CHAPTER 16

PHYSIOLOGICAL CONSEQUENCES OF THE RELATIVITY OF PERCEPTION

PERCEPTION OF THE STATES OF MATTER: A PERSONAL REMINISCENCE

The problem, as I perceived it, was how to introduce the abstract philosophical ideas of an eighteenth century philosopher into the scientific laboratories of the twentieth century. In particular, how did the anatomy and physiology of sensory perception reflect the Berkeleian notions of the relativity of existence? I did not query *whether* they did, only *how* they did. Somehow, the organism invests the world about it with the property of existence since, if there are no perceiving organisms, there is no world (using the second of Philonous' states of existence and leaving God out of our equations). What constraints does this biocentric view place on the organs which mediate the process of perception? I was not successful in publishing my earliest thoughts on this subject (1965) until nearly two decades later.

The first paper on relative perception that I succeeded in having published (in 1972) was a somewhat truncated form of my 1965 effort, and was entitled "The tactile discrimination of complex systems." In this paper, the idea of "sensory receptor" is replaced by the idea of "sensory system," for purposes of exploring how the states of matter are perceived. What anatomical-physiological system is required in order to perceive by tactile means the states of solidity, liquidity and elasticity?

In order to perceive by tactile means whether an object is solid, it was argued, a human perceiver will prod the object with her / his fingertip, pressing the object at first gently and then more firmly. When the object is pressed gently, and found not to yield to digital pressure, can the perceiver conclude that the object is solid? It would depend on his or her personal definition of "solidity," but generally, the answer would be no. A gel, for example, might not yield to very gentle digital pressure, but would not qualify for classification as a solid. If the substance being explored for solidity, such as my desk top as I write these words, does not yield under much firmer digital pressure, it will qualify as a solid. Now, as one presses firmly on the solid surface with her / his fingertip, there is compression of the tissues in the fingertip. Skin, subcutaneous tissue, and blood vessels are compressed until the solid object is placed in close apposition to the terminal phalanx (bone) of the finger. It would seem that we perceive solidity of state only when we invoke the solid tissue of the body. The tactile discrimination of the state of solidity is made only when the external object and the solid elements of the perceiving system are made contiguous. In brief, we need a solid to perceive a solid. Or, turning the matter around to express it from a biocentric point of view, we invest the world with the property of solidness only by possessing the anatomical property of solidness. By extrapolation, we might state that one can never perceive a degree of hardness in excess of the hardness of bone in the finger (cf Mohs' scale of hardness). It might also be argued that organisms without solid elements in their bodies cannot be capable of perceiving, by tactile means, the state of solidity.

Similar considerations can be extended to the tactile perception of the state of liquidity. Consider the experiment of Meissner (cited by Ruch and Fulton, 1960, p. 314), where the finger is immersed into a vessel of mercury. Meissner showed that the sense of pressure does not issue from the submerged portions of the finger, but only at the interface between air and mercury. Now, where the finger is immersed in the liquid mercury, the immersed portion is compressed and, presumably, the volume of the immersed part is reduced. The reduction in volume will occur because blood and possibly interstitial fluid will be displaced proximally within the digit (that is, in a direction away from the tip). At the boundary between the submerged and non-submerged portions of the digit, tissue is deformed slightly, which activates the mechanoreceptors. The point of this discussion is that when the perceptual apparatus is regarded as a *system*, of which the mechanoreceptors are only one part, it may be seen that the liquid elements of the fingertip must "interact" with the liquid (mercury) in order to enable the perception of the state of liquidity. A slightly more extensive argument is provided in the original paper.

In similar fashion, one might expect that only by virtue of elastic elements, such as found in muscle tendons, can one perceive the property of elasticity as found, say, in an elastic band. And, although it is not a state of matter, to perceive the magnitude of a force, one must oppose the force with a force of equal and opposite magnitude, as required by Newton's third law.

The above examples do not define a perceptual principle "crisply." Rather, they are suggestive. They suggest that not only the sensory receptor with its neural connections, but a host of other anatomical components as well, all play critical roles in the perception of the states of matter. They suggest that we deal with an entire perceptual system, rather that just with a sensory receptor. The term *perceptual unit* has already been introduced (Chapter 13), and we come to use the term to mean *the smallest and simplest configuration of anatomical structures required to mediate the process of perception in some modality*. We see even at this stage, that the perceptual unit comprises more than just the receptor-neuron complex, since bone and even blood play their part in perception of the states of matter. The composition of the perceptual unit will depend on exactly what is meant by a "modality"; for example, does the perception of the solid state qualify as a modality?

However, the states of matter examples, I think, convey a more profound message. They demonstrate, albeit in a rudimentary way, a manner in which the perceived world exists "relative to" the perceiving organism. We can say, as above, that only by the interplay of solid tissue with solid matter can solid matter be perceived. Or, we can say that solid matter can only exist *relative to* the perceiving organism if the latter is constructed of solid elements. However, this idea cannot be pushed too far in its present, elementary state. Can we not, as human beings, perceive, or "gain mental apprehension of"[1] infrared radiation, even though we cannot see it directly with our eyes? Can we not, using machines, gain apprehension of the hardness of materials that exceeds the hardness of our own tissues? Does "perception" mean only mental apprehension by direct exposure? And what does "direct" mean? More questions than answers. For me, however, these states of matter examples served just to convey a sense of reciprocity between the perceiver and the perceived, and were only a first glimmer of the required anatomical-physiological mandate for Berkeleian perceptual relativity.

I must mention that this idea of reciprocity probably predates Berkeley, and is found, embryonically, in the works of the philosopher Baruch Spinoza (1632-1677). Wrote Spinoza in *The Ethics*, Part II, Proposition XVI, Corollary II: "It follows, secondly, that *the ideas*, *which we have of external bodies*, *indicate rather the constitution of our own body* than the nature of external bodies. I have amply illustrated this in the Appendix to Part I." (My italics)

For the sake of completeness, I refer the reader also to the book by G. Spencer Brown (1969) entitled "Laws of Form." Much have I travailed with this book in an effort to determine whether the author renders into mathematical form some of the ideas of the reciprocity between perceiver and perceived that have been introduced in the states of matter examples. There is always a tendency for the undirected reader to rush foremost into the least mathematical chapters of a book (as I fear people will do to the current chapter of my own book). This tendency should be resisted, because the sense of comprehension that may be engendered by such activity is specious. So I recommend that only after paying one's dues by studying Spencer Brown's calculus in the early chapters of the book, particular attention be paid to Chapter 12, and especially his "fourth experiment." Note also his Introduction, p. xvii.

The reader is also referred to the paper on active touch by J. J. Gibson (1962).

ORIGIN OF THE ENTROPY THEORY

The states of matter argument was suggestive of the manner in which Berkeleian relativity of perception interfaced with biology, but it did not suggest to me a mathematical formalism by which one might proceed. If neuronal activity was the language spoken by sensory receptor to brain, then afferent neuronal language must, I felt, be the scientific language of Berkeleian philosophy. If that were the case, though, afferent neuronal language (say neural impulse frequency) must, in some way, express the relativity of the perceived world to the perceptual unit. Such a state of relativity might be true at a trivial level, in that different sensory receptors may be in different states of adaptation, and their respective afferents firing at different rates accordingly, but I was seeking a connection that was a little more profound.

Some year passed as I reviewed one scheme after another for importing the property of "relativity" to afferent neurons. Mathematical models came cheaply, but those models that "went through" could not be purchased. That is, the early models did not breathe life into the study of perception. The realization that information theory came off the shelf, fully equipped with a relative component took rather a long time to crystallize in my mind. When dealing with discrete variables, the entropy, H, is a function of the *a priori* probabilities, p_i, in accordance with Equation (2.1). Thus, different perceivers with different values for these *a priori* probabilities would obtain different amounts of information by perceiving the outcome of an event. You may recall the example from Chapter 2 (Information: Defined) about the biased coin that would fall heads 2/3 of the time. The perceiver who was aware of the bias received less information from the outcome of the toss of this coin than the perceiver who believed that the coin was a fair one. So information received was relative to the assumed set of probabilities, p_i.

If information theory were the mathematical medium by which Berkeleian relativity was to be linked to the biological process of perceiving, then the "relative" variable, information, must be carried by the afferent neuron, which relays sensory messages to the brain. Designating the neuronal firing rate by F (which is how the letter F came originally to be selected), it was then necessary that F be a mathematical function of H. I selected the linear function as the simplest functional dependence. Hence, $F = kH$.

It remained for H to be modeled. In the discrete case (which is not too realistic in the macroscopic biological world), it would be necessary for H to be a function of the *a priori* probabilities, p_i (see next section). In the continuous case, H must be a function of the two probability densities, p_S and p_N (for pure signal and noise, respectively). The relative nature of perception, and hence the full weight of Berkeley's philosophy, falls on these probability densities. The manner in which these probability densities have been treated should now be well known to the reader, who has studied the earlier chapters. The resulting model has enjoyed, I think, some success in the analysis of experimental data. However – and this is where our current interest lies – any factor that affects these probabilities, be it physical, emotional, pathological, will affect the neural response to external stimuli, and, therefore, will determine the mind's sensory picture of the world.

It must be noted here that information theory, in the manner we have used it, is *a* theory compatible with the fundamental Berkeleian attitude of perceptual relativity, although, admittedly, it does not encompass all details of Berkeley's philosophy. However, information theory is not necessarily *the only* theory capable of mediating Berkeley's ideas. The entropy theory is *A* mathematical theory of perception.

We might look back now and make a somewhat more educated study of Chapter 9 (The Sensory Neuron as Metachannel) and of Figure 9.2. The so-called external world ("so-called" because we can only infer its existence by activity of the mind) provides a *message* that is received by the sensory receptors. However, the neuronal report to the brain is a *metamessage*, which is a message about a message, detailing only the uncertainty of the receptor + neuron about the state of the world. The mind constructs an idealistic world analogous to the idealistic (substance-free) world of Berkeley. The mind depends for its existence on the integrity of the perceptual unit, a concept which we shall continue to build, but the reader is cautioned not to expect miracles here. However, the mind, which is the end-point in the perceptual process (cf Von Neumann and the collapse of the wave function), seems forever separated from the "objective" world, which it (the mind) creates for itself out of building-blocks which are just metastatements.

Wasn't it a lot easier just manipulating equations for simple reaction time, sensory adaptation and the like?

I am afraid to push on too far in this vein lest the reader think that this is a treatise on metaphysics, which was never intended. I am just trying to indicate the intimate relationship that subsists, connecting Berkeleian philosophy with our mathematical theory of perception, and the rather subjective nature of the world that accompanies the theory. Admittedly, we have dealt only with a rather limited range of perceptual phenomena: the sensation of stimuli of the intensity type. Nonetheless, having replaced the objective by the subjective, we should now be prepared for certain consequent changes in scientific world-view that may not be completely in accord with our previous notions of "common sense." For example, what meaning can be assigned to the existence of the universe prior to the emergence of percipient agencies?

The primary purpose of this section was to demonstrate the lineage of $F = kH$ from Berkeley's philosophy "to be is to be perceived." However, we have also seen how the $F = kH$ concept relates closely to Boltzmann's $S = -k_b H_b$ (Table 15.1), and how smoothly the H-concept merges with the quantum mechanical view of collapsing the wave function (Chapter 2). $F = kH$ thus provides a degree of unification of various branches of science.

That is,
Berkeley's relativity of perception → $F = kH \rightarrow S = -k_b H_b$:
the slender strand alluded to at the end of the previous chapter.

GENERATION OF SIGNALS BY THE PERCEPTUAL UNIT: THE DISCRETE MODEL

We recall from Chapter 2 ("The Gist of the Entropic Theory of Perception") the example of a perceiver who perceives only discrete stimuli. This model was not, of course, meant to be taken too seriously, but it served as introduction to the continuous model, which we have developed throughout the book. Let us now pick up the simple, discrete model again, as a means of exploring a problem of some epistemological concern.

Consider the hypothetical case of an organism which can perceive only stimuli of some modality that have the discrete intensities I_1, I_2, ..., I_q, and that these q intensities occur with *a priori* probabilities p_1, p_2, ..., p_q, respectively. We suppose, further, that information transmission is noise-free, and hence that each stimulus intensity gives rise to a single response (not a range of responses as in the discrete model studied in Chapter 2, note 6). The organism's perceptual H-function is then given by

$$H = -\sum_{i=1}^{q} p_i \log p_i \,, \qquad (16.1)$$

and its perceptual variable is, as usual,

$$F = kH \,, \qquad (16.2)$$

where $H = H(p_i)$. The "psychophysical law" has degenerated, since (as long as the p_i remain constant) regardless of the physical intensity of the stimulus, the expectation of exactly q intensities gives rise to the same value of the H-function, using Equation (16.1) and, therefore, to the same value of F. That is, in this strange organism, all stimuli seem, subjectively, equally intense. The F-value is controlled, however, by q, the total number of discrete intensities within the organism's sensorium. The adaptation function has also degenerated to a delta function, or perhaps to a step function; perception occurs abruptly with the identification of one stimulus from among q possibilities. Subjectively, the perceiver apprehends a sudden flash of invariant intensity, which then adapts to zero instantaneously. Although the above may seem somewhat unrealistic, the entropic principle governed by $F = kH$ still remains: magnitude of the perceptual variable is proportional to the entropy or uncertainty, H, which is, in turn, a function of the *a priori* probabilities, p_i.

We note that while all stimuli will seem equally intense subjectively for a constant set of p_i-values, the subjective magnitude will change if the values of p_i are changed.

The trappings of the H-function (which constitute the basis for the extensive experimental testing that occupied five chapters of the book) have now been stripped off completely, to permit examination of the bare epistemological core. Given the probability set, p_i, the organism receives a fixed quantity of information, H, from each percept. But how did the organism obtain values for the probabilities, p_i, in the first place? Or, expressed in another way, *How is it determined how much information the organism should receive by perceiving each stimulus*?

(i) One answer to this question is that Nature Provides. That is, just as natural forces have, somehow, produced the organism including its sensory receptors, Nature (defined as some agency external to the perceptual unit) will also instill into these receptors values for its *a priori* probabilities, thus fixing the information content of each percept.

There is nothing really wrong with this answer from a mathematical point of view. The problem centers around the physical meaning of the H-function. If it is regarded purely as a mathematical function, in accordance with which a receptor-neuron complex operates, then all goes well. If, however, the H-function signifies the magnitude of the quality which human beings call "uncertainty," then the mere installation of the p_i-values by Nature, like the setting of a series of switches, will not do. If Nature is setting the switches, then Nature understands the distribution of p_i-values; Nature is uncertain; and Nature forms part of the perceptual unit, which is a contradiction.[2]

But all this is highly metaphysical. I concede that (i) will do the job. However, I am not content with it. I do not regard Nature (i.e. some agency outside of the perceptual unit) as playing an explicit role in each act of perception.

(ii) A second answer to the question above in italics, and the one that I favor, is that Nature stays out of the process of perception, and that the values for p_i are, somehow, *self-instilled* into the perceptual unit. Since they are established by the unit itself, the unit itself is the "uncertain agency."

The reader may object that I am unreasonably and spuriously anthropomorphizing the perceptual unit; that people and animals can become uncertain, but not a set of neurons and receptors. My reply is that "the buck stops here." No longer are we at liberty to relegate the seat of human mental states upwards, to higher and higher cerebral centers that must remain, because of their inherent complexity, unlocalized and undefined. We seek here the smallest anatomical-physiological unit capable of *autonomously* expressing the human state of uncertainty.

So we seek, but can we find?

The perceptual unit itself, without aid from an external agency, must be capable of changing the values of the p_i (subject, of course, to the normalization constraint that the sum of p_i must equal unity), thereby altering the amount of information received from each percept, and changing the subjective apprehension, F, of the perceptual event. Here, again, is a reflection of Berkeleian relativity of perception to the perceiver, and a denial of absolute quantities (such as the amount of information) in the perceived entity.

How, then, does the perceptual unit determine the set of values for p_i that will generate the "correct" information content of each stimulus? I submit that, at least for this hypothesized organism, there is no correct value for information content, but rather, the unit sets the values of p_i to produce a value for information content that is consistent with the unit's own model of the world. The process is much the same as setting values for p_1 and p_2 for a coin, values that are consistent with the perceiver's model of the coin (fair coin, 2/3 and 1/3 biased coin, etc.)

If the perceptual unit does set its own probabilities relative to its own expectation or model of the world, how does it carry out this process? This question, of course, leads us to the mechanism of sensation, which is a subject that has been studiously avoided hitherto. However, without entering deeply into the problem, we can still say that the adjustment will be carried out by either digital or analog means. A digital adjustment would imply, again, a process of switch-setting in order to fix the unit's computational device to the proper probability settings. I regard this as an unlikely mechanism, although not impossible. For reasons whose basis may become clearer in the next section, I favor an analog method for setting the *a priori* probabilities. I suggest that the perceptual unit actively generates signals of the modality in question in accordance with its own, intrinsic, view or model of the world; and that this self-generation process is carried out in such a manner that the signals serve as stimuli that can be detected and perceived by the same perceptual unit. That is, if, in the world model of the perceptual unit, signals of intensity, I_1, occur 100 p_1% of the time, signals of intensity, I_2, occur 100 p_2% of the time, ..., signals of intensity, I_q, occur p_q% of the time, the unit will generate signals with intensities at these frequencies. Since the self-generated signals are then detected and perceived by the unit, each signal or stimulus will "transmit" information determined by $H(p_i)$, and will produce the subjective sensory effect, $F(p_i)$. The subjective magnitude, $F(p_i)$, is then consistent with the world-model of the perceptual unit. When externally produced stimuli are then perceived, their subjective magnitude (always the same value in this model) is matched to the number and probability of internal stimuli. The cycle is then complete, and the organism perceives intensities that are consistent with its own model of the external world, a world which it can never know "objectively."

The shadow of Berkeley.

I suggest (and I recognize that this view is not traditional) that if the external signal were not a member of the recognized stimulus set, $I_1, ..., I_q$, it would not be perceived by the organism. It must be suspected to be perceived. To perceive is to doubt. In this model of perception, doubt or suspicion or *interrogation* of the world is carried out by means of self-generated signals.

The reader may now understand my partiality towards the model of D.M. MacKay (Chapter 10, "Other Endeavors ..."), which uses a matching model with elements similar to the one above as a means of equating Fechner's and Stevens' laws. The analog model above is also reminiscent of models suggested by Hochberg (1970), and Neisser (1976, "The Perceptual Cycle").

The sequence of perception in view (i) above consists of two phases. In the first phase, Nature sets the switches, in some fashion, to provide values for the probabilities, p_i. In the second phase, the stimulus is perceived at subjective level, F, established in accordance with Nature's p_i-values.

The sequence of perception in view (ii) above also consists of two interrelated phases, which I shall call the *active phase* and the *passive phase* (Norwich 1982). The active phase consists of the setting up of uncertainty; for example, the generation of an internal signal by the perceptual unit for purposes of fixing the p_i-values. This phase may be thought of as a *calibrating* or *tuning* phase. The passive phase consists of the resolution of the uncertainty introduced by the active phase through apprehension of an external stimulus, with the consequent production of the perceptual response of magnitude, F. In a manner of speaking, the active phase asks a question, and the passive phase provides the answer. The active phase is interrogative; the passive phase is assertive.

Although the concept of self-generated signals or stimuli has been introduced here by means of an example of an organism that perceives only discrete intensities and whose sensory processes operate strictly on an $F = kH$ basis, I believe the general idea of self-generated stimuli can be approached by a number of avenues of thought (see, for example, Norwich, 1982, 1983, 1984). We shall approach it by still another avenue in the next section. I also believe that any physiological model of perception predicated upon the general concept of Berkeleian perceptual relativity will contain elements by which the perceiving system determines actively, to an extent, what it will perceive in the "outside world."[3]

GENERATION OF SIGNALS BY THE PERCEPTUAL UNIT: THE CONTINUOUS MODEL

In the continuous model developed in Chapter 9, the stimulus signal is regarded as a continuous variable, and discrete probability functions are replaced by probability density functions. Uncertainty about discrete stimulus values was replaced by uncertainty about the mean stimulus intensity. In order to calculate H using Equation (9.19), we no longer required a set of *a priori* probabilities, or even knowledge of a specific probability density function. The process of sampling the continuum, analyzed by means of the central limit theorem, seemed to provide a value of signal variance, which was all we needed in order to calculate the H-function, and, hence, the value of F. Have we, therefore, escaped from the need for active participation by the perceiving system? I think not.

We recall from Equations (9.18) and (9.19) that

$$\beta = \beta' / \sigma_R^2 , \qquad \beta' \text{ constant } > 0 , \tag{16.3}$$

so that

$$H = \tfrac{1}{2} \ln[1 + (\beta' / \sigma_R^2) I^n / t] . \qquad (9.18)\,/\,(16.4)$$

That is, the value of H depends on the value of σ_R^2, which is the variance of a reference signal. This reference signal played the part of noise in the context of communications theory. We have seen in Chapter 7 and in Figure 7.1 the necessity of introducing a reference signal if one wishes to calculate the amount of information transmitted by a continuous signal. Therefore, σ_R^2 is a necessary part of the perceptual entropy equation.

I have made various attempts to calculate the order of magnitude of σ_R^2, from available data but none of the attempts is satisfactory. So I can take the reader no further in this direction. In principle, however, σ_R^2 may be much smaller than σ_S^2; that is, the reference signal may be very much less intense than the external signal.

As we discovered in our explorations in Chapter 9, these reference signals arise, not in the "outside world," but rather within the system that *measures* the external signal, and a function of the reference signal is to limit or restrict the amount of information that can be obtained from the external signal. They may be real signals, or just an obfuscating, calibrating, or information-limiting effect. However, both in source (internal) and in function (calibrating), these reference signals are similar to the hypothesized signals that were generated by the perceptual unit of the organism that perceived only discrete stimulus intensities. Hence we should be aware – and perhaps I am not emphasizing it sufficiently – that whenever we use the fundamental Equation (9.20),

$$F = \tfrac{1}{2}k\ln(1 + \beta I^n/t)\ ,$$

we are representing the perceptual variable, F, as a function of the perceiver-dependent variable, β. In principle, any alteration of the value of β (which contains σ_R^2) by the perceiver will alter the sensory impressions that the perceiver obtains from the "outside world." If $\beta(\sigma_R^2)$ is adjusted by the perceptual system using the process of generating real signals, then the magnitude of sensation of external stimuli is, likewise, governed by these self-generated signals. Therefore, one can reason either from the overly simplified model of an organism that perceives only discrete signals, or using a somewhat more realistic model of an organism that can perceive continuously distributed signals, and, in either case, find some logical support for the existence of internally generated stimulus signals.

I would posit, therefore, that all perceptual units actively generate signals of the type which they perceive (Figure 16.1); that the interaction between the self-generated signal and the external signal is, in part, responsible for the phenomenon of "awareness" that we associate, *by definition*, with the perceptual unit. That is, to be conscious of an environmental stimulus implies that the perceiver is challenging its environment with a similar stimulus. We have noted that a perceiver must generate a force to perceive a force; that a solid element in the digit seems necessary to perceive the solid state, and so on, for other states of matter. I would extend this principle to include the sense of hearing: the auditory perceptual unit must generate audible sound if it is to perceive sound. And I would extend it to include the sense of vision: the visual perceptual unit must generate visible light if it is to perceive light signals. But shall I write "et cetera"? Does the olfactory perceptual unit generate perceptible odor? Does the gustatory unit generate tastable elements? These ideas are certainly at variance with current physiological thought.

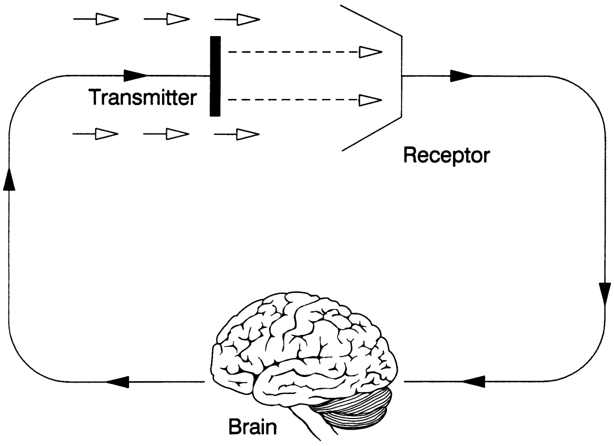

Figure 16.1 Hypothesized active and passive phases of perception (self-generated and externally generated stimuli respectively).
Active: Self-generated stimuli are issued in response to efferent neuronal signals originating (probably) in the brain, and innervating internal (physiological) transmitters (open arrowheads with dotted shafts). Passive: External stimuli arrive from the outside world (open arrowheads with solid shafts). Both types of stimuli are received by the sensory receptors. Solid arrowheads designate neuronal pathways.

In 1965 I submitted a paper to three journals, sequentially. In this paper I put forward ideas quite similar to those expressed in the latter paragraph, although argued from a more philosophical viewpoint. The paper was rejected by all three journals. Prediction from purely theoretical arguments was simply not accepted. Wrote one referee "There is absolutely no *evidence* that the retina generates light or that the ear generates sound" (my italics).

However, the years rolled by, and microphones of very small dimensions were produced and placed in the ear canals of human subjects. In 1981, P.M. Zurek[†] reported in the Journal of the Acoustical Society of America "One typically does not think of the human ear as a sound-producing organ. It came as no small surprise, therefore, when a miniature probe microphone placed in my right ear canal registered a continuous narrow-band signal of nearly-constant amplitude." So, it transpired that the ear really *does* generate sound. Interestingly, the mechanism for these emissions may have been predicted by T. Gold in 1948.

Were these emissions of sound from the ear – issuing, it turned out, from the cochlea – the self-generated stimuli required by the entropy theory of perception? I re-submitted the paper, modernized somewhat, but with its Berkeleian profile kept judiciously low, to the Journal of Theoretical Biology, one of three journals to have rejected it originally, and the only one in which the editor of 1965 was still in place. By decision of the editor, the late Dr. James Danielli, the paper was finally published, some 18 years after its original submission.[4]

So the ear does generate sound, but does the eye generate light (Norwich, 1984)? The idea that light may issue from the eye (*extramission*) can be traced back at least as far as Alcmaeon of Croton in the 5th century BCE (Lindberg, 1976). Plato, and possibly Empedocles, utilized this concept in their theories of vision. Plato's concept of visual perception seems to involve rays of light both entering and emanating from the eye. The *Timaeus* of Plato, with translation and commentary by F. M. Cornford (1937, sections 45B-46A), gives a clear account of Plato's views. However, the reasoning of the philosophers of old was quite different from our reasoning within the entropy theory.

In 1879, Fick, a physiologist, suggested that human vision toward the infrared end of the spectrum may be affected by thermal radiation issuing from the eye itself. Later reference to Planck's black-body radiation equation, however, cooled such speculation, showing that infrared effects would be minimal. In modern times, the idea of spontaneous excitation of rods within the retina has been lent some credence. The term *dark light* has been used to refer to this sort of endogenous excitation, which seems to be regarded as a type of noise (Pirenne and Marriott, 1959).

No experimental evidence of which I am aware supports the conjecture that the visual perceptual system (not necessarily the retina) generates light actively in a systematic way *as a necessary part of the visual process*. Various vision researchers have assured me that no such activity takes place as a regular part of the physiological process of vision. Still, I believe that it does and I let the conjecture stand.

NOTES

1. See definition of *perception* in Chapter 2.

2. One cannot but think of Equation (6.21), $S = k_b \ln W$, where W is the number of microstates and S is physical entropy. Is S simply a mathematical consequence of W, or, since $\ln W$ is a measure of human uncertainty, is S, somehow, dependent on human uncertainty? Most physicists, I suspect, would take the former attitude, preserving pure objectivity in physics.

3. I feel obliged to keep putting the adjective *outside* in quotation marks, because if perception is truly relative, the outside world and inside world are not obviously distinct. The outside world, or *object-language* is a model created by our minds, which speak only in *meta-language* (pages 16-7).

4. Please see the footnote on the first page of the 1983 paper in the Journal of Theoretical Biology, 1983, **102**, p 175.

†. (2003 ed. note) I seem, again, to have failed to cite the real discoverer (see Note † of Chapter 3). Although Zurek did report on otoacoustical emissions in 1981, the discoverer was D.T. Kemp: "Simulated acoustic emissions from within the human auditory system", *Journal of the Acoustical Society of America,* 64, 1386-1391, 1978.

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