of a certain size and shape, and we perceive it to be in a particular posture, whose configuration we experience immediately and automatically by proprioception, as suggested in Fig 7.7A. Besides a mere posture, we also experience forces in the world. We experience the weight of our

body as a powerful force that seems to pin us down against whatever it is that is currently supporting us, as suggested in Fig 7.7B. The downward force due to gravity offers an objective orientation to the phenomenal world. As infants, we learn to associate that force with a downward direction, as suggested in Fig. 7.7C, and we learn to oppose that downward force with a voluntary upward motive force of *levity*, that seizes our body and moves it in whatever direction we choose to direct it by an act of will. In other words, our desire to move our body is experienced as the appearance of a spatial force field which we learn has the magical effect of actually moving our body (image) in the direction of that force, as suggested in Fig. 7.7C. This primal level of consciousness must be present even for the unborn child in the womb, as well as for virtually all mobile animals who need to articulate their body for locomotion. It is hard to imagine how an animal could control its movement through the environment with any intelligence without this basic level of spatial awareness.

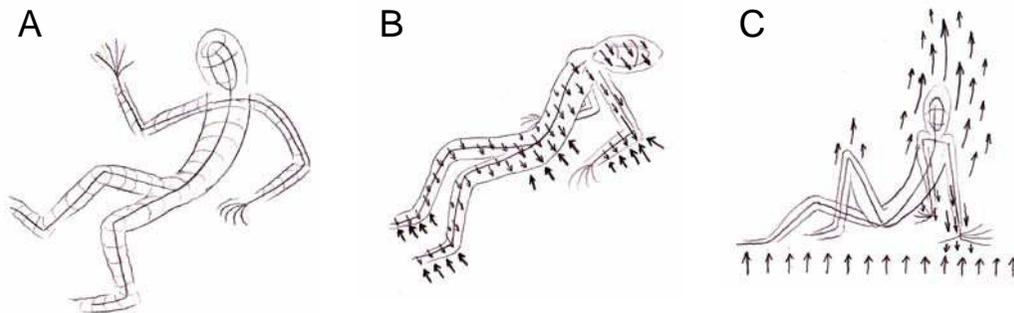


Fig. 7.7 A: The most primal experience of self consciousness is of a self in the world, that self being experienced as a spatial structure in a particular configuration or posture. B: We also experience forces of weight and mass and pressure, like the force of gravity that pins us to whatever happens to be supporting us. C: We learn to associate that force with a downward direction, and we learn to oppose that downward force with a voluntary upward force of motive intention that seizes our body-image and moves it in whatever direction we choose to direct it by an act of will.

When we open our eyes, we discover that whole sections of the external world suddenly spring alive into a vivid experience of color and light of exquisitely high resolution and fine detail, as suggested in Fig. 7.8A. Whatever direction we project our gaze, we see the world suddenly fleshed out in great detail in that direction, as suggested in Fig. 7.8B. And when we look down at our own body, it too pops into a structure of incredibly complex articulation and rich spatial detail, as suggested in Fig. 7.8C. Note the amodal 'shadows' cast by nearer objects onto more distant surfaces that they occlude.

The primary function of perception is the construction of this rich internal world of spatial reality based on the input from the various senses. This fictitious world constructed in our brain is the only reality we know, so we naturally take it to be reality itself. Careful analysis of its properties however clearly reveal its ultimately illusory nature, for example the great gaps that it contains, such as the missing rear faces of perceived objects, and the missing hemifield behind the head. There is a great deal of coherent structure in this spatial world of experience, that differentiates it from, for example, the kinds of random patterns of color and form seen in a visual hallucination. Perceived objects appear as structured wholes that tend to maintain their structural integrity and existential permanence as they move

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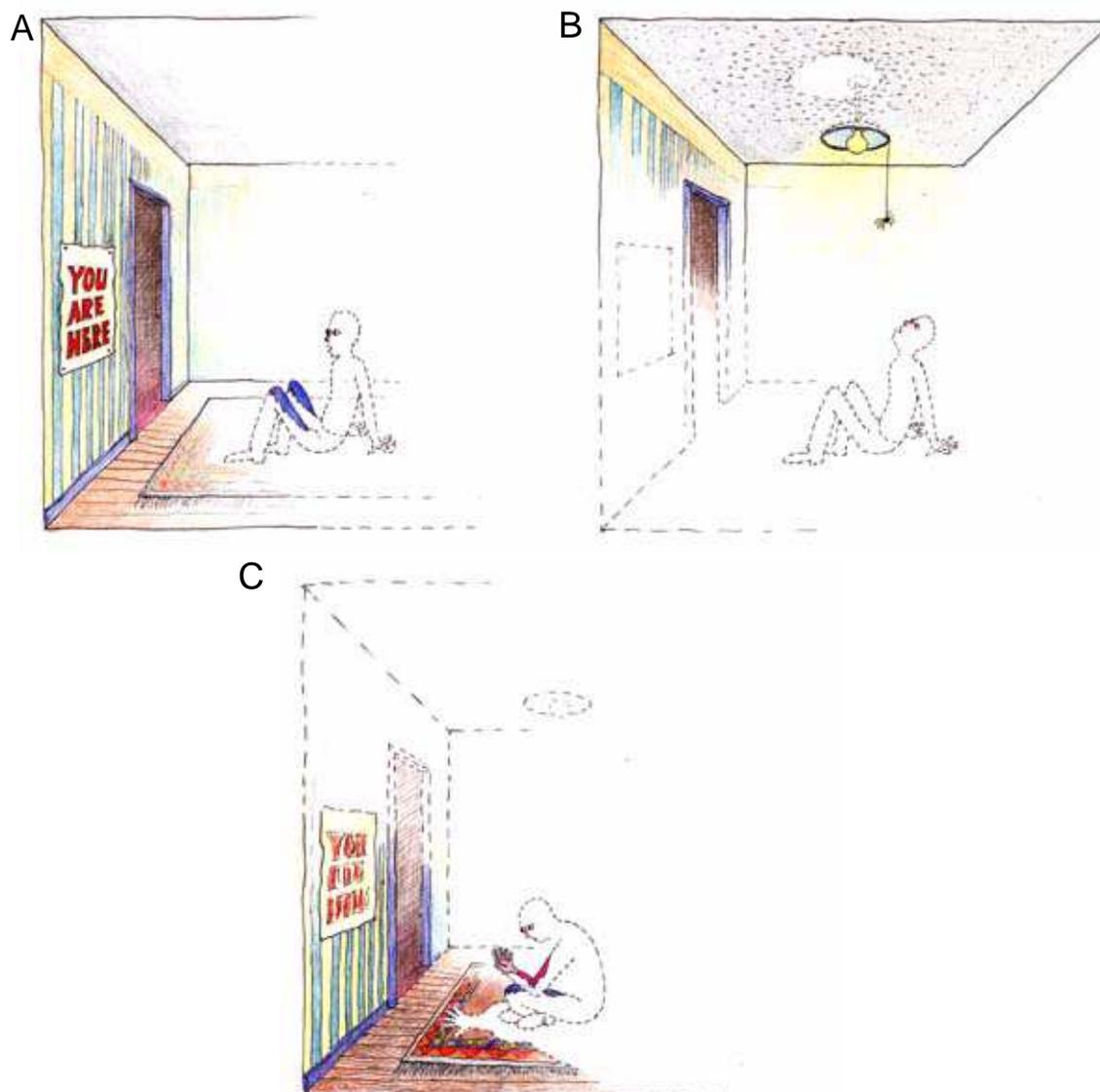


Fig. 7.8 When we open our eyes, we discover that whole sections of the external world suddenly spring into existence as a vivid experience of color and light of exquisitely high resolution and fine detail. Whatever direction we project our gaze, we see the world suddenly fleshed out in great detail in that direction. And when we look down at our own body, it too pops into a structure of incredibly complex articulation and rich spatial detail.

about in the world, and the perceived world in which perceived objects appear is itself a structured whole with its own existential permanence, in that it rotates coherently around us as we turn our body in the world, and it scrolls past us coherently as we travel through the world. It is that existential permanence and structural coherence which are the most basic primal characteristic of epistemic perception, that differentiates it from the raw sensory perception of a psychedelic hallucination, with its unstructured sequence of random shapes that morph endlessly without rhyme or reason. This epistemic perception of sensory experience is the foundational basis of all human knowledge of the external world beyond the self, and it is for the purpose of epistemic perception that the modal structures are even present in our sensory experience.

Chapter 8

Perception, Art, and Mathematics

A Dichotomy in Human Knowledge

There is a curious dichotomy in human knowledge between the methods of expression used in art, as compared to those used in science. Art and science in some sense represent polar opposites in our manner of thinking about the world. And yet at the same time there is much that they have in common. For they are both methods of communication from one mind to another, although the kind of information they are capable of communicating differs considerably between them. What are these two modes of thought, and why is there such a sharp dichotomy between them? Why are there not more intermediate forms of thought, half way between art and science? Why is it not a continuum? I propose that much of what we take to be the structure of human knowledge, such as our knowledge of mathematics and geometry, as well as those other worlds of *a priori* knowledge that confirm their own truth without reference to the external world, that that structure is actually a manifestation of the structure of the representational mechanism of our own brain rather than of the world itself. In other words, the representational principle used in the brain leaves traces or artifacts in our perception and conception of the external world. Art, music, dance, and mathematics are, I propose, all artifacts of the representational mechanism of the brain, and the common attribute that they all share in common is a tendency towards symmetry and periodicity in both simple and compound hierarchical forms. Ornamental, or decorative art is perfused with symmetrical and periodic spatial patterns in two and three dimensions in simple and complex hierarchical forms. Music too is composed of hierarchical patterns of symmetry and periodicity, expressed as temporal rather than spatial patterns, while in dance the periodicity is simultaneously temporal and spatial. And periodicity is also seen in mathematics, in the notion of the number.

Analogical versus Discrete

There is another curious dichotomy within the world of mathematics between a continuous notion of number as seen in the homogeneous continuity of the number line as an analog magnitude, and a discrete, or symbolic representation of number represented by the integers, and by their rational derivatives, the fractions. The integers dot the number line with a periodic array of infinitesimal points representing exact whole values. The rational fractions subdivide the unitary intervals of the integer grid with finer scaled periodic patterns, splitting the unitary interval into integer numbers of subdivisions, such as halves, thirds, fourths, etc., and those intervals too can be subdivided all the way to infinity. Like the tick marks on a ruler, these rational subdivisions of the number line offer a set of “handles”, a labeling scheme by which to express most any value on the number line to arbitrary precision. But there are countless numerical values that slip through the cracks of this labeling scheme, values that simply do not fall on any of the tick marks of any of the rational scales no matter how fine you slice

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them. We can “see” those values intuitively in our mental image of the number line as the tiny gaps between the tick marks of the rational subdivision grids, and those gaps are always there no matter how much we zoom up the scale, because every time we zoom to larger scale, it zooms up everything in proportion, expanding the gaps between the tick marks while the tick marks themselves remain infinitesimal in extent. If at every scale the gaps are always larger than the tick marks, as must necessarily be the case with infinitesimal tick marks, then that must be true all the way to ‘infinity’ (if such a thing exists) that within any range of scale, there is always more gap than tick mark.

The residual gaps between the tick marks reveal a gulf, or chasm between these two alternate modes of representation because irrational numbers cannot be expressed as an integer ratio, but only by an infinite series of digits which of course can never be fully tallied. So there are two aspects to the concept of number that lend themselves to different kinds of manipulation. The continuous representation allows for concrete mental imagery or a flash of intuitive understanding of the nature of number as an analog magnitude, while the discrete integer and rational system offers a more analytical symbolic scheme that lends itself to highly abstract symbolic manipulations and very exact results. Many of the great proofs in mathematics can be seen as bridges that span the gulf between these two modes of representation, presenting a rational verification for an intuitive insight that seems to be true, expressed in the indisputable language of the discrete representational mode.

This dichotomy in mathematics reflects in miniature form the larger dichotomy between art and science, or between Gestalt processes and Boolean logic. It is the same dichotomy in mental function between what has come to be known as “right brain” versus “left brain” modes of thinking¹. I propose that the dichotomies between art and science, and between continuous and discrete, analogical versus symbolic, reification and abstraction, are all reflections of a fundamental dichotomy in the code employed by the human mind for the representation of world information. A better understanding of these two modes of representation and how they relate to each other will give us a better balance between the sciences and the arts.

A Geometry of Perception

The Euclidean axioms begin with the abstractions of point, line, and plane. But these items are themselves derived from the perceptual abstractions of corner, edge, and surface. It is clear why Euclid preferred the more abstracted foundation to mathematics, because the Euclidean abstractions are more general and invariant than their perceptual counterparts. A plane has no surface characteristics, nor even a surface polarity (substance/void), and thus there are an infinite variety of planar surfaces of different polarities, colors, and surface textures which all share the planar geometry of the abstract concept of the plane. We can establish a link between mathematics and experience by defining a more

1. I use the terms “right brain” and “left brain” to contrast a holistic analogical computational strategy with the analytic, sequential, logical style of computation, even though recent evidence now suggests that these two mental strategies are not confined exclusively to their respective hemispheres.

concrete geometry involving the more reified concepts of corner, edge, and surface (among others), a geometry of perception, or *perceptimetry*, whose defined objective is to provide a geometry for the elements of perceptual experience at the level of corner, edge, and surface, and thus serve as a bridge between experience as it appears in consciousness, and the abstract geometry by which it is expressed mathematically.

A perceived or conceived edge or surface is itself a kind of abstraction, something more perfect, lawful, and symmetrical (in the most general sense) than any edge or surface found in the real world. In that sense it is like the pure concepts of Euclidean geometry. But unlike the colorless world of geometry, the perceptimetric model is expressed in the same dimensions of color and light in space as the world of our experience. It is a geometrical world painted in the colors of the artist, and it bears the same kind of relation to external reality as a cartoon picture does to the real-world scene that it depicts.

My objective in defining these new foundational axioms of mathematics is every bit as ambitious as Whitehead and Russell's (1910-1913) *Principia Mathematica*, that attempted to establish the foundations of mathematics on the basis of logic by defining a closed logical system that depends entirely on a few foundational axioms. That attempt however was shown to be impossible by Gödel's *incompleteness theorem* (Gödel 1931). Gödel proved that within any system of logic there would always be some propositions that couldn't be proven using the rules and axioms of that logical system. The implication is that *all* logical systems are inevitably incomplete; each of them contains more true statements than it can possibly prove according to its own defining set of rules. My own proposal to base mathematics on perception suffers from this same fundamental limitation; the spatial structure of visual consciousness proves nothing beyond its own existence. Solipsism is always a logical possibility that cannot be refuted. But the advantage of building mathematics on a foundation of experience is that experience is in fact the true basis of all knowledge, experience need never itself be proven, experience simply *is*, and it is by definition exactly as it is experienced, and no different. The foundations of mathematics should therefore be sought not in the rarefied realm of logical statements which are abstracted away from experience, but in the more concrete reified realm of spatial and geometrical axioms which are closer to experience than Euclidean geometry.

The Axioms of Perceptimetry

The foundational axiom of perceptual geometry is: There exists a space (in our experience, and/or in our imagination), and that space has three dimensions. Within that space we can define volumetric objects with colored surfaces. The boundaries of the objects in perceptimetric space separate volumetric regions of 'substance' from surrounding volumes of 'void'. This foundational axiom is the first coherent 'thought' of the newborn infant, although that thought appears first in nonverbal form; not as a logical statement, nor even in logical symbolic form, but rather it appears directly as a space containing colored objects. It is a space whose existence is self-evident; its presence in our experience proves (to us) its own existence. We should distinguish however between an actual experience that we are having in veridical perception, and a hypothetical experience of mental

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imagery. Although perception and imagination are both expressed in the same dimensions of color and space, perception is constrained by the configuration of external reality, while mental imagery is more general, the kind of abstraction required of the foundational basis of mathematics. The space of perceptimetry is a mathematical abstraction or formal subset of the space of mental imagery, restricted to formally defined corners, edges, and surfaces, and other spatial concepts derived from them.

Unlike Euclidean geometry, perception and mental imagery have a finite spatial resolution; we can only picture a point as small as the smallest perceptible mote of dust, no smaller. But whenever we require greater precision, all we have to do is bring things closer to our face, which effectively zooms them up to higher resolution in our internal representation of them. So too with mental imagery, which can be zoomed up and down at will without limit. It is this zooming property of the perceptual representation that inspired the infinitesimal properties of the Euclidean abstractions of point, line, and plane. A straight edge between regions of different color appears the same 'thickness' i.e. *very thin* (if such an edge can be considered to have any thickness at all) no matter how close or how far we view it from. The same property is observed in our mental image of a line, whose 'thickness' (which is *very thin*) remains the same no matter how close or how far we view it from mentally. This is also how a line is depicted in geometrical diagrams. It is the infinite re-scalability of our mental image representation that effectively gives it the infinite and infinitesimal properties of a Euclidean model, but expressed in a finite representational medium. For our formal perceptimetric space we will adopt the zooming strategy of perception because unlike the infinite resolution of Euclidean space, the finite but re-scalable property of perceptimetric space can be implemented in a real physical representation of finite resolution, as would be required in a computational model of mathematical thinking in an artificial intelligence, or in the real physical mechanism of the human brain.

The Smooth Surface

Having defined the notions of substance and void, we can now define the concept of surface that separates substance from void. In the real world objects do not always have definite surfaces, objects can simply fade with distance from the center, like the density of the earth's atmosphere with increasing altitude. Or they can be bounded by complex and chaotic surfaces, like the hair on a human head, or a landscape of trees and shrubs on the surface of the earth, that defy any attempt to define a discrete bounding surface. Even a practically perfect sphere, like a billiard ball, under microscopic examination reveals a surface as irregular and chaotic as the surface of the earth. A first step of any mathematical system is to reduce this infinite chaos to something more manageable; a cartoon approximation of reality built up of ideal concepts as in Euclidean geometry. Although modern mathematics can now define fractal surfaces with a great depth of irregularity, like the tick marks in the rational grid, even those fractal surfaces are immeasurably more regular than a true physical surface, whose 'irrational' irregularity is so profound as to defy any precise or exhaustive mathematical characterization.

Simple mathematical problems can be addressed using ideal surfaces such as plane segments meeting at sharp corners, while other problems require more flexible surfaces such as the smooth bulgy forms seen floating in a lava lamp. There is an analog logic to the lawful manner in which a floating blob of wax in a lava lamp maintains its ‘infinitely differentiable’ (smooth) surface, a logic involving surface tension and cohesion forces, that enforce a certain regularity or order on the otherwise unconstrained morphing of the blob. I propose that the logic of perceptual mathematics, as it is expressed in the human brain, is analogous to the regularizing force of surface tension and cohesion in the blob of wax in a lava lamp, that forces its shape to remain simple, and thus easier to comprehend, or to express in abstract symbolic form. Fig. 8.1A shows a smooth blobby shape as seen in a lava lamp. In the absence of extraneous forces this blob would quickly morph into a perfect sphere, so the blobby shape seen here is a compromise between the surface smoothness constraint and some extraneous random pattern of forces introduced to more clearly highlight the effect of the smoothness constraint. The regularity or smoothness of the shape of the lava lamp blob is the result of a dynamic regularizing process, although it is not a process that begins and ends at distinct times, but one that runs continuously, maintaining the blob's smoothness even as it morphs continuously from one bulgy shape to the next. I propose that a computational model of mathematical thinking must also reflect this dynamic continuous aspect of mental imagery. The most basic primal aspect of mathematical thought is the capacity to define volumetric spatial structures with the kind of simplicity or regularity that is conducive to an epistemic encoding of those simple forms.

The perceptual tendency to segment figure from ground, to perceive objects as distinct from their environments, is analogous to the surface tension and cohesion forces that pull the blob of wax in a lava lamp into a coherent whole, distinct from its surrounding void. This is the ‘Gestalt’ of Gestalt theory, a perceptual tendency to see objects as distinct centers of mass and symmetry, expressed as a cohesive force of mutual attraction in contrast to a surrounding ground. Surface tension is a force that promotes symmetry within the surface, because it acts equally at every point in the surface, and transmits tension forces readily across the surface, so at equilibrium the surface will be homogeneous because all of the forces have been equally distributed. The concept of surface is expressed in literal form by the dynamic behavior of surfaces in the representation, whose equilibrium state defines the kind of surface it represents.

The Planar Surface

The visual mind appears to have a special affinity for a surface that is not only smooth, but also flat, like the Euclidean plane. Although this preference is clearly absent from the dynamics of the lava lamp blob, it is easy enough to imagine local dynamics that would achieve this property emergently in an analog system somewhat like a lava lamp. If every local portion of a surface felt a force to tilt itself into planar alignment with adjacent surrounding regions, all those local coplanarity forces acting simultaneously across the whole surface would result in a globally flatter surface, although the exact results would depend on the details of the local dynamics. I have called this planar flattening tendency the *coplanarity constraint*. (Lehar 2003a, 2003b) If the coplanarity constraint is weak, with some tolerance to

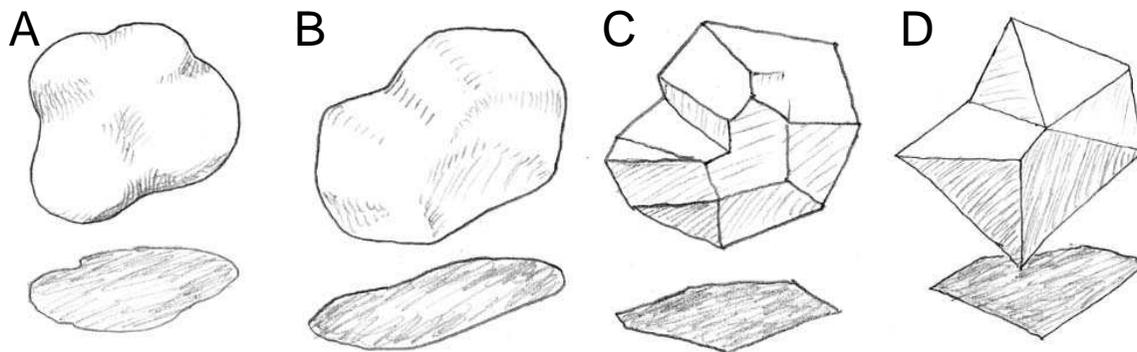


Fig. 8.1 A: Smooth rolling surfaces, like those seen on a blob of wax floating in a lava lamp. B through D: Progressively more angular shapes are achieved by gradually stiffening a coplanarity constraint, that tends to break the rolling surface into increasingly large flat facets separated by sharp corners.

deviation from exact coplanarity, the result will be smooth rolling waves that are locally flat, as suggested in Fig. 8.1B. If the coplanarity constraint is made stiffer, or more demanding, this will result in spreading sheets of even greater flatness, separated by stressful contours between locally flat sections that meet at different orientations where the coplanarity constraint abruptly breaks down, as shown in Fig. 8.1C and Fig. 8.1D. The exact results will depend on the details of the coplanarity function. For example to achieve the patterns of Fig. 8.1B and Fig. 8.1C, the coplanarity force at any point in the surface must weaken in nonlinear fashion as the surface begins to bend, weakening the coplanarity constraint, like stiff cardboard that has begun to crease, thus concentrating the bending stress to points which have already begun to bend. The focus here is on general principles however, rather than exact details of one particular implementation of those principles.

The Corner

Another kind of symmetry can be found along a corner-edge where two plane facets meet. A perceptual mechanism with an affinity to symmetry would tend to promote and enhance the symmetry of the corner, i.e. its similarity to itself in the direction along the corner, with a three-dimensional linear variation on the two-dimensional surface coplanarity constraint. I call this the *corner collinearity constraint*. Like angled roof tiles laid along the peak of a roof, adjacent local regions of a corner percept fit best when they are oriented parallel and in alignment with each other, and that alignment tendency promotes the emergence of long straight corners between angled faces. Like the force of surface tension, this Gestalt law of *good continuation* serves to simplify the configuration of the perceptometric pattern to make it simpler to comprehend epistemically. For example stiffening the coplanarity constraint would tend to morph the shape of Fig. 8.1C into the more simple and regular shape of Fig. 8.1D.

A corner has polarity, it can be concave or convex. But the corner also has an angle, and not all angles are equal. Perception has a clear preference for angles which are simpler, more regular, or have more *prägnanz*. Hochberg and Brooks (1960) showed that perception has a distinct preference for perceived angles such

as right angles, 30, and 45 degrees. This simplicity can be defined by a rational subdivision of the circle: the more symmetrical or regular the subdivision, the greater the simplicity. For example the right angle divides the circle into four equal increments of $\frac{1}{4}$ circle each, whereas 30, and 45 degrees represent rational fractions of $\frac{1}{12}$ and $\frac{1}{8}$ of a full circle respectively. Fig. 8.2A shows a *directional harmonic* series of simple corner angles based on this measure of simplicity. A corner whose angle matches one of these rational intervals is simpler than one with an irrational angle, and therefore the perceptual mechanism tends to bend the corner inward or outward to match the next nearest rational angle. The dynamic behavior of a corner in perception might be imagined something like the handle of the engine telegraph in an old fashioned steamer, illustrated in Fig. 8.2B. The engine telegraph, installed on the bridge, was used to communicate with the engine room before the invention of telephones or electrical signaling devices, to command the engineers down in the engine room to run the engines at full ahead, slow ahead, stop, slow astern, or whatever, by moving the handle to the appropriate angle, which could be seen on a repeater indicator in the engine room. The telegraph handle is equipped with a sprung roller, or *cam follower*, that rides on a cam as the handle is moved, as suggested schematically in Fig. 8.2C. This tends to lock the handle in to one of the discrete notches or indentations on the cam, thus reducing the continuous range of possible angles to a discrete subset of rational intervals.

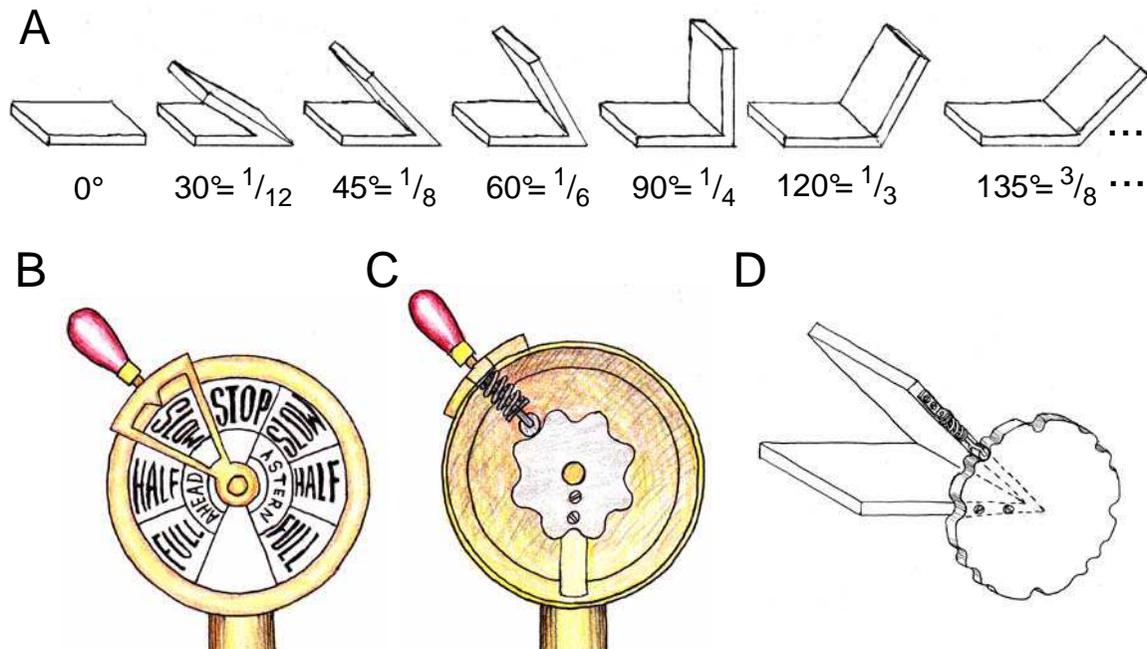


Fig. 8.2 A: Directional harmonic series showing angles that are rational fractions of a full circle. B: Engine telegraph from an old steamer. C: The cam mechanism in the engine telegraph that locks into discrete notches. D: A harmonic cam mechanism with notches at angles which are rational fractions of a full circle, with deeper notches for the lower harmonics.

The cam plate depicted in Fig. 8.2C has only eight notches at 45 degree intervals, each notch being of equal depth. I propose that in perception, the lower harmonics of directional periodicity with fewer segments are simpler than higher harmonics

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with more segments, and are thus favored by the perceptual mechanism as lower energy states. Therefore the 'notches in the cam' that control the dynamics of the perceptual corner are deeper for the angle 180 degrees (second harmonic) than for 90 degrees, (fourth harmonic) which in turn are deeper than those for 45 degrees, (eighth harmonic) and so forth up the series. Fig. 8.2D expresses this concept in the cam analogy with the metaphorical cam plate bolted to one edge at zero degrees, and the sprung roller attached to the other edge at some angle from the first. This system will lock most stably into the deeper notches of the lower harmonics, and progressively less stably into the shallower notches of the higher harmonics. The harmonic series is truncated at some highest harmonic, beyond which higher harmonics are lost in the noise, just as the tick marks on a ruler only subdivide within the limit of perceptual resolution. A pair of surfaces connected to each other by this kind of cam mechanism would tend to fall into successive notches as the dihedral angle is gradually increased from zero degrees.

Three-dimensional trihedral corners arise whenever two dihedral linear corners meet, as they do at the four corners of a tetrahedron, or the eight corners of a cube. Since each dihedral component of the trihedral corner prefers a simple rational angle, the trihedral corner as a whole also prefers a rational angle, like the three mutually orthogonal right angles at the corners of the cube, or the 60 degree angles at the corners of a regular tetrahedron, and the greatest regularity is achieved when all the dihedral corners at a vertex have the same angle.

The Platonic Solids

The Platonic solids reflect the same kind of perceptual affinity for regularity and rational intervals as the perception of angles in a dihedral corner. The guiding principle behind these solids is again the concept of symmetry, as seen in the similarity of the lengths and angles of the edges and corners of each figure. Again, the simplest forms are those with the lowest harmonic of directional periodicity, or smallest number of vertices. This makes the sphere the first, most primal shape in the Platonic solid series, shown in Fig. 8.3A, with one face and no vertices. The rest of the series can be derived from the sphere by progressively increasing the stiffness of the coplanarity constraint in a dynamic model somewhat like a lava lamp blob, which will tend to break the spherical surface into an integer number of plane faces separated by sharp corners. But there is a higher order of symmetry apparent in the Platonic solids than cannot be accounted for either by the planar symmetry of the flat surface, or the angular symmetry of the dihedral corner alone. There is an additional global symmetry of the shape as a whole, that subdivides the spherical surface into equal numbers of identical polygonal surfaces that meet at vertices that are equally spaced in solid angle around a center of symmetry. In other words, there appears to be a three-dimensional volumetric affinity for regularity and symmetry in the pattern of vertices about the center of symmetry of a perceived form, analogous to the two-dimensional preference for regularity in the individual corner-edges of the solid form, seen here in the equal spacing in solid-angle of the vertices of the platonic solids about the center of symmetry. The ideal location from which to detect that symmetry is at the center of symmetry itself, within the volumetric form, a point from which lines stretch out to all of the vertices, and a three- dimensional spherical cam-plate type mechanism works to rearrange those lines and their vertices in the most regular arrangement possible. I

propose that the mathematical appeal of the regularity in the Platonic solids series is evidence for a global regularizing tendency in the lava-lamp mechanism of our mental imagery system that tends to promote the spontaneous appearance of these regular forms just as the lava lamp tends to generate smooth blobby forms.

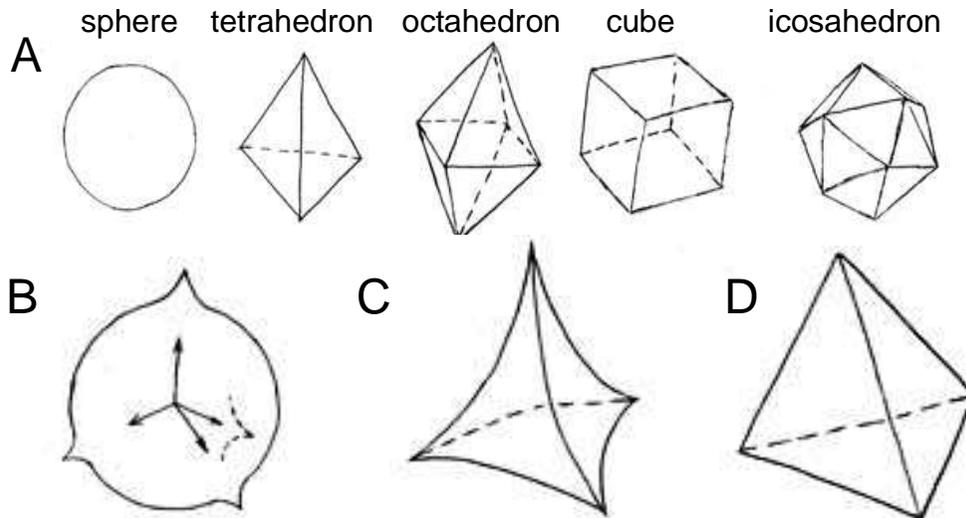


Fig. 8.3 A: Platonic solids series. B: A blob with four peaks equally spaced in solid-angle. C: Creases form between the peaks, creating curved dihedral corner-edges. D: The corner-edges are regularized by a corner consistency constraint, producing the tetrahedron.

There is a hierarchical principle evident in this representational scheme. The existence of the lower level regularization tendencies of coplanar surface completion and collinear corner completion allow the higher order global symmetry of the figure as a whole to be expressed independent of the local symmetries of corner and surface, because application of the global symmetry to a generic blob automatically fills in the flat surfaces and straight corner-edges of the whole platonic solid form. For example the fourfold symmetry of the tetrahedron can be expressed as four outward-directed vectors, which, when applied to the spherical lava lamp blob, create four peaks or sharp vertices equally spaced around the blob as suggested in Fig. 8.3B. The appearance of these peaks promotes the formation of high tension creases in the surface along the lines joining those peaks as suggested in Fig. 8.3C, by the same principle as the horizontal fold of stretched fabric that tends to form between the breasts of a woman wearing a tight blouse or top. The regularizing tendency along these corner-edges in turn tends to crease those folds into straight edges between planar surfaces, with a preference for simple rational angles between their plane surfaces, and a preference for equal angles at each vertex, resulting in the regular tetrahedron form of the Platonic solids shown in Fig. 8.3D. The global fourfold symmetry therefore encodes the entire tetrahedron shape in higher-order abstract form, but it can only do so because of the existence of the lower-order regularization tendencies of 1: the clustering tendency of the Gestalt by blob cohesion, 2: the planar surface completion of the coplanarity constraint, 3: the corner completion tendency that straightens each corner-edge to a straight edge, and 4: the corner simplicity constraint that tends to hold the dihedral planes of the

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corner at a simple rational angle. The entire Platonic solids series shown in Fig. 8.3A can therefore be produced by varying one parameter that determines the number of vertices of the central symmetry of the shape as a whole. I propose that the brain possesses this kind of symmetry engine, whose natural modes, or eigenfunctions are patterns like the Platonic solids series, and it is this symmetry mechanism in the brain that is the ultimate origin of the Platonic solids, and of the simpler Euclidean concepts of point, line, and plane. The Platonic solids therefore do not exist in some rarefied pure abstract realm where they live in absolute crystalline perfection, as suggested by Plato, but rather they are evidence of a regularizing tendency in the perceptual representation of the brain that favors certain patterns of symmetry, and the tendency towards the global regularity of the Platonic solid is no different in principle than the tendency towards local regularity of corners and surfaces.

Representation by Reification

The dynamic spatially reified representational mechanism developed above is described somewhat vaguely, and many details remain to be specified more precisely before we can determine exactly how such a system would actually behave in detail. It is more of a thought experiment at this point, rather than a fully specified model of mathematical or geometrical cognition. But even in this most general form the system demonstrates a number of important principles of human mathematical representation, and suggests how they might be replicated in an artificial system capable of mathematical thought. In the first place this model suggests that mathematical thought involves the construction of spatial structures in the mind, and that therefore thought and cognition are not pure symbolic abstractions, as is often assumed, but thought can take the form of emergent spatial structures that appear in the mind, and those structures are an essential part of mathematical thought. This is not to deny, however, the existence of an abstract or symbolic component to mathematical thought. Our mind is in distinctly different states when contemplating a cube as opposed to a tetrahedron, and that difference in state is what characterizes the abstract concepts of cube and tetrahedron. But the abstractions by themselves are meaningless, in the absence of a spatial reification mechanism with the proper affinity towards symmetry, capable of converting the abstract central symmetry into the concrete reified geometrical form that the abstraction represents. We do not just see the global symmetry in the form as an abstraction, but rather we see it as a central symmetry *of* that form, that is, we see the form itself as a reified structure at the same time as we see the central symmetry in that form. The reason why this reified aspect of mathematical thought has been so readily overlooked is that the symbolic language of mathematics records only the abstract non-spatial aspects of geometry on the assumption that the reified spatial aspect will be provided by the mind of the reader of the abstract equations in the form of a mental image, just as literary prose depends on the mind of the reader to construct the images described in the text. As in literature, it is the mental image itself that provides true understanding of the symbolic abstractions recorded in the form of equations on a page, and failure to form the correct mental image is a failure to understand the mathematical message of the equations.

For example the foundational axioms of Euclidean geometry defining the point, line, and plane, are only accepted without dispute by successive generations of geometry students because their truth is verified by mental imagery. When a student is first told that a straight line is the shortest distance between two points, a mental image appears in his mind of two points joined by a line. The student then tries various other connections between the two points, such as curved or wavy lines, and discovers by inspection that all of them are longer, and that their length always increases the more they deviate from that straight line. A sophisticated student might elaborate this thought experiment by stretching an elastic band between two points in his mental image, and observing that in its effort to pull itself in to the shortest possible length, the rubber band inevitably stretches into a straight line. When told that a line has infinitesimal thickness, the student zooms up his mental image of the line and observes that no matter how large he zooms it, the line appears always the same thickness, which is very thin. If the student allows the line to take on any thickness at all, then it is transformed into a cylinder instead of a line. And when the student is told that a line extends to infinity in opposite directions, he attempts by mental imagery to find the end of the line, and discovers that no matter how far along the line he goes, the line always continues further in the same direction. If the student allows the line to end at any point, no matter how far away, he discovers that the line has changed 'shape', it is no longer a line, but a line *segment* that has lost an essential aspect of its linear symmetry. The axioms of Euclidean geometry therefore are not dogma to be accepted on faith, but they are self-evident observations on the nature of the elements of cognitive thought or mental imagery verified by inspection, and those properties are common with, and inherited from the more reified and concrete perceptual concepts of corner, edge, and surface. That is why it is proper for the foundational basis of mathematical thought to be sought not at the higher level abstractions of logic as proposed by Whitehead and Russell (1910-1913), but at the lower, more reified level of the elements of perceptual experience. The first step, therefore, in the construction of an artificial intelligence capable of true mathematical thought must involve the construction of an analogical spatial representation with dynamic properties as suggested above.

Analogical versus Logical Thought

There are two distinct aspects to human cognition, analogical versus logical thought, and the relation between the two is similar to the relation between the continuous interval of the number line, and the integer and rational subdivision of that line at discrete points. The great advance of modern science has been accompanied by an ever increasing reliance on the logical, analytical component of thought, reducing complex problems to precise mathematical descriptions, from which precise and reliable conclusions can be drawn. A typical scientific education often urges the student to abandon the heuristic practice of solving problems by mental imagery, and to convert the problem to analytical form as early as possible in the process. This however tends to give the student of science a false impression that the analogical component of thought has no place in science, and that the analytical closed-form solutions and absolute proofs are what science is really all about. In fact, the analogical component of cognition is every bit as much a part of science as the analytical proofs, because mental imagery is essential to

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frame the problem in the first place, as it is also to understand the implications of whatever it was that was proven by the analytical manipulations. In the words of Poincaré, “It is by logic that we prove, but by intuition that we discover.” (Arnheim 1969, p. 274)

The pedantic logical positivists that emerge in great numbers with the highest marks from the very pinnacle of our educational establishments look askance at intuitive explanations that appeal to mental imagery, as if the products of mental imagery were so unreliable as to have no place in science. These people would be surely horrified at my intuitive description of the dynamic spatial model of cognition presented above, where, for example, I describe the dynamic tendency of perceptual surfaces to meet at simple rational angles with the analogy of the engine telegraph of an old steamer, depicted in Fig. 8.2B. A more rigorous mathematical description of the harmonic cam plate depicted in Fig. 8.2D might be expressed as the equation

$$r_{\theta} = r_{\max} - (r_{\max} - r_{\min}) \sum_{h=1}^{h_{\max}} \text{pos} \left(\frac{\cos\left(\frac{h\theta}{2}\right)}{h} \right)^P$$

where r_{θ} is the radius of the cam at angle θ , r_{\max} and r_{\min} are the maximum and minimum radii of the cam, h is the harmonic, an integer that ranges from 1 to h_{\max} , P is a positive integer power, and the function $\text{pos}()$ returns only the positive portion of its argument, and zero otherwise. Assuming a constant spring force s , and a frictionless sliding between the cam and the cam follower, the angular force on the cam follower f_{θ} is defined by

$$f_{\theta} = s \frac{dr_{\theta}}{d\theta}$$

Scientific papers are typically peppered with mathematical formulations of this nature, where they all too often serve more to obfuscate than to elucidate. (Wow, this guy must be really smart—I can’t understand *any* of that stuff!) whereas the heuristic intuitive explanation of the cam plate analogy is considered amateurish and imprecise, partly because it is so easily understood, but also partly because the analogy leaves many factors unspecified. It is true that this analytical description of the mechanism is a great deal more precise and concise and unambiguous than the intuitive sketch of Fig. 8.2D. But the precision is actually redundant in this case, because the purpose of the cam analogy is not to provide an exact specification for a precise mathematical model, but to demonstrate a general principle that could actually be implemented in a number of different ways. It is true that the mathematical formula can itself be left general, for example by not specifying precise values for the constants r_{\max} , r_{\min} , h_{\max} , and P . But there is one essential component that is missing from the mathematical formula which is the most important message of the mental image, and that is the imagined feel of the handle of an engine telegraph as it resists a push to dislodge it from one of its stable notches, but when pushed hard enough it overcomes the resistance and jumps ahead to fall into the next nearest notch in the cam with a positive snap, vibrating momentarily as it oscillates back and forth briefly across the new stable

point before coming to rest at its center. There is a powerful intuitive image of these discrete notches involving sensations of pressure, motion, sound, and vibration, that are entirely missing from its analytical counterpart. A good mathematician can 'read' these kinds of properties from the formula (with some effort), but most anyone can 'see' these properties intuitively in the telegraph analogy with very little effort.

What the logical positivist fails to recognize is that the mathematical formula is itself a spatial analogy that analogizes a real physical system with some pure mathematical abstraction that cannot actually exist in the real world. There has never been, nor will there ever be anything that is exactly sinusoidal in this physical universe, because a sinusoid stretches to infinity in opposite directions, and is mathematically perfect to infinite precision. No such thing can possibly exist except as an abstraction in the human mind. In this sense the mental image is no less valid than the mathematical formulation, although it is admittedly less precise. Equations have their place, as they are far superior as a description of systems that are themselves very precise, like the motions of the heavenly bodies, or the outcome of chemical reactions. When describing the operational principles of octopus locomotion, or how a boa constrictor wraps itself around its prey, however, mathematical equations are generally too stiff and brittle to capture the true essence of such dynamic analog elastic systems. And yet in the real world problems of navigating your local environment and manipulating objects, this is exactly the kind of computation that is required. This is the function that is prominently absent from mathematics, at least as it is expressed symbolically on the written page, although of course this kind of analogical computation, or exercise of mental imagery, is an indispensable part of a good mathematician's mental repertoire. But if we are to formalize mathematical thought for implementation in an artificial intelligence, we will first have to replicate this analogical function of human thinking to act as a front-end interface between the external world as revealed by sensory input, and the more analytical aspect of logic, as expressed in pure form in mathematical formalism and in the digital computer.

Analogical Thought in Mathematics

One of the great historical advances of mathematical thinking was Descartes' invention of Cartesian geometry. But why should the meaning of an equation like $y = x^2$ become clearer when we plot it on a Cartesian graph? Why can't we see the same 'squared' relationship just as clearly in the bare equation? Of course a good mathematician sees it at a glance of the formula, but he does so by making a mental image of the Cartesian plot. The plot itself needs no translation, it is already in the format that is meaningful to our mind, and that is what makes Descartes' invention so great. In fact, in this sense it was more a discovery than an invention; Descartes discovered the important principle that we can see spatial relations more clearly than any other kinds of relations. To be sure there are many mathematical manipulations which are too abstruse to be envisaged clearly, and are thus performed as a sequence of symbolic manipulations. In fact all of higher mathematics seems to have this quality, although mathematical genius is often characterized by an ability to 'see' relationships which are obscure to others, even

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before they are proven. But at the interface to the mathematical process, that is, in the formulation of the problem in the first place, and the interpretation of the results established symbolically, the mental image steps in again to become an essential part of the process.

The parabolic curve of the quadratic equation is not the only mental image of that function. It is also seen in the acceleration of a rocket as it speeds into space, a dynamic rendition of the same accelerating growth function, as if scanning a vertical cursor at uniform rate along the x axis and following the point of intersection of that vertical line with the parabolic curve. The Cartesian plot freezes that dynamic acceleration in time, and thus allows us to see the acceleration as a shape, all at once. Like the concepts of point, line, and plane, and their country cousins the corner, edge, and surface, the parabola defines a perfect shape, every point of which can be located to infinite precision. The human eye is very sensitive to parabolic curves, they can be sketched relatively easily by hand, and any imperfections in a parabolic curve can be instantly spotted even by the untrained eye. That is because there is a logic of perfect regularity in the parabolic form, something that remains constant throughout the acceleration of the curve, and that constant is the *rate* of acceleration: the speed is always increasing at a uniform rate.

The constant in the quadratic equation can be understood intuitively by analogy. Consider the hydraulic control system of a backhoe, where the deflection of a control lever causes a hydraulic piston to move, to the left when the lever is deflected left, and right when deflected right, as suggested in Fig. 8.4A. The rate of motion of the piston is proportional to the deflection of the lever, that is, the more the lever is deflected, the faster the piston moves. Mathematically we can express this relation with the equation

$$\frac{dx}{dt} = a$$

The meaning of this equation is no different in principle than the words “the speed of the piston is proportional to the deflection of the lever”, but by putting it in equation form it is as if we are adding “but perfectly so! To infinitesimal resolution, and all the way to infinity in both directions!” Now let us imagine two lever-piston assemblies connected in series so that the piston of the first system is connected to the lever of the second, as shown in Fig. 8.4B. Pushing the first lever forward one notch makes the first piston start to extend at a constant rate. That piston in turn deflects the control lever of the second system, increasing the control lever angle at a constant or uniform rate. This causes the piston of the second system to extend at a constant *acceleration*, which is to say, extend at an ever faster velocity, tracing a perfect parabolic arc in space-time. (Apologies to the logical positivists, this equation ignores the fact that the lever rotates about a pivot point, instead of sliding laterally in the x dimension, so the true equation should be

$\frac{dx}{dt} = \cos(a)$, although for small a , $\cos(a) = a$, so it is still approximately correct within limits.) The concept of the parabola as a perfect acceleration is a concept which also must have been inherited from perception. Artists and mathematicians have long conspired to create structures that are beautiful both aesthetically and

mathematically, and all mathematicians understand the concept of the beautiful theorem. There is beauty in shape, and perfect beauty in perfect shape. And there is a beautiful perfection in the concept of a stone falling freely not at a fixed velocity, but at a velocity that is changing constantly at a perfectly fixed rate. This concept must have first appeared in the minds of Newton and Leibnitz in the form of a mental image, like the uniform acceleration of the hydraulic piston. Newton and Leibnitz must have intuitively ‘seen’ the concept of uniform acceleration long before they could articulate it in words, or devise a symbology to express the concept in mathematical form.

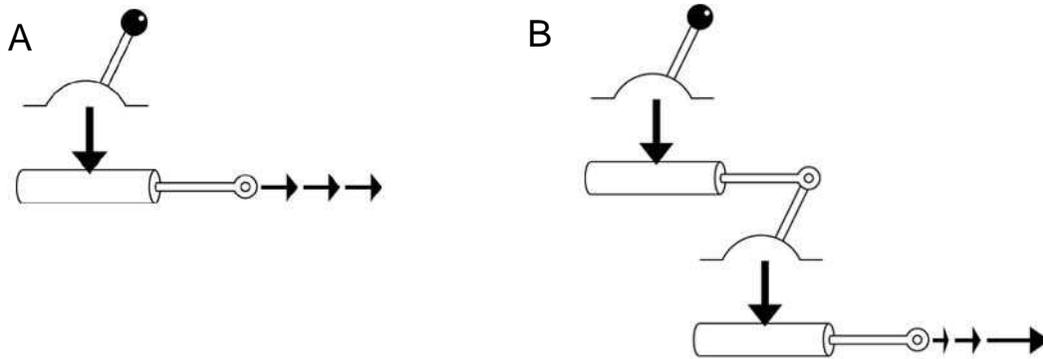


Fig. 8.4 A: A hydraulic control system as in a backhoe, where the fixed deflection of a control lever results in a uniform motion at a fixed speed of the hydraulic piston that it controls. B: A second control lever moved by the first hydraulic piston would increase in angle at a constant rate, so that the motion of the piston that it controls would accelerate at a uniform rate.

Newton's laws of motion are also mathematical expressions of laws inherited from perception. When we see a moving object, in the absence of information to the contrary, we will assume that it will continue moving at the same speed and in the same direction unless we perceive it to be acted on by a force. For example when we see a moving car disappear behind a foreground obstacle, we expect to see it emerge out the other side at the exact time predicted by its perceived velocity, and the length of the occluded path. If the car fails to emerge when expected, then we might perceive it to have collided invisibly with some obstacle behind the occluder. In other words the car is tracked perceptually even while hidden behind the occluder, although of course it is represented there in purely amodal form. I propose that Newton's discovery of this first law was just as much an act of introspection as it was of external observation. The second law corresponds to Newton's introspective discovery of the concept of perfectly uniform acceleration, which is also hard-wired in our brain. It is a regularity, like the plane, or the corner, that the brain both detects, and completes by extrapolation of the regularity.

There are a number of other regularities observed in the physical world that also reflect a regularity in our perception of the world. In his book *Dynamical Analogies*, Harry Olson (1943) shows how many dynamic concepts are mathematically equivalent across different kinds of physical systems, that is, they are modeled by the same equations. The concept of force, in physical systems, is analogous to torque in rotational systems, and to pressure in hydraulic systems, and to voltage in electrical systems, just as the concept of velocity in physical systems translates

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to rotational velocity in rotational systems, and to current or flow in hydraulic and electrical systems, and physical friction maps to viscous resistance in hydraulic systems and to electrical resistance in electric circuits. All of these systems also exhibit higher derivatives of motion. The concept of mass and inertia in physical systems corresponds to rotational inertia in rotational systems, and fluid inertia in hydraulic systems, and to capacitance and inductance in electrical circuits. I propose that these abstract properties shared in common between these different kinds of physical systems are concepts that are hard coded in the human mind in the properties of the mental image medium, although of course they also happen to be very good models of the behavior of the physical systems that they describe, which is why they evolved in the human mind in the first place. Consider the concept of mass and inertia. While it is true that Aristotle seems to have been ignorant of mass and acceleration, at least in his discussion of the behavior of falling objects, anyone who has ever swung an axe or a club has experienced its resistance to motion at the start of the swing, and its tendency to continue onward once it is set into motion. A baseball player understands the importance of decelerating his own velocity when sliding into a base, without ever having to be taught this fact explicitly, and anyone who has paddled a rowboat or canoe understands the concept of paddling backwards to bring a moving boat to a stop. The concepts of mass and acceleration therefore were hard coded in the human nervous system long before Newton formalized them as mathematical laws. And students first presented with those mathematical laws are usually puzzled by them until the teacher presents familiar examples from their own experience, verifying the truth of Newton's laws in the same way that the Euclidean axioms are confirmed, by appeal to corresponding familiar concepts already present in perception and mental imagery.

Electrical Inductance and Capacitance

I will demonstrate the contrast between the analytical and analogical modes of representation with an example from electricity, the concepts of inductance and capacitance. If the reader is not familiar with these electrical concepts, do not be discouraged, because those concepts will become perfectly clear in my analogical descriptions of them, even if the differential equations that represent the analytical descriptions of these concepts remain obscure.

When we first learn the principles of electricity, we are taught by analogy with water flowing in pipes, with current and voltage corresponding to flow and pressure in water respectively. A battery is analogous to a water pump, with inflow and outflow connections, a switch is like a valve that can be opened or closed, and a resistor is like a thin pipe or obstruction that restricts the flow. It is by these analogies that we understand intuitively for example why resistance is additive for resistors in series, but is reduced when resistors are connected in parallel. I remember my own initial puzzlement over the concepts of capacitance and inductance in electric circuits when they were first introduced. Of course I learned the formulae for current and voltage, and how they change as a function of time, so I could work the problems and produce correct answers, all in the absence of understanding of what those components were actually doing in the circuit. Capacitance and inductance only began to make sense to me intuitively when I finally figured out the corresponding water analogies.

An inductor is simply a coil of wire that generates a magnetic field whenever a current is passed through it. Fig. 8.5A shows a simple circuit containing a battery B , a resistor R , an inductor L , and a switch S . In position a the switch connects the battery across the inductor, establishing a current i , flowing clockwise around the circuit, the flow of current being a function of the voltage of the battery and the resistance of the resistor. In position b the battery is disconnected from the circuit, which now forms a loop through the resistor and the inductor. If there were no inductor in the circuit, then the current would simply turn on when the switch is in position a , and turn off when it is in position b , as shown in dashed line in Fig. 8.5B. The inductor introduces a lag in this behavior, as shown in solid line in Fig. 8.5B. When the switch is first thrown to position a , the current grows rapidly at first, then ever slower, until it equilibrates at the value it would have had in the absence of the inductor in the circuit. In other words, instead of turning on abruptly, the current starts off gradually, like a massive object accelerating in response to a force, reaching a steady speed as the driving force equilibrates with the increased resistance at higher speed. And when the switch is thrown to position b , the current does not stop immediately, as it would in the absence of the inductor, but rather it decelerates gracefully to a stop as if carried forward by momentum, as shown also in Fig. 8.5B. It is not actually momentum that produces this behavior of the inductor, but rather it is the establishment of a magnetic field by the current flowing through the coils of the inductor. It takes energy to build up the field when the current is first turned on, which accounts for the additional load when the switch is first thrown, but it requires no energy to maintain the field, so the current can climb to maximum strength once the field is established. When the switch is thrown to position b the magnetic field begins to collapse, and as it does so, it returns the energy invested in its construction by continuing the flow of current briefly without help from the battery. The water analogy for the inductor might be something like an inertial turbine wheel that is spun up to high RPMs by the flow of current through it, but produces no drag once its speed matches that of the current. When the switch is thrown to position b the turbine becomes an inertial pump, that continues to pump water through the circuit until the momentum of the spinning turbine is exhausted. This analogy offers an intuitive grasp of the dynamic principles of electrical induction.

A capacitor has a similar kind of dynamic behavior. A capacitor is built of two metal plates placed very close to each other, but separated by a tiny gap of air or electrical insulator. So the capacitor is an insulator, it blocks the flow of direct current between the two plates, but it allows alternating current to pass through, because an electrical charge on one plate induces an opposite charge on the other plate. Fig. 8.5C shows the same circuit as above, except with a capacitor C in place of the inductor. When the switch is first thrown to position a , a current begins to flow clockwise as it "fills" the capacitor with charge, but it slows rapidly to a stop due to the blocking effect of the insulator, as shown in the solid line plot of Fig. 8.5D. When the switch is thrown to position b , a brief negative current ensues, that is, the current flows briefly counter-clockwise before it again grinds to a halt as the capacitor gives up its stored electrical charge, as shown by the negative current plotted in Fig. 8.5D. The behavior of the capacitor can be understood intuitively by analogy with a rubber membrane stretched across the cross-section of the water pipe. Like the insulating gap of the capacitor, the rubber

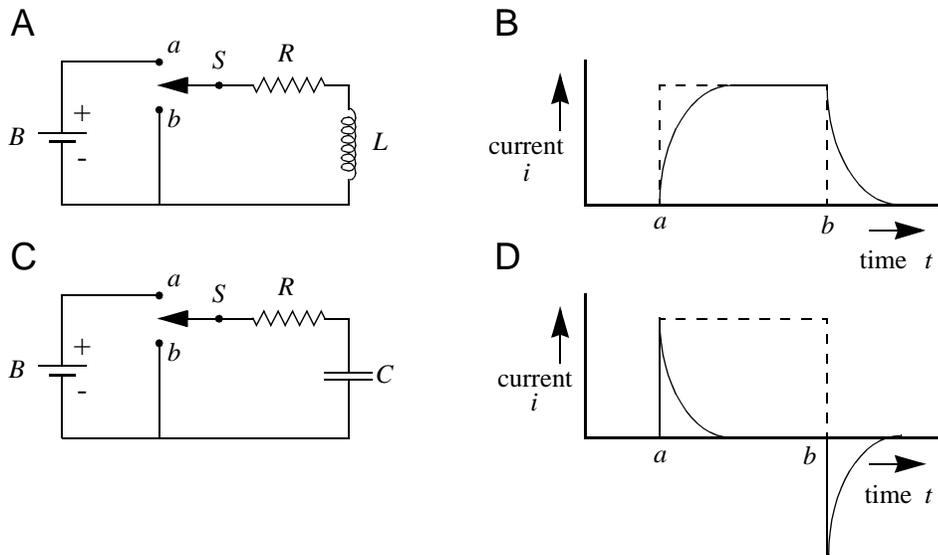


Fig. 8.5 A: A simple circuit composed of a battery B , resistor R , switch S , and inductor L . When the switch is thrown to position a , a current begins to flow through the inductor, building up to a constant value as shown in B. When the switch is then thrown to position b , the current tails off again as shown in B. C: A similar circuit with a capacitor C in place of the inductor. This time when the switch is throw to position a , a brief transient current spike ensues, as shown in D. When the switch is then thrown to position b , a brief transient current spike flows momentarily in the opposite direction.

membrane blocks the flow of direct current, but again like the capacitor, the elasticity of the membrane allows a brief transient flow of current while the membrane stretches. When the switch is thrown to position a , water is pumped into the capacitor, allowing a brief flow while the elastic membrane stretches. Once the membrane has stretched to its limit, the flow of current stops. The capacitor is storing energy at this point, in the elastic stretching of its membrane. That energy is released when the switch is throw to position b , at which point the negative current works to relax the tension on the elastic membrane and return it to its lowest-energy state.

All of the dynamic behavior described intuitively above, is expressed more rigorously and succinctly in the equations for the voltage and current across the inductor,

$$v = iR + L \frac{di}{dt} \quad (\text{EQ 1})$$

$$i = \frac{V - L \frac{dv}{dt}}{R} \quad (\text{EQ 2})$$

and the capacitor.

$$v = iR + \frac{q}{c} \quad (\text{EQ 3})$$

$$i = C \frac{dv}{dt} \quad (\text{EQ 4})$$

So we have two alternative and complementary representations: the mathematical formulation of the behavior of a capacitor and an inductor, and the explicit physical analogy worked up in enough detail to demonstrate the concept in a mental image. But although there is a stark contrast between these two modes of representation, the same kind of contrast as that between a continuous and a discrete concept of number, they are also inextricably intertwined, two faces of the same coin. For the elements of the mental image are themselves composed of quasi-geometrical, or perceptimetric concepts, like the concept of a pipe as a double cylinder of alternating void-matter-void at two distinct radii, filled with incompressible fluid of fixed volume and with a certain mass. These are geometrical abstractions more pure and symmetrical than any real world water pipe, with all its elbows and couplings, screw threads and gaskets, and different component materials. In the mental image the pipes are perfectly smooth and regular, made of homogeneous generic material, and the elbows and couplings appear in the simplest geometrically regular form. The purpose of this mental-image replica of the water analogy to the electric circuit is as a thought-experimental test bed to explore different hypothetical properties of the imagined circuit by mental trial and error.

For example we can use the mental image analogies for the inductor and capacitor to simulate an oscillation in an 'LC' circuit consisting of an inductor L , and a capacitor C , connected as shown schematically in Fig. 8.6A, and in the form of the water analogy in Figs. 8.6B through Fig. 8.6D, which uses an inertial turbine wheel for the inductor, and an elastic membrane for the capacitor. Picture the system initially in the state shown in Fig. 8.6B, with the elastic membrane of the capacitor already stretched to its limit in one direction. This represents a charge on, or voltage across the capacitor, positive on one side and negative on the other. The first thing that will happen when the mental simulation begins is a counter-clockwise flow to restore the balance and return the capacitor's diaphragm to its relaxed position. The gush of current caused by the capacitor's discharging of its load in turn spins up the inertial turbine wheel of our inductor model, so that by the time the diaphragm is relaxed, the wheel is spun up to its highest speed, as shown in Fig. 8.6C. Since the current is no longer driven by the stretched membrane of the capacitor analogue, the turbine is transformed into a propeller, pumping water counter-clockwise around the circuit and thereby loading the capacitor back up in the opposite polarity. And as the membrane reaches its limit of stretch in the opposite direction, the turbine spins to a stop, as shown in Fig. 8.6D, and the system state is a mirror image of its initial configuration, with zero current, and a reverse voltage across the capacitor. The whole thing repeats therefore with a second half-cycle in the opposite direction. Like a mathematical abstraction, the mental image contains many simplifications not found in a real physical system. Since there is no resistor in this circuit, the circuit has no resistance, so the oscillations would continue indefinitely. There is no elasticity to the pipe, nor to the incompressible fluid within it, the only elasticity is that provided explicitly in the diaphragm of the capacitor analogue; and there is no inertia to the flowing fluid, the only inertia is that provided explicitly by the inertial mass of the turbine wheel of the inductor analogue.

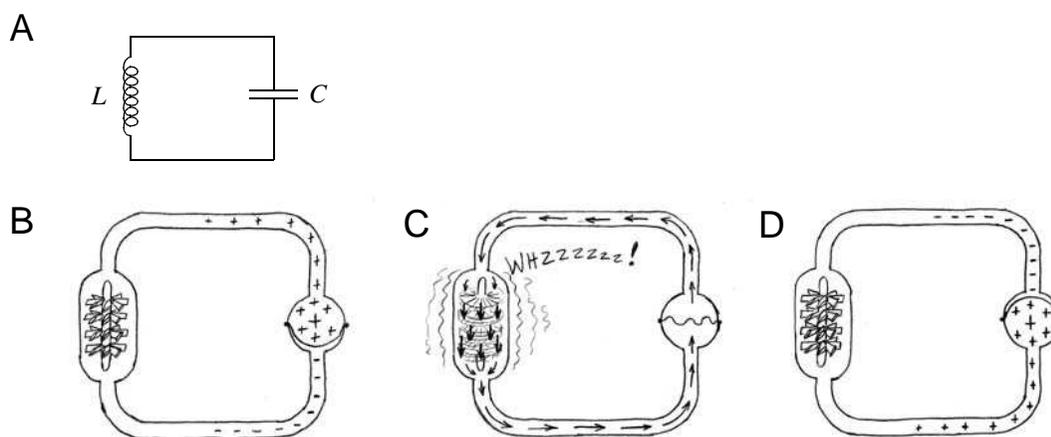


Fig. 8.6 A: An “LC” circuit composed of an inductor L and a capacitor C . B through D: The water analogy for the “LC” circuit with an inertial turbine wheel for the inductor, and an elastic membrane stretched across the pipe for the capacitor.

We could achieve the same results mathematically, by solving the equations for various variables describing the behavior of the circuit, and the mathematical result will be more precise and correct. This shows the contrast between the two alternate modes of human thought, the left-brained analytical sequential logical approach, and the right-brained analogical Gestalt manner of thought. These two modes of thought are complementary and interdependent; they cannot function without each other. One provides precision and definiteness, the other provides meaning and context. One defines the functional relationships in abstract symbolic form, the other reifies that function into specific pressures and motions within extended volumes and surfaces in a mental image. And the same bipolar schism between a precise abstracted skeleton and a reified filled-in continuum pervades the representation at every level. It is seen in the contrast between the perceptimetric concepts of corner, edge, and surface, with their filled-in reified volumes of substance and void, and the corresponding Euclidean abstractions of point, line, and plane, that are entirely devoid of volume or substance of any sort. A similar contrast is seen in art in the contrast between the faint sketch lines with which the artist begins a sketch by outlining the central axis of symmetry, and the final surface veneer of color spread over the whole painted surface. In science it is seen in the contrast between the kurt mathematical formulation of a physical system, and our mental image of that system in action. And the schism is seen also in mathematics, in the contrast between the continuous and the rational scales. It is not surprising that there should be these two modes of thought; they are merely opposite ends of a kind of representational spectrum. What is interesting is that there is a peculiar gap between these complementary modes of thought. The perceptimetric formulation of moving volumes of inertial and elastic substance embedded in a void in an explicitly reified spatial representation, is the missing link between our world of experience, and the mathematical formalisms with which we express that experience in symbolic form.

Inductance and capacitance are properties not only of inductors and capacitors, but in fact every electrical component, even a simple piece of wire, has an inductance and a capacitance, just as it has resistance and conductance. Every wire that has a current flowing through it, also has a magnetic field around it, and that field takes energy to construct. And every wire has a capacitance, that is, it 'fills up' with electric charge with a certain elasticity, like water in an elastic pipe that swells a bit under internal pressure. In fact the mathematical abstractions corresponding to inductance and capacitance are directly related to their mechanical analogs, inertia and elasticity, and those properties in turn are inherited directly from the spatial perceptual representation in the brain, where they are expressed directly in literal form as an inertia and elasticity of objects represented therein. It is because of the existence of these properties in our mental representation that we can even picture the water flowing in the hydraulic analogy with enough inertia to spin up and spin down the turbine of our capacitor analogue. The concepts of force, mass, and acceleration were known to the analogical mind long before they were ever formalized in Newton's laws of motion. And the concepts of inductance and capacitance were known to the analogical mind in the concepts of inertia and elasticity.

Regularization in Art

The perceptual tendency towards geometrical regularization is evident in still more compelling form in the patterns seen in art and visual ornament. Throughout history and across cultures there are common principles seen in all decorative arts, in particular the properties of symmetry and periodicity in both simple and compound hierarchical form, as well as a simplicity and elegance of the repeating forms. The principles of perceptual regularization can be seen in the most pure form in the patterns of ornament with which we decorate our clothing, pots, wallpaper, furniture, and virtually every item we use, most especially items of particular symbolic or ceremonial value. The regularization tendency is not confined to abstract or non-representational art, but it also appears to greater or lesser degree in representational art, because as Weber showed (Weber 2002) even the most faithful 'realistic' artistic depiction is always simpler or more regular than the real-world pattern it attempts to portray. And the elements of that simplicity offer clues to the analytical strategy used by the brain to encode spatial structures. Leonardo Da Vinci sketched the amodal structures that he perceived embedded in the human form, shown in Fig. 8.7A, that help him characterize that form as a compound of simpler geometrical elements. Similar sketched skeletons are seen in 'how to draw' books, where the basic technique is to sketch out the global skeleton of the perceived form in simple Euclidean primitives, and then to flesh out that regular skeleton with a veneer of surface qualities. The central skeleton is the primal shape or pattern observed 'in' the perceived object, that makes sense of its more irregular external contours. Representational art varies widely in the degree of stylization of the representation; that is, how much the regularity detected in the represented object is amplified or exaggerated in the representation for aesthetic purposes. Realistic art comes closer to the irregularity of forms found in nature, capturing the accidental postures or configurations of the arbitrary moment in time, while stylized art is more regular and geometrical, capturing the enduring timeless pattern as if averaged over a longer period of

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observation. But even the most realistic art is always simpler and more regular than the natural scene that it depicts, because the scene has passed first through the filter of the artist's mind, where the regularizing processes in his brain have picked out and highlighted its regularities, and it is through those regularities that the artist communicates that shape to the viewer. (Weber 2002 p. 90-91, 102)

Fig. 8.7B shows the female figure from Keratea in Attica (now in Berlin) as one example of a stylized form. The complex shape of a human form can be interpreted in countless different ways; in this case the artist has chosen to pick out the pillar-like quality of the robed form, that is, the vertical 'symmetry' is emphasized, like the symmetry of a pillar, every part of which is similar to parts that are higher or lower. This symmetry is only approximate, of course, since the body does in fact get wider and narrower at different heights, but this artist has expressed that variation as a smooth and regular swelling and shrinking of the body as it sweeps from top to bottom, following another pattern of regularity. The pattern of shrinking from the shoulders to the waist, and swelling again to the hips before tapering off gracefully towards the feet, expresses a lawful and regular pattern of growth and decay characteristic of the female form, with accelerating and decelerating growth at different levels, smoothly blended with mathematical perfection. There is further regularity seen in the near-perfect periodicity of the folds of fabric and of the tresses of hair, along with a rather stiff and stereotyped posture that holds neck and shoulders at a perfect right angle, and the legs in perfect parallel symmetry.

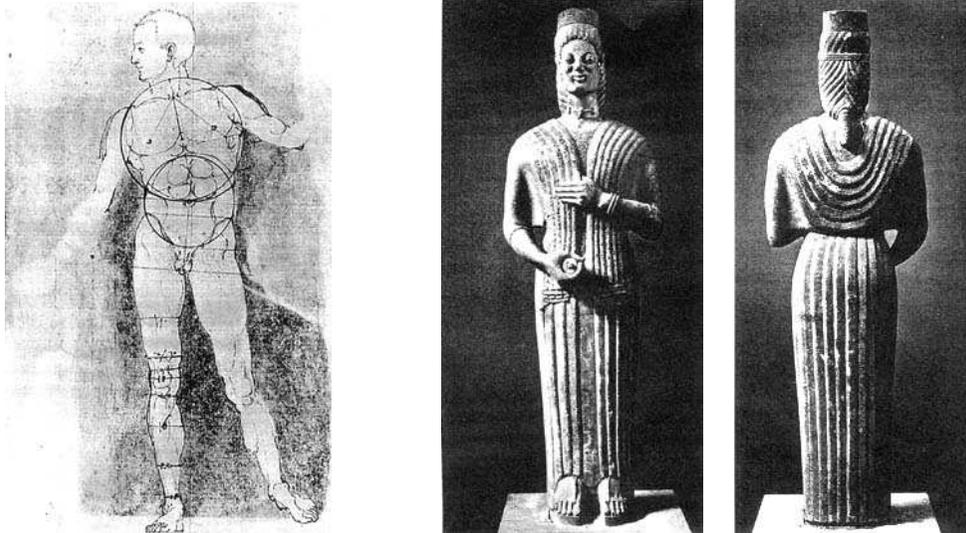


Fig. 8.7 A: Leonardo Da Vinci's sketch of the human form, with sketch lines indicating the amodal geometrical elements of which he perceives that compound form to be composed. B: Female figure from Keratea in Attica, showing how the irregular forms of the human body are expressed in a regularized form that exaggerates the symmetries, periodicities, and other regularities detected in that form.

Factoring Combined Patterns of Regularity

The vertical 'symmetry' of the female figure from Keratea is distorted or modulated by the swelling and shrinking pattern, so as to be no longer strictly 'symmetric', and yet the vertical symmetry is still clearly apparent despite this violation of its perfect symmetry. There is an important combinatorial principle observed in this aspect of art. The various symmetries detected in a form are observed to modulate each other, and thereby to violate the strict pattern of the symmetries themselves, and yet these disrupted or violated symmetries are perfectly apparent to the human observer. The folds of a hanging robe create a pattern that is approximately periodic, but not perfectly so, and yet we perceive the regularity hidden in the irregular folding pattern, and amplify that regularity in our artistic depiction of the robe. This demonstrates that the pattern detection mechanism in the human mind does not require perfectly regular patterns for the regularity to be detected, but will find the next nearest regularity that matches any particular irregular pattern. We see regularity even where there is none, and it is by that regularity that we interpret the shapes we perceive. (Weber 2002) For example Fig. 8.8A shows a shape that is immediately recognized as a wobbly cube. The cubical shape is perceived perfectly clearly through the wobble, just as the wobble is perceived perfectly clearly in the cube. Each shape is modulated by the other, and thus, both of them lose the perfect crystalline symmetry of their unmodulated form. This combinatorial aspect of perceptual representation poses perhaps the greatest challenge to computational models of perception because it suggests a recognition system whose templates or stored patterns are expressed not as rigid prototypical exemplars, as seen in the crystalline forms of the Platonic solids, but as some kind of elastic templates that can find a match to an elastically warped or deformed exemplar of the pattern that they are tuned to detect. For example the irregular triangles depicted in Fig. 8.8B are all recognized as variations of the same basic form, while the quadrilaterals depicted in Fig. 8.8C are all recognized as a distinctly different form.

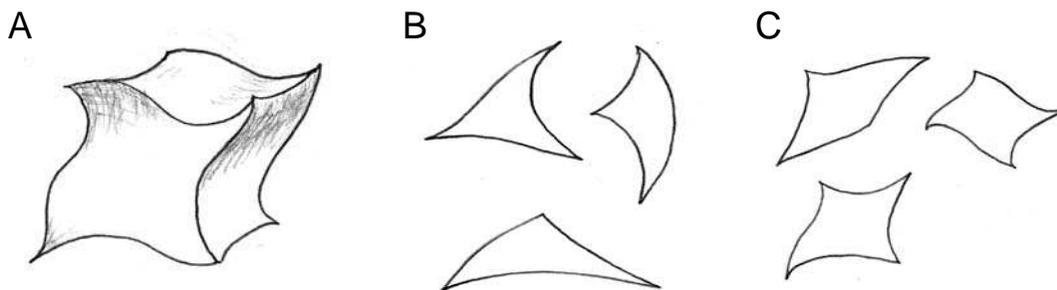


Fig. 8.8 A: This figure is immediately recognizable as a wobbly cube, whose cubical and wobbly components are both perceived embedded in the form. B: These distorted triangles are perceived to be both triangular and distorted, and immediately distinguishable from C: distorted quadrilaterals.

Categorical Quantization

There is an important general principle exemplified by this quantization of perceptual states that relates to the fundamental basis of mathematical representation in the brain. The only difference between a triangle and a quadrilateral is the number of vertices, which are 3 and 4 respectively. An elastic shape can be morphed through a great range of different configurations while maintaining its distinct recognizable symmetry. The addition of extra vertices, on the other hand, shifts the mutated shape into a different recognitional category; it is perceived to have a different characteristic form. The transitions between categories tend to be fairly abrupt. And those boundaries are found at the point where the central symmetry of the object has changed into a different discrete category. When a triangle grows an extra vertex, it falls into the category of a quadrilateral, with a four-fold rather than three-fold central symmetry. Visual categorization therefore appears to be based on a symmetry representation scheme.

The same general principle was seen in the perception of angles, as discussed above with the engine telegraph analogy. The 'notches' in the cam of Fig. 8.2C that fix the stable points of the system, also define the categories of angles represented in that system. It is a categorization scheme based on the symmetry of the angle relative to the full circle. And the reason why this kind of categorization is useful is because angles that are similar to each other can often be considered for practical purposes to be identical, and thus they can be treated the same behaviorally. For example an angle that falls in the range 90 degrees plus or minus a few degrees can be considered under most practical circumstances to be a right angle. It is this quantization in our recognition of angles that corresponds to the general categorization of angles into acute, obtuse, and right angles, general concepts that are meaningful across a wide range of cognitive tasks. And whenever greater precision is required in our treatment of angles, that precision can be attained by further subdivision of the general angle categories into smaller integer subdivisions, by the same principle that the unitary interval of the number line is subdivided by the rational fractions. This hierarchical subdivision of angle space can be seen in the traditional marking of a compass card into the cardinal headings of North, South, East, and West, and its fractal-like subdivision first into North-East, South-East, South-West, and North-West, and then on to North-North-East and East-North-East, and so forth, each new level doubling the number of subdivisions of the previous level, as shown in Fig. 8.9A. A different subdivision is used in the modern compass card that divides the circle into 360 degrees, as shown in Fig. 8.9B, the reason for this particular choice being that 360 divides neatly into integer halves (180 degrees) quarters (90 degrees), eighths (45 degrees) thirds (120 degrees), sixths (60 degrees), twelfths (30 degrees) and so forth, thus hitting a number of different harmonics of directional periodicity with an integer number of degrees. The quantization of the continuous range of perceptual experience into rationally determined discrete states is the fundamental basis of mathematical thought essential for categorizing our experience into meaningful chunks. It is the principle behind generalization in cognition, whereby continuous regions of perceptual feature space are encoded by a single point in that space representing the prototypical exemplar, or ideal

manifestation of the concept in its most pure form, like the perfect Platonic solids. But that perfect form marks only the center of a larger volume of feature space, corresponding to the range of morphed versions of that same basic shape, and that region is sharply bounded from adjacent regions at points of central symmetry change.

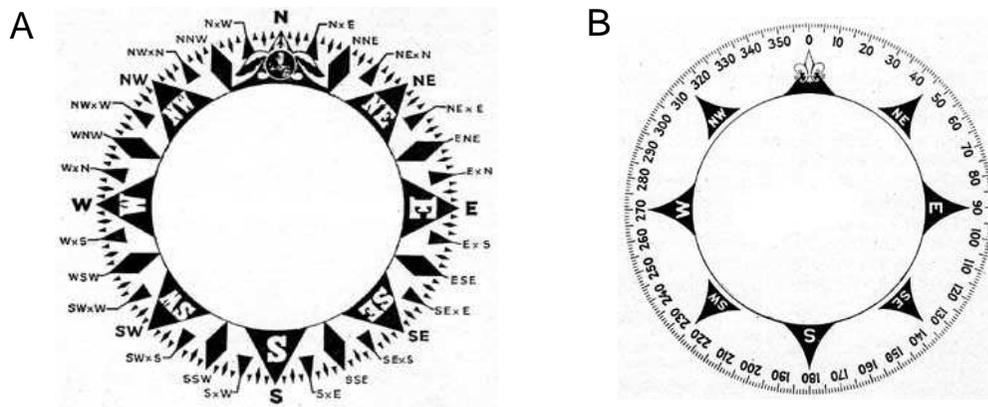


Fig. 8.9 A: Traditional compass card marked in a fractal subdivision based on quarters, eighths, sixteenths, and thirty-secondths of a full circle. B: Modern compass card marked in degrees of which there are 360 in a full circle, because that number divides evenly into halves, quarters, eighths, thirds, sixths, twelfths, etc. with integer numbers of degrees.

Music, Art, and Mathematics

Since ancient times there has been a recognition of some kind of connection between music, art, and mathematics. All have to do with regularity and with pattern. They all concern symmetry and periodicity, across space and/or time, and they are all known to have the potential to give aesthetic pleasure. The common principle that binds these otherwise diverse aspects of human experience is a search for pattern and regularity in the irregular chaos of our sensory world. We hear many sounds in a forest blowing with wind and rain. But if any sound should be periodic in any way, whether it be the creaking of a tree, or the chirping of a bird, or a periodic sound of footfalls, it captures our immediate attention as an item of greater interest. And when we imitate the sounds of nature, we do so with patterns that are immeasurably more regular and simplistic than their natural audio counterparts. The sound of a babbling brook is actually nothing like “babble babble babble”, nor is a dog’s bark like “ruff ruff”, and neither does a trickling stream really sound like “trickle trickle trickle”. But the best evidence for our symmetry and periodicity based representation of sound can be found in the sounds that we generate for their own sake because we find them to be intrinsically pleasing. In other words it is found in the patterns of music throughout the ages and across cultures. Whatever the stylistic differences across human music, there are some features that all music shares in common, and that is periodicity and symmetry of melodic and rhythmic patterns, in both simple and compound hierarchical forms.

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The visual system demonstrates more examples of our affinity for symmetry and periodicity in the patterns that we find aesthetically pleasing. It is our love of symmetry that makes us appreciate the colorful symmetries of flowers. And of course in visual art and ornament we find an endless variety of different kinds of symmetry and periodicity, from prayer mandalas, to Gothic cathedrals, to Greek temples, to clothing and wallpaper patterns. All appear to be a celebration of the conjoined principles of symmetry and periodicity. As I have shown, mathematics and geometry are themselves a celebration of symmetry in its most general form, from the spherical symmetry of a point, to the linear symmetry of a line, to the planar symmetry of the plane, to the central symmetry of the Platonic solid, to the accelerating symmetry of the parabola. More symmetry is found in the perceptual categorization of angles, and systems of angle representation used by different cultures, as well as in the integer and rational subdivision of the number line.

Ornamental patterns are the artistic equivalent of pure mathematics, a celebration of pattern for its own sake, rather than as a representation of something else. And the patterns of ornament are observed to explore every type of symmetry or regularity imaginable. Fig. 8.10 shows some ornamental patterns selected from Speltz (1910) from a range of diverse cultures. What is immediately apparent in these regular forms is that the human mind is sensitive to higher orders of symmetry beyond those that can be achieved by local symmetry forces, like those proposed for coplanar and corner completion processes discussed above. These patterns are much more complex than the Platonic solids, and yet their central framework is always related to some simple geometrical recipe, which is then geometrically subdivided into smaller component patterns of regularity creating patterns of patterns of patterns. The fact that we can detect these higher order patterns of symmetry in a stimulus pre-attentively and automatically, is direct evidence that our brain is sensitive to these higher orders of symmetry, and their ubiquitous presence in ornament is further suggestive evidence for a symmetry-based representation scheme in the brain.

Visual Pathologies and Hallucination

The intimate relation between ornamental and representational art can be seen in a few unique and interesting cases of artists who are afflicted with certain psychoses that manifest themselves in the artist's work. Jürgen Weber (2003, p. 13) cites the paintings of Carolus Horn, some of which are reproduced in Fig. 8.11. The paintings in this figure are arranged in chronological sequence, marking the progress of Horn's disease with ever increasing geometrical regularities and symmetries in the paintings emerging as the disease progresses. In other words, there is a progression from near-realism in Fig. 8.11A, to an ever more ornamental depiction as seen in Fig. 8.11F. A similar progression is observed in the art of Louis Wain, an illustrator from the last century whose generally realistic pictures of cats gradually transformed into ever more regular ornamental patterns, as seen in Fig. 8.12. What is interesting in these examples of visual pathology is that the most debilitated, and thus presumably most 'primitive' patterns, are virtually identical to the patterns of ornament as seen for example in a Gothic cathedral. This is at the same time somewhat surprising, but also somewhat expected. The Gothic cathedral, and similar examples of ornamental art, are often considered to represent the pinnacle of artistic achievement. They are examples of Great Art.

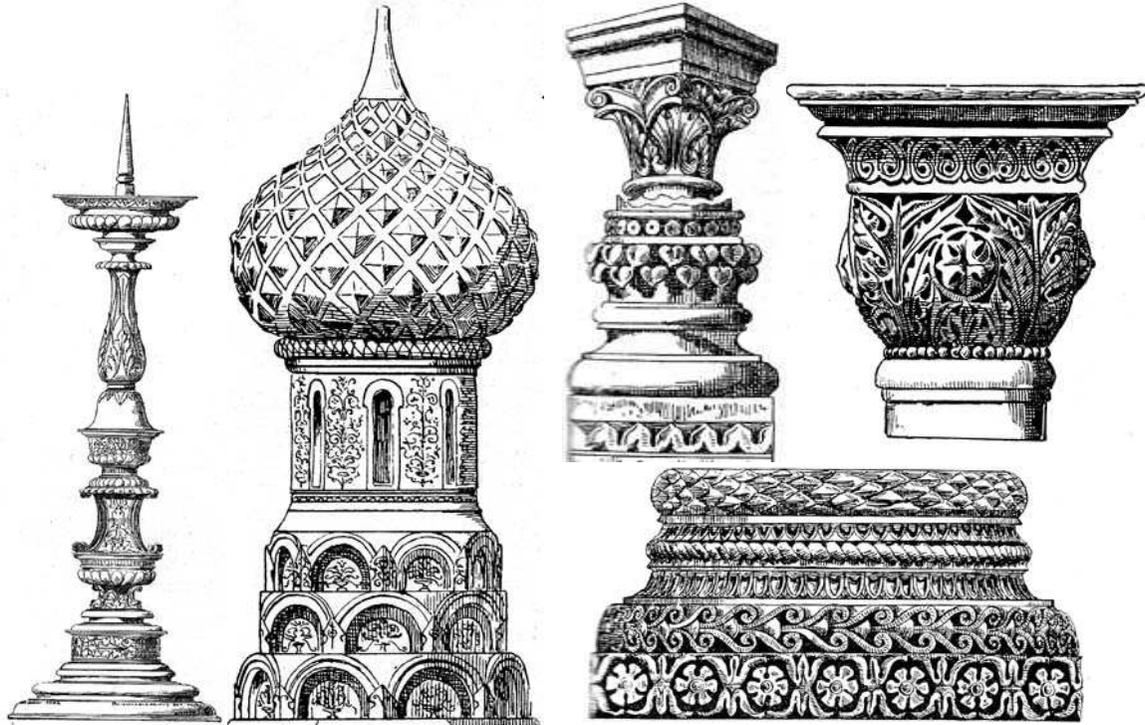


Fig. 8.10 Some ornamental patterns selected from Speltz (1910).

Why then do we see ornament emerging in the art of the mentally impaired? For myself, I find the ornamental patterns in Figs. 8.11 and 8.12 to be aesthetically pleasing, perhaps more so even than the realistic paintings at the beginning of those series. On the other hand realistic art is more difficult to produce than ornamental art; it requires greater skill and practice to produce a realistic likeness than a geometrical design. I propose that the same is also true of the representational mechanism in the brain. It is simpler for the brain to construct simple regular patterns than the irregular patterns found in nature, because of the brain's natural affinity to symmetry and regularity. Furthermore, the brain expresses the irregular patterns of nature in terms of the symmetries that it finds in them.

Consider for example the more realistic picture of the cat shown in Fig. 8.13A, or perhaps imagine a view of the cat itself that served as the subject of this painting. The human eye automatically picks out the regularities in this irregular stimulus, such as the bilateral symmetry of the face, and the circular crown of fur surrounding it, the triangle formed by the ears, nose, and mouth, and the larger triangle of the mouth and ears. It also picks out smaller more local symmetries, like the quasi-regular tufts of fur in that circular crown. These regularities are seen 'in' the stimulus in an invisible amodal fashion, as if the irregular texture of the cat were mounted on a geometrically regular amodal framework, somewhat like the ornamental depictions in Fig. 8.13C and D. In normal perception these frameworks remain amodal, and thus 'invisible,' an abstracted recognition of pattern hidden in the stimulus. But is the shape of a cat's face more like the concentric circular pattern of Fig. 8.13C, or is it more like the triangular patterns of Fig. 8.13D? The answer is *both*. Both of these patterns of symmetry, and many more, are all perceived to be hidden 'in' the stimulus, where they compete with

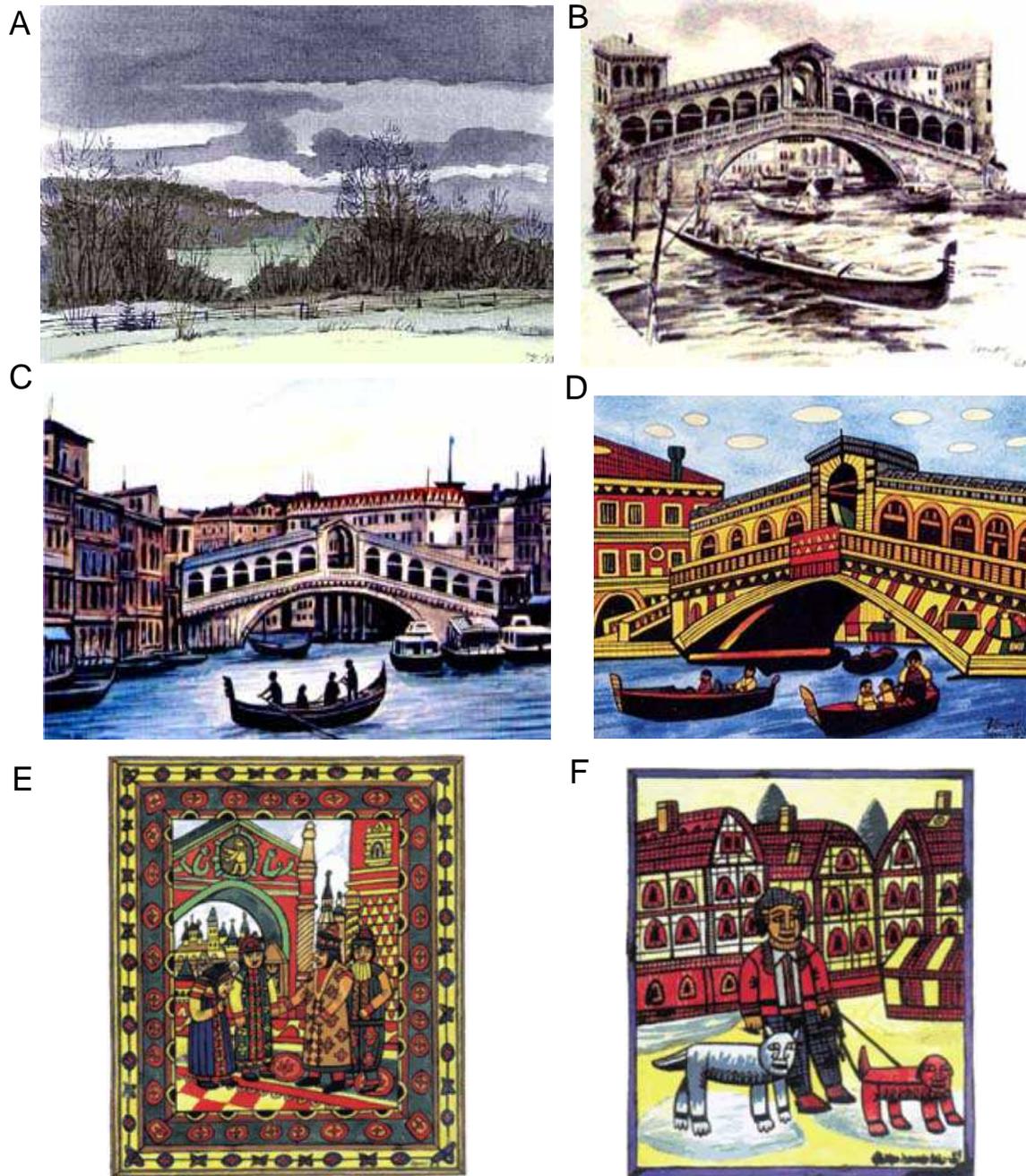


Fig. 8.11 A series of paintings by Carolus Horn, an artist who was afflicted with a progressive visual agnosia, that manifested itself as a progressive increase in the symmetry, periodicity, and regularity of his paintings.

each other, producing a shifting unstable pattern of hidden structure that fluctuates in a chaotic unstable manner between them. When the artist tries to locate the nose in relation to the two eyes, he sees momentarily a triangle of a particular orientation and aspect ratio joining the eyes and the nose, and it is by that 'imagined' triangle that he locates the nose relative to the eyes in his sketch. When he attempts to locate the ears with respect to the face as a whole, he sees the ears momentarily as two triangles riding on the circumference of the circle of

the face. Focal attention tends to bring out one pattern of symmetry over the others, picking it out momentarily from the visual chaos of competing patterns of regularity seen in the stimulus.



Fig. 8.12 A series of paintings by artist Louis Wain, who was afflicted with a progressive psychosis that manifested itself as a progressive increase in the symmetry, periodicity, and regularity of his paintings.

Jürgen Weber (2003) makes the crucial observation that even the realistic depiction, like the perceptual experience it replicates, is itself very much simplified compared to the visual confusion of the stimulus, and it is by the patterns of symmetry that we perceive in a stimulus that we 'see' the shape of the stimulus at all. Once we recognize the constructive or generative function of perception, we can see a parallel between human perception and computer generated imagery by ray-tracing algorithms. In the early days of synthetic imagery, everything was defined in terms of simple geometrical primitives, cubes, spheres, and cylinders,

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and so forth, which produced simplistic 'naive art' renditions of reality. As the state of the art progressed, we began to see new shapes, such as smoothly curving surfaces defined by sinusoids, paraboloids, and ellipses, and finally the mathematics of fractals revolutionized synthetic scenery, creating irregular mountain and forest patterns almost indistinguishable from the irregularities found in nature. But however close these synthetic scenes approach the appearance of reality, they are always necessarily simplified renditions of that reality, and that simplicity is expressed in the regular primitives employed in the representational code used to generate those scenes. As in perception, the mathematical principles of that representation can be seen in the unnatural regularities found in the generated scene. I propose therefore that the visual experience of simple creatures, such as birds and reptiles, is likely to be more regular and geometrical than our own experience, that is, they most likely see the world somewhat like the ornamental patterns of Fig. 8.12 and 8.13. A lizard in a forest does not see the visual chaos and irregularity of the forest that is the experience of the human observer, but rather it most likely has a simplified, more regular visual experience that looks more like the interior of a gothic cathedral, with geometrically regular trees with symmetrical branches arching overhead, arrayed in geometrically regular rows like the pillars of the cathedral. As with computer generated imagery, the sophistication of the human visual system is manifest in its capacity to express greater chaos and irregularity in the scenes of our experience.

Further evidence in support of this thesis is seen in the effects of psychedelic substances such as LSD. A prominent feature of the LSD experience, also seen in hallucinogen-inspired art, is a greater symmetry and periodicity of the experienced world. In fact, Fig. 8.12A is a pretty good depiction of the psychedelic experience, with regular patterns of grids, lattice work, or paisley patterns emerging from the chaotically textured portions of the scene, as seen here in the background of that picture, as well as in the increased regularity of the tufts of fur. Complete ornamental patterns such as those in Fig. 8.12C and D are also seen under the influence of hallucinogenic substances, as reported by Heinrich Klüver (1966), especially when the subjects are placed in a dark room with reduced visual stimulation. Klüver's subjects reported seeing regular geometrical patterns that they described as lattice, fretwork, filigree, honeycomb, and chessboard patterns. This free-wheeling hallucination of geometrical primitives reveals the eigenfunctions of the visual system, or the natural resonances of its representational structure. In the next chapter I present a harmonic resonance theory as an explanation for this regularizing tendency of human vision.

Chapter 9

Harmonic Resonance in the Brain

Harmonic Resonance Theory

In chapter one we began with an epistemological investigation into the source of human knowledge, and we came to the conclusion that all knowledge is ultimately based on experience. We continued the epistemological quest therefore with a phenomenological examination of the structure of conscious experience, and its implications for our knowledge of the world. The spatially reified analogical nature of experience in turn led us to postulate a spatially reified analogical representational mechanism, whose dynamic principles of operation were elaborated in chapter 8. So far our discussion has been based exclusively on the observed properties of phenomenal experience, and our modeling has been based exclusively on that experience, being a model of experience. In this chapter I introduce a harmonic resonance theory (Lehar 1999, 2003a, 2003b) whereby I propose that standing waves of electrochemical oscillation in the brain perform a computational and representational function that is central to the principle of operation of the brain. This might seem at first sight to be an abrupt departure from pure perceptual modeling to a neurophysiological theory of perceptual representation in the brain. I will show however that harmonic resonance is not really a specific neurophysiological theory at this point, but more of a general computational principle based on the unique properties of harmonic resonance in general, not only harmonic resonance in brains. The holistic spatial properties of harmonic resonance are so unique in the world of physical systems as to represent an entirely new principle of computation, as it is employed in biological computation, that simply cannot be divorced from the resonance itself, although those same unique holistic properties are common to all forms of resonance. In Lehar (2003a, 2003b) I discussed the fact that the phenomena of spatial standing waves of harmonic resonance are observed in a wide range of physical systems, from acoustical vibrations in cavities, to vibrations of solids, to laser and maser phenomena, and even chemical harmonic resonances in reaction diffusion systems. (Turing 1952, Prigogine & Nicolis 1967, Winfree 1974, Welsh et al. 1983) In all of these guises harmonic resonance exhibits certain general principles which remain constant through the different physical manifestations of resonance. For example the spatial size of a standing wave is directly related to its frequency of oscillation, larger patterns requiring longer wavelengths that oscillate more slowly than smaller patterns, and thus require less energy to maintain. And there are special mathematical properties of the higher harmonics on a fundamental frequency, each of which is a rational fraction of the frequency of the fundamental pattern, and thereby corresponds to rational subdivisions of the spatial pattern of the standing wave. These general properties are common to all resonances, acoustical, electrical, or chemical, and it is these properties that are exploited by the brain.

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What Is Harmonic Resonance?

Harmonic resonance is a strange and unique phenomenon with many powerful properties as a principle of representation and computation. To discuss the nature of resonance itself, independent of its various particular physical manifestations, let us consider a resonance in the abstracted perceptometric terms of volumes of substance suspended in a void, somewhat like a floating blob of wax in a lava lamp. For simplicity, let us picture a void with a spherical blob floating at its center. If we just add to this model of substance the properties of elasticity and inertia, then we have the minimal requirements for harmonic resonance of the most general form. All we need to do now is initialize the representation in a non-equilibrium state. For example if we initialize the system with the sphere elastically compressed to a smaller radius, as depicted in Fig. 9.1 A, then its elasticity would tend to bounce it back outward to its equilibrium radius, as suggested by the outward arrows in the top row of Fig. 9.1A. But by the time it reaches the equilibrium radius (depicted in dashed lines) it will have built up some outward momentum, which will carry it onward to a radial overshoot, with the elastic sphere in a stretched state as it reaches its maximal radius, as shown in the second row of Fig. 9.1A. The stress of the stretched state in turn accelerates the sphere back inward through the second half-wave of oscillation, as suggested by the converging arrows in the figure. This inward compression again overshoots the equilibrium radius and returns the sphere to its initial compressed state, and the inward and outward motions would repeat in endless identical cycles in the absence of frictional losses.

There are many other patterns of symmetrical distortion of the sphere that also lead to periodic oscillations. Column B of Fig. 9.1 depicts a horizontal oscillation that begins with an elastic compression on the right and a rarefaction on the left of the sphere. This causes a motion from left to right in the first half-cycle of the oscillation, as suggested by the arrows in the first row of figure 9.1B. Again, this motion overshoots the center, and results in a reverse pattern of deformation, with compression on the right and rarefaction on the left, which in turn triggers the second half-cycle of the oscillation with a motion from right to left, as suggested in the second row of Fig. 9.1B. Two other patterns of symmetrical distortion are depicted in Fig. 9.1 C and D, that lead to different patterns of endless oscillation corresponding to different spherical harmonic standing waves. The oscillation of Fig. 9.1 C alternates between an elastic contraction of the poles and a bulging at the equator, deforming the sphere into an *oblate* spheroid, as shown in the first row of figure 9.1C, and a complementary contraction of the equator and an extension of the poles, to form a *prolate* spheroid, as shown in the second row of Fig. 9.1C. And the oscillation of Fig. 9.1D alternates between a horizontal and a vertical elastic stretching that deforms the sphere alternately between a vertical and a horizontal ellipsoid, with major axes oriented at right angles to each other. These four modes of spherical harmonic resonance are only a few of the infinite series of symmetrical patterns of oscillation that are observed in spherical harmonic oscillations.

There are a number of alternate ways to visualize these oscillations. Rows 1 and 2 of Fig. 9.1 show the peak force fields through the first and second half-cycles of oscillation respectively. Another way to visualize the oscillation is to ignore the

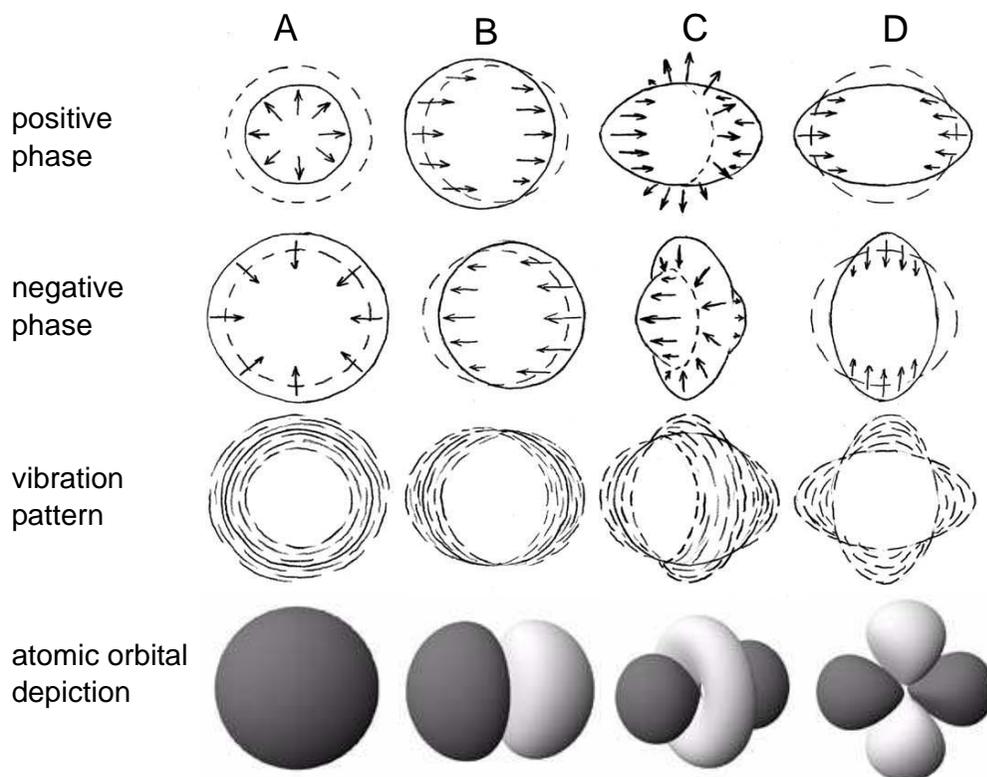


Fig. 9.1 Four modes of spherical harmonic resonance depicting for each mode the positive and negative phase of the first and second half-cycles of the oscillation, the vibration pattern, and the atomic orbitals convention used to depict the standing wave resonances of atomic orbitals.

phase, and consider the motion as a pattern of vibration alternating rapidly between two states, as depicted for each mode in the third row of Fig. 9.1. This is the way that an oscillation is perceived when its frequency is too fast for the eye to keep up with, like the vibration of a guitar string when it is plucked. Finally, the last row in Fig. 9.1 labeled 'Atomic Orbital Depiction', depicts each harmonic standing wave using the convention commonly employed to depict spherical harmonic modes of atomic orbitals, the orbital patterns, or "shells," occupied by negative electrons around a positively charged atomic nucleus. All of the atomic orbital figures in this book were generated by the program *Orbital Viewer*¹. These plots correspond to the pattern of elastic stress through the sphere, the force that is responsible for setting the mass into motion in the first place. For example the left/right vibration of Fig. 9.1B is triggered by a compression on one side, indicated in light shade, and a rarefaction on the other, indicated by darker shade the atomic orbital convention. In a fluid resonance this field corresponds to the pressure differential that causes fluid to flow from regions of higher to regions of lower pressure, like the pressure pulses in an inductor/capacitor (LC) circuit. This pressure differential alternates with the phase of the oscillation, reversing polarity through the second half-cycle. In the atomic orbital, this spatial field of alternating

1. *Orbital Viewer* by David Manthey is an excellent program available free of charge from <http://www.orbitals.com/orb/ov.htm>.

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polarity represents a three-dimensional surface or slice through a probability field at a fixed threshold such as 90% probability of an electron being present within the boundary circumscribed by the closed surface. Although the mathematical formulation of a standing wave resonance of an elastic sphere differ in detail from those of an electron orbital, the basic modes, or patterns of lobes and nodes, are common to all spherical resonances.

Some of the standing wave phenomena of an elastic blob can be seen in the vibration of little droplets of water on a steel plate, as demonstrated by Hans Jenny (1974), shown in Fig. 9.2. Again the mathematical details of this resonance differ somewhat from the standing wave patterns of a freely suspended spherical blob. Since these droplets are flattened by gravity against the vibrating plate, the resonance occurs principally in the horizontal direction, as flat 2-D shapes, although the volumetric component of these resonances is clearly evident. As with all resonances, the clearest and stablest patterns emerge when the vibrations occur at certain discrete frequencies corresponding to the natural harmonics of the droplet, forming a series of geometrical patterns of vertices, with the vibrational frequency of each pattern being a function of the number of vertices of the pattern. So we see here the spontaneous emergence of a series of regular symmetrical and periodic patterns from a homogeneous continuous substrate. Like the notches in the cam plate, these patterns arise in discrete steps, whose frequencies are related by simple integer ratios to the frequency of the fundamental vibration of the droplet. The patterns cannot be sustained in parts, but must be present whole, in order to maintain the dynamic balance and symmetry between the different parts of the oscillation against each other. There is a holistic global aspect to harmonic resonance which is unique to this paradigm of representation that underlies all of the holistic perceptual phenomena identified by Gestalt theory.

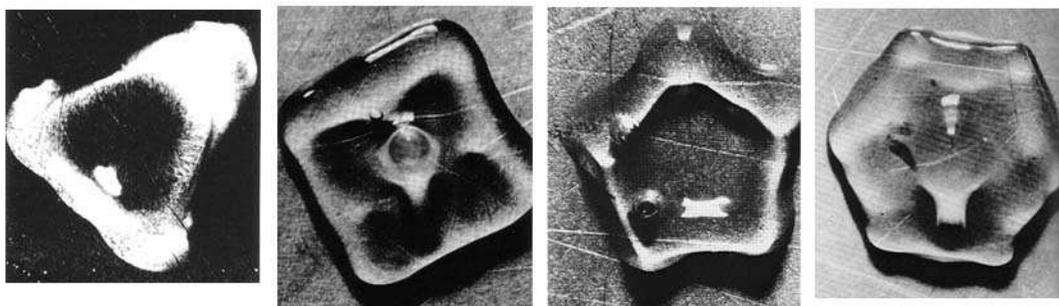


Fig. 9.2 Droplets of water on a vibrating steel plate take on simple geometrical forms like the Platonic solids, due to a standing wave resonance throughout the body of the vibrating droplet. (From Jenny 1974)

Higher Harmonics of Spherical Symmetry

The four patterns of standing waves of figure 9.1 are only the first few of an endless series of patterns of endless patterns, infinite series of infinite series, in fantastically complex hierarchical families based on ever higher orders of

symmetry. For example the spherical-symmetric standing wave of Fig. 9.1A is the first of a series of higher order patterns of spherical symmetry, the first three of the series are shown in Fig. 9.3A in atomic orbital convention. These harmonics define a periodic pattern of concentric shells of alternating compression and rarefaction. That is, through the first half-cycle of oscillation the light shaded shells expand, while the dark shaded shells contract, and those motions reverse through the second half-cycle. This spherical-symmetric radial oscillation is known as the 's' mode orbital in the atomic orbitals literature.

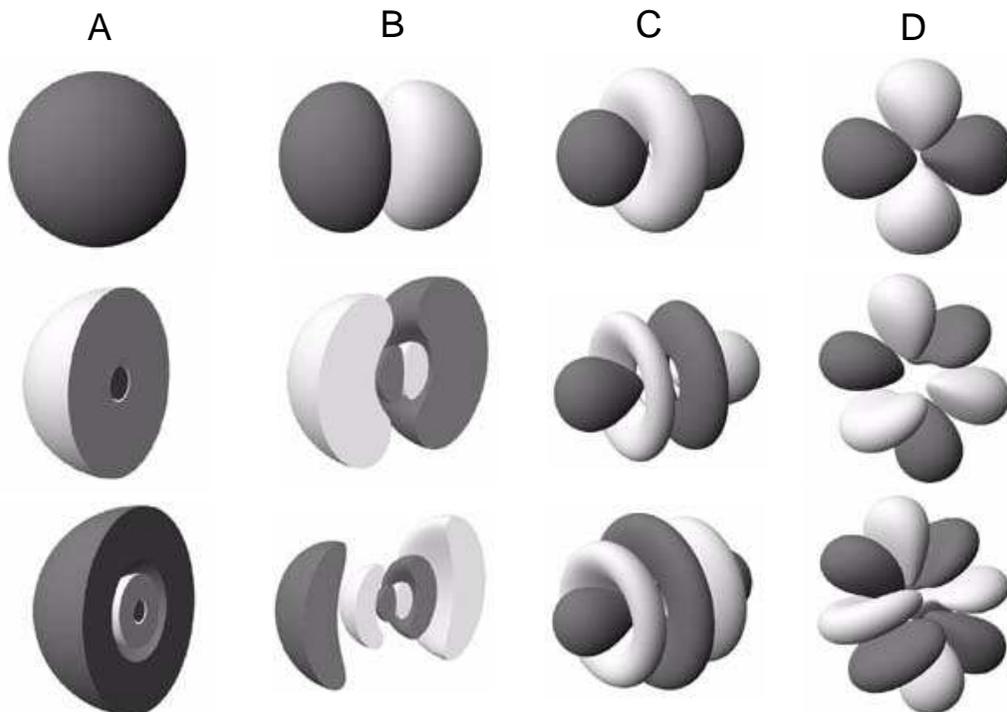


Fig. 9.3 Each of the atomic orbital patterns depicted in Fig. 9.1 A through D are just the first of a series that continues as shown here, showing the original patterns (first row) and the next two patterns in each series (rows 2 and 3). Four of the patterns are shown cut away, to reveal their internal structure.

The second standing wave pattern shown in Fig. 9.1B defines a polarity-reversal across one spatial dimension, which is the first of a series of higher order alternations shown in Fig. 9.3B, that have the same bipolar contrast in one dimension, along with a radial-concentric periodicity within each of those opposite poles. This standing wave pattern corresponds to the '*p*' mode of the atomic orbitals. There can actually be up to three resonances of this form present independently in one spherical resonance, as long as they are at mutually orthogonal orientations, and therefore there can be up to three *p*-mode electrons at every level in the atom.

The radial-axial oscillation shown in Fig. 9.1C is the first of a series of periodic radial-axial patterns shown in Fig. 9.3C, that are shaped like doughnuts strung on a rail, with a circular symmetry around the linear axis of symmetry, and an angular periodicity from pole to pole, like the periodic subdivisions of the lines of latitude on a globe. And the vertical-horizontal oscillation of figure 9.1D is the first of a

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series of periodic alternations around the circumference of a circle around a linear axis of symmetry, like the periodic subdivisions of the lines of longitude on the globe, as shown in Fig. 9.3D. Each of these patterns of symmetry represents its own unique infinite series based on one kind of symmetry or another.

Besides these different series, there are also innumerable hybrid series that combine symmetries from two or more of these pure-bred families. For example the standing wave patterns shown in Fig. 9.4A and Fig. 9.4B are hybrids of the lines of attitude of Fig. 9.3 D, and the lines of longitude of Fig. 9.3E. The full diversity of different spherical harmonic standing wave patterns that occur in atomic orbitals can be seen for example in the Grand Orbital Table by Manthey at <http://www.orbitals.com/orb/orbtable.htm>. It is a truly spectacular display of geometrical beauty and mathematical perfection.

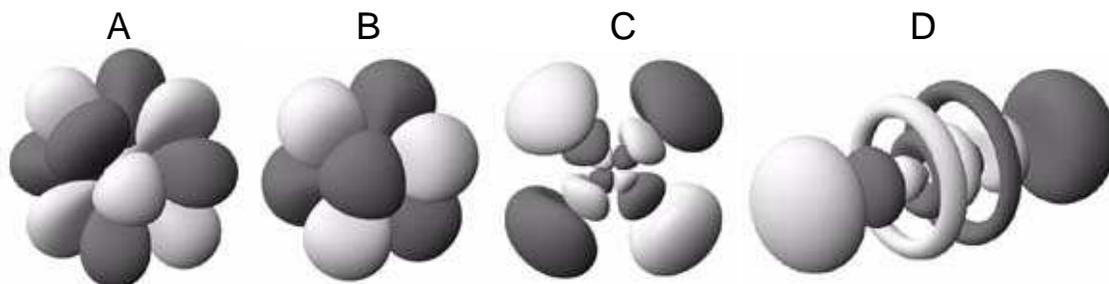


Fig. 9.4 These atomic orbital patterns are hybrids of the pure-bred families shown in Fig. 9.2, combining axial, radial, and concentric symmetries in various combinations.

One-Dimensional Resonances

The rich complexity of patterns available in even a simple linear resonator demonstrate the powerful pattern formation principle active in harmonic resonance. Consider a resonator cavity in the shape of a long tube with closed ends. There is a strong preference for the system to oscillate at its fundamental frequency and its higher harmonics, which are integer multiples of the frequency of the fundamental. For example the *even* harmonic series is like stepping up the musical scale by octaves, each frequency being double that of the previous step, as seen in the successive subdivisions of the unit interval depicted in Fig. 9.5A. The standing waves corresponding to this series of tones represents a series of subdivisions like the traditional compass rose. In other words, each higher (spatial frequency) level contains the same nodes as the next lower level, plus new nodes located exactly in between those nodes. The odd harmonics shown in Fig. 9.5B break out of the fractal-similarity of the even harmonic scale. For example the interval of $1/3$ is not a rational fraction of the lower harmonic interval of $1/2$; and the next higher odd interval of $1/5$ th is no regular subdivision of $1/3$, so every new harmonic of the odd series starts a whole new basis set of intervals, which can thus be further subdivided into either even or odd subdivisions. Fig. 9.5C shows the subdivision of the primal interval of one third into sixths and then twelfths, and Fig. 9.5D shows the primal interval of one fifth, further subdivided into tenths, twentieths, etc. There are also 'power law' subdivision series of the odd intervals. For example the interval of a third of a third of a third, shown in Fig. 9.5E, or a fourth of a fourth of a fourth, shown in Fig. 9.5F, and so forth. Every one of these

patterns in each of these families of standing waves defines an array of nodes at periodic intervals, a grid of evenly spaced points along the number line that correspond to the rational fractions of the unitary interval. Taken together, all of these families of grids of points of all possible harmonics correspond exactly to all of the discrete values expressible as a rational number, that is, a number that can be expressed as a ratio of two intervals. For example the rational value $3/8^{\text{th}}$ corresponds to three of the intervals of the eighth-harmonic resonance pattern of Fig. 9.5A (8), while $7/16^{\text{th}}$ corresponds to 7 of the 16^{th} units of Fig. 9.5A (16).

The different discrete patterns of intervals possible in standing wave resonance together define an elaborate hierarchy of endless patterns of endless patterns, every one of which is lawfully related to every other in the family hierarchy. This entire self-organizing pattern system is implicitly present wherever harmonic resonance standing waves are found, and nature has exploited this self-organizing principle of physical matter and adopted it as a means to represent spatial structure in living organisms.

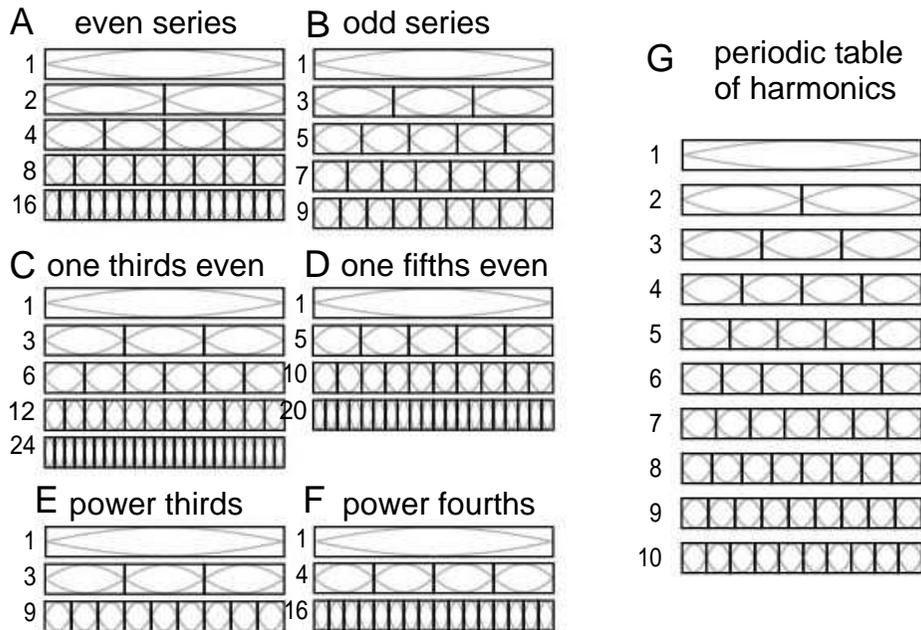


Fig. 9.5 A through F: Various patterns of regular subdivision of the fundamental interval into integer multiples. Every member of each of these series is a natural resonance or higher harmonic of the fundamental resonance of the vibration cavity. G: If the various resonance patterns are sorted as a function of the energy required to sustain them, they define a regular ascending scale of integer values, the true origin of the concept of the integer number.

Resonance Energy

Although harmonic resonance defines an infinite series of infinite series of periodicities, these standing waves are not equal, some are more 'stable' than others, that is, they require less energy to sustain the resonance, and thus they are more likely to emerge. The different energies required for the different resonances offers a sorting scheme or sequence based on the energy of each

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wavelength of resonance, the energy being a function of the wavelength. The $1/3$ harmonic interval is smaller than the $1/2$ interval, but larger than $1/4$. So a sequence based on energy should go from 1 to $1/2$ to $1/3$ to $1/4$ and so on, alternating between the even and odd harmonic series in a regular ascending pattern. This produces the periodic table of linear harmonics, shown in Fig. 9.5G. I propose that this property of harmonic resonance is the original basis of the concept of the integers.

Something of this quantization of an analog mechanism can be experienced when playing around with a bugle. The bugle is the simplest brass instrument, because it has no valves or sliders, so it is essentially a simple length of pipe with a mouthpiece at one end, and a bell at the other. It is relatively easy to blow the lowest note, the fundamental¹. If you blow harder and purse your lips tighter, thereby injecting more energy into the resonance, the bugle will tend to jump up to the next higher resonant frequency with a little hop, like the roller on our engine telegraph cam popping from one notch to the next. And like the notches of the cam plate on our engine telegraph, the bugle has deeper notches at the cardinal ratios; the octave, the fifth, and the third, and smaller notches for the lesser intervals of the second, fourth, sixth, and seventh. (Note that the musical terminology of 'fifth' and 'third', etc. does not correspond to the rational intervals of $1/5$ th and $1/3$ rd, but to the fifth, or third note respectively of the scale of notes defined by the octave arbitrarily subdivided into 8 whole notes by ancient convention) The octave interval corresponds to the ratio 2:1, the fifth corresponds to 3:2, the third is 5:4, etc. as explained in Lehar (2003, p. 245-247, figure 11.5). Actually a good bugler can make their bugle 'cry', stretching the note elastically to a higher pitch through a gradual slide, although the bugle shows a preference for dropping into the nearest available harmonic, just as the engine telegraph can be held beyond the center of a cam notch by pressure, although it snaps back to the center of the notch when released. This is the principle behind the concept of the prototype in recognition, whereby the lowest energy rendition of a spatial concept is its simplest most regular or symmetrical form, and similar or related forms are recognized as distorted renditions of that simplest configuration, and thus fall into the categorical region of feature space ruled by that perfectly regular prototypical form. This relates also to the Gestalt principle of prägnanz, and to Occam's razor, that the simplest, most regular interpretation is favored over more complex or irrational ones.

The families of different infinite series of patterns seen in one-dimensional resonances pale in comparison to the even richer and more variegated families of patterns of infinite series for the spherical symmetries of Figs. 9.2, the major families of patterns being defined in terms of radial periodicity (Fig. 9.2A), directional periodicity (Fig. 9.2B), axial periodicity (Fig. 9.2C), and circumferential periodicity (Fig. 9.2D), with compound or hybrid series being defined by various combinations of these major families, resulting in an extraordinary number of patterns in the periodic series of spherical resonance. In every one of these periodic series, the resonance tends to favor an integer array of discrete

1. Actually, for technical reasons well beyond the scope of this discussion, the lowest note of a bugle is in fact its first harmonic, rather than the fundamental, but the general principle remains.

resonances, and those resonances quantize a continuous space of possible shape into discrete points of perfectly symmetrical pattern, like the subdivision of the number line into perfect rational intervals. This is the property of harmonic resonance that makes it so useful as a representation of spatial structure.

Static-Dynamic Energy Structures

There is something very interesting in this concept of resonant oscillation. By pushing the system out of equilibrium in the first place, we have invested energy into it, and that energy remains stored in the dynamic oscillations that we have set into motion. There is now more than just a blob in the void. Now there is a blob, *and* there is a structured spatial field that is made of nothing but energy. And that energy is intermediate between kinetic and potential energy. It can be seen as kinetic energy because of the repeated symmetrical reciprocating motions of the masses about the various centers, and it can be seen as potential energy of elastic stress, whose magnitude rises and falls sinusoidally in exact counterphase with the strain that it induces. But more generally, the resonance as a whole can be considered to be a static structure built of energy, with a certain fixed pattern of dynamic oscillation. It is something that has suddenly come into existence that was not there before, that requires energy for its construction, and releases energy in its destruction, although it is not composed of any physical substance, it is merely a ghostly pattern of vibration superimposed on the physical substrate that sustains it, like a spirit possessing a physical body, or a mind inhabiting a brain.

Nodes as Features

There is another interesting aspect of harmonic resonance and that is its powerful affinity to strict symmetry and periodicity. In order for a resonance to be sustained, it must be in perfect balance across some center of symmetry, with opposite motions balancing each other in a dynamic dance, and the standing waves in a resonating system spontaneously and effortlessly 'compute' these discrete axes of symmetry by an analogical process. There is something very special that appears as part of the resonance, and that is a *node*, in the form of a point, line, or surface. It is a region in which there is no motion, because it marks a center of symmetry between the balanced and complementary forces and motions on either side of that nodal boundary. I have proposed elsewhere (Lehar 2003a, 2003b) that the nodes of standing wave resonances in the brain represent the central symmetries of recognized features, whether simple local features such as corners and surfaces, or more complex features like whole Platonic solids.

For example the polarity-reversal in the standing wave pattern of Fig. 9.1B occurs across a central plane, between the positive and negative phase regions, as suggested in Fig. 9.6A. This simple mode of spherical resonance exhibits the planar symmetry of the local surface coplanarity constraint. Here is a mechanism with a three-dimensional spatial structure that emerges spontaneously from a standing wave resonance in a homogeneous resonating substrate. The nodes for the standing wave pattern of Fig. 9.1D form two planes intersecting at right angles to each other, as shown in Fig. 9.6B. This standing wave corresponds to the three-dimensional corner-edges of the corner completion constraint. Higher harmonics

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of this same circumferential periodicity represent still greater subdivision of the circle into smaller angles that are integer ratios of the full circle. The equatorial/polar resonance shown in figure 9.1C defines nodal surfaces in the form of two cones that meet point-to-point at the center, as shown in figure 9.4C. At the higher harmonics the nodal patterns of these same resonances define a polar coordinate grid.

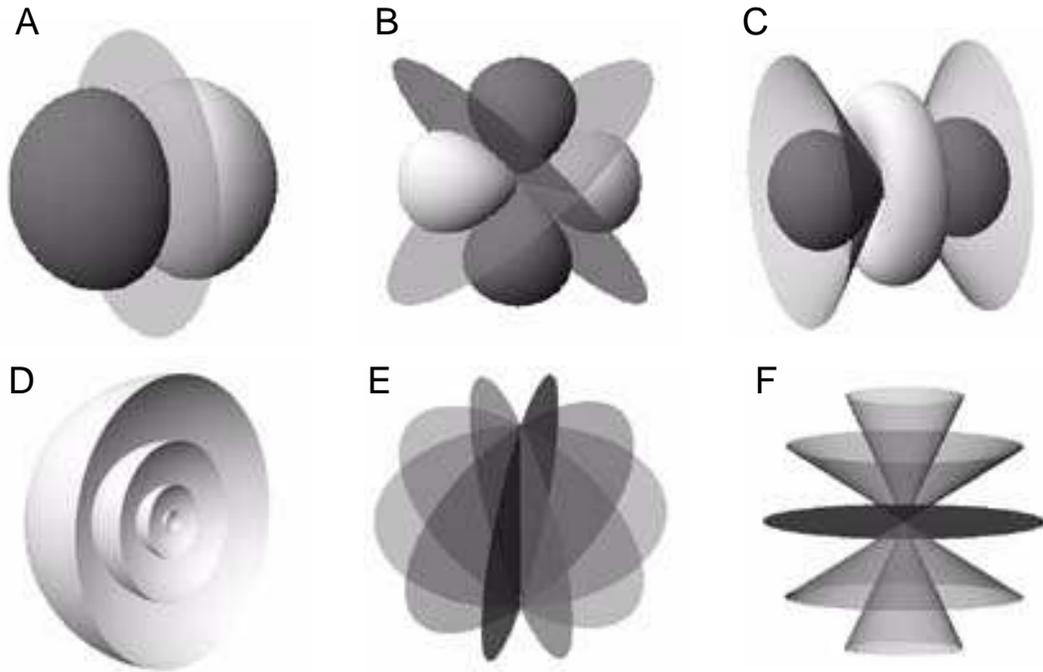


Fig. 9.6 A through C: Nodal surfaces through three atomic orbital patterns. D through F: Nodal surfaces for higher harmonics of certain orbital patterns define concentric shells, planes of longitude, and cones of latitude.

The nodes of the spherical-symmetric waveform of the **s**-mode vibration, taken to higher harmonics, defines a set of concentric shells about a center, as shown in Fig. 9.4D. The circumferential periodicity of the waveform of Fig. 9.1D defines, at the higher harmonics, a set of planes of longitude intersecting through a central polar axis, as shown in Fig. 9.4E, while the equatorial/polar oscillation of Fig. 9.1C defines a set of cones of latitude at the higher harmonics, as shown in Fig. 9.4F. What we have here is a dynamic analog mechanism with a natural tendency to subdivide the spherical space of its resonance into simple symmetric geometrical patterns, which in turn serve as the basis set for the representation of geometrical form expressed in terms of those patterns of symmetry. Standing wave resonance brings discrete order out of a featural continuum, subdividing the continuous range into discrete intervals by a geometrical formula based on symmetry, which is a natural emergent property of standing waves of harmonic resonance. I propose that the axioms of Euclidean geometry, and also those of perceptual geometry, are based on these patterns of symmetry of the standing wave resonances in the human brain. The Euclidean plane derives from the node of the bipolar standing wave shown in Fig. 9.4A. The line located at the intersection of two planes derives from the nodes of the four-fold resonance depicted in Fig. 9.4B. This resonance also relates to the three-dimensional corner between orthogonally intersecting planes, as in the corner-edges of a cube. The Euclidean

cone derives from the equatorial/polar standing wave resonance depicted in Fig. 9.4C, complete even with the feature of two cones aligned point-to-point. Note how in all three cases, the pure Euclidean concepts of plane, line, and cone, correspond to the nodal pattern alone, while the perceptimetric concepts of surface, corner, and solid cone, are a combination between the nodal pattern, and the *sign* of the phase of the standing wave pattern, shaded darker and lighter in the atomic orbitals depictions. For example if positive phase (light shade) is designated as substance, and the negative phase (dark shade) as void, then the phase fills in the entire volumes on either side of the nodal plane in Fig. 9.4A with substance and void respectively. (The sign of the phase, independent of its magnitude, fills in the entire volume on either side of the nodal planes, not just the blobby volumes shaded darker and lighter gray in Fig. 9.4A.) So the dichotomy between amodal versus modal, abstracted versus reified, discrete versus continuous, digital versus analog, corresponds to the dichotomy in the standing wave representation between the bare nodal pattern itself, as a sketch of central symmetry, as opposed to the filled-in volumes of positive and negative polarity which are separated by the pattern of those nodal planes. The phase represents the spatial continuum filling the volumes between nodal planes, while the nodal planes separate volumes of opposite phase across a transition surface which has something of the infinitely-rescalable property of the Euclidean plane, that is, its “thickness” is infinitely thin, at least in theory, and an intersection of these planes define an infinitely thin line.

A Spatial Addressing Scheme

The pattern of nodes of a spatial standing wave can serve as a volumetric spatial addressing scheme, a way to label every point in the volume of the resonating system depending on whether it is in the positive or negative phase portion of the pattern. It is this addressing property that is used in *embryological morphogenesis* to define the spatial pattern of different tissues in the developing embryo. For example the periodic pattern of segments of the body of an insect are determined in this manner. Insect embryonic development begins with a fertilized egg that divides repeatedly into smaller and more numerous cells, which then form an elliptical blob, a conglomeration of a multitude of essentially identical cells. Then, at some critical point in its development a periodic banded pattern is seen to emerge as revealed by appropriate staining techniques, shown in Fig. 9.7A. This pattern indicates an alternating pattern of concentration of morphogens, i.e. chemicals that permanently mark the underlying tissue for future development. The mechanism behind the emergence of this periodic pattern is a chemical harmonic resonance known as *reaction diffusion* (Turing, 1952; Prigogine & Nicolis, 1967; Winfree, 1974; Welsh, Gomata, & Burgess, 1983) in which a continuous chemical reaction converts some morphogen P to a different morphogen S , while a concurrent chemical reaction converts morphogen S back into P . (see Gilbert, 1988, pp. 655–661, for a summary). The result of this circular reaction is a periodic pattern of alternating chemical concentration between volumes with a high concentration of P , between adjacent regions with high concentration of S .

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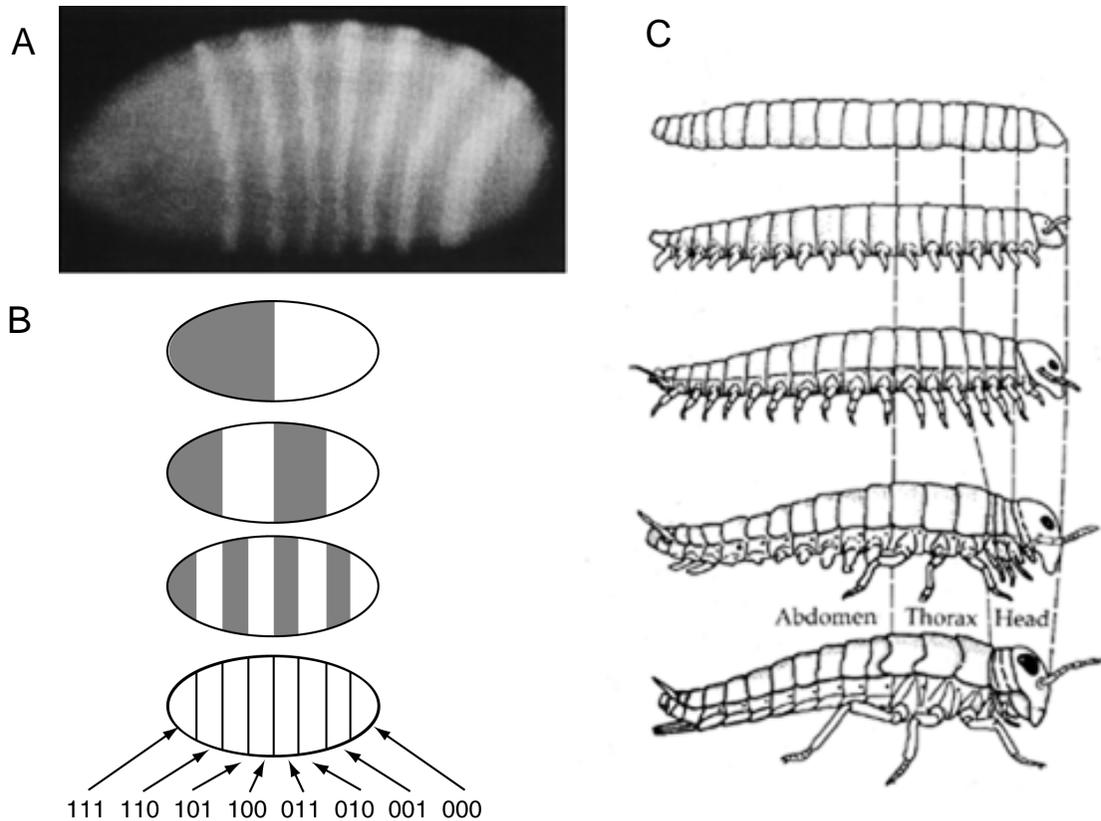


Fig. 9.7 A: insect embryo stained to reveal the banded pattern of the morphogens that determine the segments of the insect body. B: A hierarchical addressing code determined by three separate morphogens whose binary combinations uniquely identify each segment in the insect body. C: Insect evolution as the progressive emergence of various homeotic genes that apply exclusively to particular body segments. (From Gilbert 1988, p. 654)

In a vibrational resonance the phase of the vibration can be detected at any point in the volume of the resonating system by comparison with a reference wave, shared in common throughout the resonating volume. In fact, the fundamental resonance standing wave can serve as this reference wave. Consider an elastic sphere oscillating to the spherically-symmetric *s*-mode standing wave shown in Fig. 9.1A. Every point in the volume of the sphere experiences the alternating contraction and expansion of the sphere in perfect synchrony throughout its volume. If there is an additional horizontal standing wave as depicted in Fig. 9.1B, the frequency of that higher harmonic will be double that of the fundamental spherical resonance, because it divides the unitary volume into two equal halves. Every point in the resonating sphere can compute its location within this higher harmonic standing wave by comparing the relative phases of the first and second harmonic resonances. In regions of positive phase (shaded lighter in Fig. 9.1B) the two harmonics are in synch, that is, they both expand and contract simultaneously, whereas in regions of negative phase (darker shade) they expand and contract in counterphase, the one expands while the other contracts. The same principle applies to all the higher harmonics, thus providing a spatial

addressing scheme whereby every point in the volume can measure its own location locally, relative to any of the many higher harmonic standing waves on the fundamental.

Fig. 9.7B presents a schematic depiction of an embryonic insect larva, divided into segments by three higher harmonics on the fundamental resonance across the embryo as a whole. In morphogenesis each of these higher harmonics are regulated by a different chemical harmonic resonance, using distinct morphogens. The three morphogens in effect define a binary map of location within the embryo, as suggested in Fig. 9.7B, where each bit of the binary code represents the concentration of one of the three morphogens which can be either high or low. The morphogens in turn serve to activate or deactivate the expression of particular genes within their segment, dictating for example that one segment should develop legs, while another develops antennae, etc. Genes that express the spatial structure of the embryo in this manner are known as *homeotic* genes. Fig. 9.7C (from Gilbert 1988) shows a diagrammatic representation of insect evolution as it relates to the progressive emergence of various homeotic genes, each one modifying the morphology of particular parts of the body. One resonance is seen in the periodicity of the segmented body as a whole. A higher harmonic on this fundamental pattern defines a pair of legs for each segment. Another still higher harmonic generates periodic resonances on each leg, forming multiple segments along each leg, and then further sub-harmonics amplify and suppress the gene controlling the formation of legs in each segment following a global pattern, amplifying the legs in the anterior half of the body (thorax) while suppressing them in the posterior portion (abdomen). Simple worms like Annelids, (including earthworms and leeches) exhibit only the simplest segmented periodicity, whereas evolutionarily more advanced species progressively exhibit the higher order patterns of the insect body plan, they become more structured, less symmetrical.

What is evident in this unique principle of spatial representation is a certain context-sensitivity, that the spatial influences of each morphogen modify each other in an elastic Gestalt manner unlike any other spatial representation scheme devised by man. The degree of fractal self-similarity between parts is a prominent characteristic of this mode of representation, as seen in the similarity of body segments to each other, the similarity of the segments of the body to the segments of each leg, the similarity of individual segments of each leg to each other, the similarity between the legs and the antennae, and so forth.

Elastic Templates

The use of harmonic resonances as an architectural blueprint of geometrical form has very interesting consequences. Unlike a blueprint used in engineering, the harmonic representation is remarkably flexible and adaptive, automatically compensating for any irregularities in the tissue. The periodic boundaries of alternating segments in the embryo are not defined by measurement from some fixed reference point, as is the practice in mechanical engineering, but rather they are determined by a dynamic interaction involving every point in the volume of the tissue simultaneously. This makes the architectural plan adaptive to deformations in the embryonic tissue. Fig. 9.8A shows how the periodic banded pattern of the

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embryonic insect might respond to a deformation in the geometry of the embryo, generating segments of equal volume but dissimilar geometry. When the geometrical distortion exceeds some limit, the pattern will abruptly break into a different mode, generating discrete new features, as suggested in Fig. 9.8B. It is this property of harmonic resonances that accounts for the remarkable adaptability to distortion observed in morphological development. Wolpert (1987) describes a series of experiments that demonstrate this adaptability in the development of the embryonic chick wing. There is a morphogen released by certain cells in the wing bud of a chick embryo that determines the orientation of the chick's wing, that is, it fixes which side the asymmetrical "thumb" should appear. During a critical stage of development Wolpert grafted such cells from one embryo into a limb bud of another embryo opposite to the original cells. This produced wings such as those shown in Fig. 9.8C, D, and E depending on how early during development the surgery was performed. This discrete, "all-or-nothing" behavior in the emergence of individual digits is again analogous to the discrete harmonics of a bugle, and the notches in the cam plate. What is remarkable in these mutations is that when the global pattern of the limb is made to bifurcate unnaturally, all of the muscles, tendons, nerves and blood vessels also bifurcate as if this were part of the original design. The same phenomenon is seen in the most impressive form in Siamese twins and other natural malformations. This kind of remarkable adaptability in the body plan is a fundamental property of the harmonic representation which is unparalleled by any scheme or system used in human engineering.

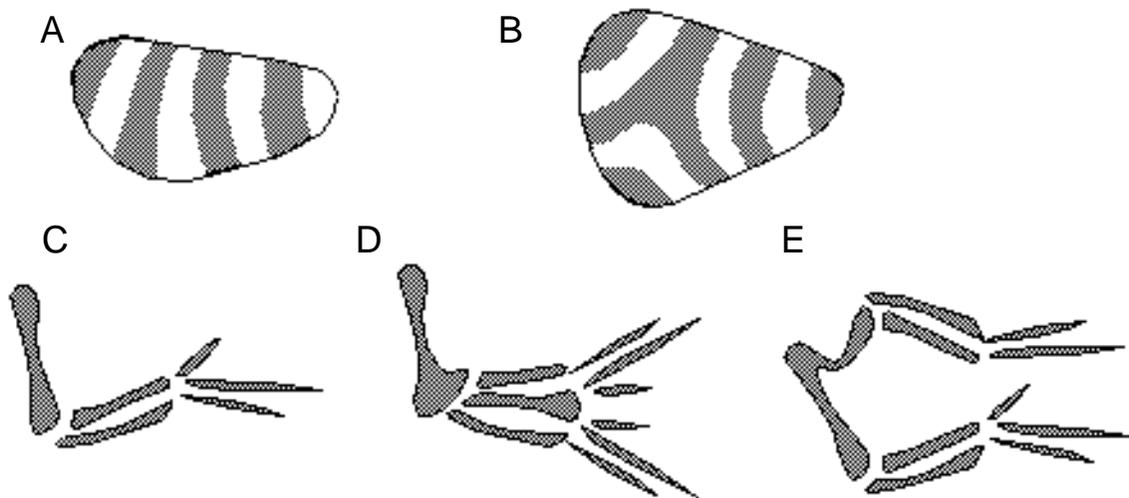


Fig. 9.8 A: The deformed pattern of banding that might be expected on a deformed or irregular insect embryo. B: When the deformation gets more extreme, a discrete transition would be expected, with the emergence of new bands. C-E: Deformations in a chick wing due to manipulations of the embryo during different stages of development. (Adapted from Wolpert et al., 1987)

It should be noted in the comparison between the chemical resonances in morphogenesis and resonances in general, that there is one significant difference between them. In normal resonance the structure of the periodic pattern is governed chiefly by resonance alone. In morphogenesis the resonance typically

occurs only during some critical period during development, although the pattern that it “imprints” on the underlying tissue is permanent. After the imprinting the tissue continues to grow, often at different rates in different regions of the pattern, because the pattern itself influences the growth rate. That is why the developing insect body exhibits creases or grooves between the segments, because the rate of growth of the tissue is apparently retarded in the region of the nodes relative to the antinodes. Similarly, the embryonic hand of a human fetus begins initially as a symmetrical paddle shape, with a perfectly geometrical fan-shaped pattern of radial bones for the hand and fingers, like a hand with the fingers splayed out, and a periodic pattern in the radial dimension dividing each finger into periodic segments arrayed in concentric arcs. During the subsequent growth the hand becomes considerably more irregular as different parts grow at different rates, resulting in the distorted periodicity of the mature hand shape. This is a different kind of deformation than that discussed as a property of the resonance itself, wherein the alternating segments necessarily remain of exactly the same volume even if contorted geometrically, a constraint that no longer holds when the resonance has expired and only its imprinted shadow remains on the still-growing tissue. Morphogenesis is resonance with “memory”, where the imprinting creates a permanent record or trace of the transient standing wave pattern. There are intermediate, more dynamic forms of morphogenesis, as seen for example in the way that a salamander regenerates a lost limb, producing a complete and perfect replica of the original limb. In this case the resonance does not just occur at a critical period, but must operate continuously, both while the limb is re-growing to its full size, and even continuously thereafter, in order to maintain the limb in its pre-programmed configuration through future injuries. In fact, this same kind of adaptive “resonance with memory” must be active even in higher animals including humans to account for the remarkable ability of the body to heal itself after injury. While the human body cannot fully regenerate whole limbs or repair large wounds, it can regenerate minor damage by healing wounds with a controlled re-growth that grows rapidly to close the wound, but knows exactly where to stop when the healing is complete. Even with the loss of whole limbs, although the human body cannot restore the whole limb, it does seal up the severed end of the remaining portion of the limb with a smooth and continuous covering of layered tissue equipped with veins and arteries and sensory nerves, and this new skin automatically smooths out any initial irregularities to create a smooth and rounded stump. It is quite remarkable how precisely the body knows its own limits when healing a wound, as if it were employing a volumetric spatial template to determine where to grow and where to stop, which suggests that some kind of chemical standing wave process persists continuously in the human body, constantly maintaining its form according to a pre-planned but elastic template.

Evolutionary Implications

The reaction-diffusion observed in embryological morphogenesis offers an *existence proof* that standing waves both *can* and *do* serve as a principle for spatial representation in biological systems, and at the same time it demonstrates the power and flexibility of that representation to unanticipated variations in the body plan. It should come as no surprise therefore that the brain and nervous

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system also employ this remarkably flexible and adaptive principle of spatial representation for sensory, cognitive, and motor processing. The principles of this standing wave system are clearly evident in the patterns of motion seen in the most primitive creatures. For example leeches, one of the simplest of worms, swim through the water by way of sinusoidal undulations of their body that propagate like travelling waves from head to tail. Similar sinusoidal oscillations are seen in the body motions of fishes and snakes, as well as in the cyclic motion of the feet of a centipede, and many of the simplest creatures such as jellyfish, with simple unstructured nervous systems also exhibit a waving of tentacles in synchronized travelling waves. In fact, a synchronized waving motion is even observed in single-celled organisms like the paramecium, whose microscopic cigar-shaped body is propelled through the water by a rhythmic beating of its *cilia*, tiny hairlike fibers made up of bundles of the protein tubulin. The fact that the cilia of the paramecium beat in synchronized waves suggests that the cilia do not operate independently, but they must be causally coupled into a larger pattern of travelling waves sweeping continuously along the body of the tiny creature. This is harmonic resonance at the tiniest biological scale, in the absence of any kind of central nervous system. If the paramecium has a tiny spark of consciousness, that consciousness must surely take the form of an integrated wavelike experience through the body of the creature as a whole, due to the intimate causal coupling between its parts that unite it into a single synchronized whole. A similar integration is observed in simple multi-cellular creatures like the Hydra, a tiny polyp of the phylum *Cnidaria*, whose simple unstructured nervous system is composed of a network of undifferentiated cells that span the entire surface of the tiny creature in a uniform network, somewhat like a fishnet stocking. The neural fibers that connect the network can propagate activation in both directions equally, and the primitive synapses that form wherever such fibers cross also transmit activation in both directions. Activation applied at one point on the hydra has been observed to spread outward from that point like the expanding rings on a pond after a stone is tossed in, and waves of activation meet and cross each other at the opposite side of the creature's cylindrical body or tentacle, resulting in the so-called "echo effect" back at the point of stimulation. And yet despite the simplicity of this neural architecture, the hydra is capable of remarkably sophisticated spatial behavior, from waving its tentacles about in search of food, to drawing food snagged by a tentacle back to its mouth, to peristaltic "swallowing" contractions of its cylindrical body, to "regurgitation" reverse contractions to expel the undigested remains, to various patterns of locomotion including a form of walking in which the hydra bends over and seizes the ground with its tentacles, flips itself upside-down in a somersault to step back down on its "foot", and it repeats this process as necessary to get to where it is going. All this with the simplest unstructured nervous system in the form of a homogeneous net that just propagates signals in all directions equally. If we are ever to understand the principle behind the human brain and nervous system, surely we must begin by understanding how these simplest of nervous systems operate. Only a harmonic resonance theory could possibly account for such structured spatial behavior from such a simple unstructured nervous system.

A Simple Creature

So how would a harmonic resonance theory account for the wavelike body motions of simple creatures? Let us discuss a very simple hypothetical organism of minimal complexity to demonstrate the principle of motor control by way of a standing wave representation. Picture a simple multi cellular organism in the form of a spherical blob of essentially undifferentiated cells. The organism does not need a nervous system, but operates by direct electrical contact between adjacent cells in the tissue. Let us suppose further that each cell has a natural tendency to oscillate at some basic frequency. The cells of the cardiac muscle are individual oscillators of this sort. In vitro, each cell behaves as an independent oscillator, vibrating electrically to its own natural rhythm. But when cardiac muscle cells are placed in contact with each other, they automatically lock into synchrony with each other and oscillate in unison. When connected in their proper place in the three-dimensional volume of the intact heart, the cardiac muscle sways to synchronized waves of contraction and extension that sweep back and forth across the heart as a whole, with electrical activation jumping directly from cell to cell, unmediated by any neural pathway. The spatiotemporal pattern of this cyclic oscillation is not dictated or choreographed by signals from the cardiac nerve, because the cyclic contraction is observed to continue even after the cardiac nerve has been severed. The nerve serves merely to control or modulate the rate of these endogenous cardiac contractions as dictated by signals sent down from the brain.

I propose a principle of motor control for our simple blob organism based on the phase difference between a standing wave and a reference wave, using the fundamental resonance as the reference wave. The reference wave is a common oscillation of the bulk tissue as a whole, with every point simultaneously alternating between electrically positive and negative in endless cycles. A zeroth-harmonic vibration alone represents no posture, that is, the relaxed state, which for our blob organism is the spherical shape. Higher harmonics on this zeroth harmonic reference wave represent postural deformations in the patterns dictated by the standing wave in question. A first harmonic standing wave is oriented in a particular direction, like the horizontal waveform shown in Fig. 9.1B. This pattern of positive and negative regions might be coded to represent, for example, muscular extension in the positive regions, and contraction in the negative regions. Although the resonance itself is a cyclic phenomenon, the standing wave pattern is static, that is, the phase relationship between the fundamental and the higher harmonic expresses a static pattern of extension/contraction across the whole organism. A single standing wave therefore encodes not an oscillation, but a static posture, as a spatial pattern of extension and contraction in the volume of the sphere of cells, and every individual cell interprets that pattern at the volumetric location that that cell occupies. The standing wave therefore offers a volumetric spatial template of a specific three-dimensional shape.

Let us return to the spherical resonances of Fig. 9.1, reproduced here again in Fig. 9.10, and consider how they would work as a representation of postural form. The fundamental, or zeroth harmonic of Fig. 9.10A represents a spherically symmetric posture, with positive phase corresponding to a uniform expansion of the spherical body to a larger radius, whereas the negative phase represents a global contraction to smaller spherical radius. (I am not concerned here with the

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biological asymmetry that in fact muscles only contract, and that extension must be provided by some balancing mechanism; my focus is on the principles of the control mechanism and how it represents spatial information) Fig. 9.10B shows the first harmonic **p**-mode vibration, with extension across one half of the spherical organism, and contraction across the other. Fig. 9.10C shows the posture due to the polar/equatorial resonance of Fig. 9.1C, deforming the sphere between either an oblate spheroid, wide around the equator, or a prolate spheroid with a narrow waist and tall pole-to-pole height. And Fig. 9.10D shows the postures that alternate between a vertical and a horizontal solid ellipsoid.

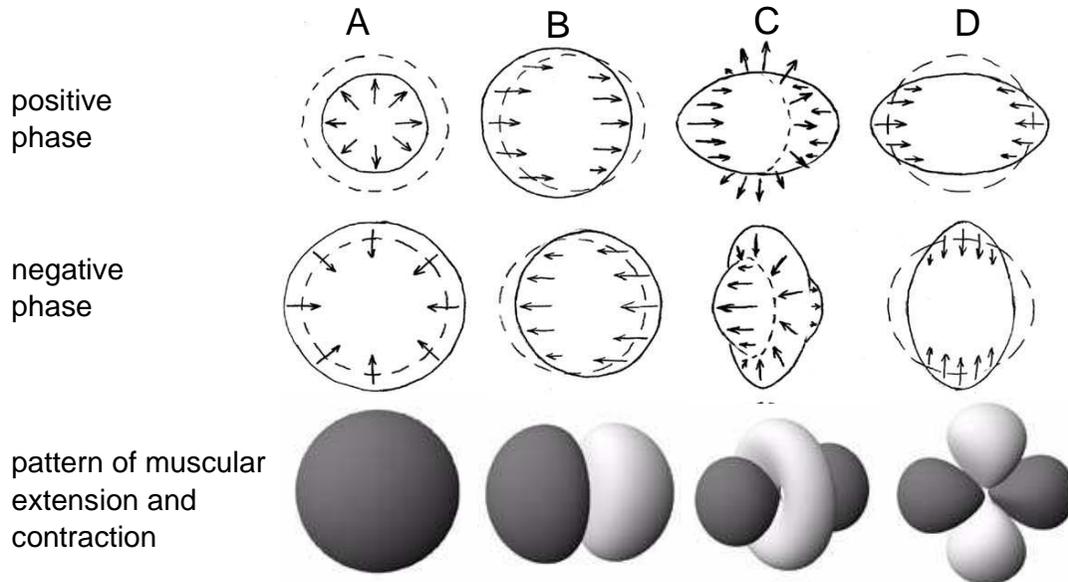


Fig. 9.10 Four modes of spherical harmonic resonance as in Fig. 9.1, showing how these four standing wave patterns translate to a motor posture pattern, with volumes of extension marked by positive-phase regions, and contraction by negative-phase regions of the different standing waves.

The atomic orbitals depiction in the bottom row in Fig. 9.10 is now labeled “pattern of muscular extension and contraction”. Dark regions represent the positive phase, and mark volumes of muscular extension, whereas light regions represent the negative phase, specifying muscular contraction. Each of these motor patterns comes in positive and negative phase modes, which are complementary opposites with their patterns of expansion and contraction reversed.

The standing wave is serving as a spatial template, just like a neural receptive or projective field in the neural network paradigm, except that there is no physical structure or template needed to define the pattern, but rather the pattern emerges from the matrix of resonating cells, like a note emerging from a bugle. And the very same mechanism that defines one pattern of posture, defines the whole array of them. Finally, the spatial patterns defined by these standing waves are not confined to one orientation, as would be the case for any kind of receptive field, or template model of spatial representation, but every one of these patterns can emerge at any orientation. The control system of the organism comes down to a resonating system with a tendency to resonate like a musical instrument blowing a

note, and some kind of feedback control system to control the patterns of resonance in the system, by the same principle that a musician controls the resonances in his instrument by damping the vibration at specific points (opening the holes in a flute, pressing the string with a finger, for string instruments).

Sensory Integration

The same holistic global aspects of a standing wave representation that serve so well for motor control, also offer unique advantages for sensory processing. The most challenging problem of sensory function is how to meaningfully integrate the vast quantity of sensory input into a single coherent and balanced view of the environment. For example if every cell of our simple blob creature were equipped with a pressure sensor, how could the organism make sense of that multitude of individual pressure sensations? How, but for a spatial template, could the organism see not the sensations, as a multitude of individual experiences, but the spatial *pattern* of those sensations? The answer is by the emergence of spatial standing waves that automatically adjust themselves to copy or replicate the pattern of the stimulus. For this to occur, there must be a way for sensory stimuli to influence the global pattern of standing waves in some way, as the inverse of the motor function whereby the phase of a higher harmonic relative to the fundamental determines the local extension/contraction value. For example if all the cells in the lower half of the blob organism experienced higher than average pressure, whereas cells across the upper half detected reduced pressure, then the bipolar global pattern of pressure would stimulate the emergence of a bipolar, or first harmonic standing wave shown in Fig. 9.1B, with its positive-phase hemisphere oriented towards the bottom, and negative-phase hemisphere oriented upward. If on the other hand the creature was caught between the prongs of a biologist's tweezers, it would feel two pressure peaks oriented in polar-opposite directions, i.e. a pattern of pressure that matches the equatorial/polar standing wave of Fig. 9.1C.

The same principle would apply to other sensory modalities. For example if every cell of the blob organism were also sensitive to light, then each photosensitive cell could be devised to modulate that cell to favor either the positive or negative phase of oscillation, based on the intensity of the light detected. This would in turn stimulate the emergence of a separate standing wave pattern, this time expressing the global pattern of external illumination inferred, based on the spatial pattern of photosensory signals across the body of the organism. The spatial integration of the sensory stimulation across a sensory surface like the retina therefore is implemented by constructing a standing wave across the tissue of the retina, whose spatial pattern matches the pattern of the stimulation. The standing wave thus encodes the entire pattern as a whole, in a holistic Gestalt manner, and the pattern of that standing wave can be communicated up the optic nerve in the form of a vibration of a characteristic frequency and waveform. If the Lateral Geniculate Nucleus (LGN), which is the waystation in the brain where the optic signal first arrives, is constructed as a resonator with similar resonance tuning to that of the retina, this temporal oscillation from the optic nerve will be sufficient to regenerate a similar standing wave in the LGN, and presumably another similar standing wave in the primary visual cortex (V1), and more similar standing waves in the higher visual areas, V2, V3, V4, etc. Each of these standing wave patterns

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is coupled to all of the others with reciprocal feed forward and feedback connections (except perhaps the retina) that keep the patterns in the diverse cortical areas coupled to express the same essential pattern, with minor variations in the different cortical maps.

From Structure to Motion

Static standing waves can be easily converted into dynamic travelling waves by interference between two standing waves of different frequencies, in the manner of the Lissajou figures on an oscilloscope produced by interference between two sine waves. When the frequencies of the two component waves are very close, they generate long-wavelength 'beats' as they wander in and out of phase with each other, resulting in Lissajou figures that cycle endlessly through a fixed circular series of motions. Similarly, in our blob organism, a double resonance involving two signals close in frequency, results in endless cycling between positive and negative phase renditions of its characteristic pattern, producing a cyclic pattern of extension and contraction as seen in the rhythmic movements of walking or swimming.

For example if the fundamental frequency of the natural oscillation of the blob as a whole, is split into two signals of equal strength, then varying the frequency of one relative to the other results in a first harmonic oscillation or pulsation of the whole pattern between positive and negative phase, and like "beats" heard between musical tones; the closer the frequencies, the slower the pulsing. In our blob organism this would correspond to a periodic contraction and expansion of the body as a whole, as seen in the pulsing contractions of many primitive organisms, such as jellyfish. By locking the phase between the two signals, the posture can be frozen at any point in the cycle, back to a static posture, which can be held in either the extended or contracted phase, or at any point in between.

Two tones of similar frequency in the first harmonic frequency band, approximately twice the frequency of the fundamental, would result in a cyclic alternation between the positive and negative phase renditions of the bipolar first harmonic standing wave, contracting alternately left then right, between the two phase patterns of Fig. 9.10B. In other words, the static pattern of bipolar extension/contraction, which is governed by a standing wave resonance, becomes a dynamic cyclic pattern that rotates slowly through the phase of the first harmonic pattern resulting in periodic contraction and extension of the body in one direction, but at a rate that is very much slower than the oscillation itself that defines the standing wave, and the rate of that slower oscillation can be varied all the way to zero oscillation, that is, back to a static pattern, at will. And so also for the higher harmonics, each one capable of representing either a static posture, or a cyclic alternation between two complementary posture patterns. More complex motor patterns are then achieved by combinations of patterns of different frequencies.

Now obviously sensory and motor functions are far more complex in reality than this simple model suggests, and even simple creatures like caterpillars and centipedes possess a central nervous system that channels the patterns of neural information in a far more restrictive fashion within the nervous system than suggested above. But the principle behind the sensory recognition, and motor

generation of spatial patterns, must have evolved from the simpler kind of nervous system, like that of the hydra, and even the single-celled paramecium. Although the electrical oscillations in an insect's nervous system are confined to linear neural pathways between ganglia arrayed along its spinal chord, there must still be spatial patterns of standing waves in each of those ganglia to determine the pattern of contraction of the pair of legs controlled by that ganglion, and all of those individual pattern generators in the ganglia along the spinal chord are clearly coupled to each other through the spinal chord. If all of the standing wave patterns in the different ganglia of a centipede were in perfect synchrony, the many legs would march in lock-step synchrony like a platoon marching in a parade. If, on the other hand, a small phase lag is introduced between segments, this would produce the periodic/cyclic motion of the feet seen so clearly in the walking centipede. Similar patterns of symmetrical and periodic motions are seen in insects and animals with every possible configuration of legs, fins, tentacles, and wings.

Hallucinogen-Inspired Art

We can get an idea of how the standing waves might look like in the nervous system, if they could be made visible, in the hallucinogen-inspired art of Alex Grey¹. Fig. 9.11 shows three paintings by Alex Grey that reveal a kind of grid, or framework, around which perceived structures are constructed, involving symmetry and periodicity in both simple and compound hierarchical forms. These strange geometrical grids and latticework patterns are observed to be interwoven in the fabric of experienced reality. The pictures of our experience are built up out of patterns of standing waves, and the artifacts due to those resonances become manifest under psychedelic intoxication. This is not the only possible explanation for these phenomena. There is an alternative view that the geometrical patterns observed under psychedelic intoxication are a magical mystical view of a normally hidden or invisible framework of reality, the beautifully regular and organized patterns of God's creation. Alex Grey is a mystic, and that is his understanding of what he is depicting in his paintings. But the representationalist view highlights the fact that the patterns of our experience are not out in the world itself, but in fact all of our experience is necessarily confined to the interior of our own brain. I propose that the geometrical regularity and symmetry observed in the psychedelic experience is a property of our order-loving brains, rather than of the external world that it depicts. The real world beyond experience is most likely far more ugly and irregular than the beautiful world of our inner experience. Under LSD, as in Alex Grey's paintings, the internal feedback is cranked up to produce the kind of exaggerated regularity observed in visual art and ornament. Isn't it curious that our churches, temples, and other places of worship are often decorated with the most stupendously elaborate ornamental designs, as if to lull the believer into a more relaxed, inward-focused, meditative state of mind—to live for a while in an earthly paradise of divine order and regularity.

1. A large collection of Alex Grey's beautiful and inspirational work can be found on-line at <http://www.alexgrey.com/>

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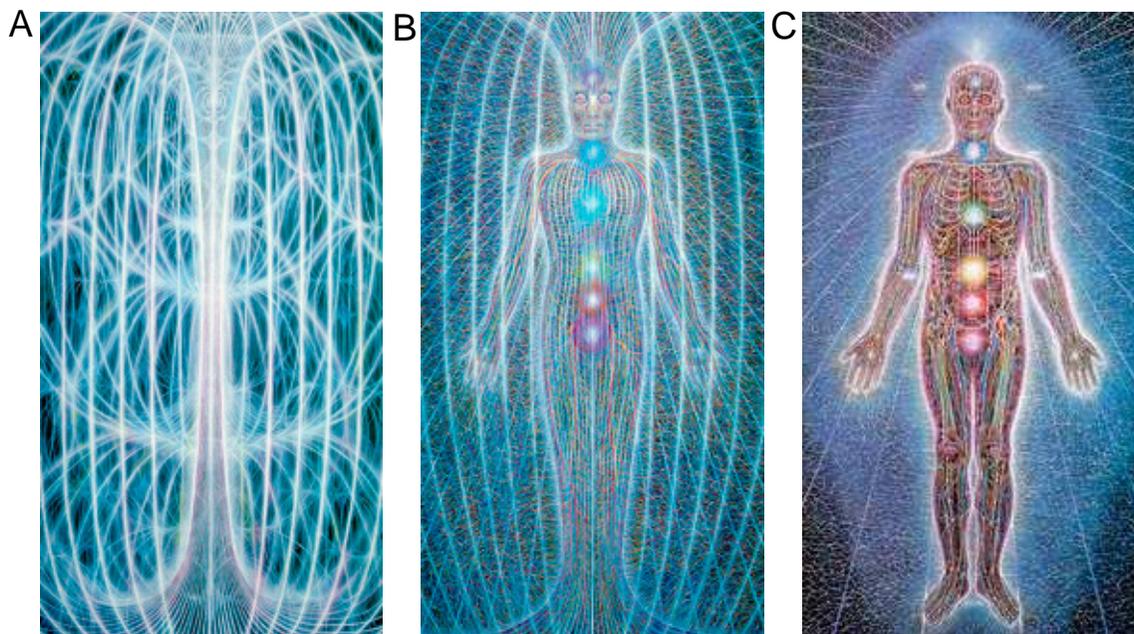


Fig. 9.11 Paintings by Alex Grey. A: *Universal Mind Lattice*. B: *Spiritual Energy System*. C: *Psychic Energy System*. These paintings reveal the underlying periodic and symmetrical framework observed in the psychedelic experience, which reflects the harmonic resonance standing wave principle behind the perceptual representation.

Standing waves are the spatial template, the mechanism that actually translates a multitude of sensory signals into a single coherent spatial pattern, and that translates a general motor command to a very specific pattern of extension and contraction across the body. And it is the elasticity, adaptability, flexibility, and invariance of the principle of standing waves, that account for the elasticity, adaptability, flexibility, and invariance seen in so much of sensory and motor function. And the regularity, symmetry, and periodicity, seen in cognitive concepts such as the Euclidean solids, and the Platonic solids series, and in the concepts of point, line, and plane, are patterns of symmetry and geometric perfection inherited directly from the physical properties of harmonic resonance. Standing waves are the patterns or templates by which we think our spatial thoughts. Perhaps that is why, when we listen carefully in complete silence, we hear a high-frequency hum, whine, or “buzz”, as the experience is described when under the influence of alcohol or drugs. And perhaps harmonic resonance in the brain is why we spontaneously tap our toes and jangle our bones when we hear a rhythmic melody going off in our head. Music and dance are the extravagant exuberance of a nervous system just overflowing with a propensity to oscillate in dynamic symmetrical and periodic patterns in hierarchical orders of complexity.

Chapter 10

Representation and Reality

Logic and Truth

Whenever we seek absolute certainty or truth, there is a strong tendency to turn to logic, with its comfortable Boolean distinctions between TRUE and FALSE, RIGHT and WRONG, BLACK and WHITE. Although we recognize that there are always gray areas in between these absolutist extremes, our final analysis on important issues always tends towards the more binary view of reality, as if this binary black and white world were a more reliable aspect of external reality. Is this tendency towards the Boolean justified? Is our stark dichotomized view of reality closer to the real truth? Or is it merely a mental mechanism to break us out of a deadlock between undecidable alternatives, to avoid getting stuck in dithering indecision exactly half way between? In all of human cognitive thought, there is this dichotomy between the continuous and the discrete. In fact, these are both indispensable and complementary aspects of the way our brain represents reality. There is a tendency in academic, legal, and logical circles to lean heavily towards the Boolean logical aspect of our view of reality to the exclusion of the analogical aspect of our understanding. This trend came to its purist peak with the *logical positivist* movement of the 1930's (Carnap 1959) whose message was to reduce all scientific discussion to rigorous logic applied to strictly verifiable facts. This would automatically invalidate all efforts to communicate our private mental states (Ryle 1949). For example it is supposedly invalid to report that your experience of the world appears in the form of a spatial structure, because that statement is impossible to verify objectively. While this inclination towards hard logic and irrefutable evidence is indispensable for the purposes of abstract reasoning, decision making, and for categorization, it can give us a distorted view of reality if we consider the Boolean aspects of the world to be the raw naked Truth itself, and all the truth there is. In fact, the Boolean aspect of reality is a symbolic conclusion that our brain has arrived at by some process. The Boolean aspect of the perceived world is a property of our mind, more than an aspect of reality, because reality itself is closer in nature to the analogical representation. There are some aspects of truth which can only be perceived and communicated by way of a holistic analogical method of reasoning, that violates the strict demands of logical positivism. For instance, the fact that the world appears as a spatial structure seems absolutely TRUE to me, and could only be FALSE in others if their visual apparatus were to operate on significantly different principles than mine, which is verifiably FALSE.

The core principle behind this dichotomized representation of external reality originates in the distinction between sensory and motor function, input and output, a dichotomy that exists in the most primitive volitionally mobile organisms. Consider for example the experience of a simple organism like the earthworm. The sensory experience of an earthworm is most likely to be a parallel analog structured experience, an experience of the texture of surrounding earth around its quasi-cylindrical body. It feels waves of textured sensation sliding down its

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body from head towards tail, as a dynamic analog spatial continuum studded with discrete moving textured features. The propulsive motor control of the earthworm also takes the form of spatially continuous waves of extension and contraction travelling down the worm's body. But when it comes to deciding which way the worm should go next, whether to turn this way or that, this process has a distinctly discrete or Boolean aspect to it, because the worm can only go one way at a time. If the worm encounters a small obstacle directly in its path, it faces a discrete choice, and there must be some process, somewhat like the cam mechanism on the steamship telegraph, that chooses one direction over the alternatives, even in cases where the alternatives appear equally appealing. This, I propose, is the origin of the Boolean decision making logic that has developed to such a high level of sophistication in the human brain, and to even higher level of perfection in the digital computer. While sensation is essentially parallel in nature, to reflect the parallel presence of an analog external world, motor control is discrete in the sense that there is only one body, and that body must choose to move in one way at a time. In the purest cases this choice reduces to a Boolean one, with just two alternatives of opposite polarity. The binary, polarized aspect of Boolean logic is inherited directly from the binary, polarized nature of standing waves, with their symmetrically opposed positive and negative phase regions.

Boolean logic is not restricted to the central decision making function, but actually pervades the entire sensorymotor hierarchy in the function of perceptual categorization. There is a Boolean logic to the recognition of a perceived shape, for example whether an irregular rock appears closer in shape to a sphere or a cube or a tetrahedron. In ambiguous cases the identity of the rock tends to shift unstably between discrete states. This discrete switching is seen most clearly in ambiguous stimuli like the Rorschach ink blot figures shown in Fig. 10.1A and B, as different parts of the stimulus pop in and out of distinct recognition states. A discrete switching is also observed when seeing patterns in clouds, as in Fig. 10.1C, as different parts of the cloud are abruptly recognized as looking like this or that familiar figure. And there is also a discrete aspect to the highest level, most sophisticated recognition of a scene as a whole as one that is safe and reassuring, or threatening and dangerous, a percept that can also change abruptly to its polar opposite at a moment's notice. At every level of the perceptual hierarchy there are discrete recognition processes taking place, like relays that snap into place in response to key features, although those discrete choices are often made in parallel, or "asynchronously," across the visual field, and they are made "unconsciously" in the sense that all we experience is the end result of the process, as the recognized items appear in experience ready-made, fully reified as volumetric structures, at the locations they are perceived to occupy in perceived space.

The analogical and discrete aspects of experience can be separated somewhat by the practice of meditation, during which one tends to ignore the results of recognition or categorization processes, seeing only the shapes and colors of the world, with little regard to their identity and significance. The separation is necessarily incomplete, since a process of low level recognition or categorization is required to even see objects of a particular shape and color at any location. But during meditation the outcome of the recognition process is basically ignored, allowing the mind to freely interpret and re-interpret the world as an unstable and

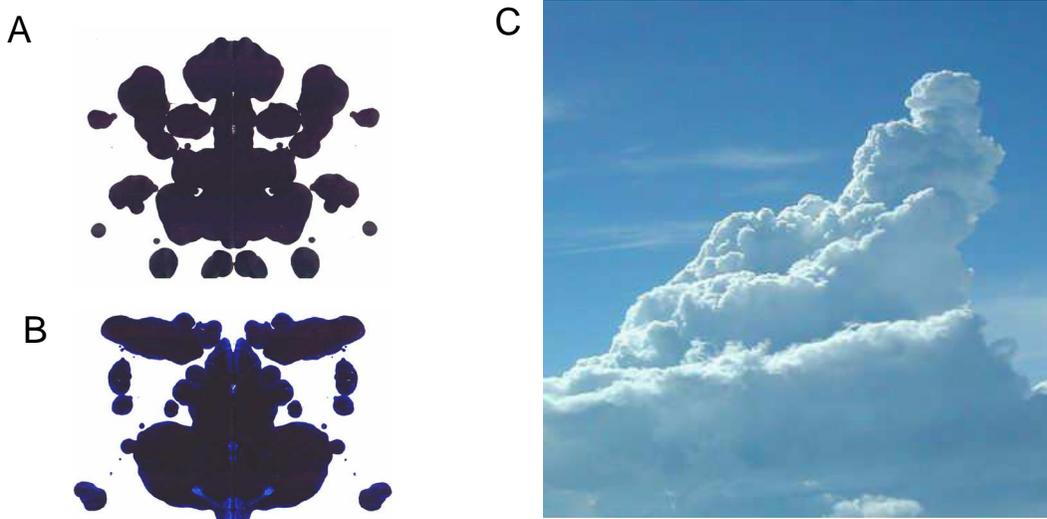


Fig. 10.1 A and B: Rorschach style ink-blot patterns that pop back and forth between discrete recognition states. C: The patterns seen in clouds also pop into distinct recognition states as they are perceived as similar to this or that familiar object.

shifting experience, whose individual pieces do not necessarily cohere in a single self-consistent world view, as they do during normal consciousness. The result is an experience in which regions of the visual field often morph and shift unstably from one interpretation to another, exactly as observed in the LSD experience. This shifting instability between alternative interpretations is captured perfectly in surrealistic paintings like Salvador Dali's *Three Ages of Man*, shown in Fig. 10.2. Note how whole sections of the visual field invert in depth, changing from a volumetric void to a solid volume, or the reverse, and the global ambiguity in the whole picture prevents the percept from settling on any single global interpretation.

Although the reversals are discrete, in the sense that the same surfaces invert back and forth between two or more discrete volumetric interpretations, each reversal is a reversal of a spatially extended volumetric structure, the analogical component of the experience. It is rare that perception remains in this multi-stable state. Under normal states of consciousness the percept generally pops into a single unambiguous interpretation, fostering the illusion that that interpretation is reality itself. The discrete symbolic process of recognition therefore is not a pure Boolean abstraction, but rests intimately on some lower-level analogical process whose operational principles, and indeed whose very existence, are not sufficiently recognized in the literature. Consider for example the central "head" in Fig. 10.2, that vacillates between the percept of a convex solid head, and a concave hollow void. What is the process by which the percept adopts either one of the two interpretations in the first place? How do we choose one (or more) interpretation(s) from amongst an infinite range of alternatives? And how do we reify that chosen interpretation as a vivid spatial structure? We don't really know, all we see is the end result of that process, and its stark Boolean tendency to flip abruptly from one state to another. I propose that the principle behind the emergence of perceived forms in perception is analogous to the more abstracted

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emergence of concepts when contemplating a cognitive situation, for that also occurs by a parallel analog process of weighing a great volume of ambiguous evidence simultaneously in parallel. This is the principle behind the phenomenon of *judgment*, an intelligent analogical constructive or generative process of spatial reasoning, which is the one aspect of human logic which has evaded capture in the formalism of Boolean logic.



Fig. 10.2 Salvador Dalí's *Three Ages of Man*. The profound spatial ambiguity inherent in this picture causes it to pop back and forth alternately between discrete states in which every part of the percept converts to a completely different volumetric spatial configuration.

Logic and Law

A somewhat extreme form of Boolean logic can be seen in the practice of formal logic and in law, whose method is to begin by characterizing reality in terms of discrete truths and falsehoods. We can see this human cognitive tendency in exaggerated form in the artificial world of games and sport. The game board is marked with clear grid or checkerboard patterns, and is populated by discrete token or figures, which are moved around in very discrete, stereotyped ways, so as to limit the range of possible actions to a more finite set. The sports field is marked out in bold bright lines between “in” and “out” regions, and the game is defined with strict rules and discrete objectives such as sinking a ball in a goal, whose successful achievement is easily confirmed to have either happened or not, with (ideally) absolute certainty. And so too with the legal system, where we bring discrete items into evidence, and respect rigidly discrete boundaries or thresholds, such as whether someone is over or under 18 years of age, or driving at speed either over or under 65 miles per hour, or with a licence that is either

valid or expired, etc. The logic of a legal argument is similar to the logic of the digital computer. Beginning with the given initial facts, the algorithm follows a discrete sequence of steps whereby the initial state of facts is transformed into a final state of facts by way of a strictly defined stereotyped system of logic, like the logic that determines whether a move in a game is legal or not. This is the aspect of logic that is captured by the Turing machine.

The digital computer embodies the ideal of logical perfection as a physical manifestation of the pure rules of discrete mathematics and logic. If the computer is given correct and certain information as input, you can count on it to reliably produce a correct and certain output. The same is true in the case of law. In clear cases devoid of ambiguity, the Boolean logic of law works very well. A licence expired means GUILTY. A speed greater than 65 m.p.h. means GUILTY. This kind of logic has the additional advantage that there is no limit to the depth of levels to which it can be extended. This is exactly why this paradigm of thought is so useful in establishing an unambiguous framework for knowledge. But there is something that is lost in the trade-off in return for this wonderful certainty. The system breaks down in principle when the initial facts are themselves not knowable with discrete certainty; when the input is neither TRUE nor FALSE, but something in between. At that point the Boolean logic simply collapses, because it is not defined to compute values of HALF-TRUE or 0.75-GUILTY. And yet it is always possible to come up with intermediate cases. A driver's licence may seem at face value to be expired, but the driver may have submitted a renewal application with a check for the renewal fee, and that application had gotten lost on the way to the Department of Motor Vehicles, so in this case an apparently invalid licence turns out to perhaps be valid with some uncertainty. The reliability and accuracy of a vehicle's speed as measured by a radar device is limited by the reliability and accuracy of the device, as well as the skill and fairness of its operator. A car clocked at 66 m.p.h. might actually have been travelling at 64 or 68 m.p.h., or perhaps the cop is lying, and the car was actually travelling at 30 m.p.h. It is both understandable and desirable that the legal system attempts to establish these initial facts with as close to certainty as it possibly can, before applying its strict Boolean logic to the facts. But when the facts themselves have a certainty which is intermediate between certainly TRUE and certainly FALSE, then that requires application of human *judgment* on the part of the judge or of the jury, and that aspect of the decision making process has never been codified in the stark unambiguous terms of the Boolean logic that applies in clear-cut cases. And yet this judgment aspect of thought is the most interesting and most intelligent aspect of human cognition, and thus it is the most important for us to understand and ultimately replicate.

The Fuzzy Logic Solution

The most straightforward solution to the grey areas in logic and law is to allow the variables to take on intermediate values, as proposed in fuzzy logic (Zadeh, 1965, Hajek 1998). In the case of the dubious driver's licence, we might assign the LICENCE_EXPIRED variable a truth value of 0.5, or 0.75, instead of 1 or strictly TRUE. Fuzzy logic versions of the logical operators of AND and OR are defined to operate on these fuzzy values. For example the fuzzy AND function in the term (A AND B) is computed as $\text{MIN}(A, B)$, whereas fuzzy OR in (A OR B) is computed as the $\text{MAX}(A, B)$. If A and B have Boolean values of exactly 0 or 1, then these fuzzy

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operators produce the same results as their Boolean logic counterparts, otherwise they produce intermediate analog values, that can be thought of as probabilities on the truth value of their variables. Although fuzzy logic can be useful for devising analog control systems, it does not resolve the uncertainties in the analog truth values, but merely passes them on through the logic system, to produce analog or intermediate valued logic results, such as HALF-GUILTY or 0.75-GUILTY. Of course a hard threshold can be set at any point along the logical chain, for example at a value of 0.5, so that values that come in over or under the threshold get set to 1 and 0 respectively. But the threshold can actually be set anywhere, for example at 0.25 or 0.75, and there is no rigorously principled way to determine where the threshold should be set in the general case. It is exactly because of these uncertainties that Boolean logic avoids these intermediate states, and is only defined for values of exactly 0 or 1, for which a rigorously principled system of logic *can* be defined.

It is a strange quirk of Boolean logic that it simply remains “undefined” when given values intermediate between zero and one, because in any real physical implementation of a Boolean computer, it is impossible to guarantee that values of variables always remain within those limits except by providing a mechanism like the cam plate of the steamship telegraph that snaps into the next nearest Boolean state. But any Boolean computer, for example the standard digital computer, can be operated in the range for which it was not defined, by providing an input value that is intermediate between zero and five volts (for those computers that assign the value FALSE to zero volts and TRUE to five volts) and the computer is sure to produce *some* kind of result, although the manufacturer cannot guarantee the correctness or consistency of that result. So although Boolean logic in the abstract can be simply “undefined” in the face of intermediate values, in a real physical implementation those intermediate values cannot be ruled out so easily.

But the real problem with fuzzy logic is that it does nothing to resolve or reduce the ambiguity or uncertainty in the initial measurement, but merely passes it along, where its uncertainty mixes with other uncertainties to produce a rather uncertain conclusion. The genius of human perception is in the way it handles ambiguity in an intelligent manner. The secret of human perceptual logic is to go back beyond the given facts, whatever their inherent certainty might be, and hypothesize instead on the probability of events and circumstances beyond those sensory inputs, by constructing a detailed spatial model of the world outside.

Judgment

The secret principle of perception is to model external reality itself, beyond the sensory surface, and that model is expressed as a volumetric spatial structure. The spatial extendedness of the operations of spatial logic are apparent in visual illusions, where spatially extended illusory surfaces are observed. When the visual system hypothesizes the presence of a triangle, and hypothesizes that it is right there exposed to full view, it expresses that hypothesis as a spatial image of the hypothetical triangle, for all the world as if it were a real triangle right there in front of us. It is this capacity for spatial reification of abstract concepts that characterizes the most essential aspect of human intelligence and understanding. The reification function is clearly manifest in amodal perception, especially of

simple geometrical shapes. But the same kind of reification also applies to the more abstract kind of judgment involved, for example, in a court of law, although it is a reification at a higher, more abstracted level.

At the lowest perceptual level we perceive volumetric geometrical wholes with modal exposed faces. At the next higher cognitive level, we perceive objects as made out of substance, with volume, mass, and elasticity or brittleness, each with a characteristic feel when we hold it, and sound when we knock it. At the next higher level of cognitive understanding, objects take on meanings and purposes: books for reading, chairs for sitting, houses for shelter, etc. At the highest cognitive level, our volumetric amodal model of the world includes an understanding of the story of our lives, our memories and aspirations, our framework of reality, and of course it includes an understanding of other minds. We understand passions and relationships, desires and animosities, each concept marked with a powerful emotional sensation and vibrant sensuality as irrationally unique and arbitrary as the modal colors of visual experience. When we see violence between two people, we “paint” both people in our mind with anger and pain, as brilliant and jarring as a fire engine with sirens wailing. When we see one as beating the other, the “color” of his mood changes to angry triumph, while that of his victim changes to fear and submission, in our perception. And when we ourselves get involved in a fight, we see the same colors of anger and fear “painted” throughout our egocentric volume, or body-image, and this vibrant sensation of quivering rage injects extra energy into all of our actions. We use the same kinds of feelings to understand the behavior of others as we observe arising spontaneously in ourselves as a causal factor in our own behavior. And it is because of this common symbology of representation that we feel empathy and understanding for the experiences of others. We cannot help but to “feel their pain” as soon as we perceive it.

The judgment exercised by a judge or a jury, or by a pilot thinking his way out of a perilous situation, or a lover deciding whether to marry or not, is nothing like a Boolean process, but rather it involves the mental construction of a complete artificial world, painted with all the motives and motivations, physical laws and causal relations, by which we understand the otherwise unfathomable motions of the world. The soundness of a man’s judgment depends on the completeness and fidelity of his mental model, to the external world of which it is a replica. Consider, for example, a murder case that might be a case of justifiable homicide, and thus requires fine judgment as to whether the perpetrator is guilty of murder or justifiable homicide. For example, the victim might be a burglar shot by the owner of the house he was burgling, or a rapist shot by the husband or father of his victim. One can imagine a range or spectrum of cases, from those in which the homicide was unquestionably justified, to those in which it was clearly a case of murder. But what is the process of judgment that is used to come down one way or another in any one case? This is exactly the kind of situation where Boolean logic fails completely, or produces results that are so capricious and unpredictable as to be worse than just rolling dice. The analogical thought process, on the other hand, offers an explanation for this aspect of judgment, even if that explanation involves computational principles and processes which are currently beyond our capacity to replicate technologically.

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The process of judgment in the homicide case involves the question “what would a reasonable person do in that circumstance?”, and that question is applied both to the imagined experience of the killer and to his victim. And since most people consider their self to be a reasonable person, this process reduces to imagining yourself in the situation of the killer, and his victim, each in turn, something that all of us do instinctively, even if we are not jurors on the case. When you hear the facts of the case, the evidence of forcible entry, the body in the hallway, the gun on the table, and the spent shell on the carpet, you flesh out these facts with a vivid mental image of the burglar, like a transparent ghost, breaking in the door, confronting the home owner, and getting shot on the spot, as an amodal action framework that holds together the peripheral facts on which it is based. It is the invariant structure that makes the simplest sense of the given evidence. For that most vital judgment of motive, we focus on the “feelings” of the killer at the moment of confrontation. If he is driven by anger or rage or blood lust, that would define a certain character of behavior—we could imagine him in great detail in angry agitation, whereas if his principal feeling was mortal fear for his own safety, then we would imagine a different suite of possible actions consistent with that particular feeling. Like the author of a detective story, we can manipulate the hypothetical events any way we like in our mind, building up various scenarios to test them for plausibility. It is at this point that the evidence can sway the case this way or that. Any evidence consistent with angry behavior suggests the angry state of mind, and likewise with the fearful state of mind. It is in this manner that a tiny scrap of evidence—the direction the bullet entered the body, the position of the killer and his victim the moment of the shooting, these might be enough to tip the scales of judgment from justifiable homicide to first degree murder. Although the decision appears to hinge on this or that scrap of critical evidence, what it *really* hinges on is not those scraps of evidence, or the Boolean conclusions that they suggest, but on the larger picture suggested by all of the evidence taken together, or the self-consistency of competing alternative interpretations, and how many unlikely assumptions each one contains.

Unlike its Boolean alter-ego, the analogical judgment function does not produce reliably stable results. As we all know, people differ in the matter of judgment, whether political, religious, or concerning one's personal life. We all know that there are no absolute answers to questions like “Should I marry her?” or “What do I do next?” Even after we discover the computational principles behind human judgment, and have learned to replicate them in an artificial intelligence, there are many parameters or free variables that brains can have, while still being fully intelligent and perfectly functional minds, as we see in the great variety of personalities in our acquaintance. And these different personalities come to different conclusions on matters of judgment, demonstrating that unlike Boolean logic, the process of human judgment does not produce strictly deterministic results, but depends on the delicate balance of innumerable parameters for which correct values cannot be objectively determined. It is presumably no accident that human nature has settled on the strategy of diversity in human personalities in every population, so that every population has some who are bold, and some who are timid, some conservative, some risk-takers, some industrious, some philanderers, some spendthrift, some thrifty. There is no single best template for this range of personalities, because different personalities succeed differently in

different times and circumstances. The bold and aggressive triumph in times of victory, and suffer in times of defeat. The timid stay safe in times of danger, but miss opportunities in times of prosperity. The amorous spread their seed in times of free love, but are persecuted in times of puritanical zeal. Rapists and murderers make out well in times of complete chaos, but are incarcerated or executed in times of stability. Furthermore, people do not act individually, but different personality types interact with each other in synergistic ways to form larger interacting units, such as families, tribes, and corporations, in which individuals take on specialized roles that suit specialized personality types. What is extraordinary is the great variety of different personality types that emerge from the combinatorial configuration of a relatively small number of personality parameters re-arranged almost randomly every new generation. Unlike the perfection of Boolean logic, there is no single right answer to any question of judgment, even the supreme court has differences of judgment between its learned members on questions of law, because of profound differences in their world views.

Judgmental Bias

Boolean logic therefore incorporates an implicit hypothetical: IF we agree on the initial truth states of certain initial variables, THEN the conclusion follows logically. OTHERWISE all bets are off, and we wind up arguing endlessly over the initial facts. But the interpretation of those initial facts itself often depends heavily on the final conclusion. We see the primal facts differently based on how we see the final conclusion, just as much as we reach the final conclusions from the initial facts, as in the more normal bottom-up course of Boolean logic. This “catch-22” in the interpretation of the evidence is what often leads to highly polarized opinions on controversial topics. For example a gun control advocate, who is incensed at the thought of needless killing, would be naturally inclined to suppose that our hypothetical scenario is a case of murder by an over-zealous gun nut delighted for an excuse to fire his piece, whereas a gun-rights activist, who is incensed at the thought of burglars invading people’s homes, would be naturally inclined to suppose that this is a case of righteous self-defense. Both the pro- and the anti-gun activist sees this little cameo as a possible exemplar of their favorite stereotyped event—the berserk gun nut, or the innocent victim in self-defense, respectively. This kind of bias, a tendency to see the facts as we wish them to be, is an inevitable part of the process of judgment that simply cannot be eliminated, because the “problem” of pre-conceived views of possible stereotyped events, and strong emotional responses to certain types of events, is the very mechanism by which judgment is exercised. We perceive the evil of guns as the horror we experience when we contemplate the rabid gun-nut scenario, of the man who kills needlessly only because a gun is available. And we perceive the evil of excessive gun control in the horror we experience when we contemplate the self-defense scenario, and how desperately grateful we would be to have a gun available if we were surprised by a violent intruder. These emotionally charged mental images are the mechanism we use to exercise judgment. The problem of judgmental bias only emerges if we place undue emphasis on one mental image over the other, as

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is likely to be done by either an over-zealous gun control advocate, or a rabid gun nut. But forming the mental image complete with its emotional overtones is the very essence of the function of judgment.

Blind Justice

The statue of “Lady Justice” is often depicted with a blindfold over her eyes, as in Fig. 10.3. What is the meaning of this symbology? It means that justice will be meted out equally, without regard to irrelevant circumstances such as whether the defendant is rich or poor, black or white, articulate or plain spoken, knowledgeable or ignorant. The blindfold over Lady Justice’s eyes is a reflection of the logical positivist imperative to filter all the facts of the case to a set of reduced truth values that supposedly express only the significant or relevant facts. While this may be a laudable goal in cases where pure facts can be established with certainty, the metaphorical blindfold over Lady Justice’s eyes actually represents an erroneous conception of the role of logic and reason in the process of judgment. Unlike Boolean logic, judgment is a process that requires eyes wide open to *all* of the available facts, whether or not they seem relevant to the case initially. The apparently extraneous facts can often be decisive in cases where initial truth values cannot be reliably assigned in advance. Judgment is a Gestalt process that operates by summing together innumerable tiny fragments of evidence in parallel, and testing them against competing reified models of events fleshed out in as much detail as the available evidence will allow. While it would be a miscarriage of justice if a defendant were convicted solely on the basis of the fact that he was covered in lurid tattoos, or that he had prior convictions for domestic abuse, or that he was a deadbeat dad, or that he was chronically unemployed, or that he was unshaven, with shifty eyes, or that he was surly and disrespectful in court, or that he was addicted to heroine or crack cocaine, nevertheless, if it happened that *all* of the above happened to be true of a defendant, then at some point the preponderance of all this irrelevant evidence will tend to sway our judgment, not because people are inherently unfair, but quite to the contrary, because at some point it is fair to make a judgment on a man’s character which will influence the perception of their probable guilt, *if* the more substantial facts of the case are also consistent with that guilt. If a juror must be denied access to these apparently irrelevant facts because they would *unduly* sway his judgment on the case, then this juror’s judgment is already so impaired as to disqualify him from serving on the jury at all, because it is exactly for his best judgment that he is serving on the case in the first place.

The profound problems inherent in the reductionist blindfolded paradigm of judicial reasoning can be seen in a recent prominent murder case, the O.J. Simpson trial. Everybody knows that O.J. did it. Only a madman could conclude otherwise. And yet a lengthy legal process involving hundreds of investigators, litigants, lawyers, jurists, jurors, and police, spending millions of dollars over the course of many months, failed to conclude what anyone of ordinary intelligence now knows beyond a shadow of doubt, that O.J. is guilty of murder in the first degree. How could this baroque system of “justice” fail to establish what is so plainly manifest for all to see? And why is O.J.’s guilt so certain to the reasonable man? The reason why the justice system failed to find justice for O.J.’s victims was exactly because Lady Justice had her blindfold on, and refused to see the most prominent



Fig. 10.3 Lady Justice with her blindfold on. The metaphorical blindfold actually reflects an erroneous view of the essential role of judgment in judicial logic.

facts of the case. Like a good system of Boolean logic, the case proceeded on the detail issues, such as whether this or that item was taken into evidence properly, or whether this glove did or did not fit O.J.'s hand, and even whether Mark Fuhrman, a police investigator on the case, was or was not a "racist." All of these were facts of the case, and thus the proper objects of consideration. But what was missing entirely from the discussion of the case was the Big Picture, the consideration of all of the evidence simultaneously, and the implications of that evidence for the two competing reified scenarios, one in which O.J. murdered his two victims, and the other in which somebody *else* perpetrated the crime. The ordinary commonsense man knew long before the final verdict that O.J. was most likely guilty based on the fact of his very guilty behavior right after the time of the murder, including the long, low speed car chase aired live on nationwide television, during which O. J. threatened to take his own life. What other explanation could there reasonably be? The very event that brought public attention to the case, also clinched the case in the eyes of any reasonable man, at least in the absence of *compelling* evidence to the contrary to offer an alternative explanation for this obviously guilty behavior. Add to that the fact O. J. was known to have a violent temper, and had a history of domestic abuse, that he was fabulously wealthy and could afford the very best lawyers that money could buy who would be sure to pull out all the stops in his defense, these facts also sway the reasonable man, even if they are inadmissible for consideration in court. Because these are also relevant facts, although they are relevant only to the process of judgment. In the realm of pure Boolean abstraction these "facts" have no hard truth-values that can be objectively established, so they remain inadmissible. Even if these "facts" could be established to be TRUE, they are of such a high order of abstraction that they simply cannot be processed

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meaningfully within the Boolean paradigm. And yet it is exactly these high level abstracted “facts” or factors that fuel the process of judgment, because they help sketch out a larger framework of an explanation for events, a framework that serves the purpose of understanding. Perhaps we are biased if we perceive O. J. Simpson to be violent, or a wife abuser, and perhaps we are biased if we perceive him as a good father, or a great sports hero. But the solution to judgmental bias is not to eliminate these emotionally-charged mental images from our mind altogether, and replace them with dispassionate Boolean truth values, that is a solution that throws the baby out with the bathwater, and results in a representation with no understanding, like a digital computer. The images of the wealthy sports hero, the wife beater, the innocent victim, the father, the husband, the murderer, these are all aspects or components of our complete picture of the man, and they appear in our mental image simultaneously, each with different, often vascillating magnitudes. An unbiased view of reality is not one in which such facts have no impact whatsoever, but rather, one in which the various components of our mental image are finely balanced, so that in the absence of specific evidence, we would not be predisposed to favor the view of O. J. as a father or a sports hero, over the view of him as a wife beater and murderer. Ideally our final judgment should be finely balanced in a neutral stance before it is swayed by the preponderance of the evidence. But it is counterproductive to try to eliminate all preconceived notions and apparently irrelevant evidence in a misguided attempt to eliminate bias, because those notions are the very mechanism by which we understand reality.

I should mention at this point that I do not fault the justice system for its conservative tendency to rather risk releasing a guilty man than convicting an innocent one. That safeguard is an essential part of our justice system, part of the price we have to pay for our freedom from arbitrary justice. I choose the legal system only as one example of the common logical positivist tendency to express reality as a network of Boolean rules, and how that system of rules breaks down if it is applied in the absence of judgment. For judgment is required even to set the limits of our network of Boolean logic, the point where the Boolean truth values should give way to judgment. For if Boolean logic is extended beyond where it reasonably applies, it leads to the kind of bureaucratic bungling absurdity seen all too commonly throughout our justice system. In the interests of legal rigor, the justice system has bent over backwards into an absurd posture where it often allows complete nonsense to pass for reason. And the reason for this absurd posture is that the logical positivist component of legal logic has been allowed to dominate over judgment, in a misguided attempt to replace judgment by strict logic. For example it is common practice for defendants to raise a number of alternative and mutually contradictory defenses, without having to commit to any one of them definitively. To take a case from my own experience, I once called the police to report a young fellow breaking into cars. When months later I appeared as a witness in court, the defendant’s attorney claimed that 1: the defendant had been nowhere near the scene of the crime; 2: he was at the crime scene at time of the crime, but had observed somebody *else* committing the crime; and 3: yes the defendant was at the crime scene, and he himself broke into the car, but the prosecution did not have the owner of the car there in court to disclaim that he had given the defendant *permission* to break into his car! The defendant ran *all three*

of these defenses simultaneously, even though each one contradicts all the others. And on this faulty reasoning the defendant was released, because the prosecution could not prove beyond a shadow of doubt that all three possible stories were 100% certain to be FALSE. This is the most absurd violation of common sense, everyone knows that it is a sure sign of guilt when you can't even get your story straight, and start telling inconsistent and contradictory stories. The third defense is so absurd as to be *laughable* anywhere else but in the bizarro-world of the so-called "justice" system!

A similar absurdity was seen in the O.J. Simpson case, with the accusation that Mark Fuhrman was a "racist." The significance of this possible fact was that it opened the slimmest *possibility* that Mark Fuhrman was so hateful of black people in general that he deliberately tampered with the evidence just to convict a black man for the crime, thus single-handedly letting the "real killer" run free. Although there is a slim possibility that Mark Fuhrman is a racist (truth value = 0.3?) and an even slimmer possibility that he would deliberately convict an innocent man in violation of his professional oath, at risk to his professional career, and for no personal gain whatsoever (truth value = 0.01?) this version of events is so vanishingly unlikely that it is amazing that such absurd claims can be made in a court of law with a straight face. In fact, the probability of this interpretation should be stacked against that other alternative interpretation, which is that O.J. and his dream team were *playing the race card!* The truth value of that one is right up there close to 0.9999, and everyone knew this to be the case, as it was discussed extensively in the media, and yet by the bizarre rules of the court of law this most obvious fact was inadmissible for consideration.

The founding fathers of the American republic had a good understanding of the role of judgment in jurisprudence, and they understood that the human mind is the only known vehicle for producing judgment, and that individual minds differ in the matter of judgment. That is why they established a jury of one's peers as the final arbiter of legal justice, not abstract rules interpreted by a learned judge. But in order to exercise judgment, the jury must be free to see. Remove the blindfold and let the jury have access to *all* of the available evidence, even if some of that evidence might "bias" the judgmentally-impaired. If you can't trust to the good judgment of your jurors, then you might as well trash the whole system, because the whole system is predicated on the assumption that juries can be trusted to exercise good judgment. And juries can be trusted, if they are just allowed to use their judgment in the widest sense. That was the original intent of the jury, to have ordinary commonsense people be the final arbiter of whether they see justice being served. To call out *Nonsense!* wherever nonsense rears its ugly head! Unfortunately the trend in our legal system over the centuries has been in the opposite direction, putting the blindfold on the jury and allowing them to see less and less of the facts for fear that they might bias their judgment. Judges often give juries strict instructions on what they may or may not consider when weighing the case, thus changing their role from that of exercising judgment over the overall justice of the case as a whole, to deciding individual issues and letting the Boolean logic of the law do the rest. The practice of "jury nullification" is today roundly decried as a miscarriage of justice, whereas the original intent of the founding fathers was that a jury has a duty to release a man, even if guilty, if they believe the law he violated to be unjust. And with the emergence of mandatory

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minimum sentencing, we are even restricting the judgment of the judge, and asking him to behave more like a stupid Boolean flip-flop than an intelligent human being.

The problems of the legal system are of course far more complex than this simplistic analysis might suggest. I am no legal scholar, and I do not propose to change the law based on this simplistic analysis. My purpose in raising these problems of the justice system is to point out the stark distinction between the function of logic, as expressed in the Boolean paradigm and in the logical structure of written law, and the kind of judgment required to process uncertain information, and to show how a legal system (as originally intended) can be devised to make use of both aspects of reason, using a well informed human mind, with eyes wide open to all available facts, both in the jury and in the judge, as the only known means of exercising the indispensable function of judgment. The stark rigor of Boolean logic is sometimes held up as the paragon of logical thinking, as if real justice and reason will prevail once we have eliminated the "human factor" and replaced our judges and juries by stupid Boolean flip-flops and logic gates. But this misguided search for rigor is based on a misunderstanding of the essential function of judgment, and how it relates to the process of logical reasoning and written codes of law.

The creeping advance of logical positivism over sound judgment is now seen in many different walks of life. It is seen in the ever growing requirements for formally accredited degrees and certifications for ever more jobs and professions, reducing the judgment of choosing a candidate for employment to a simple tally of his formal credentials. It is seen in academia in the ever growing array of rules governing mandatory pre-requisites, or who may take which class, and which classes are required for which degrees, transforming the educational system into an elaborate system of hoops to be jumped in just the right sequence, with the result that the people who emerge from the pinnacle of the academic establishment with the highest credentials are often the best hoop-jumpers, rather than those with the broadest vision or deepest understanding of their field. Boolean logic has invaded virtually every profession and trade in the form of an ever expanding set of rules and regulations that specify in ever greater detail things like building codes that set standards for materials and structures, mandatory medical procedures designed to prevent law suits rather than to benefit the patient, union rules that strictly limit who is authorized to do what work, independent of a person's ability or availability to do that work, and so on and so forth wherever we look. There is nothing wrong with rules and regulations as such, and many of those rules have contributed greatly to safety and efficiency. These are the necessary trappings of an ever more complex and information-driven society. Rules and regulations only become absurd when they are carried beyond the point of reason. You know there is a problem when you start to see obviously guilty people walking free, students taking unnecessary classes to fulfill their formal requirements, grossly incompetent employees with impressive formal qualifications, lofty academics with no vision for the larger issues of their chosen fields, medical practices governed by lawyers rather than by medical professionals, and unnecessary and burdensome rules and regulations that strictly specify every detail of our lives. All of these are evidence of bureaucratic

rules which have grown beyond the point of common sense, and have begun to work contrary to the very goals of their original intent. It is a brittle and inflexible system that adapts poorly to local special circumstances.

The general solution to all of these excesses of formal logic is to give the end-user as far as possible, the freedom and authority to exercise their best judgment whenever they find that the formal rules are in violation of common sense. Juries should be free to call *Nonsense!* wherever they see it. Doctors and nurses should be free to follow their own best medical judgment. Candidates for a job should be chosen on an overall assessment of their character and personality as a whole, by an ineffable Gestalt process of judgment, as well as by a tally of their formal qualifications. Builders and carpenters should be free to deviate from building codes in cases where they make no sense. In general, everyone should be free to exercise their best judgment in the interpretation of the rules, because the whole system of rules and regulations turns into an absurd monstrosity whenever it is extended beyond the point of common sense.

There are examples of systems of collective judgment that work reasonably well. For example, in stark contrast to the crippling logical formality in many courts of law, is the legal process followed for a congressional hearing. When a man is called up to testify before the Senate, the senators take turns asking direct questions on any subject under the sun, and generally the truth emerges more reliably than in a normal court of law with its rigid restrictions on who can ask what from whom. There is never a question of inadmissible evidence having to be concealed from the senators, on the assumption that the senators can be trusted to exercise good judgment in considering which evidence to include or exclude. I never understood the justification for the right of a defendant to plead the fifth ammendment, the right not to testify if that testimony would incriminate him. Is this plea not just a frank admission of guilt? Why may jurors not consider it such? Surely the direct testimony of the defendant would be the single most reliable pointer to guilt if the defendant were guilty. In a world governed by common sense reason, this testimony would be the most admissible and telling of all the evidence.

The alternative paradigm to the bureaucratic system of rules and regulations, is a hierarchy of managers and administrators, every one of whom is given wide latitude to exercise judgement within their local domain, but they are also held accountable for any gross violations that occur under their watch. It is much easier to identify violations after the fact, than to formulate rules to try to prevent all possible violations in advance. The combination of judgment and responsibility at every level of the hierarchy, with the head of every department being responsible for all that occurs under him, offers a more flexible paradigm of organizational control than a massive bureaucratic system of rules. This is the basic principle behind capitalism, to distribute production across as many parallel streams as the market will bear, allowing each the widest judgment in the way they run their business, but under the constant the threat of bankruptcy if they should fail in *any* vital function. This is the principle behind federalism, allowing states, counties, and municipalities, to have their own local rules as much as possible. Like the bureaucratic paradigm, the hierarchy of responsibility is a pure ideal that cannot exist in its pure form, but must find an optimal compromise in combination with the

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bureaucratic paradigm. Any system of collective judgment must be recorded in the form of written rules, It is just a matter of emphasis in the balance of judgment against strict rules, making sure that the most valuable human function of judgment is allowed to play its essential role in the system, and that it not be superceded by a stupid set of rigid rules.

Theories and Paradigms

My father is a very devout and fervent believer in God. I am an avowed atheist. When my father and I sit on a park bench, we see the same world around us in immediate experience. We see the same park with the same trees under the same sky. And we see similar structures and relations in our conceptual understanding of the world. We both understand how trees and grass grow, and how a city maintains parks, and why parks are considered a worthwhile investment, and we know what kind of people come to parks, what brings them here, and what they do when they come. We both have a clear understanding of the functional infrastructure of our world. But when we get to the outer framework that supposedly holds it all together, the reason for its being, at that point we see two very different worlds. I see a chaotic random universe driven by powerful explosions in space, in which human existence is just an accident of history, where my father sees an intelligent and purposeful God with whom he has an intimate personal relationship, and that God supposedly plans everything that happens in the minutest detail in the service of some larger purpose. Could two world views be any more divergent? This is the ultimate paradigmatic level, the foundational structure on which we hang the rest of our knowledge of the world. It is the structure that gives purpose and meaning to the whole rest of our constructed world. In this sense the outer framework is the most important part of our picture of reality, because an error at this global structural level is likely to warp our whole world view. And yet this level of reality is the most distantly removed from the raw sense-data of experience, the only thing we can know with absolute certainty. This abstract framework is based on more levels of hidden assumptions and indirect uncertainties than anything else in our world of knowledge. It is the flimsiest tissue of explanations most distantly removed from the certain world of direct observation, and yet we cling like grim death to these core beliefs as if they were the most important thing in the world. Perhaps this tenacious clinging is a compensation for the tenuous nature of what we are clinging to. If we held our core convictions with an uncertainty commensurate with the uncertainty of the core truths themselves, we would be forever flitting from this theory to that, never settling permanently anywhere. Instead, it seems that we examine all the philosophical alternatives, usually during some formative period in our adolescence, and choose the core philosophy with which we feel most aesthetically comfortable, the one that seems (to us) to contain less unlikely or improbable assumptions, and one that suits our own personality and fulfills our emotional needs. And having once made our selection, we tend to cling to that world view with the determination of a helmsman clinging to a guiding star to keep his course from wavering. In the end, paradigmatic choices are made by the process of judgment, a process of summing up innumerable facts of questionable certainty and coming up with a final most likely picture of the world.

Thomas Kuhn (1970) explains how the progress of science is characterized by a series of paradigmatic leaps, jarring jolts during which our foundational assumptions are shaken to the core. At the end of each of these little earthquakes of understanding, we see the world from a new perspective. Looking back on the whole series of revolutions, we get the mistaken impression that there has been a steady and regular progress towards the ultimate goal of more complete understanding. In retrospect we see clearly how in each case the old paradigm was wrong, and the new one was right. If only we had been there to point it out to them at the time, we might have saved a lot of useless debate! But Kuhn notes that these things are nowhere near so obvious at the time, because generally, during times of paradigmatic debate, the definitive evidence that proves one paradigm right and the other wrong is not yet available, and that the choice of paradigm must be made not by the normal rules of evidence, as when comparing different theories, but on some kind of intuitive or aesthetic sense that is impossible to tally up as a rigorous logical argument.

Consider the ancient debate between Ptolemy's earth-centered universe and Copernicus' heliocentric system. We now know that Copernicus was right, and the earth does indeed orbit the sun. But at the time of the debate, the available evidence could not distinguish between the two models of celestial motion, both of them produced relatively accurate predictions for the motions of heavenly bodies, although they did so using quite different calculations. How should a reasonable man make a choice on a paradigmatic question before the definitive evidence has come in? The answer is by judgment; that is, you make a mental image of the earth-centered model, and you make a mental image of the heliocentric model, and you "play" each model in your mind as a dynamic mental image, watching the various parts move until you understand how the model works, and finally you make a kind of analog hunch estimate as to which model contains less dubious assumptions or unlikely contrivances. You make a judgment of Occam's razor—the simplest explanation is most likely to be right. That is not the kind of choice that can be reduced to a Boolean truth formula.

Like the God and angels that make sense of my father's world, and the physical science and evolution theory that make sense of mine, the foundational assumptions are part of that flimsiest tissue of compound uncertainties that are the most remote from the certain world of direct observation or modal experience. It is no wonder that we make errors in this most abstracted level of human knowledge, or that there is such a great diversity of paradigmatic views of the world held by otherwise intelligent people, sometimes willing to kill each other *en masse* over differences in their phantom worlds. But the paradigmatic level represents only the highest, most tenuous branches of the tree of knowledge, whose roots are anchored in the solid ground of modal experience. While some portion of the tree of knowledge is logically structured, like a set of axioms and the theorems derived from them, the vast majority of the tree of knowledge is much more abstract and tenuous, giving us approximate knowledge or good judgment over an astonishingly wide range of subjects, only a tiny subset of which can be established with certainty to be absolutely true by the strict rules of formal logic. Judgment and the power of mental imagery are the primary mode of human cognitive thought.

Chapter 11

The Perception of Time

An Analogical Principle of Representation

The most direct and immediate aspect of conscious experience is the experience of a space that is extended in three dimensions, containing volumetric objects that are perceived to occupy portions of that space. But there is one more primary dimension to conscious experience which we have not yet addressed in our quantitative model of experience, and that is the experience of time. In chapter 4 we discussed the difference between subjective time and the objective frozen time known to science. In this chapter the focus will be exclusively on subjective time, as it is experienced in consciousness. As in our discussion of the perception of space, the focus will be on the epistemology of time perception, that is, on the information content of the experience of space and time, and how it might be represented in an explicit model designed on the same basic principles as our own experience of time. Understanding the essential principle behind the experience of time is equivalent to specifying the computational function performed by that experience, or more correctly, performed by the mechanism underlying that experience.

There are certain general over-arching principles that we can recognize in our analysis of spatial perception that will serve as guidelines as to the principles behind our representation of time. The most general principle of spatial perception is that it is an analogical representation. That is, space is represented in the mind by space itself. Given the representationalist insight, how could it possibly be otherwise? If space were represented in the brain in some abstract symbolic form, as is most often assumed, then our experience would necessarily be confined to an abstracted experience. The fact that our experience of space is manifestly extended in three spatial dimensions, and the fact that perceived objects are experienced as occupying some volumetric region of that perceived space, is direct and incontrovertible evidence for an explicit spatial representation in the brain. And the existence of that spatial representation is the necessary prerequisite for our ability to experience space as a space. Our experience of space is necessarily of the same dimensionality as the neurophysiological representation of space in our brain. Extending this same general principle to the perception of time, we can say that time is represented in the brain by time. In fact, we have no way of knowing whether time even exists in the external world, at least in the form that we experience it. Our experience of time is mediated by our mental representation of time, and therefore it is a virtual tautology (even if not immediately obvious to naive contemplation) that time must be represented in the brain by time itself, or at least by the kind of time that we experience time to be.

So what is the analogical way to represent temporal events? Consider the concept “my grandmother will be here in one minute”. The ‘grandmother’ part of the concept is easy enough to represent analogically, we can represent her by a three-dimensional volumetric rendition, or explicit spatial model of grandmother. But how can we push that grandmother into the future without having her

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disappear altogether? How can we distinguish the concept of grandmother here and now, from grandmother at some future time? Clearly we need another dimension in our representation to encode this extra dimension of experience. That brings us into a four-dimensional space, something that is difficult to imagine with our three-dimensional minds. But not all dimensions are spatial dimensions. Mathematically, a dimension is just a variable that can take on a range of different values. For example a cube is extended in three spatial dimensions, but a colored cube can also vary through a range of different colors. In perceptual color space color can vary through the three independent dimensions of hue, intensity, and saturation. So a colored cube is actually a six-dimensional object, although only three of those dimensions are spatial dimensions. We only need one additional dimension however to represent time, and it is not really a spatial dimension. In Einstein's space-time universe time is very much like another spatial dimension, but our concern here is with the perceptual experience of time, and that experience has only a one-dimensional variability, ranging from past, through present, toward future time. For simplicity in the presentation of the present theory therefore, in order to facilitate mental imaging of a difficult concept, I will use the dimension of color to represent the additional dimension of time required in our perceptual representation. Specifically, I propose the dimension of hue (ignoring intensity and saturation) ordered in the one-dimensional span of the color spectrum that ranges from red, orange, and yellow, through green, towards blue, indigo, and violet. For simplicity let us say that past is mapped to red, orange, and yellow, while future is mapped to blue, indigo, and violet, with the present moment represented by the color green. By this convention, the image of my grandmother at the present moment would be represented by an explicit three-dimensional rendition of my grandmother colored green, whereas the concept of grandmother in the near future is expressed as a volumetric model of grandmother colored some shade of blue.

But the concept of the impending appearance of grandmother in my perceptual or mental image space is more than a ghostly rendition of grandmother as if she were already here, except that she is not actually present. There is a pregnancy to the perception of future events, a sense of impending occurrence that is expected to take place or become actual after some interval. The concept of a future event, expressed analogically, is something like an alarm clock or time bomb set to 'go off' at some future time, where 'going off' means the real or actual presence of grandmother in my present experience. So the concept of 'grandmother will be here soon' is expressed as an image of grandmother painted some shade of blue, along with the ticking of the time bomb, bringing that future event ever closer to the present moment. With every tick of that clock, the event becomes ever more impending. Therefore the clock mechanism must be expressed as an automatic progression of the image of future events from more remote, to less remote future time, until they actually hit the present moment. In other words, as soon as the concept of the soon-to-appear grandmother appears in my mind, it immediately begins to change color smoothly and continuously from blue, to bluish-green, and eventually to green, representing the present moment. The moment that grandmother turns green, in our colored-time analogy, is the moment I expect her to actually appear here and now.

An expectation of a future event is necessarily amodal, like a mental image,

because the future is by definition not yet real. Furthermore, grandmother may or may not appear at the moment she is expected, so even the green grandmother image is an amodal experience, it is an expectation which may or may not be confirmed by actual events. But failure of grandmother to appear on expected schedule would be a surprising or unexpected experience, something that appears as an unexpected absence; something that should have occurred, and is conspicuous in its failure to have occurred, like a negative image of grandmother that appears suddenly in our mental image, as if to say “Where is grandmother? The grandmother that looks like *this*? She should be right here right now!”

If grandmother does appear on schedule, and show her face momentarily at the door, for example, before rushing off again, then that event is expressed in modal form in our perceptual experience as a vivid three-dimensional experience of grandmother here and now. The modal appearance of grandmother as a perceived event, although predicted by the green time-image of the expected event, is however distinct from that temporal prediction, a modal manifestation of an amodal expectation. And having appeared and subsequently disappeared, grandmother moves from a present event to a past event recorded in memory. The amodal green image of grandmother that was our expectation of her appearance, confirmed by the actual event marked by a modal rendition of grandmother superimposed on our green expectation, now fades into a memory of that modal event expressed again in amodal form with an ever-advancing time stamp. In other words the green coloring in our color-time analogy automatically continues fading from the green of the present, through yellow, towards orange and red. We now have a representation that can express past, present, and future events in a reified form, using space and time, as we perceive them, to represent space and time respectively.

This model expresses of course only the information content of our experience of space and time, the color metaphor is introduced only as a means to describe the phenomenon of a mental image of an imagined object at a certain location which however is not its present location, but only its location in some past or future time. Objects from different times do not collide with each other even in the same place, although objects that are both in the same past, present, or future time will collide with other objects at the same location and the same time. In our analogy, the blue image of grandmother would collide with a blue image of grandfather at the exact same location, but not with a red image of grandfather, which would merely indicate that grandfather had been here before, and grandmother is expected here soon.

Bounded in Space, Bounded in Time

One of the fundamental problems inherent in an explicit analogical representation of space is the question of how a finite spatial representation can encode the essentially infinite space of our external environment. As we saw in chapter 6, the solution to this problem was to employ a nonlinear representational scale, that maps the infinity of external space to a finite bounded scale by mapping the center of the space around the egocentric point at the highest spatial resolution (i.e. the distance used in the representation relative to the objective external distance that it represents), and to use a progressively diminishing representational scale for

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portions of space more distant from the egocentric point. This same problem exists also for the representation of time, and therefore a similar solution suggests itself for expressing the temporal dimension. In fact, introspective examination confirms this nonlinear mapping in our perception of time. We are acutely aware of the temporal extent of time intervals near the specious moment of the present, with progressively diminished temporal resolution for times that are more removed towards past and future. Figure 11.1 depicts the nonlinear time scale from the infinite past to the infinite future, all expressed in the finite bounded range that we have mapped to the color spectrum.

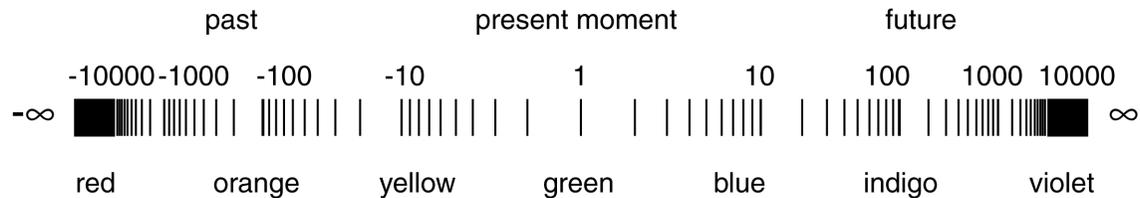


Fig. 11.1 Nonlinear time scale arranged symmetrically about the present moment, encoding an infinite span of time within a finite representational range. A spectral coding analogy is proposed, mapping the colors red, orange, and yellow to past, blue, indigo, and violet to future, and green for the present moment.

As in the perception of space, there are the familiar concepts of the infinite past, time immemorial, long, long ago, and the infinite future, happily ever after, forever and ever amen. As in the concept of infinity in our conception of space, the concepts of long long ago, and of forever and ever till the end of time, are natural concepts that even young children grasp with relative ease, as we can see for example in the number of myths and fairy tales that begin and end with these comforting words. For in the absence of these infinite notions, time would be abruptly truncated in our mental conception of it. If our temporal representation had an abrupt cut-off, for example at a temporal distance of a decade or century in past or future, then not only would we have difficulty remembering or predicting events beyond that range, but we would have difficulty even conceptualizing the notion of time so remote from the present. In fact we can always conceptualize events before or after the most remote events of the past or future, just as we can always imagine a distance beyond any remote distance that might be named. As in the case of distance, our perception of time is greatly reduced in its conceptual resolution at great distance from the present moment, although our ability to expand that scale improves with maturity and with practice and experience. Nevertheless, most people have difficulty distinguishing any significant difference between one million, and ten million, or a hundred million years into the past or future, except of course for the arithmetic recognition that they are related by powers of ten. Our system of numbers with which we express time intervals inform us of their relative magnitudes arithmetically. But in the more familiar folk conception of time, there is little difference between long ago, and long, long, ago. Both are so remote into the past as to be insignificant in the present context. And as in the case of infinity, a concept which should be impossible to conceptualize but for our unique nonlinear mapping of space, the concepts of "it has always been that way" and "so it will remain for ever and ever," which would strike us dumb if we really understood the true magnitude of these innocent words, are in

fact a natural and intuitive part of the mental lexicon of ideas, even of young children.

To quantify this principle of the representation of perceptual time and space in a form that can be implemented in an artificial intelligence, we can modify our quantitative model of perceived space as follows. Beginning with the volumetric spherical representation of space developed in chapter 6 (see Fig. 6.1) every point of which encodes a separate and distinct point of either substance or void, we can add that every volumetric point of this volumetric model space must actually encode not only a single point or 'voxel' of perceived space, but a range of points, or discrete '*ticksels*' of information (the word 'voxel' is derived from 'volume pixel'; thus the word 'ticksel' derives from 'temporal pixel'. You heard it here first!) each with its own discrete potential for encoding either substance or void. As in our earlier discussion of the spatial representation, I will sometimes discuss this representation in discrete terms of voxels and ticksels, not only because this is the form in which it would have to be implemented in today's discrete computer architectures, but also because our analytical mind sometimes grasps the discrete concept more readily than the 'right brained' concept of a continuous analog space or time. Nevertheless, phenomenological examination suggests that both perceived space and perceived time seem to be analog quantities, so I will switch back and forth between the continuous and the discrete description, using whichever makes the point most clearly.

If every voxel of perceived space contains a range of ticksels of perceived time, in the finite bounded range from perceptual 'time immemorial' to perceptual eternity, then another way to depict this extra dimension of experience is as a row of discrete volumetric spheres, one for each ticksel throughout the range, as suggested in Fig. 11.2. Each of these spheres encodes a volumetric spatial image of space for a particular point in time. The sphere at the far left in Fig. 11.2 encodes our mental image of the structure of experience at time immemorial, or minus infinity on the time scale, and thus this sphere should be imagined to be painted red in our color metaphor, while the volumetric sphere at the far right should be imagined painted violet, representing the structure of experience at time eternal, or positive infinity. The central sphere should be imagined to be depicted in green, representing the specious moment of present experience. The present-time sphere also appears simultaneously in modal form, painted in vivid experienced colors as a present time experience. The rest of the temporal range from past toward future can express only amodal experience of either memories or expectations. These are the dimensions of our spatiotemporal experience, and thus these are the dimensions that would be required in a quantitative model of that experience in an artificial replica of our mental mechanism. Although the different-time spheres are depicted in Fig. 11.2 in a linear array, that is only for the purposes of illustration. They all actually represent the same space, although at different times, so these spheres can also be imagined to be superimposed on the same location, which is as they are experienced. We separate them here merely for illustration. In the continuous formulation of this concept the row of discrete spheres would merge into cylindrical continuum extended along the time dimension through a finite range, every 'slice' of which is actually a three-dimensional sphere.

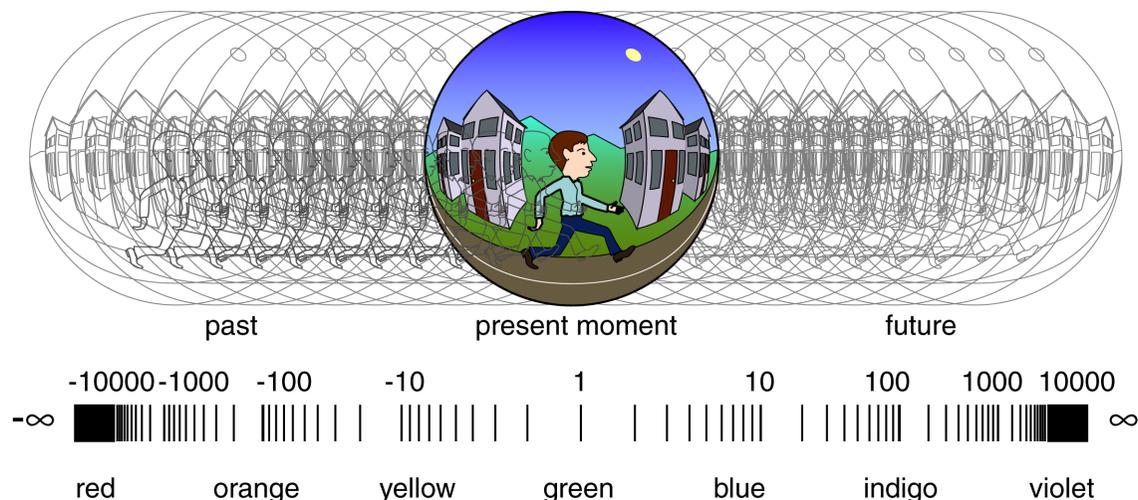


Fig. 11.2 The dimensions of spatiotemporal experience are three spatial dimension, and one temporal dimension, like a row of three-dimensional perceptual spheres arrayed along the time dimension.

Motion Perception

Having developed our representational substrate for expressing the information content of spatiotemporal experience, let us examine how this mechanism would encode the simple experience of moving objects. Time is intimately connected with motion; if there were no motion, then there would be no time either. I propose that the perception of time developed evolutionarily from the more primitive perception of motion, tracking events from the most immediate past to the most immediate future. This most primal aspect of perception, common to some of the simplest organisms, will surely shed light on the principles behind the representation of time in higher animals and humans. If we begin with the assumption that the time representation of an object fades progressively from present or future time towards the past, it follows that a moving object leaves behind it a fading memory trace whose time-stamp color fades continuously from the fresh green of the present moment, at the location where the object is currently perceived modally, through yellow and orange towards red, as suggested in figure 11.3 A. The gradient of this color change, or the rate at which it blends from one hue to the next with distance along the trace, indicates the speed of motion; a fast moving object will have a shallow gradient as suggested in figure 11.3 A, whereas a slow moving object will leave a steeper gradient of time-stamp color change, as suggested in Fig. 11.3B. The time-trace of a stationary object will trail only in the time dimension, that is, the entire trail with all its colors will be superimposed on the present location of the perceived object, as suggested in Fig. 11.3C. The gradient of the time-stamp trace therefore encodes the velocity of the perceived object.

The velocity information encoded in the time trace can be used to predict the future trajectory of a moving object by a kind of completion by symmetry, in the general sense of the word, through the space and time dimensions, based on the representative sample principle, that is, on the assumption that the motion observed so far is representative of the future trajectory of the same object. For

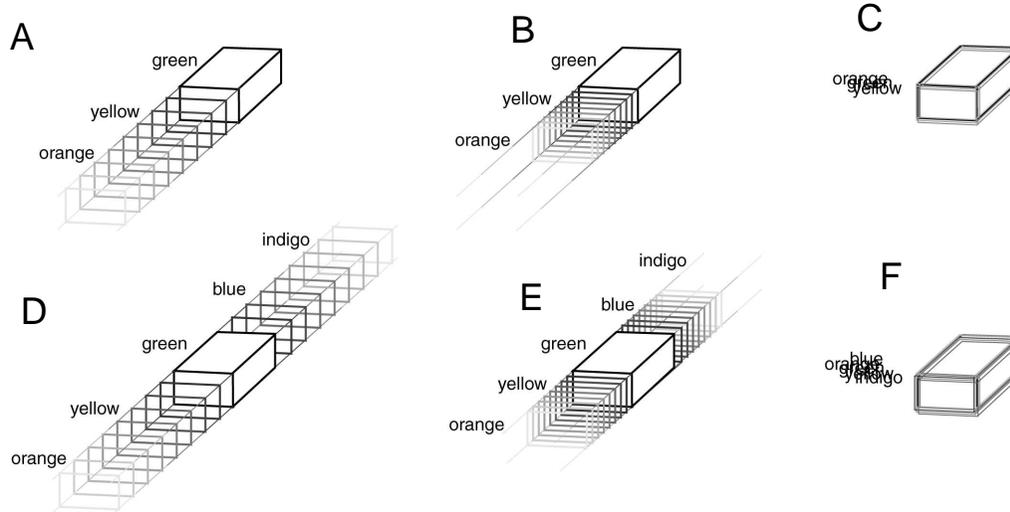


Figure 11.3 A moving object leaves behind a fading memory trace of time-stamped images of that object, with a flatter gradient for faster motion (A) and steeper gradient for slower motion (B). The entire memory trace is collapsed onto the present position in the case of stationary objects (C). The future motion of an object is predicted perceptually by a symmetrical mirroring of the past time trace into a future time projection.(D, E, and F, respectively).

example the uniform motion in a straight line, depicted in figure 11.3A, ‘predicts’ a future space-time trajectory as shown in Fig. 11.3D, whereas the slower moving object in Fig. 11.3B predicts a slower motion projected forward, as shown in Fig. 11.3E. The stationary object of Fig. 11.3C projects a stationary future prediction, shown in Fig. 11.3F, with the entire time trace and future prediction superimposed on the same location in space.

Phenomenological verification of this theory of motion perception can be found in a number of different perceptual phenomena. It is seen in our experience of a moving object that disappears momentarily behind a foreground occluder. The percept goes amodal at the moment of the occlusion, but a percept of motion remains nonetheless, in the form of an expectation that the object will reappear at the precise time and place and velocity suggested by its velocity before it disappeared. Failure to reappear on schedule, or perhaps to reappear at all, immediately triggers an experience of some unseen event behind the occluder that must be responsible for this violation of our perceptual expectation. Further evidence can be seen when watching a moving object like a speeding car. We become anxious of an impending collision as soon as an obstacle enters a danger zone extending outward in front of the vehicle, like an amodal shadow or projection, and the length of this path of danger is proportional to the perceived speed of the vehicle. Gibson and Crooks (1938) proposed exactly this kind of perceptual projection to account for motion perception. (as discussed in Lehar 2003, p. 227 and Fig. 11.7) Still further evidence comes from the phenomenon of apparent motion, seen in its simplest form in the alternate flashing of two adjacent lights, which promotes the percept of a single light that jumps back and forth between the two bulbs. In the apparent motion phenomenon the percept is illusory, that is, subjects report seeing the light as a moving object, even though

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there is no actual motion involved.

More Complex Paths

The same general principle of motion perception applies not only to linear motion at constant velocity, but also to other more complex patterns of motion so long as they remain regular and thus predictable. For example an object perceived to be following a curved trajectory is time-projected forward at the same rate of curvature, as suggested in Fig. 11.4A. An object observed to be accelerating will be expected to continue accelerating at a uniform rate, as suggested in Fig. 11.4B, while an object perceived to be decelerating is projected to continue decelerating at a uniform rate to a stop at some point, as suggested in Fig. 11.4 C. This is how we judge, for example, whether we are braking hard enough to stop before an obstacle ahead when we are driving a car. Significantly, when braking to avoid a collision, our visual attention is fixated on the obstacle ahead, as if we are trying to “see” whether our future projection stops before the obstacle at the current rate of deceleration. And the perceptual projection can even follow other patterns of regular motion. For example an object observed to be weaving side-to-side as it advances, will be expected perceptually to continue that wavy motion, as suggested in Fig. 11.4D. Perception also tracks the motion of objects under the uniform pull of gravity. For example we can predict the trajectory of a baseball tossed up in the air, as an invisible amodal projection that arcs gracefully up and then down again with uniform downward acceleration, as suggested in Fig 11.4E.

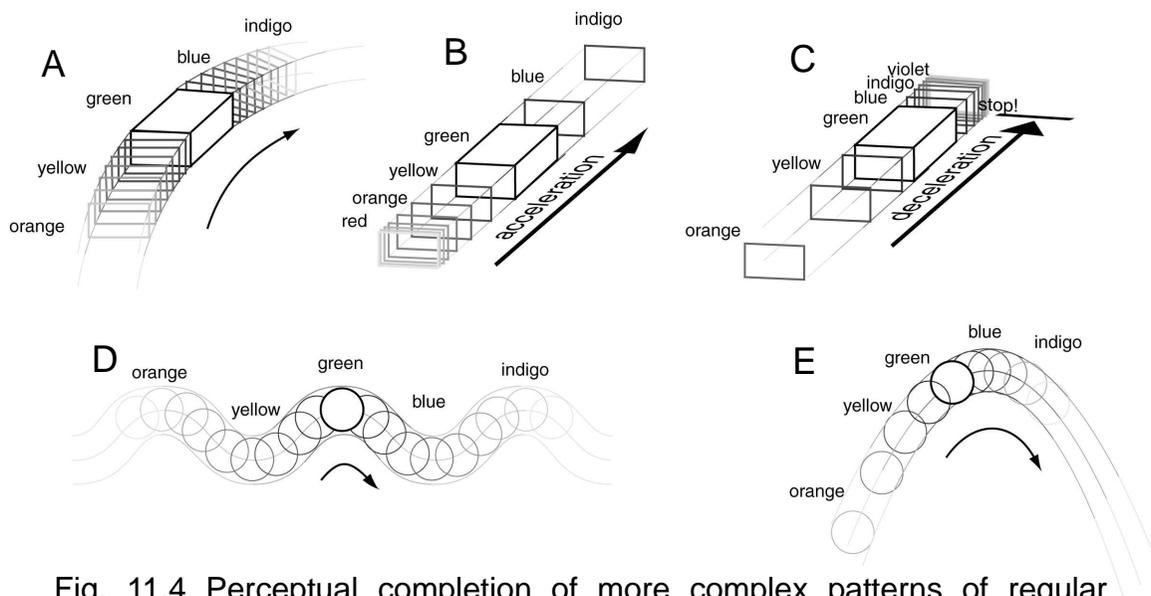


Fig. 11.4 Perceptual completion of more complex patterns of regular motion, including A: a curved trajectory, B: acceleration, C: deceleration to a stop, D: sinusoidal oscillating motion, and E: accelerated motion as in a baseball that is tossed. In every case, the regularity detected in the past memory trace (yellow, orange, and red, in our color analogy) is extrapolated outward into the future projection (blue, indigo, and violet).

Collision and Interception

The principle of forward-projection for predicting the future trajectory of moving objects serves as a useful strategy for calculating potential collisions between

moving objects, or for planning a collision, or interception of a moving object as, for example, when catching a flying baseball. We can tell when two moving objects are on a collision course when 1: their forward-projected trajectories intersect in space, and 2: when those forward projections intersect at the same future time. Fig. 11.5 shows two objects on a collision course, as can be seen by the fact that at the point where their trajectories intersect, both trajectories are indigo, in our color analogy, that is, they will both be at that point of intersection at the same future time. Fig. 11.5B on the other hand shows moving objects that will pass safely clear of each other, because by the time the slower object arrives at the point of intersection, which will be in the indigo time frame, the other object will have already passed the point of intersection.

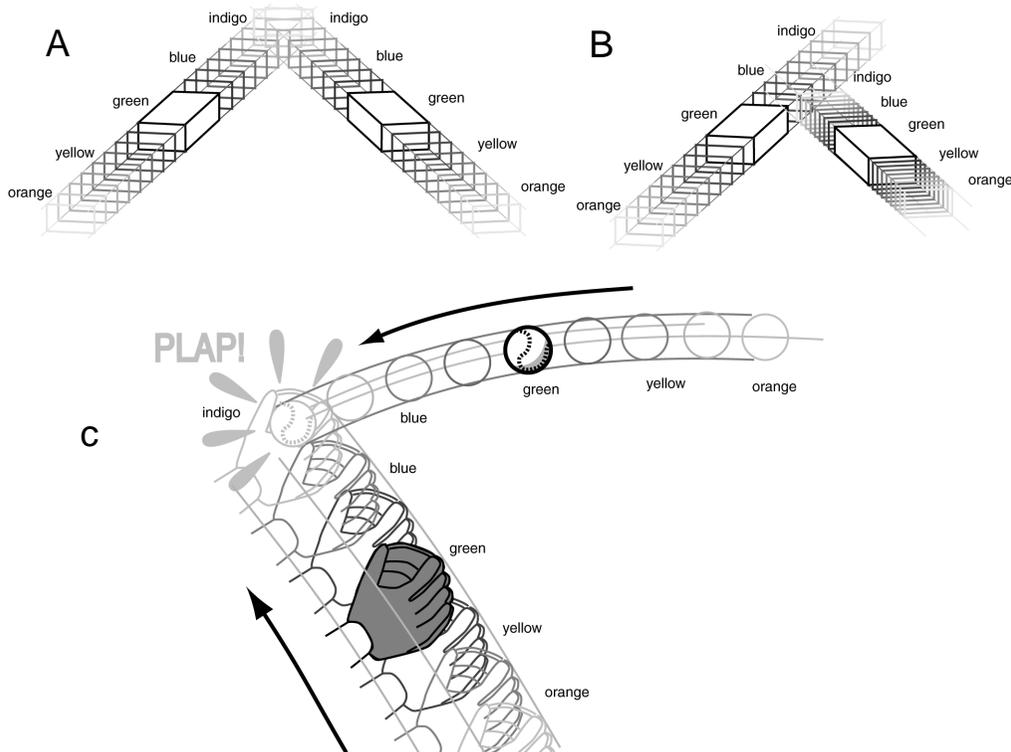


Fig. 11.5 A: A collision course is indicated by the fact that the future-projections of the two moving objects intersect at a point that represents the same future-time for both objects. B: No collision is expected here because the two objects are expected to cross paths at different times. C: A flying baseball can be intercepted by adjusting the future-projection of your catching mitt to intersect the future-projection of the ball at some point in future space-time.

The same basic principle of perceptual projection can also be employed to compute an interception path, for example when trying to catch a flying baseball. As soon as the ball has been observed long enough to produce a reasonable projection of its future path, the computation is to set the catching hand into motion at a speed and in a direction that creates a future-time projection that intersects the projection of the flying ball, with the point of intersection set to occur at the same future time, or color, in our color analogy. For example the catcher depicted in Fig. 11.5C has matched the trajectory of his catching hand to intersect

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that of the ball, with the interception due to occur at future-time indigo. Note that the catching event in Fig. 11.5C is depicted entirely in “indigo”, that is, it is not perceived to have occurred, but is only expected to occur at some future time, complete with a mental-image expectation of an energetic impact at that time. As the ball continues to approach, the task is to fine-tune the motor projection to hit the spatiotemporal target, given the most recent updates and refinements of the projected trajectory of the ball and hand. If no corrections need to be made, the glove and the ball just coast into each other, as if they were sliding on rails, every moment of that experience being composed of a simultaneous continuum from past memory, through present time, to expected future events, all embedded in a three-dimensional volumetric space.

Evidence

The evidence for a spatially reified volumetric spatiotemporal projection mechanism in perception can be found in a number of low level visual phenomena that exhibit exactly these properties. Consider the phenomenon of apparent motion. In the simplest case this consists of a pair of alternately blinking lights, resulting in a perceptual experience of a light moving back and forth between the blinking bulbs. It is clear that nothing is moving in this stimulus, and yet motion is perceived, and the motion percept is localized to a very particular trajectory that takes it exactly from one flash to the next. There is clearly a spatiotemporal reification taking place here, reconstructing the most likely explanation for the alternate flashing of the lights. And that “explanation” is experienced as a literal model of the objects and motions that it represents.

Further evidence for the low-level preattentive nature of this modeling of motion can be seen in dramatic form in the phenomenon of *smooth pursuit eye movement* (Carpenter 1977). When viewing stationary scenes, the human eye normally travels in short jerks or saccades, remaining briefly stationary between these irregular jumps. When tracking an object in irregular motion, like a flying insect, the eye chases after the target in similar saccades, but due to the time required to process the information gleaned in each momentary view, the eye always lags behind the movement that it tries to follow, by a predictable amount. When the eye tracks a regular motion on the other hand, for example straight motion at constant velocity, a significant difference is observed. Instead of lagging behind the moving object, and moving in jerky saccades, the eye tracks the object in one smooth motion whose speed and direction exactly match that of the target. In other words, the visual system compensates for the time lag inherent in neural processing, pointing always exactly at the moving target, instead of lagging behind in space and time. This computational function is similar to that performed by a marksman who ‘leads’ a moving target by aiming his rifle at the point in space that the target is expected to occupy after the time delay required for the flight of the bullet, except in perception the brain “paints in” or reifies the object at the location where it is expected to actually exist at the present moment, rather than the location it was last observed to occupy. What is interesting in smooth pursuit eye movement is that the eye has been found to be capable of tracking not only linear motion, but also motion that follows predictable patterns, such as a back and forth sinusoidal oscillation, or a repeating triangle-wave, or square-wave pattern, although motions more complex than that leave the eye trailing behind in

saccadic jerks.

Unpredictable Motion

Not all motion follows a regular pattern conducive to predicting its future course. Many patterns of motion are irregular and unpredictable, some due to random factors like the halting motion of a rain droplet running down a window pane, and some due to deliberate defense strategies, like the jerky changing motion of a rabbit pursued by a fox. But although these motions contain unpredictable components, there are aspects of those motions which are nevertheless constrained by physical factors. A water droplet that is observed to advance haltingly in short irregular bursts, would be perceived to change its character if it ran suddenly down to the bottom of the pane in a single continuous motion. Likewise, the jerky unpredictable path of a rabbit would be perceived to have changed fundamentally if it were to suddenly dash forward in a straight line. We are even sensitive to changes in the character of the unpredictable motion. For example we can feel the frantic desperation of the rabbit if the pursuing fox begins to close the gap, as evidenced by a more jerky and frantic pattern in its irregular motion. So our perception of a pattern of motion is not always expressed as a simple projection into future space-time, but in the case of irregular motion, our perception captures a higher level invariant of the unpredictable motion which, although unable to give us a clear prediction of the future path, still gives us perceptual information about the general nature of that path, or at least where it is *not* likely to lead next. Phenomenologically, this kind of prediction seems to work somewhat as follows. After seeing two or three abrupt reversals of the rabbit's path, we get a general sense of where the rabbit seems to be headed in the form of a spatial probability field that extends outward through a range of angles. We would not expect, for example, that the rabbit would turn 180 degrees and head back towards the fox, so the probability field projection of its future path remains bounded to some general range of directions. We also get a general sense of the approximate frequency of the reversals, and the average change in direction at each reversal, and we also note that the reversals generally tend to alternate from left to right then left again, although not strictly so. Having extracted these general dynamic characteristics of the rabbit's irregular path, we can now, for example, unconsciously time the interval since the last reversal, and anticipate an ever increasing probability of another reversal as that interval approaches the average interval for the observed reversals. The fox might, for example, attempt to preempt the rabbit's next dodge by turning the moment it expects the rabbit to turn.

Ego-Motion

One final piece of the puzzle must be added to our model of motion perception, and that is the perception of the motion of the self through the environment. This can be expressed in our representation by a motion of the environment backwards around us, that is, by representing every object in the perceived world to move backwards coherently relative to our body-image that remains fixed at the center of perceived space. This is suggested in Fig. 11.6A, where the house and the street and sidewalk and everything else, are projected forward in time, backward

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in space, to predict our egocentric motion relative to the external world into the immediate future. Note that due to the nonlinear distance scale in this spherical representation, a coherent motion of the environment at a constant velocity is expressed as a nonlinear 'fish-eye' motion or vector field, where the most rapid relative motion is observed at the center of the space, and ever slower motion towards the periphery. This non-uniform vector field in perceptual space represents a uniform coherent motion of the environment in external space, that is, we perceive the environment to be scrolling past us at a uniform rate, because equal distances in the distorted grid of perceptual space are traversed in equal intervals of time. And as the objects in the surrounding environment scroll past us in perceptual space, they too leave memory traces as suggested in Fig. 11.6A, which in turn project future projections of that uniform motion backwards in space, forwards in time.

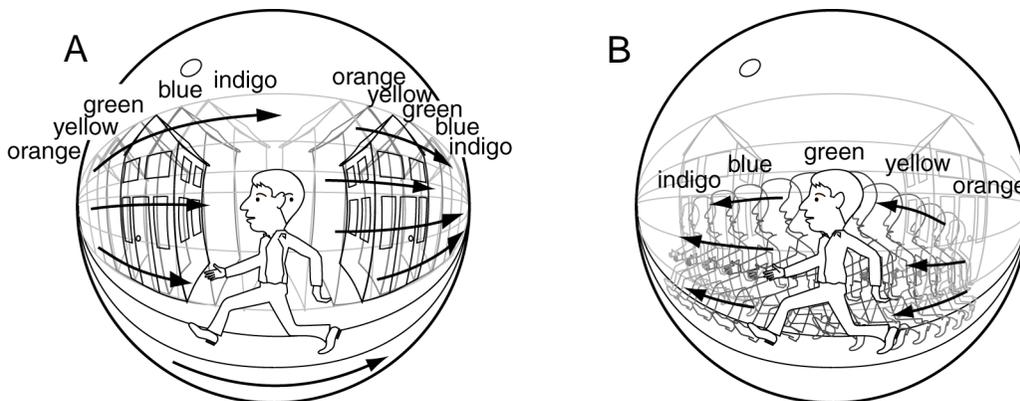


Fig. 11.6 A: Ego motion through the world is expressed as a backward motion of the surrounding world into the future, as with any other moving object. B: At the same time a forward-projection is also computed on the body-image, as with any moving object. These two projections which are computed simultaneously, can be compared to determine at what future time the body is expected to be at some future space location relative to the environment.

The body image located around the egocentric point also leaves a fading time-trace in memory, as shown in the 'wake' of memory trailing astern, and that trace in turn projects a 'bow-wave' of prediction up ahead, computed by symmetry, as shown in Fig. 11.6B. Unlike the memory trace and predictive projections of moving objects shown in Fig. 11.6A, the trace and projections of the body image remain stationary at the center of the representational space, and grow only wider and narrower about the egocentric point in space-time, with higher or lower forward velocity respectively. The time trace/projections of the world and of the self can be compared directly, since they operate on a common time scale. For example looking into the future of the moving environment in Fig. 11.6A, let us focus on the future time labeled 'indigo' in our color/time analogy (depicted in the lightest shade of gray). At time *indigo*, the house that is now ahead of us, will be about to pass by our right shoulder. Looking at the body-image trace/projection in Fig. 11.6B, we see that the body-image at time *indigo* is expected to be at the location depicted by the light shading. At time *indigo*, therefore, the house up ahead will be at the location where we are now, and we will be at the location where the house is now.

It is by these literal extrapolations into space and time that we conceptualize our desires to get to this or the other place, and how we actualize those desires with actual body motions that accomplish the desired result.

Temporal Closure

If the patterns of visual ornament offer clues as to the kinds of symmetry and periodicity that are the eigenfunctions of spatial perception, the patterns of symmetry and periodicity in music offer a clue to the concept of closure in temporal perception. There is a strong tendency for melodies to form complete closed cyclic patterns, wherein the final note of the melody seems to set up to launch into another repeat of the same melodic pattern, suggesting an endless repetition of the same basic theme, like the many verses of a song. For example in a simple tune like “Mary Had a Little Lamb”, the melody repeats exactly with each verse of the song, and the repetitions occur in an exact periodic sequence, with exactly one beat of pause or silence between the last note of the previous verse and the first note of the next. The repetition in musical melody is also often of a hierarchical or fractal nature, also reminiscent of the patterns of visual ornament. For example each verse of the example song is itself composed of two halves,

Mary had a little lamb, Little lamb, little lamb,

Mary had a little lamb with fleece as white as snow

and each of those halves also divide up into neat quarters,

Mary had a little lamb,

Little lamb, little lamb,

Mary had a little lamb

with fleece as white as snow

while each of those quarters further divide up into eights,

Mary had a

little lamb,

Little lamb,

little lamb,

and so forth, with a kind of patterned periodicity with a measure of similarity or symmetry, between the individual elements at each hierarchical level. The same pattern of hierarchical order is seen in more complex and elaborate form in the *exposition, development, recapitulation, and coda* of the symphony form of classical music, and the *introduction, body, and conclusion*, of a scientific paper. The common characteristic is to work from the general to the specific, from the wide view to the narrow specialty focus, and then back out again to a retrospective wide view, as in the summary or conclusion, recapitulation and coda, in a peculiar space-time mimicry of the fish-eye warp in perceived space.

In the cognitive realm we see some of this pattern of hierarchical symmetry and periodicity in short vignettes, or story fragments, as seen for example in cartoon

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stories, and in television commercials. A man comes to the door and knocks. Another man opens the door. They shake hands in greeting. One man passes a package to the other man. They shake hands again. The door is closed. And the man leaves again. Or, a man is shown using an inferior product on a television commercial. The product breaks. The man expresses anger and frustration. Then a scene showing him going to the store. He purchases the superior product. Then we see him back at home using the new superior product. The scene closes with the man expressing exuberant delight, in a symmetrical reverse parody of his original anger and frustration. Joseph Campbell (1949) documented the stereotyped pattern of the story line common to so many ancient and modern myths and legends, starting with a protagonist who is in some kind of dire trouble, who sets out on a journey where he has to overcome a series of great obstacles and challenges. He wins in the end, through perseverance and determination, and lives happily ever after. We see that same basic pattern in all human literature and media, from two minute television commercials, to half-hour sit-coms, to epic three-hour movies, to great novels that require days or weeks to read. And within each of those larger works, there are often smaller patterns within patterns, each with the same pattern of introduction, development, crisis, and resolution in a fractal self-similar hierarchy. These are the patterns by which we frame our lives, bracketed by the twin book-ends of “once upon a time” and “happily ever after”. At every level of human experience, from sensation, to perception, to cognition, we see the twin features of symmetry and periodicity in endless permutations and combinations, that reflect harmonic resonance principle of representation that underlies the operation of the human brain.

The Big Picture

With the addition of the dimension of temporal perception, our model of perceptual experience is complete, we now have all the basic computational elements required for an autonomous intelligent agent with a structured experience of its own surroundings. Although the computational details of this mechanism, which are extraordinarily complex, remain to be specified, we can now at least see the problem as a whole, and how it might work for a simple organism. In the most general terms, perception involves a three-dimensional volumetric spatial model of a surrounding world, complete with a replica of our own body at the center of that space. Every point in this volumetric matrix can also express a finite range in an orthogonal time dimension, in which objects and events can be encoded at specific locations and times. The structured world of experience is painted not only in perceived volumes and perceived colors, but by a still higher level process different objects in a perceived scene are automatically “painted” with the motivational “colors” of attractiveness and repulsiveness, and those concepts are defined by the attraction and repulsion that they exert on the body-image. When an object is perceived to be beautiful or attractive, it exerts a force of attraction between the perceived object and the body-image in the perceived world, and that force of attraction in turn stimulates a pattern of locomotion to propagate the body in the direction of the attractive force.

In order to clarify the computational functionality of this unique principle of spatial reasoning, let us consider how it might be implemented in an artificial robotic intelligence using conventional computer hardware. A robot based on

representationalist principles would be equipped with a volumetric spatial representation of its local environment, complete with an image of the robot's own body at the center of that space, as suggested in Fig. 11.7A. A desire to move in a certain direction can now be expressed as a spatial projection function that projects the robot's body-image forward in perceptual space, as suggested in Fig. 11.7B, like a series of frames from a movie, each time-stamped for one instant further into the future than the last, projected into forward space and future time. This is the reified rendition of the motor act, constructed, or filled-in, as volumes moving through space and time. This forward projection allows the detection of potential collisions with objects by detecting volumetric objects that penetrate or violate the projected path, as suggested in Fig. 11.7B, by the same kind of computation as in a ray-tracing algorithm.

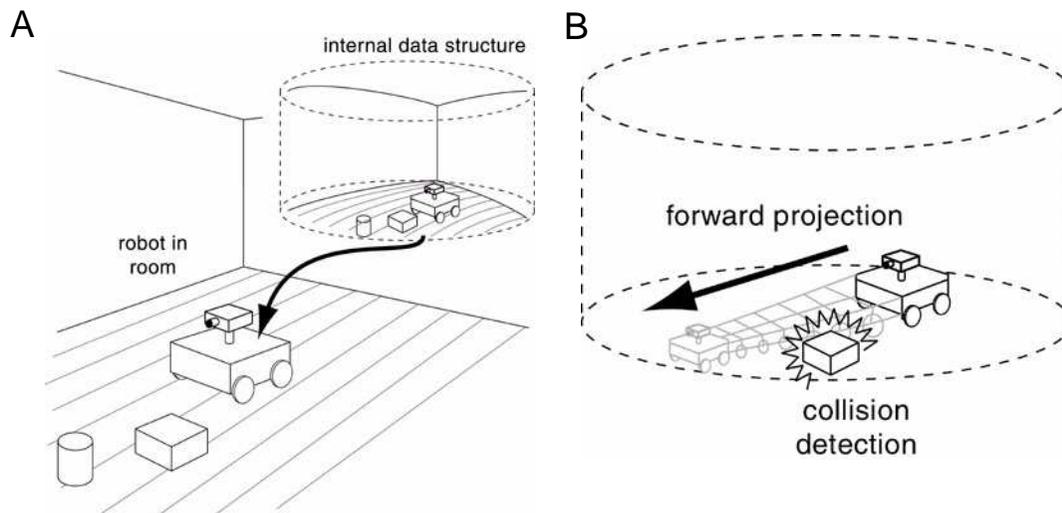


Fig. 11.7 A: A robot based on representationalist principles must possess a volumetric spatial representation of its immediate environment. B: A desire to move forward is expressed as a spatial projection of the robot's body-image forward in space and time. Potential collisions are detected wherever the projection collides with objects in that space.

To avoid collisions, potential obstacles should be marked with a repulsive field that emanates outward in all directions, repelling the forward-projected path away from it, as suggested in Fig. 11.8A. An object recognized as a target is marked with an attractive field that draws the end of the forward-projected path of the robot toward itself, as suggested in Fig. 11.8B. While computing a path, the forward projection drifts about like an elephant trunk, weaving this way and that, until it finds an optimal configuration for the given environment, attaining the target while avoiding obstacles. The projected motion can then be executed at any time by simply following the projected path, frame by frame. As the robot moves forward through the world, the internal model of the world is translated backward coherently, with the robot's body-image fixed at the center as the world scrolls by.

With today's fast parallel hardware it is just becoming feasible to contemplate this kind of intensive volumetric spatial computation. The purpose of this analogical representational strategy is that it offers a more robust and general analogical principle of motor control and planning than the more abstract, analytical or symbolic representation of surrounding space more commonly assumed. But

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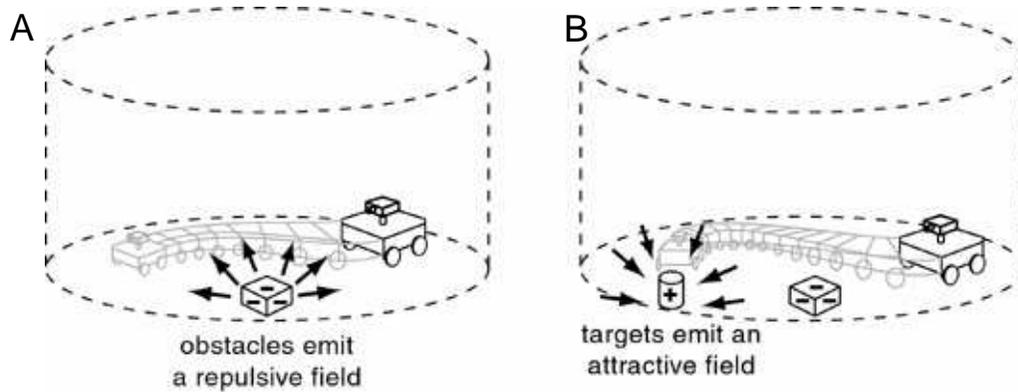


Fig. 11.8 A: Potential obstacles are marked by a repulsive field that repels the robot's forward-projection away from them. B: Objects perceived to be targets are marked with an attractive field that attracts the end of the robot's forward-projection towards itself. This projected motor plan can then be executed at any time by simply following the projected path frame by frame to the target.

parallel analogical computation is inherently inefficient when expressed in a digital sequential algorithm, so computer simulations of analogical spatial logic can offer insights into the spatial algorithms used in the brain, but in order for those computations to be at all practical, they must ultimately be expressed in the same parallel analogical manner as it is computed in the brain.

Chapter 12

A Quest For Meaning

Discovered and Revealed Knowledge

The greatest revolution in human knowledge that has led to the outstanding success of the western world has been the adoption of *discovered* knowledge as the most reliable path toward the truth. The straightest path toward the truth is by way of eternal skepticism. In previous cultures, and in religion today, the preferred path has always been *revealed* knowledge, especially when it concerns questions of ultimate truth, such as the existence of God, or the purpose of the universe. This natural tendency to rely on received knowledge stems from our individual experiences as children, when we learn that our parents and teachers are the most reliable sources of knowledge; they always seem to know more than we do. As we grow to adulthood however, we discover that the experts differ profoundly, especially on those same primal questions of ultimate truth. There is a strange 'catch-22' in the choice between discovered and revealed knowledge. If God did exist, and created this universe for our benefit, then His word, as recorded in the Bible, would indeed be the most reliable source of Truth. But the only evidence for the existence of God is the Bible, whose reliability itself depends on the existence of God. The powerful human inclination to believe in God is an echo of our childhood experience, when we found great comfort in the knowledge that our parents are watching over us. Like children, our role is to worship (respect) and obey, and not concern ourselves with the larger issues which are God's concern. But there are deeply troubling aspects of this faith in revealed knowledge. If the Bible were indeed the word of the creator of the universe, then why does it fail to mention those profoundly significant truths which have since been discovered by science? Why is there no mention in the Bible of the fact that our physical bodies evolved from those of the apes? If evolution were the mechanism chosen by God to create man, why is this most central fact completely absent from the Holy Book? Why instead are we told a tale of creation through Adam and Eve, a story which is totally inconsistent with scientific fact? Why is there no mention in the Bible of the most profound and earth-shattering fact of the Big Bang? Or of the countless billions of other galaxies in the universe, each populated by billions of stars of which our own sun is but one? Or that all matter is composed of positive and negative particles, whose powerful attraction to each other make up the physical substance of the universe around us? Or even the basic fact that the earth rotates under the sky, rather than the other way round as it appears to the naive observer? Surely these most primal facts of the universe should have been the first things presented in Genesis. If God does exist, and wishes us to believe in Him, why does He make himself completely undetectable by scientific means? Why does He choose to reveal Himself through an ancient manuscript of questionable origin, full of contradictions, and totally indistinguishable from a manuscript written by mortals? If God endowed us with a rational mind, why would he require us to abandon our reason on questions of the greatest consequence and import? The same argument holds also for the sacred texts of all other religions and faiths. The very fact that there are multiple mutually

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inconsistent faiths is itself proof that no more than one of them can possibly be true. The profound inconsistencies between discovered and revealed knowledge cast the most profound doubt on the reliability of revealed knowledge as a path toward the truth.

Further grounds for suspicion of revealed knowledge as a path towards the truth can be found by observing the systematic differences between the picture of the world revealed by religion as contrasted with that revealed by science. Most religions provide an anthropocentric view of a God who cares deeply about our individual thoughts and feelings. But the history of scientific discovery has been characterized by a regular progression of *anthrodecentralization*, demoting humans from the central position in the universe under the personal supervision of God, to lost creatures on the surface of a tiny blip of matter orbiting a very unremarkable star, among countless billions of stars in an unremarkable galaxy amongst countless billions of other galaxies as far as the telescopic eye can see. There is an egocentric, self-aggrandizing aspect to religious belief that suggest an ulterior motive to the world view that it promulgates, elevating man from a lowly beast whose existence is a consequence of some cosmic accident, to a noble supernatural creature who transcends the animal body that he appears to occupy, and whose existence on this earth plays a vital role in some great cosmic battle of forces.

Another glaring inconsistency in most religious belief is the idea of God as a perfect being, who advocates love of one's neighbor, self-sacrifice, and altruistic cooperation, while the entire web of life on this planet, supposedly His creation, is characterized by an eternal mortal struggle between competing organisms, from the tiniest microscopic competition between microbes, competition between plants for sunlight, competition between herbivores for plants, and between predators and prey, and between different predators for the same pray, desperate struggles against parasites and diseases, all the way to the violent wars of conquest and annihilation that have characterized human history since time immemorial. Our very intelligence and agility and inventiveness are surely a direct product of countless millennia of armed struggle with our human and animal enemies, as evidenced by the fact that to this day, the most dramatic technological and organizational advances are made at the most rapid rate during times of war and national conflict. We have yet to take account of the full implications of Darwin's theory of evolution for the nature of our selves, and our place in the world.

If religion is so obviously at odds with the observed facts of the universe, why then does it continue to this day to hold so many in its sway? Why is it that so many even in the modern western world hold to some version of religious, spiritual, or paranormal belief? The answer to that question is manifold; religion serves a variety of diverse functions that benefit both the individual and society as a whole. It is only as a path toward real truth that religion is such an abysmal failure. In the first place, religion has always served as the long-term memory of a people. Whenever a culture went through cataclysmic experiences, whether by war, famine, or pestilence, or periods of profound moral decay leading to widespread misery and despair, the lessons of those experiences have always found their way into the mores of the culture as a whole, as passed on through the cultural heritage from generation to generation. This function of religion was particularly

important in the days before the invention of the written word, when it served as the only method to pass on to future generations the hard-won lessons of the past. Different cultures experimented with different belief systems, from Gods that demanded human sacrifice, cannibalism, or self mutilation, to cults of war and aggression, as well as beliefs of care and nurturing and cooperation. During the endless tribal conflicts in prehistoric and historic times, these different belief systems clashed with each other constantly, resulting in a kind of Darwinian natural selection of ideas, whereby cultures with the best belief systems were the ones that prevailed and propagated. But the exact formula for success is not fixed, but varies along with environmental circumstances. In times of peace and prosperity, and in island peoples isolated from aggressive neighbors, cultures of peaceful coexistence emerged, whereas in continental regions populated by many diverse tribes, cultures of war and aggression came to the fore, while peaceful cultures faced annihilation or enslavement. But while outward aggression served the survival needs of many cultures, inward cooperation has also always been an essential factor for survival, because cultures capable of greater cooperation could organize larger armies for aggression and defense, and thus we saw a progressive development into historic times of ever larger cultural organizations, from family groups, to tribes, to kingdoms, to empires, whose size was limited only by their ability to maintain their internal cohesion. That ability has always been dependent on a culture's social and political organizations, that is, its ability to coordinate the actions of large numbers of people toward a common goal, and that ability has historically been tied to a common belief system. It is no accident that in times of war, famine, and pestilence, people turn to God, while in times of peace and prosperity people return to hedonism and selfish concerns.

The evolution of military and political organizations through a competitive clash of cultures has survived into modern times, although it is no longer expressed in explicitly religious terms. Nevertheless, there was still a large component of faith involved in the twentieth century conflicts between democracy, fascism, and communism, which were as much wars of ideas and ideologies as they were of competition for global resources. To this day many see Marxism and Naziism as not only unworkable, but as intrinsically 'evil', while tolerance for diversity and compassion for the weak are considered intrinsically 'good'. Although the modern clash of cultures is no longer expressed in religious terms, the moral issues that are at stake are as profound as those of the religious conflicts of the past. This function of religious belief has been incorporated into our modern secular society in a form that is no longer considered to be religion as such. Science and law have to a large extent taken over the function of religion as the long-term memory of a people, and with the invention of the written word, that memory now stretches very much farther back in time, and contains vastly more information than any one individual can possibly assimilate. We each see one small aspect of the vast repository of accumulated world knowledge. In our rapidly changing technological world, the very advantage of religious dogma, that is, its stability and resistance to change across generations, has become its most crippling drawback. Religion simply cannot keep up with the rapid advances in technology such as genetic engineering, medical science and reproductive technology, that shift the moral scales of the modern world.

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Although the function of religion for the culture as a whole has been largely supplanted by secular institutions such as schools, libraries, and the legal system, religion continues to serve a central function in the life of the individual, for whom it continues to be useful in a number of ways. In the first place, the philosophical aspects of religion spare the individual from endless and futile agonizing over imponderables, such as the ultimate origin, and ultimate fate of the universe, and our place in the grand scheme of things. Since no satisfactory answer can possibly be formulated for these ultimate questions, it gives us great comfort to simply trust in God to worry about those issues, allowing us to focus our attention instead on the immediate concerns of our daily lives. This too is a reflection of the conditions of our infancy, when it was for our parents to worry about paying the bills while we busied ourselves with our toys in the nursery. The only victim of this pragmatic philosophy of life is the real Truth, for those of us who care about such things.

But one of the greatest benefits of religion for the individual is the sense of *meaning* and *value* that it offers. A quest for meaning is one of our most urgent and passionate needs. Without meaning, life is hardly even worth living, especially in times of hardship or conflict, when our everyday lives can seem intolerable if not guided by a larger goal. People go to no end of trouble to find some kind of meaning in their existence, even if that meaning has to be invented from scratch. For despite the power of modern science to discover real truth, science is profoundly disappointing in the area of meaning. That alone accounts for the large number of believers even amongst the scientific elite, who casually ignore the stark inconsistencies in the religious account of the world, in return for the meaning it gives to their lives. It is a trade-off that I am not willing to make. If it turns out that this universe is really devoid of meaning, if it is just a cataclysmic accident that just happened to take place, if our lives are no more significant in the grand scheme of things than the mould that grows on an abandoned crust of bread, I would rather live a life devoid of meaning than to buy meaning at the expense of the truth. There is beauty and wonder in truth exactly because it is true, and that beauty pales when we modify the truth to suit our egocentric needs. But is the universe truly devoid of meaning? Or have we yet to discover the meaning behind it all? Can science after all offer some kind of meaning to the truth that it reveals? In chapter 5 we already extended science from the colorless insensate world of the pure physicalist, to include the color and light and feeling of the world of sensory experience. Can we expand science once more to include meaning?

Meaning In the Universe

In contrast to the world of science, the world of our experience is simply teeming with meaning of different sorts and at many different levels. We all choose for ourselves a personal philosophy that makes our own lives worth living to ourselves. We set ourselves career and family goals that give us satisfaction when we attain them, and frustration and disappointment whenever we fail. And we feel the great passions of personal relationships, and grief at the loss of loved ones. At a more immediate level we experience many little rewards and frustrations of our daily lives, from the tedium of getting ourselves dressed and groomed in the morning, to transporting ourselves to and from our jobs through

traffic, to the minor power struggles and personality conflicts with competitors and coworkers, bosses and customers, and dealing with mechanical breakdowns and endless maintenance and resupply tasks. At a still more immediate and petty level we feel innumerable tiny needs, like the need to read to the end of the page, the need to turn to the next page, the need to shift our body occasionally to relieve the tiniest cramping or discomfort, or to stop and take a break. These tiny needs and mini-objectives, although they are of much lesser magnitude, seem to be expressed in the same language of desire and frustration as the larger daily needs, and the still larger passions of our lives as a whole. It is these emotional forces that impel us to act. In the absence of all emotion, there would be no incentive for us to do anything at all—we would sit completely still and stare vacantly into space like a Yogi engaged in meditation. Even the relaxed act of passively observing our environment around us is colored by a miniscule urge or curiosity to examine first this and then that object around us, each object or pattern calling to us like a little naked temptress, inviting us to explore them with our eyes, but having had our very brief little fling with them, we find that their tiny allure quickly fades, and our eye wanders off toward the next most alluring or interesting item to catch our gaze, in a micro-miniature mockery of the larger patterns of our lifetime passions and relationships. The language of pleasure and pain, joy and frustration, are the motive force that set us into motion, just as the tension of a clock spring makes the gears and cogs of the clockwork turn. Urgency and desire correspond to a force that tries to move something in some direction; frustration corresponds to an obstacle blocking that force, and pleasure or satisfaction corresponds to a motion that acts to relieve that motive force.

Meaning and feeling are intimately related, the only difference between them being a level of complexity. This is seen most clearly in the case of very primitive feelings such as pain and pleasure. A pain is meaningful to us because it causes us to urgently act to relieve the pain, just as pleasure is meaningful because it causes us to act in pursuit of it. The meaning of acute pain and ecstatic pleasure are very simple and primal, they tend to produce very simple aversive or attractive behavior. But there is no difference in principle between an excruciating pain, and the more tolerable discomfort of boredom, like the boredom of a tedious job or a large repetitive task. Both of them serve to spur us into action, although the pain triggers a more primitive immediate jerky action, whereas boredom tends to promote a more complex and elaborate chain of thought about prospective action. Similarly, the primal pleasure of sexual orgasm, or of a hit of crack from a crack pipe, motivate only a simple primitive behavior, such as seeking sexual release from pornography or prostitution, or setting off in search of a crack dealer. The more noble lofty allure of a beautiful mathematical theorem, or of the love of a good woman whether she is beautiful or not, lead to immeasurably more complex and less predictably stereotyped behavior, such as exploring the implications of the theorem, and the life long commitment to marriage and family, respectively. Things are meaningful to us if they promise us feelings of pain or pleasure, whether immediate or deferred. Something that promises no such sensual reward is as meaningless to us as a string of random numbers. There is an interesting contrast between numbers and colors. Both carry information, and yet color carries more than just information, color carries with it also a primal feeling, or mood, which acts a reward in and of itself. It gives us sensory pleasure to gaze

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upon a lurid shade of pink, as it does to see that pink in a beautiful sunset. These experiences are thereby intrinsically meaningful to our lives, not for any promise of sensory reward, but for the immediate sensory reward inherent in simply experiencing them. We feel a similar aesthetic pleasure from beautifully symmetrical and periodic patterns, as seen in the patterns of visual ornament, which is why we adorn our bodies and our living spaces with items that we perceive to be aesthetically pleasing.

The meaning we see in things is meaningful because of its potential to provide either immediate or promised sensory experience, and sensory experience is that which moves us, both literally and metaphorically, driving our body to some kind of response or action. Setting aside the question of the subjective feeling of the feeling itself, or as philosophers put it, the “what it is like” aspect of feeling, these are the functional effects of meaning and feeling on our behavior. Is this functional analysis of the behavioral implications of emotion and feelings merely an analogy? Are we merely playing with words? Or is there some deeper connection between our experience of feelings and actual forces out in the physical world? Can we say that a clock feels an urgency to start turning its gears and cogs due to the the urgent passion of its tightly-wound spring? Or are the forces in a physical mechanism totally devoid of any experience of tension or urgency? The answer to this question would have profound implications for our view of our selves and our place in the world. In fact this issue is very much parallel to the question of pan-experientialism discussed in chapter 5. While we cannot in principle ever prove the issue definitively one way or the other, if we accept the standard conservative assumption that the only entities capable of feeling or passion are animals above a certain level of complexity, or animals of any sort, or living things, etc. then we are necessarily doomed to a dualist ontology in which the experience of pleasure, pain, and passion, reside in a separate rarefied realm that makes no direct contact with the material universe known to science, because experience would supposedly come into existence at some abrupt threshold of physical complexity where only a gradual transition is observed in the corresponding physical system. This kind of ontology seems much more credible from the perspective of a fully dualist philosophy whereby mind is something very different than the matter that temporarily sustains it in a human body. If we accept the modern materialist view that mind is nothing other than the functioning of the physical brain, then it seems more likely that the experiential aspects of mind, including feelings of pain and pleasure, sorrow and joy, are themselves merely a more complex organization of something more basic and primitive that is present in all matter and energy. As in the question of pan-experientialism discussed in chapter 5, my intent is not to suggest that inanimate matter is capable of complex emotions in any kind of human sense, nor even of a sense of self as the experiencer of those passions. The only requirement for a self-consistent physicalist explanation of the relation of mind to matter is that the nature of proto-experience of inanimate matter, however primitive it might be, is necessarily such that when rearranged in the complex structure of a living human brain, that proto-experience becomes the magnificent splendor of human conscious awareness. The difference between animate and inanimate experience is not a question of different substance, or profoundly

different ontology, but merely one of a more complex organization of the very same kind of primal substance, and that primal substance manifests itself in both objective external, and subjective experiential aspects.

The Unity of All Things

One of the most profound discoveries of twentieth century science was the fact that matter and energy are not separate and distinct entities in a profoundly dualized universe, but that matter and energy, and even empty space, are different forms of the same underlying existent in a highly unified universe. Matter can come into existence by simply applying energy to empty space, producing symmetrically opposed pairs of particles of matter and of anti-matter. If this particle/anti-particle pair should come into contact again, they immediately annihilate each other again, releasing a burst of energy equal to that used in their creation. In other words, energy comes in two forms, a static form that we call matter, and a dynamic form that we call electromagnetic radiation, both of which are different states of empty space. In fact modern science teaches us that particles of matter are standing waves of energy, like a wave travelling round and round in a circle, interfering with itself constructively as it goes round endlessly. In the words of Robert Alexander,

Every stone is light, slowed down and tied in a knot; and light is every stone's dream.

In chapter 9 we discussed atomic orbitals as wave functions, or standing waves, as the manner in which electrons 'orbit' around the atomic nucleus. It is the harmonic resonance aspect of these electron orbitals that accounts for the discreteness of their shells, because they only occur at radii, and in configurations around the nucleus where they interfere with themselves constructively. That discrete behavior in turn is responsible for the periodicity of the periodic table of elements, and the discrete energy levels absorbed or emitted by atomic electrons. A similar resonance holds within the nucleus of the atom, because the primal particles of which the nucleus is composed are themselves defined by the various discrete resonances at which the particle interferes with itself constructively. One might say therefore that the universe is fundamentally analog and continuous in nature. The only thing that makes the universe discrete is the phenomenon of harmonic resonance, which is responsible for the discrete nature of all of the particles that make up matter.

The existence of matter and energy in the universe is therefore a manifestation of some kind of disequilibrium, a remnant of the cataclysmic de-equilibration caused by the Big Bang. Like the disturbance on the surface of a pond when a stone is thrown into it, all of the travelling waves of electromagnetic radiation, and the standing waves of physical particles, can be seen as a frantic attempt to restore the equilibrium, and to return the universe to a state of placid rest. Particles exert forces on one another, from the strong nuclear forces that hold the atomic nucleus together, to the weaker electrical attraction for example between positive protons and negative electrons, to the still weaker force of gravitational attraction that draws all matter towards all other matter. If a wound clock spring feels its tension as a passionate urgency, then surely electrically charged particles feel an urgent attraction to particles of the opposite electrical charge, just as particles of matter feel an urgent gravitational attraction to all other matter. In anthropocentric terms,

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matter has a profound love for other matter, and that love is manifested by an eternal force of attraction that draws matter toward itself. It is love that holds protons and electrons to each other to create bulk matter, and that holds the matter of the earth in the form of a giant sphere, and it is love between the earth, moon, and sun that locks them into their eternal orbital dance, and that holds the sun in its place in the great spinning wheel of the galaxy.

The use of the loaded anthropocentric term 'love' is not intended to suggest anything like the complex human emotion of love, but merely to suggest that there exists a continuum between the noble Platonic love between two people locked in lifelong mutual commitment, the more fleeting romance of an illicit affair, the still more fleeting but passionately urgent desire for sexual release in prostitution or masturbation, and the frantic panicky love of life itself manifested by a drowning man struggling and gasping for breath. As the complexity of the emotion diminishes along this spectrum of desire, the intensity and passion of the experience increase. The agonized writhing of a man under extreme torture, for example when nailed to a cross in crucifixion, can hardly be called volitional behavior, it is automatic, like the behavior of a simple automaton, driven by primal feelings of excruciating pain. But the mindlessness of that primal driving force does not in any way diminish its intensity, but rather it accentuates it. If we extrapolate from this spectrum of experience into the still more mindless behavior of simple animals, plants, and inanimate matter, then surely the quality of their subjective experience must continue to increase in intensity even as it diminishes in complexity. Or, arguing from the other direction, we can say that if inanimate matter, plants, and simple animals, had no subjective experience of their own functional behavior, then we too, who are also composed of matter and energy, would necessarily be insensate automatons, like the proverbial 'zombies' proposed by philosophers of consciousness. The fact that we do experience the passions and urges of our own mental function is direct and incontrovertible evidence that a physical process taking place in a physical mechanism can under certain conditions feel passions and urges. Surely the time has come to finally accept the full implications of Darwin's theory of evolution, and acknowledge the fundamental unity that pervades the entire tree of life and beyond.

Besides the fact that simple primal urges tend to be experienced more intensely than more complex higher inclinations, there is further reason to believe that the intrinsic experience of inanimate matter is more intense than the experience of mental activity. Consider the contrast between the experience of our brain being aware of its own structure, and the experience of our body, as a physical object, being independently aware of its own physical structure. If we assume that the intensity of experience correlates with the magnitude of forces and energy of the mechanism that is having those experiences, then it follows that the experience of our own mental activity must be very much lesser in magnitude than the experience of our physical body of itself. Once we acknowledge that the body that we see in our experience is not our physical body but merely a mental replica of it, and if we accept pan-experientialism, then it becomes clear that our body must experience itself independently of our experience of it in our brain; that is, it must experience the forces of tension in its muscles and sinews, pressure and current in its blood vessels, and the stresses and strains of its bones under physical load, and only a small fraction of these sensations are detected and communicated by

nerves up to the brain. Our body does not see a clear picture of itself as we see in our experience, but rather there exist numerous structured fields of forces and stress that experience their own structure and spatial configuration, just as we experience the structured forces in the representational mechanism of our brain. But the forces in a brain are considerably lesser in magnitude than the larger physical forces that they control, for the same reason that the electrical voltages and currents in a robot's computer brain are very much less than those of the electrical motors that drive its robotic limbs. Like a computer, the brain computes quickly and efficiently by using tiny voltages and currents in its computational processes, and those tiny signals must be amplified by the muscles to convert them to much greater physical forces in the body.

The harmonic resonance theory of brain function presented in chapter 9 suggests a profound unity or similarity between the most basic primal resonances of matter and energy in the universe, and the larger resonances within our own brain. Consider the patterns of electron orbitals around the nucleus of an atom. Electrons are held to the nucleus by an electrostatic attraction; the more positive protons there are in the nucleus, the more negative electrons are attracted to that nucleus until the total charge is balanced. But the electrons also jostle with each other for position in their orbital shells, due to their mutual force of repulsion, like the competitive relationship between different wives in a polygamous marriage. Some orbitals are more stable or comfortable than others, depending on the spherical resonances of those electrons around the central nucleus. For example in the atomic structures of many familiar elements, the atom is most "happy" when it has eight electrons in its outermost shell. The outer shell is full when it has its full complement of eight electrons, called an *octet*, and feels "dissatisfied" when it has either more or less than that complement. A full shell is whole, harmonically speaking, a micro-miniature analog to the human sense of aesthetic wholeness when a pattern is seen as complete, whether it be a curved line that closes on itself to form a full circle, a more complex pattern of lines and shapes to form a complete symmetrical figure, or the satisfying finale of a musical melody, whose last note closes the pattern of the melody as a whole. If the harmonic resonance theory is true, then this similarity between atomic and brain resonances is more than just an analogy, it is a fundamental similarity in operational principle, occurring only at a very different scale of size and of complexity. This yearning for wholeness by the outermost electron shell, known as the *valence* shell containing the *valence* electrons, accounts for many of the chemical interactions that bind atoms to each other in the formation of molecules. For example the oxygen atom has 8 protons in its nucleus, and therefore it attracts 8 electrons to itself to become electrically neutral. Two of these electrons fill the first shell near the nucleus, leaving the remaining 6 electrons to partially fill the octet of the outer valence shell. This leaves two holes, or vacancies in the valence shell, where the resonance would be more whole or complete if only two additional electrons were to come and fill the void. The resonance yearns for these additional electrons to complete its wholeness, as passionately as a lover seeks the wholeness of sexual gratification, or an artist seeks the closure of a complete work. But should extra electrons arrive to fill that need, they would bring the balance of electrical charge into the negative, and thus they would be repelled from the atom electrically, even though they are attracted to it harmonically. Oxygen meets these conflicting needs

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with a compromise. In free oxygen gas, pairs of oxygen atoms hook up and share a pair of their electrons with each other. That is, at the point where the two atoms meet, each atom contributes two electrons to a common pool of four shared electrons, allowing those four electrons to contribute to the valence shells of both atoms simultaneously. This brings the total in each valence shell up to the full octet, although this comes at the cost of a certain “cramping” in the pattern of each of the participating atom’s orbitals, as their outer electrons are bent forcefully away from the natural relaxed positions that they occupy when the atoms are isolated. The global symmetry or harmony of the octet rule comes at the cost of a local tension or asymmetry within each atom, binding the two atoms into an O_2 union with the same kind of trade-offs and tensions as a marriage between a man and a woman, wherein each individual bends or warps their selfish desires in the interests of the larger union as a whole. Oxygen finds a much happier relationship when it meets two hydrogen atoms to form a molecule of water, because each hydrogen atom contributes its single superfluous electron to fill the void of the oxygen atom’s desire. In doing so, the hydrogen atoms are also happier harmonically speaking, glad to be rid of the burden of their supernumerary electron.

As in the case of atomic orbitals, the larger structure of the standing wave patterns in our brain emerges spontaneously from a resonating system composed of innumerable sub-units of living cells at one scale, still smaller molecules at another scale, and still smaller atoms that make up those molecules at yet a smaller scale, and still smaller minute but intense patterns of nuclear forces within the nucleus of each atom at the smallest scale. If the pattern of protons and neutrons in the nucleus had an influence on the pattern of electrons in their atomic orbitals, if those inner and outer structural forces were coupled or connected, then the pattern of the electron orbitals would be “aware” of the pattern of the nucleus that they orbit. But the pattern of nucleons is so minute relative to the scale of the orbiting electrons that the electrons do not causally “feel” the nuclear structure at all, except for its total positive charge that holds them in spherical orbit around it. The pattern of electron orbitals does not change when the nucleus rotates to different orientations. They are separate systems causally speaking, and thus their proto-experiences must also be de-coupled.

Molecules on the other hand do experience the orientations of their component atom’s electron shells. For example a water molecule composed of two hydrogen and one oxygen atom always appears in a triangular configuration, with an angle of 105 degrees between the two hydrogen atoms, because those are the “cam-plate slots” defined by the larger configuration of the molecule as a whole (to use the cam analogy illustrated in Fig. 8.3C). The molecule “feels” the structure of its component orbitals, just as the orbitals “feel” the larger structure of the molecule as it bends them into the stressful posture required by the molecule as a whole. At a larger scale again, individual molecules bind into larger structures of bulk matter, resulting in the spontaneous emergence of larger fields of coupled forces. When atoms of iron with a sprinkling of carbon link up to create a slab of steel, the size of the slab is many billions of times larger than the atoms of which it is composed. But those atoms are locked together so tightly that they propagate causal forces throughout the bulk of the slab, resulting in the spontaneous emergence of a larger global entity with its own natural resonances. When struck with a hammer,

the steel rings like a bell, in a large-scale replica of the kind of resonances seen at the level of its component atomic orbitals. The steel slab has an awareness of its own spatial structure when it is struck, as seen in the holistic harmonic resonance pattern that emerges in the ringing steel. The resonance of the steel is a larger global entity on the size scale of the slab as a whole, and that resonance is relatively independent of the individual atoms of which it is composed. A very similar resonance can be evoked from a slab of brass or bronze of the same shape, but composed of different atomic elements. And so too are the larger spatial patterns of standing waves across the bulk tissue of the brain relatively independent of the individual neurons by which those standing waves are instantiated. That is why our conscious experience remains entirely devoid of an experience of the component neurons, molecules, and atoms, by which that experience is sustained. The larger structure of our global consciousness appears out of nowhere when the elemental components of our brain are assembled, like the ringing of a bell after its metal is cast, and that larger structure vanishes without a trace when our brain decays into inanimate matter again, like the ringing of a bell that has corroded to a pile of rust.

It is interesting to note that in bulk metals, the outer valence electrons are so loosely bound to the atomic nucleus that they jump freely from one atom to the next, so that the valence electrons are not really attached to individual atoms in a chunk of metal, but flow freely through the bulk metal as a “sea” of electrons. Given the modern view of the electron as a wave function spread out over space, as opposed to the old-fashioned notion of the electron as a pinpoint particle, we can see that this sea of electrons flowing through the bulk metal defines a larger global entity in the form of a volumetric spatial continuum superimposed on the volume occupied by the discrete metallic atoms. It is the presence of this sea of free-flowing electrons in metals that account for the many characteristic properties of metals. For example metals conduct electricity because an excess or deficit of electrons at any point redistributes itself immediately through the bulk of the metal, like water flowing within a hollow vessel. The same sea of electrons accounts for the fact that metals conduct heat, because the thermal energy of vibrating atoms is also communicated rapidly through the bulk metal by the electron sea, and it also accounts for the malleability and ductility of metal, the fact that it can be rolled, pressed, stretched, and worked like wet clay, without cracking or splitting, because the electron sea fills in small cracks or fissures, and thus holds the atoms together more flexibly than the more aloof atoms of a non-metal. And the sea of electrons also accounts for the fact that metals are shiny, and that they ring like a bell when struck. Although atoms and electrons come in discrete quanta which we call particles, this nomenclature is somewhat misleading, because each atom is actually an extended field-like structure that fades smoothly with distance from its center, and the electron sea is a fuzzy field-like continuum superimposed on the matrix of component atoms. The modern view of matter is much more like a continuum than the traditional “stick and ball” models of atoms we were taught in grade school. Likewise, an electrolytic liquid such as the saline solution bathing both the interior and exterior of neurons in the brain is also functionally speaking more like a volumetric spatial continuum, that conducts a flow of electrical charge through the bulk of the liquid with almost as much ease as the flow of current through metals. It is this volumetric spatial continuous character of fields of

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oscillating electrical charge across the brain that must underlie the volumetric spatially continuous nature of visuospatial experience. Like the current that flows through a wire, our conscious awareness is anchored not to the atoms and molecules of the brain, but to the free-flowing fields of energy coursing around and between those atoms as a spatial continuum.

Everything is Relative

We can never prove that inanimate matter has experience, all we know is that the matter and energy of which our complex brains are composed does have such experience, and therefore by an extension of the representative sample principle, we can say that if the tiny corner of the universe which *is* our mental “self”, which is the only piece of the universe that we can ever know what it is like to be, is indeed conscious of its own existence, then there would have to be compelling evidence to the contrary to suppose that our brains are the only thing in the universe that has this property of self-consciousness. What are the implications of this pan-experiential view? What difference does it make to our lives whether or not the universe around us is, like we ourselves, also aware of its own existence? Can the idea that the physical universe feels immense urges and passions finally offer some kind of meaning for our own lives? Does the pan-experientialist view provide the meaning that is so prominently lacking from the pure physicalist account of the universe? Can we read some kind of motivational right and wrong from the physical universe around us? The answer, unfortunately, seems to be no, at least as far as I can tell.

If physical matter and energy are conscious of their own existence, then we can get an insight into what it must feel like to be inanimate matter. The planet earth is held together by an immense love of matter for its own self. The innumerable billions of atoms of which the earth is composed coalesced from the myriad particles floating in this region of the galaxy some four and a half billion years ago. As they agglomerated into a larger mass, that mass began to feel emergent global forces that squeezed it into its spherical shape. To this day, the immense forces of compression due to gravity are opposed by the resistance of matter to being compressed. Every atom and molecule of the interior of the planet feels the squeeze due to the insistent pressure of its many adjacent neighbors, and it pushes back outward against that pressure, thus holding the entire sphere from collapsing in on itself. Radioactive decay in the core of the earth is caused by unstable atoms which were squeezed long ago into uncomfortable postures by the immense pressure within some long dead star, and they are only now unkinking their limbs and kicking out again into a more stable and comfortable posture. The innumerable kicks, each snapping like the release of a mouse trap, agitate the molecules in their neighborhood into intense thermal vibration, and that greater vibration increases the average spacing between molecules, reducing the density of the hot agitated substance. Those hot patches of magma near the core of the earth in turn create larger emergent flows of convection in the magma, releasing the bottled-up heat of the interior of the planet towards the surface where the earth's substance meets the boundless void. A scummy film of continental rock, made of lighter stuff than the igneous rock of the mantle, floats in patches on the surface of the planet like cream floating on hot coffee. Like the floating cream, the continents drift about, riding on the convective flows of the fluid

on which they float. At points in the surface where the convective currents converge to descend back to the depths, the floating continental slabs above them converge and collide, and their rocky mass rumbles and groans as they grind painfully past each other in a battle of forces of immense scale. We tiny creatures living on the thinnest film of biosphere infecting the outermost surface of the crust, occasionally “feel their pain” in the form of earthquakes that rattle our houses, and occasionally crush us to death. Should we care about the immense cataclysmic battle of forces that is happening beneath our feet? And if the grinding torment of the churning earth seems immense to a human scale, consider the immensely greater torment going on in the sun. Just as we ourselves are made of the substance of the universe, so too is the sun. Like ourselves, it is a larger global entity, a separate blob floating in the void, with a primal consciousness of its own spatial structure. The only difference between the awareness of inanimate matter and of brains is that the awareness of brains is *representational*, it represents something else beyond itself by mimicking the structure of that external entity in effigy in its own internal structure, whereas the awareness of inanimate matter is confined to a direct awareness of itself, and nothing beyond itself.

It is only by a kind of anthropocentric parochialism that humans are so intently concerned with finding life elsewhere in the universe, as if the many lifeless worlds in our own solar system and beyond were of little or no consequence except for their potential as a past or future home to life. The human brain is by no means the most complex organ in the universe. The planets venus, and Jupiter, and Saturn, with their violent and energetic convective motions of their atmospheres and geospheres, are immeasurably more complex, energetic, and consequential in than the tiny blobs of jellyish life squirming about in the thin biosphere on the surface of the earth. The convective gyrations of the material of those planets is not a random, chaotic, or meaningless motion, but is more like the meaningful writhing of a man nailed to a cross, urgently redistributing the painful heat of energetic thermal agitation from one part of the planet to another, creating globally structured patterns of motion at least as purposeful as the motions of an amoeba, but immensely more consequential and ponderous. If our own conscious awareness is mediated by standing waves of electrochemical resonance, the sun also sustains unspeakably immense energetic resonances through its bulk spherical structure. Fig. 12.1A shows one of the standing wave oscillations that have been measured in the sun, as it heaves in and out in enormous patterns of oscillation, ringing like a giant bell. Surely the sun must have some primal awareness of this immense pattern of vibration, even if it has neither memories nor aspirations, nor even a sense of itself as an entity in a surrounding void, but merely of the energetic patterns of vibration coursing through its spherical volume. The titanic magnetic storms that rage across the face of the sun must experience themselves somewhat like the formless chaotic thoughts in the mind of a man profoundly intoxicated. The sun too has urges and passions. It has a passion to contain itself gravitationally, pulling itself together by the love of its own substance for itself, balanced against an equal and opposite desire for outward expansion in response to the fiery reactions taking place within its core. The immense pressures and temperatures at the core of the sun are so extreme as to smash its component atoms together, as pairs of hydrogen atoms fuse into helium atoms in

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an atomic fusion reaction, and the energy released by this energetic union keeps the fires burning in the core of the sun that keep the sun inflated like a giant balloon.

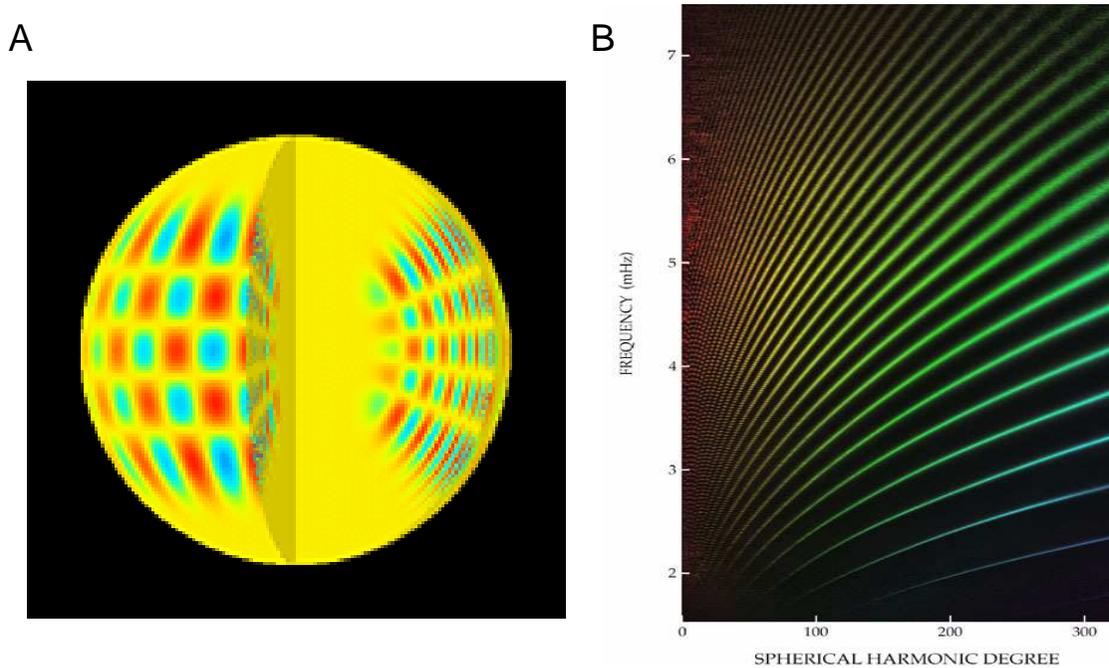


Fig. 12.1 A: Standing wave patterns in the volume of the sun, reflecting back and forth between the surface and deeper layers. This is just one of many standing waves simultaneously present in the vibrations of the sun. B: A plot of the zonal spectrum of vibrations measured on the surface of the sun by doppler imagery, showing the magnitude of “acoustical” resonance of the sun for every standing wave, or **p**-mode modulation. Every peak in B corresponds to a single standing wave pattern like the one in A.

The standing wave pattern in Fig. 12.1A is only one of hundreds or thousands of similar patterns with different spatial frequencies, all resonating simultaneously through the volume of the sun. Fig. 12.1B shows a zonal spectrum of the vibrations measured on the surface of the sun by doppler imagery, showing the magnitude of resonance of the sun for every discrete standing wave pattern (or **p**-mode modulation) through a range of frequencies. Every one of the discrete peaks or bright dots seen along the left edge of Fig. 12.1B corresponds to a single standing wave pattern like the one in Fig. 12.1A. These peaks are related to each other by harmonic relations, that is, they span the frequency dimension with a periodic array of peaks, like the notes of some gigantic celestial chord played by the great organ of the sun, blaring out into space like the trumpet of Gabriel.

What is our place in this cataclysmic battle of cosmic forces? Do we have a stake in this struggle? Does it serve any purpose for us to empathize with the tortured and agonized heaving of that immense God? The atoms and molecules of our bodies seem to think so. When we stand exposed to the sun, the energetic writhing of its component atoms is so intense, that even from a distance of 93 million miles the atoms of our body feel that distant pain, and writhe in sympathy with the agony of the sun, heating the tissues of our skin, and even breaking the

occasional chemical bond, breaking down the tissue of our body by direct exposure to the tortured sun. Like the electromagnetic storms that dance over the face of the sun, we as living creatures depend for our very existence on the continuing warmth and energy from this turbulent star. Our personal motivations are not only orthogonal to, but actually opposed to the objectives of the sun. It will be a tragic day for all life on earth when the sun finally accomplishes its objective of fusing most of its hydrogen into helium, and subsequently balloons out into a red giant large enough to swallow the earth in its orbit within its glowing body. All life on earth will be burnt to a cinder as the bulk of our planet gets absorbed into the material of the sun. Although the sun is immensely powerful and ponderously massive, and its immense torment is truly awesome to contemplate, the sun is nothing like the kinds of Gods that primitive peoples have invented in their mythologies. Although I can “worship” the sun by recognizing its fellowship as being composed of the same elemental substance as my own self, I also know that the sun remains unaware of, and totally indifferent to my existence. It is not capable of anything like the kind of representational thought that even a fly or a caterpillar can muster. The sun is a primal beast so primitive as to have virtually nothing in common with the kind of intelligence seen in living animals, even of the simplest sort. In fact, the causal processes within a physical system like the sun are so profoundly different from those in living brains and nervous systems as to have virtually nothing whatsoever in common with them except their both being causal structures. Neither is there any connection or parallel between the primitive incentives and motivations of the sun, and the incentives for survival, feeding, and mating, seen in living creatures. Our objectives are totally orthogonal to those of the inanimate entities in our physical environment.

The incongruity between the primal motives and motivations of inanimate and animate matter should hardly be surprising, considering the motivational incongruity even between different living creatures, whether of the same, or of different species. The feeding instincts of a predator are necessarily opposed to the survival instincts of its prey, as are the incentives of a parasite relative to those of its host. Even different individuals of the same species can have objectives which are diametrically opposed to each other. Men in mortal combat over some contested resource, or over a difference in political ideology, also have diametrically opposed motives and motivations. In fact, of values and motivations, one can truly say that *everything is relative*. Consider for example those values which humankind now generally considers to be unequivocally “good” or “evil”. We are all agreed, for example, that killing babies is intrinsically evil. But that was not always the case. There were many societies of the past in which killing babies was considered “good”, or at least not outright “bad”, whether it was the killing of babies of a competing tribe or race, or some kind of human sacrifice. Furthermore, humans as a species have many mortal enemies on the planet, most particularly other large predators at the top of the food chain, most of whom have already been driven to extinction by our global success, as well as our relatives among the great apes, chimpanzees and gorillas for instance, who would be in the best position to profit from the extinction of our particular species. For all of these competing species, the killing of human babies and adults alike would be “good”

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from their perspective. It is in this sense that an objective scientific world view appears totally devoid of objective meaning or of values in the moral sense of the word.

A Scientific Morality

Lest we descend into a kind of moral relativism in which there is no such thing as good nor evil, right or wrong, I should qualify my claim that all moral values are relative, with the proviso that they are relative only to one's objectives. For any given set of objectives, the morality, or more generally, the *logic* of attaining those objectives does become objectively clear. For example if we choose our objective to be physical survival, then it becomes objectively "bad" to engage in risky behaviors. If we choose an additional objective which is to have fun, or perhaps to accomplish some self-set mission or goal for our life, then the promise of any particular behavior towards that objective should be balanced against the risk to our survival, as might be computed using any of the well known statistical techniques to optimize such conflicting considerations. Once the objectives have been clearly defined, then morality becomes identically equal to logic or reason. It is only on the question of setting the prime objectives themselves that people come into irresolvable conflict. For example in the debate over abortion, the differences between "pro life" and "pro choice" camps stems from a different set of ultimate objectives, not a difference in logic or reason, and therefore logic and reason are useless in such debates. If one believes in God, and believes that God forbids the killing of any human life for whatever reason, then abortion must remain intrinsically evil no matter what the circumstances might be. If on the other hand one believes that people are simply animals without immortal souls, and that our civil laws should be designed to maximize our individual life, liberty, and pursuit of happiness, then the abortion issue becomes a pragmatic question of deciding whether the misery caused by the death of a neurologically primitive embryo outweighs the misery due to the birth of an unwanted child into the world. The founding fathers of the American republic had the wisdom to choose a legal basis that allows for the greatest diversity of views on these foundational moral issues. If we cannot objectively determine which viewpoint is more correct than which other, then let the law be formulated such as to allow all viewpoints simultaneously, at least to the point that one person's viewpoint does not impinge on the freedom of another person with a different view. It is ok, for example, to consider abortion to be a moral outrage and an abomination, and thus to avoid abortions in one's own life, and even to excoriate those who continue to perform them. But it is quite another to interfere with another person's equally firmly held conviction that abortion is not in fact evil, or to interfere with their freedom to engage in that practice for themselves if they so choose. If however one has a moral view that advocates the killing of those who engage in a practice of which one disapproves, that viewpoint is anathema to a diverse and tolerant society, and the holders of that view should be locked up and deprived of their freedom to act on those beliefs.

What of the morality of the tolerant diverse society itself? We naturally assume that tolerance for diversity is intrinsically "good" in and of itself, at least those of us who had the good fortune to be raised in an enlightened tolerant society. Is this really so? If Adolf Hitler and the Nazis had won the last great war, and if they had

ultimately come to rule the entire planet with their philosophy of totalitarian control, and if they had succeeded in the extinction of competing races and ideologies, then of course as victors, they would have been the authors of both the history, and the morality of those events. If “might is right”, then whichever political philosophy is the winner of the global struggle for survival *de facto* becomes the right and moral way. Are we again plunged into moral relativism? Is our system of tolerance and diversity only morally right due to the accident of history that we won the last great war? No. The reason that the enlightened western view has come to prominence is not because of the accident of history, but for the pragmatic reason that it is the way that has been found to work best. And the fact that it is the way that works best, is exactly the reason for its moral righteousness.

Although to a simplistic analysis, it may seem that exterminating people of other beliefs or races might seem advantageous to a dominant group (if they can get away with it), in fact social diversity, both racial as well as diversity of ideas, is as powerfully advantageous to a civilization as is biodiversity within any species, as well as biodiversity between species in a diversified ecosystem. Diversity lends flexibility and adaptability to changing circumstances. Biodiversity within a species is a defense against disease and parasites, by ensuring that not every individual will fall prey to a new virulent strain of disease. Biodiversity within a species is the very prerequisite for natural selection, the greater the diversity, the greater the potential for the species to adapt to changing circumstances. The giraffe could never have evolved its longer neck if individual giraffes did not naturally vary in the length of their necks. And so too does diversity serve the changing needs of society. During times of war and conflict, we need brave heroes who are mindless of their own personal safety, and who have the natural aggression and physical endurance that marks a good soldier. During times of peace and plenty, these brave heroes are no longer needed, nor are they revered, but rather their kind tends to be reviled by the peaceful bankers and brokers and accountants who thrive in more placid times. The warrior types sink back into quiet obscurity, desperately seeking gainful employment, at least until the outbreak of the next hostilities, at which time they are once more hailed and celebrated, and called on to save the nation against our enemies. Nobody can be sure in advance which traits of individuals, races, or ideologies, will ultimately turn out to be the best, so it is wise to hedge one's bets by pursuing all individuals, races, and ideologies in parallel, as long as they remain confined under the larger umbrella of tolerance for the diversity amongst them.

Although a simplistic analysis might suggest the superiority of a centralized totalitarian system of command and control, as opposed to the constant chaos and conflict inherent in a democratic and diversified ideology, history has shown again and again that totalitarianism suffers three fatal flaws: first, that it is hard to find a wise man to place in control of the totalitarian state. In fact, the very kinds of people who tend to rise to power in totalitarian states are exactly the worst kinds of people to be running those states. Secondly, even if a benevolent dictator could be found, it is impossible for one man at the top to understand all of the problems throughout the social hierarchy. A diversified capitalistic system has been found pragmatically to be more workable, wherein individuals at all levels of the hierarchical organization of society have the authority to exercise their judgement in their local domain, because a thousand heads solving a thousand local

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problems in parallel is more efficient than one head trying to solve them all from a distance. Thirdly, a dictatorship always raises the problem of succession when the leader dies, which typically leads to cataclysmic wars of succession that threaten to tear the state apart. If leadership is inherited in a well defined system of succession, passing power, for example, automatically to the eldest male heir, the long term result is an inbred dynasty whose descendents seem to become ever less fit for their ruling position, since they are never challenged to demonstrate their competency to anyone, except to occasional usurpers who challenge the succession in cataclysmic revolutions. A Darwinian competition between candidates for power, repeated at regular intervals as in democratic elections, is the most stable system yet devised for establishing the succession of leaders in an enlightened modern nation. As in the pursuit of knowledge, the best attitude of the governed to those that govern them is eternal skepticism, and regular elections serve to clear out the unscrupulous and the incompetents that inevitably converge on the corridors of power.

A simplistic analysis might suggest the efficiency of a slave economy, in which the workers do not need to be compensated beyond providing for their basic bodily needs. But history has shown again and again (not only in the most recent American experiment with slavery) that free men work harder and smarter than men who are driven by fear and compulsion, and that a symbiotic arrangement that profits both the employer and the employee equally is the more efficient organization. Besides, the more heavily a society relies on its slaves to take on ever more of the drudge work of the nation, the greater the probability of an insurrection, and thus the more resources must be spent on the unproductive tasks of coercive supervision, and recovery and punishment of runaway slaves. It is that pragmatic law which dictates the true evil of slavery and moral superiority of freedom.

Like the religions of the past, our systems of ethics and morality merely echo or reflect the pragmatic rules which have been discovered by trial and error to be the most successful, and the fact that they are successful is exactly what makes them morally right. It is fitting therefore that the etymological origin of the word "reason" is the French word "raison", meaning "correct" or "right", for moral rightness is indeed merely a manifestation of logic or reason, at least once a consensus has been attained on the ultimate goals which are sought by that reason. Just as a spring drives a clockwork which in turn provides the means for relieving the tension of that spring, so too does reason and logic serve as the optimal mechanism to most efficiently pursue the objectives set by the primal objectives of the culture and of the individual.

The Quest for Meaning

Whatever the ultimate fate of mankind, whether we eventually spread out across the universe, or simply destroy ourselves in our collective ignorance, one thing that has been consistently true throughout human history is that knowledge has always been *good*. Knowledge has helped us read the heavens to understand the seasons, and knowledge of plants and seeds has helped us cultivate crops for our survival. Knowledge of materials and of technology has given us weapons and tools. With our tools we have reaped our crops, and built shelters for ourselves

and for storage of our crops, which has made us ever more independent of our physical environment. With our weapons we have challenged each other in endless wars of mortal conflict, and those wars have sharpened our wits, and accelerated the growth of our intelligence. Knowledge of numbers and of science and chemistry have given us the modern world, and knowledge of the principles of human organization have given us modern government, education, and industry. The evidence that knowledge is good is so compelling that in my personal philosophy I have adopted knowledge as an end in and of itself. I believe that knowledge is *good*. This is admittedly an article of faith, like any dogma or religious creed. I believe it to be true, because it seems so to me, and I don't expect anyone else to adopt this faith unless they feel spiritually moved to do so. I call my faith *scientism*, to contrast it with science itself. Science is by definition devoid of any kind of value or objective. Science can help us answer any question we might pose, but it is silent on the issue of which questions are important to have answered. The addition of a value judgement even to science itself perverts science to a religion, and thus makes it no longer science as such. Scientism is therefore unabashedly a religious faith, a faith that declares science as the highest value, because science and discovered knowledge are the straightest path toward the truth, and the knowledge of truth is what I believe to be good. Unlike other religious faiths, Scientism does not require a belief in any incredible fantasies such as immaterial spirits and life after death; in fact it explicitly excludes them, at least until such time that those entities can be demonstrated to exist as scientifically verifiable facts.

Our personal experience of this world is something like the experience of waking up in a strange place and momentarily not knowing where we are, or how we got here, or perhaps even who or what we are. Collectively as a species we are still in the earliest stages of this awakening. Having recently survived the most desperate and destructive series of endless wars amongst ourselves, we are just beginning to discover ways to interact with each other that do not involve mass slaughter with ever deadlier and more horrible weapons. Having been locked for countless millennia in a desperate struggle for survival against war, famine, and pestilence, we are now for the first time experiencing collectively the material success that is the reward of a rational scientific approach to the problems that face mankind. That material success has given us the leisure to spend time contemplating the larger issues of the world we find ourselves in. I have not personally found an objective answer to the quest for meaning in this universe. I cannot say that living matter, or intelligent life is objectively any more meaningful or "good" than the chaotic paroxysms of the inanimate matter of stars and planets as they hurtle endlessly through the vast emptiness of the cosmos. But like the waking man, I know one thing, and that is that we need to gather more knowledge before we can come to any firm conclusions about the larger questions of our existence and of our ultimate objectives. I believe that knowledge is good, and it is in the pursuit of knowledge that I present this phenomenological epistemology.

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