GENERAL SYSTEMS
Volume XVIII, 1973

ON THE NEUROPHYSIOLOGICAL BASIS OF WAR*

A. S. Iberall

INTRODUCTION

Aggressive behavior and human warfare have been topics for technical discussion for some time. The subject passed with serious scientific concern across the minds of at least three of the great modern innovators — Marx, Darwin, and Freud. However, it went firmly on the scientific agenda with Dart's discovery of bashed-in baboon skulls associated with australopithecine remains and his suggestion that this represents an illustration of the ancient and primary nature of aggression in man. With no attempt at exhaustiveness, the names of some of the more recent contributors to the problem and the literature they have produced may be found in McCarthy, et al. (1964), Lorenz (1966), Fried, et al. (1968), Montagu (1968, 1969), Scott (1969), and Alland (1972). In particular, we wish to reform the views of Monod (1971), Scott (1969), and Alland (1972), which some will find apparently in opposition, to provide a new biophysical hypothesis for human warfare. The physical basis for such a hypothesis may be extracted from Iberall (1972).

Monod. Monod's view is that selection pressure on the upright australopithecines forced articulate symbolization and then, from emergent language, human culture. Beyond coordination and representation in this new primate's cortex, a cognitive frame of reference was coded for, in which internal simulation and programming were possible. A program for learning thus became man's genetic heritage.

Simulation and language made man master of his domain. This created further pressure toward group behavior. But, having mastered his environment, man's own species became his only adversary. Tribal warfare has become the important evolutionary factor.

Scott. Scott has been quite influential in ethological circles in providing a classification for behavioral modalities (for example, see Scott 1962). His view (1969) is that group fighting, part of agonistic behavior, is rare among animals. At most, it is reported among only two phyla—arthropods and vertebrates. He points out that much of agonistic behavior is ritualistic. In many species in which dominant-subordinate behavior exists, once the social order is established, threat and avoidance substitute for fighting. Finally, in mammals, in the great majority of cases wherein agonistic behavior is a prominent part of social organization, it is confined to fighting among individuals. But this, he points out, is definitely not the case in human warfare. He examines various primate species as models for human precultural social life and essentially finds no general evolutionary tendency toward group warfare in other than humans. (Other authors do not find any particularly convincing evidence for organized aggressive activities before the Upper Pleistocene, i.e., before H. Sapiens Neanderthalis and H. Sapiens Sapiens.—Author's note.)

In military organization, Scott believes that a major motivational system is allelomimetic (acting like the rest of the group) as well as agonistic. He finally opts for the thesis that a major cause of destructive fighting, when it occurs in animal societies, is social disorganization. In humans, at the age of late male adolescence, there is a period almost a decade long following the youth's taking leave of the primary family and prior to his establishing a new one. This age is marked by high violence. While this period of disorganization of social participation does not directly make for warfare, it can be organized by providing some kind of external threat.

Alland. Alland reacts to biological determinism, in particular, using Ardrey, Lorenz, and Morris as symbolic spokesmen, by a reductio ad absurdum of their reductionist theory. If human nature is to blame for warfare and violence, there can be no human responsibility, and all calls for social action are useless. He takes up specific challenges and refutations of competition, aggression, and territoriality as human "instincts." Man is an open social animal with potential for both aggressive and cooperative behavior. Which behavior emerges depends largely on the nature of society.

We do not wish to use Alland as a straw man, but an instinct theory of behavior is not accepted by very many thoughtful reductionists, and the branching character of evolutionary behavior is not bound to a genetic code. Instead, it emerges epigenetically in response to its surrounding milieu (Yates, et al. 1972), society being one of the major "solvents" for human behavior.

We propose to reconcile these views by a more embracing thesis.

THESIS

"Purpose" or "goals" emerges in a system from the properties related to its underlying atom-

*This report was developed out of work supported by contract with the U. S. Army Manpower Resources Research and Development Center, which is gratefully acknowledged.

istic associations. Monod (1971) expressed the theme for the genetic code; Iberall (1971a) expressed it for social behavior. Iberall identified goals as the emergent properties that stem from the dynamic equations of change for a system (e.g., the hydrodynamic equations of change). The equations of change are associated with the summational invariants of an ensemble of the underlying atomistic entities which comprise the system. In Monod's illustration, the atomistic entities are the molecules that make up stereo-specific molecular ensembles in the genetic code. In Iberall's illustration, the atomistic entities first comprised the cellular ensembles that make up the brain; second, the individuals that make up human society which are associated with the summational invariants. While many readers may consider such language to be jargon and semantic juggling, nevertheless, there is a new movement afoot to establish laws of societies of all sorts on a common statistical thermodynamical foundation. See, for example, Gal-Or (1972) and references therein.

It is clear that there are social animals, and in fact some crude construct is possible to account for the more primitive aspects of a unified sociobiology (see, for example, Wilson 1972). However, our concern is with the higher species, primates in particular. It is clear that a dominant-subordinate male leadership relationship is quite commonly established in many primate species and is likely traceable to specific relations in the mammalian brain. In particular, we are concerned with the brain of the upstanding primate whose behavioral reactions are no longer tied so tightly to the older "smell" brain (or, using MacLean's preferable nomenclature, the paleomammalian cortex, or limbic system). This brain is free to let selection pressure lead the animal into exploring the newly emergent world of the neocortex, particular the visual cortex. Man par excellence is a visual animal. (The extensive contributions of such investigators as MacLean and Delgado to the command-control activities of the brain can be profitably examined for pieces of the story. See for example, MacLean 1970, Delgado 1969).

What did the selection pressure on the "see" brain lead to? One branch of emergent behavior obviously led to tool making. That is now documented back to 2-1/2 million years ago by Leakey and colleagues.

However, as Monod well puts it, the selection pressure on the cortical structure of the upstanding australopithecine, whose evolution for ideation barely kept ahead of physical evolution, finally forced articulation. But when? Here we differ with most investigators who are much more expert than we are. We propose that speech only came into existence about 40,000 years ago (Iberall 1972). That is, we suggest that high speed human speech, rich in abstraction, did not exist in any fossil man through Neanderthal and likely could not have been born until a time near the end of the Neanderthalers or the beginning of Cro-Magnon men. We have assembled our sparse evidence for the theses elsewhere (Iberall 1972, p. 223-227, 228). It is based on the question of whether handed tools existed with equal number before Upper Paleolithic times, and a predominance of right handed tools since Neolithic times. The suggestion is made that dominant handedness may be correlated with the dysymmetry of a speech center. Added evidence now includes the observation (Lieberman, et al., 1972) that Neanderthal man likely had a supralaryngeal pharynx which was inadequate for the production of the phoneme structure of the human language.[1]

A recent article of Leopold and Ardrey (1972) points out that Oakley's review indicated the sudden spread of hearths 40,000 years ago, at which point in time man added fire-making to his cultural heritage.

What theme can we infer from these and many other observations—that primates are gregarious? That they form bands and tribes? That they develop social structures and orders which differ between primate species, even close primate species? All of these statements can be backed by large amounts of hard observational evidence (to cite one illustrative reference, see Eisenberg, et al. 1972), but they still do not account for human culture and for warfare. There are correlations between ethlogical observations and neurophysiological observations sufficient to account for fighting, for individual fighting, for ritualistic fighting, for playing and fighting, but not for the intraspecies fighting of organized group against group.

Let us take the cue from Monod but add some physics. The extensive sight sensorium requires a large degree of abstraction. In our opinion, it raises the logic level from a denumerable arithmetic logic to a geometric field logic (Bloch, et al. 1971). The brain must cope with and interpret complex geometric relationships (both in upstanding hominids and in birds). That capability, in one line of development, leads to tools. The use of tools puts further pressure on developing comprehension of even more complex relations, not only of subject-self and object-other, but also of a third dy-

1. Namely, the new born human, chimpanzee, and Neanderthal man did not have an accoustically useful pharynx. "There is practically no supralaryngeal portion of the pharynx present in the direct airway out from the larynx when the soft palate shuts off the nasal cavity in the chimpanzee, Neanderthal, and newborn man. In adult man, half of the supralaryngeal vocal tract is formed by the pharyngeal cavity.". While cruder or slower symbolization might have been possible earlier, it would seem that an abstract language structure fully capable of processing information at neural rates (e.g., 5-10 signals per second) was not feasible without modern human phoneme capability and some particular brain capability.

namic entity—an artifact that can transpose from self to other and yet is neither self nor other, but is an intermediary, a "tool". This abstraction of tool puts even greater pressure on the cortex to develop an abstractional capability broad enough to encompass not only this triangular relation but any "polygonal" relation in which any vertex representing various sensory input modalities can be jointed or correlated or translated into an identification with any other vertex. The coordination center that leads to internal language capability was thereby advantaged. The point of understanding the issue of abstraction is, When? We date it late, e.g., 40,000 years ago, to make it a distinctive genetic event to be associated with modern man but, being amateurs at the game of developmental biology, our "guess" should be taken in that spirit. In general, we can agree that culture in a modern sense also came into existence by or at about that time (Oakley 1961, Klein 1969, Iberall 1972).

The start up of a modern fixed-settlement style of life did not begin until after the passage of another 30,000 years, i.e., until the Mesolithic times of perhaps 11,000 to 12,000 years ago (Mellaart 1965). The explosion of urbanization is viewed as having begun perhaps 6,500 years ago. Thus 30,000 years of pressure may have been required to take a "fix" on the consequence of language in the form of a formal social structure that could be transmitted as a learned culture. Monod's concept of internal simulation and programming is certainly an appealing one.

We still need a biophysical basis for the transformation to intraspecies conflict. One finally has occurred to the author.

The use of abstraction by internal simulation,[2] instead of via the more direct neurally connected lines of touch, feel, smell, taste, see, permits one to leave the track of (or to make an internal excursion from) the sense of a specific state-by-state identification of the changing scene. The identification can then drift or become lost in the brain as an abstraction; for example, man can fantasize. At the same time, the capability of abstracting and simulating speeds up the internal processing of information. The brain provides a "fire," a "high temperature" source that processes quickly and indefatigably.[3] It drives the internal fluxes of ideation into instability. Ideas in the end are the abstract, perhaps deformed, trace of neural activity (John 1968, 1972; Iberall 1972b). Out of these unstable fluxes, the "hydrodynamic" turbulence of thought, new structural forms (patterned forms) emerge. Abstractions—goals, values, friends, enemies—come into being, but not immediately. As speech is practiced and developed, its forms emerge under selection pressure. Killing man becomes an abstraction, then a tolerable abstraction. This is to be distinguished from killing a man. (Note, if I talk about killing one's mother, or father, or sister, or brother, or friend, or an innocent, or a child, this immediately evokes a feeling of horror. Yet it was precisely these thoughts and themes which furnished the foundations for Greek tragedy 2500 years ago. The artistic achievement thus represented is another of man's great abstractions of language. It is no longer a wonder that all of these themes of drama emerged almost simultaneously.)

Thus in the abstraction of language applied to social living, in which abstractions are not guides for conduct but are patterned "entities" which free the cortex for increasing circles of action, the concept of warfare becomes feasible. And, as Scott suggests, it can be almost easily introduced when images of social disorganization program themselves in the mind, and it can be most easily manipulated by threat. Whose threat? During each generation, as Freud implies, the old discharge their hostility on the young. Warfare takes place—the innocent young (war is a young man's game) against the young and innocent—until the intensity of social disorganization subsides. The more primitive epimeletic (care-giving) and et-epimeletic (care-soliciting) behavior (Scott 1962) that is clearly programmed in domesticable animals, including the primates, can now be caught up in the turbulent, unstable turmoil of confused messages from the limbic system, processed by this new cortex with its complex coordination center. Sex, food, aggressive action all become intermixed. Can very many observers, after a moderate amount of social conditioning, withstand the visual pulse-stirring imagery presented by high speed, sex, high living, and violence?[4]

In particular, warfare emerges from the cooperative instability of heated up ideational abstractions in a disturbed social period, coupled with allelomimetic (cooperative) social behavior brought to a focus by an accepted threat. While the rising "temperature" takes place in individual brains, people and circumstances fan the reverberating fires into a socially cooperative mode or

2. An abstraction can only be called into being by some simulation or representation. As an "abstraction," it is not the thing in itself.

3. While fire and temperature may be regarded as metaphors, they are not meant as such. In an active ensemble of entities, temperature is the summation of kinetic energy of the atomistic particles. If the atomistic action, e.g., nerve impulses, is high but not derived from an inertial character, "temperature" would be an appropriate measure of activity but the metrics, the weights, would not be particle mass. Brian Goodwin has used the concept at the cellular level; here it is being used at the neural level.

4. To cite a very typical illustration, any reader of Puzo's current novel, The Godfather, may time his pulse when he watches the motion picture made from the novel, as the scene in which the dead horse is found in bed approaches. The example chosen is highly colored, but it illustrates quite aptly how volatile and easily connected the autonomic responses can be.

mood of social antagonism of one group against another. A nonlinear limit cycle of sustained warfare activity ensues until the cooperative modal energy subsides and drains away. The latter point has been described by Richardson (1948). Then a new generation cycle starts.

Why isn't the individual more of a killer? The internal coordination center which led to speech did not convey that much of a selective advantage to man as an individual. As an individual, man is more nearly an ordinary primate. He can do fairly well as an individual competitor in the ecology, but not exceptionally. He becomes exceptional only when organized into society. Then there is a tremendous feedback amplification of his individual activities, coordinated by his coordination center. Thus the instability that expresses itself in killing by the individual generally occurs only with extreme personal duress, is very rare,[5] and is most commonly directed at close family (i.e., to a well known person). On the other hand, the social instability governed by communicational coupling is tremendous.

Obviously this internal instability model—partly biochemical, partly bioelectric, partly mechanistic, involving specific brain structures and their interacting flux streams—in which the resolving nonlinear limit cycle stability emerges from cross-correlation operators (illustrated in other systems' contexts in Bloch, et al. 1971, Iberall 1971b) is likely a general model for the emergence of all behavioral modalities. It is just the "purely" social modalities, involving coupling links external to the organism, that have thus far escaped analytic attention.

In summary, information channeled through lower levels (e.g., hypothalamus, pituitary) reaches the limbic system where data are processed in each channel of activity (e.g., food, sex, agonistic behavior). The information also passes to the cortex which, with its coordination center, spreads and diffuses the channeled information into a multichanneled response. The limbic system and lower centers are thus repeatedly confronted with ever broadening inputs. The "reverberations" continue as long as any suitable source of input information, whether external or internal, is present. Response does not have to be "appropriate" to the originating channel. The system thus becomes linearly unstable. It is only stabilized, as in hydrodynamic turbulent fields, by finding a complex constellation of channels by which the internal circulating signals can be maintained near equilibrium. This complex of channels represents the complex behavioral modes of the socialized human.[6]

We are confronted by dual competing processes. On one hand, in the local neural net the nervous system is self energizing; on the other hand, it is laterally inhibiting (i.e., self-quenching). Selection pressure on the highly occupied visual cortex puts a premium on the development of a higher "Q" response (less inhibition); thus, a pressure toward a coordination center. But if the damping is too little, a jittery schizogenic system would emerge (for example, note the behavioral responses in very small mammals). The emergent compromise that took place was an increasing "Q" achieved by the higher diffusion into lateral channels to make up for lateral inhibition, but not to the extent of making the system wild. What emerged was a system without too much mental reinforcement or too much mental damping. This, for the first time, 40,000 years ago, distinguished man from other primates and in fact from all other mammals.

ADDENDUM

In a recent personal communication, the author was criticized by Dr. Leiberman who in essence makes the following points critical of the author's outlook.

1. The brain of Neanderthal man was lateralized (source: Beule, Vallois Fossil Men). This might make the concept of a sudden appearance of an abstract coordination capability dubious.

2. Neanderthaloids of 100 to 200,000 years ago had human-like vocal tracts. Thus they might have had both a functional and an actual capability of human-like speech.

3. Classic Neanderthal man likely was a more primitive fossil stock that survived into modern times. Thus lack of human-like speech capability for Neanderthal does not prove that earlier homo (the pithecanthropines and neanderthaloids, who were the "first" homo or hominids very near homos) could not speak.

4. Neural and anatomical abilities stay in step in the long run but they do not have to be synchronized. The operative chain can be circular and also evolutionary. Yet, Lieberman willingly states that:

5. The process of gradual development of proto-human language and culture may perhaps have reached a point where some rapid change in behavioral patterns occurred 40,000 years ago (so

5. This is not to imply any relative measure in numbers of individual killings versus organized warfare killings. The fact is that both behaviors are rare. That is why species preservation can be achieved by essentially "rare" reproductive activities; that is, families of humans do not have to reproduce very many more than two per family to hold population near constant.

6. One must note, from a neurophysiological panel discussion at the 1972 American Society for Cybernetics (Harnad, Goldstein) Meeting, that what we have referred to here as up-down (neocortex-limbic system) instability, may very well involve left-right (hemispheric) instability. The point of our paper is to suggest, not pinpoint absolutely, neural mechanisms.

that parallel hominid developments were exterminated).

As an amateur, the author is still willing to put forth the following argument. Modern man has a language coordination center. He has a capability for a complete range of abstraction, accessible at neural rates (e.g., of the order of 10 symbols per second). The abstraction of tools goes back to much earlier fossil hominids, e.g., australopithecines 2 million years ago. The full abstract range of culture starts more nearly 40,000 years ago with modern man (for example, the abstraction of art forms). There must be a neural or anatomical change associated with that evolutionary emergence. Thus it is preferable to date a particular brain change with the time at which the capability emerged. While the author would agree with no need for "immediate" synchronization, it would be hard to accept time delays of much more than 5000 years for application of capabilities. It is a physical observation, almost a dogma, that when a physical configuration or force bound structure is not explicitly excluded it comes into being, i.e., that which is not physically excluded occurs. Time delays are most often transit or process delays, or velocity delays in assembling small numbers.

Some further pursuit of the neuroanatomical questions with J. Ariëns Kappers (personal communication) has revealed the following.

Since my original sources of information were the second-hand recollections of Warren McCulloch summarizing results he had learned from C. U. Ariëns Kappers, the check is informative. J. Ariëns refers to published material of his uncle, C. U. Ariëns, which (loosely phrased) indicate (1) some lateralization of the lobes of Pithecanthropus, as well as Neanderthal and modern men. (Proc. Roy. Acad. Sci., Amsterdam, 32, 189, 1929). (2) Neanderthal showed further dissymmetry; i.e., in observations in the inferior frontal sulcus, both a ramus interior and anterior is found quite pronounced in the left lobe. In more modern man, under this fissure lies the region of Brodman, which in the left acts a part in speech. By comparison with Pithecanthropus, in Neanderthal the inferior frontal convolution has enlarged dorsally and frontally. (The Evolution of the Nervous System, Bohn, Haarlem, 1930, p. 237.). (3) In Neanderthal, some unidexterity seems to have existed. However, K. Bouman "personally tested the fitting of prehistoric implements of Moustier [Neanderthal man of 40,000 years ago] in his right and left hand, found about an equal number fitting left as well as right, whereas with Solutrean implements [modern man 20,000 years ago] the right hand prevails." Accepting some person to person to person distortion in both space, memory, and time, the thread is remarkably similar to the exchanges that the author had with McCulloch over these points.

Thus J. Ariëns Kappers summarizes C. U. Ariëns' opinions, with which the author concurs, that

1. Neanderthal (at least in some) showed development of the motor speech center of Broca on the left beyond that in Pithecanthropus and the apes.

2. Unidexterity was supposed to have existed in Neanderthal because of a slightly larger left hemisphere and a somewhat heavier right humerus.

3. But the results obtained by Bouman do not speak for well-developed handedness in Neanderthal, whereas modern man in the Solutrean period [20,000 years ago] seems to have exhibited right handedness.

Obviously, J. Ariëns Kappers points out, it is difficult to make deductions on the presence of speech ability simply on the ground of fissuration patterns. But, on the other hand, the author proposes a specific hypothetical line to provide a basis for consideration of a particular thesis. The findings of Lieberman, it would seem, fit in and still support the trend of the thesis. The model outline, in recapitulation, is the following table.

		Speech at neural rates	Time in past years
Australopithecus	Tools of equal handedness	No	2×10^6
Pithecanthropus[1]	Tools of equal handedness	No	500,000
Neanderthal	Tools of equal handedness (some unidexterity)	No	50,000
Modern man	Tools of equal handedness	?	40,000
Modern man	Right handed preference	Likely	20,000
End of last glaciers		Likely	14,000
Modern man (mesolithic)		Likely	12,000
Modern man (neolithic)		Likely	10,000

1. The term Pithecanthropus, the older term, is used loosely to denote those fossils now generally identified as belonging to the genus, homo, in particular, Homo Erectus. Also the thesis is being vigorously pursued by young Leakey, with increasing evidence that tool-using homo existed contemporaneous with the Australopithecines.

Was there a 20,000 year gap from equal to preferred handedness in modern man? Was there a similar gap in speech? The author has no evidence. Might there have been a nominal 5000 to 25,000 year delay in the onset of speeded up modern technological development, even with speech? Yes, if the hunting patterns of an ice age still gripping the relevant geographical areas continued to dominate man's genetic adaption and his activities. It is more plausible that, upon the end of the ice age, progress "quickly" (e.g., a few thousand years) drove tool-making, speaking man toward his modern technological societies.

REFERENCES

ALLAND, A. The Human Imperative. New York: Columbia U. Press, 1972.

BLOCH, E., CARDON, S., IBERALL, A., JACOBOWITZ, D., KORNACKER, K., LIPETZ, L., McCULLOCH, W., URQUHART, J., WEINBERG, M., and YATES, F. Introduction to a Biological Systems Science, NASA Contractor Report, CR-1720, Feb. 1971.

DELGADO, J., MIR, D. "Fragmental Organization of Emotional Behavior in the Monkey Brain." Ann. N.Y. Acad. Sci., 159, p. 731, 1969.

EISENBERG, J., MUCKENHIRN, N., RUDRAN, R. "The Relation Between Ecology and Social Structure in Primates." Science, 176, p. 863, 1972.

FRIED, M., HARRIS, M., MURPHY, R., eds. War: The Anthropology of Armed Conflict and Aggression. New York: Natural History Press, 1968.

GAL-OR, B. "The Crisis about the Origin of Irreversibility and Time Anisotropy" Science, 176, (4030), p. 11, 1972.

IBERALL, A. "A Systems Science Theoretic for Goals or the Engineering for Psychology, Sociology, and So Forth." J. Dyn. Syst. Meas., Control, Trans. ASME, Series G. 93, p. 206, 1971a.

__________. "A Contribution to the Theory of Turbulent Flow Between Parallel Plates," in Seventh Symposium Naval Hydrodynamics, ONR, Washington, D.C. 1971b.

__________. Toward a General Science of Viable Systems. New York: McGraw-Hill, 1972a.

__________. "On a Third Dimensional Manifold of Human Mind—A Speculation on its Embodiment." Int. J. Psychobio., 2, p. 219, 1972b.

JOHN, E. Mechanisms of Memory. New York: Academic Press, 1968.

__________. "Switchboard versus Statistical Theories of Learning and Memory" (ms. in review for 1972 publication).

KLEIN, R. "Mousterian Cultures in European Russia." Science, 165, p. 257, 1969.

LEOPOLD, A., ARDREY, R. Science, 176, p. 512, 1972.

LIEBERMAN, P., CRELIN, E., KLATT, D. Amer. Anthropologist, 74, p. 287, 1972.

LORENZ, K. On Aggression. New York: Harcourt, Brace and World, 1966.

MacLEAN, P. "The Triune Brain, Emotion and Scientific Bias," in F. Schmitt, ed. The Neurosciences: Second Study Program, New York: Rockefeller U. Press, 1970.

McCARTHY, J., EBLING, F., eds. The Natural History of Aggression. New York: Academic Press, 1964.

MELLAART, J. Earliest Civilization of the Near East. New York: McGraw-Hill, 1965.

MONOD, J. Chance and Necessity. New York: Knopf, 1971.

MONTAGU, A. Man and Aggression. New York: Oxford Press, 1968.

__________. Man: His First Two Million Years. New York: Columbia U. Press, 1969.

OAKLEY, K. Man the Tool-Maker. Chicago: Univ. of Chicago Press, 1961.

RICHARDSON, L. "War Moods." Psychometrika, 13 (147), p. 197, 1948.

SCOTT, J., HAVEZ, E., eds. The Behavior of Domestic Animals. Philadelphia: Williams and Wilkins, 1962.

SCOTT, J. "Biological Basis of Human Warfare: An Interdisciplinary Problem," in M. and C. Sherif, eds. Interdisciplinary Relationships in the Social Sciences. Chicago: Aldine, 1969.

WILSON, E. The Insect Societies. Cambridge, Mass.: Harvard Univ. Press, 1972.

YATES, F., MARSH, D., IBERALL, A "Integration of the Whole Organism—A Foundation for a Theoretical Biology," in Behnke, J., ed., Challenging Biological Problems: Directions Toward Their Solution. New York: Oxford Press, 1972.