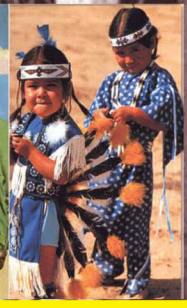
NAVAJO INFANCY

An Ethological Study of Child Development



James S. Chisholm

With a new introduction by Cary Michael Carney

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For
Dine dóó bą aɬchiní yazhi dóó
Madelene

CONTENTS

INTRODUCTION TO THE TRANSACTION EDITION

In *Navajo Infancy*, James S. Chisholm brings to bear a wealth of concepts and methods of classic ethology, of social-cultural anthropology, and myriad techniques of multi-variant analysis on the relationship of human nature and nurture/culture. The issue of nature versus nurture is a seminal concern in anthropological investigations, one that could conceivably be inferred in virtually every attempt within the discipline that has ever sought to go beyond mere observation and description. This widespread attention notwithstanding, nature versus nurture has nearly always been approached or presented in just such an adversarial light, nature *versus* nurture. When recognition has been granted that the causal agent of human behavior is not necessarily one or the other, but that both act and interact together, the recognition is usually limited to just that, the bare admission that they do interact. Little has been forthcoming as to how they do so, or to any causal relationships or their directions. That is the crux of Chisholm's research. *Navajo Infancy* is a classic in this field.

Chisholm presents a strong case for the process of human development serving as a bridge, both phylogenetically and ontogenetically, between nature and culture. His premise is that behavioral adaptability in human infants and children is the result of our evolutionary biology. He argues we have a tendency toward behavioral plasticity with concomitant complex and sophisticated environmental tracking mechanisms that carry clear survival value, which are manifested in human behavior and development, including social and cultural behavior.

Chisholm concerns himself with the wide-ranging topics of what factors are present concerning change and continuity in Navajo infant development, what can be discerned in the way of apparent adaptation, what may be implied in terms of cause and effect, and how human evolution may contribute to the various adaptation phenomena and to ultimate developmental outcomes. His is not

yet another work of nature versus nurture. His is one of nature and nurture. How they may be perceived to interact, not just that they do, and how evolutionary desirable outcomes may result across a broad range of variance or "perturbation" within the environment.

He begins by recognizing the futility of the nature versus nurture approach, calling for the need to explain how they do so. He sees studying each separately as valuable only as a prelude to seeing their action together. Chisholm posits culture as arising from nature, via the evolutionary process of adaptation, making culture an issue of natural selection. In doing so, he develops a detailed case for natural selection as having influenced and concurrently being influenced by an extended, post-natal development of human brains, operating within the context of parental investment and social interaction.

Chisholm seems to admit a bias of sorts toward the contribution of nature in calling for an expanded recognition of our physiology as providing a more significant contribution to ultimate successful developmental outcomes. He sees this heightened contribution in the sense that, relative to the great range and diversity of environmental or cultural influences on development, there is a demonstrably, strikingly limited number of developmental outcomes. Our evolution as a species appears to have established a propensity for normal development under all but the most disrupted of environments. This may be interpreted as an almost Lamarkian stance.

The focus of Chisholm's research is the post-natal development of Navajo infants. Of specific interest is the Navajo practice of cradleboarding. This "cradleboarding" practice is seen as a potential disruption of the mother-infant interaction, a perturbation in the environment of Navajo infancy, one with possible impact on the subsequent development of the child. Specifically, Chisholm looks at the mother-infant interaction, socialization in general, and the level of fear of strangers.

He selected a finite population in and around Cottonwood Springs Trading Post, a notably isolated portion of the Navajo Reservation, retaining much in the way of traditional Navajo culture, practices, and patterns. This area had little, albeit measurable, interaction with the wider surrounding society. By happenstance, in the course of his research Chisholm met a small group of Anglo-American parents who had adopted such cradleboards for their own use. Thus he was able to encompass an unexpected cross-cultural aspect to his research as well.

As to why the cradleboard could be an appropriate topic for studying personal development as environmental adaptation, the cradleboard's essence is motor restraint. This restraint occurs at a physiological level only. There appears to be no evidence of motor development or psychological impact, primarily due to its limited and short-term use. Cradleboards are a babysitting device, a way to restrain and locate the infant, freeing the mother to engage in chores or activities.

Cradleboards create a lowered arousal level, or involve one (there is considerable question of which leads to which). Being on the cradleboard usually induces

sleep, a lowered heart rate variability, lowered respiration variability, and lowered motor activity. Cradleboards are most definitely not used as mini-jails. They do not serve to train subdued behavior, but are more used when called forth by subdued behavior. If the infant "wants out," he/she is released.

The Navajo cradleboard has historically drawn the attention of anthropologists and the lay public alike. The cradleboard itself is as much an icon of Native America as the warbonnet, tomahawk, tipi, or peace pipe; and quite possibly as inaccurate or little understood. Past research regarding the cradleboard has frequently been more inductive than empirical, and has often been more a reflection of the Anglo-American perspective being applied. Unsubstantiated stereotypes notwithstanding, cradleboards have not been used in a "papoose-style" strapping of the infant on the mother's back, and serve very little use as transportation. Navajo cradleboards serve much the same purpose as playpens. They are primarily a babysitting device. In fact, they are remarkably similar in design and in usage to the child safety seats used in our automobiles.

The principal difference is cradleboards were and are generally employed to simply restrain and locate the child—any use for transportation is generally inadvertent and coincidental, a simply moving of the infant when needed without going to the trouble of removing him/her from the board. Most of the time while the child is on the board, the board is lying down (if the child is asleep), or propped up (if awake). In comparison, our use of child safety seats is primarily for transport (although the automobile is actually doing the moving—the seat is still serving the purpose of restraining and locating the child), with correspondingly occasional and inadvertent use for child-sitting (leaving a sleeping infant in the seat and setting both nearby in a park, backyard, or so on).

Chisholm's extended field work revealed much of an objective nature about cradleboarding as practiced by the Navajo. From its first observation by Anglo-American society, cradleboarding seemed so different, so alien to our own practices that its impact on any subsequent difference in Navajo demeanor or social behavior seemed an easy inference. Moreover, Chisholm finds cradleboards to be a brief and relatively minor factor in Navajo infant life, with the infant exercising a great deal of freedom and power regarding its use. Instead of being used to subdue, it appears more to come into use when the child becomes subdued, often simply a handy way to let him/her nap safely while the mother tends to other things. Likewise, as mentioned, as soon as the child becomes restive ("wants out"), he/she is released from the board. Chisholm finds no statistical evidence for any such inferred impact on subsequent behavior patterns.

As to the impact of cradleboarding on mother-infant interaction, if anything, analysis indicates a positive or fostering effect. Since, when cradleboarded, the infant is typically more subdued, it is a period of lessened interaction in any case. Since arousal and heightened activity results in release, the implication is mother stays close at hand and is monitoring the infant. Being released allows

normal, active levels of interaction to proceed unimpaired. In fact, the use of the cradleboard may actually expand opportunities for mother-infant interaction in that it allows the infant to be safeguarded near at hand, in visual and verbal contact with the mother while the mother tends to other necessary activities. Such use of the cradleboard may actually be seen as contributing to the opportunity for increased interaction.

Turning his attention to fear of strangers, Chisholm again found no significant statistical relationship with cradleboarding. What was forthcoming was a more mundane apparent cause, that of simple social isolation. Extensive analysis found a pattern of no real difference between Navajo and Anglo-American infants in terms of initial fear of strangers (in the first few months of life), then increasing fear of strangers evidenced in both beginning at six to nine months, becoming more so until age 15-16 months. After two years, the Navajo children retained this fearful behavior, while the Anglo-American pattern dropped to nearly none.

As mentioned, statistical analysis showed no relationship to the use of cradleboarding. What was found was a direct relationship to distance from the trading post. Fear of strangers was clearly statistically associated with the distance from the post (up to 40 miles over very primitive or no roads), and the corresponding shrinking of the size of the camp in which the child lived. Both have a very pronounced effect on a child's opportunities to interact with others, especially strangers.

Finding no significant impact on the part of the cradleboard as an environmental disturbance, Chisholm addresses the simple observation that Navajo and Anglo-American infants are different at birth. Navajo infants are quieter and less irritable. This "quieter" aspect does impact interaction, with the mother and with everyone else. Quiet wheels do not get greased. Chisholm sees this as neither cultural, nor genetic. He sees it as very likely physiological, nurture in a physical sense. He notes that Navajo mothers tend to have lower blood pressure during pregnancy, and frequently even have a simpler diet and lower measurable psychosocial stress levels during pregnancy. All of this may contribute to quieter, less irritable infants as an ultimate consequence and reflection of the non-intrusive adult behavioral styles within the Navajo culture.

Ultimately, investigating cradleboarding as a perturbation of the environment of Navajo mother-infant interaction operates on the assumption that motor restraint impacts infant arousal and activity level, which in turn impacts interaction and attachment process. Cradleboarding is associated with arousal and activity level, and does impact maternal behavioral and interaction. But it apparently does not do so to a sufficient level and constitute a true perturbation, certainly not a lasting one.

Chisholm theorizes that the process of adaptation should predict an evolutionary valuable behavioral plasticity in dealing with such perturbations. The inference is that the lack of lasting effects from cradleboarding may reflect such corrective adaptation behavior by both mother and infant in that:

1. when state of activity and arousal increases, Navajo infants do cry to be released, and the mothers do report removal is "up to" the child;
2. upon release, at the end of any cradleboard period, there was a two- to three-minute period of intense affectionate interaction, a sort of "catching up"; and
3. the infant is much more likely to be on the cradleboard away from home—this may actually strengthen mother-infant interaction when away from home, and even make it possible to travel with the mother close at hand.

Thus, in terms of the larger context of social development within cultural patterns and differences, Chisholm's arguments seem to support his hypothesis that we are evolutionarily hard-wired to develop in desirable, valuable fashion in all but the most disrupted of environments. The cradleboard, however strange and exotic it may have once appeared to Anglo-American eyes, is not sufficiently disruptive, nor sufficiently employed in a disruptive manner to have a significant negative impact on infant development. What differences exist between the two cultures seems to stem not from such cultural artifacts, or genetics, but from subtle physiological differences arising from long term behavioral and lifestyle variations.

Chisholm's work is rightly considered a classic. This is not just a reflection of his thoroughness, attention to detail, and exhaustive level of objectivity, but as a powerful indication and confirmation of just how subtle and intricate are the factors that come to bear on and are enmeshed within human development, behavior, and culture.

Mike Carney
Catoosa, Oklahoma

Biographical Note

Cary Michael (Mike) Carney was born in Tulsa, Oklahoma, in 1944, and still resides in the area, on an acreage near Catoosa, with his wife, Pam, and a veritable petting zoo of animals. His current position is as a civilian Education Services Specialist for the U.S. Army, serving in Kansas City as program manager for the ASVAB student testing program in Kansas and Missouri. Carney is a graduate of the University of Tulsa and Oklahoma State University. He has authored "Native American Higher Education in the United States," Transaction Publishers (1999).

PREFACE

The opposition between nature and culture to which I attached much importance at one time now seems to be of primarily methodological importance.

Claude Levi-Strauss
The Savage Mind

In the pages to follow a variety of topics and issues are discussed. Although this book is about the Navajo and their children, it is also about social and cultural anthropology, human ethology, evolutionary theory, human biology, and developmental psychology. The real subject matter, however, is the relationship between nature and culture. Disciplinary boundaries are the bane of all disciplines, but perhaps because my father was a chemist and my mother a poet I simply grew up with a fascination for conceptual bridges. The book, then, is about how the process of development might constitute a phylogenetic and ontogenetic bridge between nature and culture.

Chapter 1 describes the process of adaptation and outlines the evolutionary biological reasons why the process of development constitutes an important adaptive mechanism, especially for *K*-selected species. This chapter also argues that an evolutionary approach to the process of development would predict increasing degrees of behavioral plasticity during development in *K*-selected species, especially our hominid ancestors; this argument is juxtaposed to the growing suspicion in developmental psychology that early experience and constitution may affect later behavior only under the most stable environmental circumstances. Chapter 2 describes the Navajo, concentrating on those aspects of the Navajo environment (social and physical) which seem to have been the most stable over the years and which are most likely to affect child development. Chapter 3 focuses specifically on the cradleboard, an aspect of the environment of Navajo infancy that has considerable theoretical interest, since one set of theories and data suggest that it should have long-term effects on behavior while another set suggests that it should not. Chapter 4 describes my research, including use of the techniques of human ethology and assessment of the behavior of newborn infants. Also included is research on a group of Anglo-American infants who

were also using the cradleboard. This chapter compares and contrasts the environments of infancy that characterized both the Navajo and Anglo-American families. Chapter 5 provides a detailed description of the behavior of newborn Navajo and Anglo-American infants. It also provides an analysis of the prenatal influences on group differences in behavior that appeared and suggests that gene pool differences are not likely to be the best explanation of these differences. Chapter 6 describes the development of fear of strangers in Navajo and Anglo-American children and analyzes both within- and between-group differences in fear of strangers in terms of cradleboard use and the larger aspects of the social environment of infancy. Chapters 7 and 8 concentrate on analyses of Navajo and Anglo-American mother–infant interaction. The former describes how the cradleboard has the effects on mother–infant interaction that were predicted, but also shows that these effects seem to hold only while the infant is actually on the cradleboard. The latter focuses on how the larger social context affects both within- and between-group differences in patterns of mother–infant interaction. A summary and synthesis of my findings concludes the volume. This chapter discusses the reasons why the effects of the cradleboard do not last and why differences in the larger social context of development might be expected to have effects that last longer than those of the cradleboard. Also discussed are Navajo and Anglo differences in neonatal behavior, fear of strangers, and patterns of mother–infant interaction from the standpoint of both temperament and cultural beliefs and values about appropriate behavior. Drawing on the evolutionary approach to development presented in Chapter 1, I conclude that genetically based developmental rules are a likely explanation of why the cradleboard seems to have no lasting effect on behavioral development but that for good evolutionary biological reasons the proximate causes of group differences in children's behavior are likely to be social-cultural differences in the environment of infancy.

The field research on which this book is based was carried out during the years 1974 to 1976 in a Navajo community that I have called Cottonwood Springs. It is to the people of the Navajo Nation and Cottonwood Springs that I owe the greatest debt for this book, for they not only allowed me onto their land and into their homes, they did it with their characteristic warmth and quiet good humor. My work is dedicated to them and their children, for if I have seen anything, it is they who showed it to me.

My research was supported financially by a grant from The Harry Frank Guggenheim Foundation to Nick Blurton Jones of the Institute of Child Health, University of London, and by a grant from the National Science Foundation. I gratefully acknowledge the support and encouragement of

these institutions. I am also indebted to the Research Allocations Committee of the University of New Mexico for financial aid in the preparation of this book for publication.

At every stage in the development of this work I received such support, encouragement, and very practical assistance from so many others that authorship might appropriately be shared with a long list of colleagues and friends. My name alone must be listed, however, not to monopolize any credit, but to absolve the others from my shortcomings. Even the following list of those deserving special thanks could be expanded.

To Nick Blurton Jones and Robin Fox I owe my greatest intellectual debt. In the early years of my anthropology studies at Rutgers, Robin provided the crucial environment for giving my developing interests in evolutionary theory a productive direction. Lionel Tiger and Jane Lancaster were also instrumental in this developmental process. This background provided me with an opportunity to work with Nick Blurton Jones at the Institute of Child Health in London. This was especially and continually rewarding, not the least because of the special group that Nick established in the Institute's Ethology Section. This group included Fae Hall, Rob Woodson, Elizette da Costa-Woodson, Barry Carter, John Richer, Sue Pollock, Maggie Evans, and Midge Elias.

My time at Cottonwood Springs was one of the most enjoyable two years one could hope to have anywhere. For making it so enjoyable, and for contributions of a very practical nature, I would like to quietly single out for special thanks Madelene, Joe and Nancy, Harold and Stella, Pat and Lydia, Jimmy and Emily, LeRoy and Barbara, Willie and Sue, Margo, Nellie, and Kathy, and the staff at the Cottonwood Springs Clinic.

I will also long be indebted to Berry Brazelton and Heidi Als of Boston's Children's Hospital Medical Center for introducing me to the pleasures of newborn infants and for teaching me how to make some sense out of their behavior. To John Porvaznik and the staff of the Tuba City Indian Health Service Hospital I offer many thanks for making it possible to gather my data on Navajo neonatal behavior.

V. K. Burbank, Mel Konner, and Marjorie Shostak have not only been good friends from the very beginnings of this work, but they also provided welcome advice and support during the work itself, and have continued to do so. They were also with me at the Flagstaff restaurant where I first saw an Anglo-American infant on a cradleboard. We all talked with the child's mother and father and with their encouragement I met the other infants and their parents in what became the Flagstaff comparison group. This was a delightful group of people, and their hospitality and interest have meant a great deal to me.

In the final stages of manuscript preparation a number of people provided help and encouragement that made the denouement as pleasurable as the preparation and the fieldwork. Those whom I would like to specially thank are Bonnie and Farley Sullivan, Tim Perper, Bill Powers, Linda Cordell, Scott Rushforth, Pat Draper, Henry Harpending, Louise Lamphere, and Charlie Super.

James Chisholm

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Development in an Evolutionary Context

THE PROCESS OF ADAPTATION

IN 1859, with his *Origin of Species*, Charles Darwin initiated a paradigm shift that is not yet complete. When refinements in his theory of adaptation by natural selection have shifted this paradigm beyond the final barriers of vitalism, it will no longer be as appropriate to introduce works such as this one with the statement that the nature-culture dichotomy is false. This is a tiresome dichotomy, and in its several forms it has hindered theory and research in the life and social and behavioral sciences for too long. On the one hand, it is still too often accepted as a matter of extreme and naive faith that it is *either* nature *or* culture, that nature only proposes while culture disposes, and thought too often stops at the boundaries of academic disciplines. On the other hand, it is not enough to effect a synthesis and extension of thought across academic disciplines by acts of naive will: to argue that of course it is *both* nature *and* culture, that they go together and interact, and that man is naturally cultural may be true, but it is also to make wishful statements. If this tiresome dichotomy is to be removed from the realm of belief systems and politics and placed properly in the realm of scientific analysis, it is not enough to naively assume or deny that nature and culture interact—it must be shown how they interact.

To describe how nature and culture interact, it is necessary first to separate them in order to see how they go together. It is necessary to treat their interaction as problematical and to trace in as much detail as possible the causal pathways whereby one can logically proceed from nature to culture. The important word here is neither "nature" nor "culture," but "proceed," because in describing processes, one also provides explanations:

> Explanation is not achieved by description of the patterns of regularity, no matter how meticulous and adequate, nor by replacing this description by other abstractions congruent with it, but by exhibiting what *makes* the pattern, i.e., certain processes. To study social forms it is certainly necessary but hardly sufficient to be able to describe them. To give an explanation of social forms, it is sufficient to describe the processes that generate the form (Barth, 1966:2; original emphasis).

The process that I will describe in order to proceed from nature to culture is the process of adaptation by natural selection, and the purpose of this chapter is to discuss the nature of this process and to show how it is relevant both to the nature–culture problem and to theories of child development.

Levels of Explanation

There is an instructive parallel between the fields of evolutionary biology and developmental psychology: both sciences face the task of explaining change and continuity over time. In recent years, a number of developmental psychologists and evolutionary bologists have begun to question the notions of stability and continuity that have been the keystones of their respective sciences for several decades. The developmental psychologists have begun to question the notion that early constitutional or experiential factors are related in any simple way to an individual's later behavior and the evolutionary biologists have begun to question the notion that early phylogenetic events and conditions are related in any simple way to a species' later behavior (or morphology). The developmental psychologists' questions have arisen from the paucity of evidence that early ontogenetic events and conditions matter very much except under the most stable environmental conditions (see, for example, Kagan, Kearsley, and Zelazo, 1978; Brim and Kagan, 1980) and from the more positive growing theoretical recognition of the high degree of adaptability of the developing child (see Bateson, 1976; Dunn, 1976; Sameroff, 1975; Sameroff and Chandler, 1975; Waddington, 1975a). The evolutionary biologists' questions have arisen from the paucity of clear evidence in the fossil record for continuous gradual evolution and from the growing theoretical recognition of the possibility that the process of adaptation by natural selection may often drive evolution through a series of "punctuated equilibria": "Certainly the fossil record is poor, but the jerkiness you see is not the result of gaps, it is the consequence of the jerky mode of evolutionary change" (Gould, quoted in Levin, 1980:883; see also Eldridge and Gould, 1972; Gould, 1977; Gould and Eldrige, 1977; Stanley, 1979).

At the same time that there is growing discomfort over the issues of change and continuity in developmental psychology and evolutionary biology, the task of explaining both is being approached more and more in ethology with the realization that behavior must be explained at many levels simultaneously. The most elegant formulation of this explanatory approach was put forth by Tinbergen (1951, 1963) who stated that when we ask why a behavior has occurred we must in fact ask at least four separate questions: what are the factors, internal and external to the organism, that caused the behavior to occur at the moment it did (*immediate or proximal causation*)? What are the maturational and experiential factors in the organism's life history that underlie its capacity or predisposition to perform this behavior (*ontogeny*)? Does the behavior in question affect the organism's reproductive success or inclusive fitness (*distal or ultimate causation*)? What is the evolutionary history of the capacity of members of this species to perform this behavior (*phylogeny*)? Most of the barren furor of nature-culture or nature-nurture debates stems from the failure to realize that these levels of explanation are separate, but are also complementary and not mutually exclusive. In fact, a complete explanation requires complex multivariate explanations at each level and an understanding of how the explanations at each level are related to each other.

Because evolutionary biology deals with change and continuity in entire populations over millions of years, it has of necessity been most concerned with questions about phylogeny and ultimate causation—adaptation by natural selection that changes gene frequencies in populations. A species' phylogeny is its history, and the process of adaptation by natural selection is the process that generates this history. Even with our incomplete understanding of this process, it has been possible to generate an immense variety of living and social forms from an original range of fewer and more simple forms. On the other hand, because developmental psychology deals with change and continuity in the lives of individuals over only a few years, it has of necessity been most concerned with questions about ontogeny and immediate causation. However, these obvious differences in scale and scope do not prevent developmental psychology from making use of the most essential conceptual tool of evolutionary biology—the concept of adaptation by natural selection—for there is a concept of adaptation by natural selection that is not limited to changes in gene frequencies in populations. In this concept, the process of adaptation is one that occurs every day throughout the lives of individuals, and it is a concept as appropriate to questions about immediate causation and ontogeny as it is to questions about ultimate causation and phylogeny.

Development of the Phenotype

This concept of adaptation has been most clearly formulated by Slobodkin and Rapoport (1974), who arrived at their definition from the fields of evolutionary biology and game theory. Fundamental to this and all concepts of adaptation by natural selection is the notion that adaptation is a process involving the interaction of *genotype* (the genetic endowment of possibilities) and environment over an all-important time dimension. One of the more common mistakes, and not just for those with little training in evolutionary biology, is the potentially compounding one of confusing genotype and phenotype. Natural selection operates on *phenotypes* (the actualization of a genetic possibility) and not directly on the genotype. As Waddington put it: ". . . there is an essential indeterminancy in the relations between [the] phenotype and the genotype . . ." (1968:364). In the realm of behavior, for example, the capacity of an organism to display absolutely any behavior that it does is, by definition, located in the organism's genotype. But natural selection does not operate on capacities or potentials no matter how deeply coded in the organism's genotype. Natural selection operates on the actual *expression* of behavior—which is an aspect of the phenotype. Waddington (1968, 1975b) even suggests that models of evolution that are formulated only in terms of the genotype may be of limited relevance to human evolution, where the "essential indeterminancy" between genotype and phenotype is probably adaptive and has probably been selected for. It is also commonly overlooked that an organism's phenotype has a temporal dimension, that the phenotype develops over time. This makes it impossible to adequately describe the phenotype without reference to a particular time or stage in the organism's life history—from zygote to death. Or, as Lumsden and Wilson (1981) have recently put it in their discussion of human epigenetics,

> It has become clear that the future of general microevolutionary studies lies in the refocusing of genetic analysis on development. This is particularly the case for human social behavior, the class of phenotypes most removed from the DNA templates (1981:238).

Epigenesis is the process of gene–environment interaction that begins with the first translation of RNA from DNA in the zygote, continues through all phases of embryological and fetal development, all phases of postnatal maturation, and all phases of behavioral and cognitive development, and ends only at death. In their new book, *Genes, Mind, and Culture,* Lumsden and Wilson treat the nature–culture problem as a gene–environment interaction problem, and they argue that the best approach to the nature–culture problem is through the study of development because

there are epigenetic rules that govern the development of the phenotype. An epigenetic rule is "any regularity during epigenesis that channels the development of an anatomical, physiological, cognitive, or behavioral trait in a particular direction" (1981:370). All epigenetic rules, they claim, have a genetic basis, but some are flexible, permitting the development of a wide variety of phenotypes in a wide variety of environments while others are virtually inflexible, permitting the development of variant phenotypes only under the most special environmental conditions. I will return to this discussion in the final chapter.

One example of a class of relatively inflexible epigenetic rules are those that seem to govern maturation in general and that make the rate, sequence, and timing of metabolic, neurological, endocrine, and morphologic development so environmentally stable. Stable though the development of these systems may be, however, the complex of genes that buffer them against most environmental fluctuations do not buffer them against all such fluctuations and are themselves, of course, subject to phylogenetic change. The *potential* flexibility inherent even in these otherwise relatively inflexible gene complexes can be appreciated in terms of what has been called the "operon model" (Jacob and Monod, 1961). Although strictly applicable only to prokaryote cells, it is often suggested that something analogous to the operon model will be found to operate in eukaryote cells and higher organisms (e.g., Plomin *et al.*, 1980). To understand this model, it is important to understand that by itself the DNA molecule does almost nothing, but that it exists in a biochemical environment which not only *enables* the DNA to replicate itself, but also *uses* the information stored in the DNA to manufacture amino acids, proteins, enzymes, hormones, neurotransmitters, and so on—which go on in turn, to make more and different proteins, enzymes, hormones. In the operon model, *structural genes* are the ones that initiate the biochemical developmental processes that lead ultimately to the phenotype—the morphological and behavioral structures of the organism. At this level of ontogeny the laws of chemistry are also epigenetic rules. But these structural genes are under the direct on-off control of *operator genes,* and these operator genes are under the control of *regulator genes,* which, in turn, are sensitive or responsive to fluctuations in the biochemical environment of the cell. Not only does this arrangement mean that the actual operation of the structural genes may be influenced by extraorganismic environmental factors which influence the biochemical environment of the cell, it also provides a basis which at present is poorly understood, for the operation of natural selection to alter the rate, sequence, and timing of the development of species' metabolic, neurological, endocrine, and behavioral systems. The significance of

natural selection for changes in organisms' rates of development will be dealt with in a later section, but it is worth mentioning here that there is good reason to believe that this sort of evolution can, and has, occurred: comparing the proteins and amino acids (initial products in the biochemical processes initiated by information contained in DNA) of humans and chimpanzees, King and Wilson (1975) determined that these macromolecules of the two species were 99% identical. This figure means that humans and chimpanzees are separated by a genetic distance actually less than that which ordinarily separates two species of the same genus. They suggest that the obvious anatomical and behavioral differences between humans and chimpanzees are the result not of changes in structural genes, but of changes in the regulator genes which have led to ontogenetic differences in the expression of essentially the same structural genes. In a sense, then, a portion of the difference between human and chimpanzee is due to differences in epigenetic rules.

Neither the nature, number, nor degree of flexibility of human epigenetic rules is known, but in humans and nonhuman primates it is known that learning plays a massive role in development. Undoubtedly there are epigenetic rules influencing learning, making some things "easy to learn" and other things "hard to learn" (cf. Lumsden and Wilson, 1981, especially Chapters 2 and 3), but such rules are surely among the most flexible, for human learning is clearly very highly dependent on the environment in which the learning occurred. This means that an adaptively crucial aspect of the development of the human phenotype is environmentally labile—that is, it is determined much more by the developmental history of interactions between organism and environment. Thus, for humans at least, the impact of natural selection has depended to a great extent on the ontogenetic, life-historical preservation of the effects of previous adaptations to the environment of development. I will return later to a discussion of this "preservation."

It has been necessary here to stress that the phenotype has a temporal dimension, that it develops, because the central point of Slobodkin and Rapoport's concept of adaptation by natural selection is that adaptation is a process that is not limited to changes in the genotype, but instead specifically includes and depends upon the organism's phenotypical, immediate behavioral responses to the environment throughout its life. A corollary of this point is that because adaptation is a process, it can best be understood by focusing explicitly on these immediate behavioral responses to "environmental perturbations." This contrasts with other strategies for studying adaptation which look for such massive responses as differential reproductive success, changes in demographic patterns, and changes in gene frequencies in entire populations.

Environmental Perturbations

For Slobodkin and Rapoport, an environmental perturbation is a departure from some mean, variance, or periodicity value of some component of the organism's environment for some period in its lifetime. Perturbations have the qualities of magnitude or force of impact, speed of onset, relative novelty, frequency, and duration. A perturbation is recognized by the organism to the extent that it perceives or experiences some stress as a result of the departure from the mean value of the environmental component.

Use of the word *stress* here does not imply a model based on pathology. Rather, Slobodkin and Rapoport's concept of the process of adaptation is a model of both the development of pathology and the maintenance of nonpathology, for two reasons. First, the distinction between pathology and nonpathology is relatively arbitrary; if pathology develops, it must develop from a state that is initially nonpathological. Second, the case can easily be made that life and development are stressful and that stress itself is normal. One current view in medicine, for example, is that health is a process "potentially measurable by the individual's ability to rally from insults, whether chemical, physical, infectious, psychological, or social" (Audy, 1971, quoted in Vayda and McCay, 1975:239). What is pathological, then, is stress (an insult, a perturbation) to which the organism cannot successfully respond. Adaptation itself is defined as a successful response to an environmental perturbation.

Successful Responses

The core of Slobodkin and Rapoport's concept of adaptation, the successful response to an environmental perturbation, is defined with explicit attention to the temporal or processual nature of adaptation: a successful response is one in which the next time the organism meets that same perturbation it can respond with less cost. Cost to the organism must be determined empirically in each particular case, but is defined generally as anything that tends to decrease the organism's capacity to make a successful response to any perturbation. This cost may be in resources consumed, energy expended, or simply time lost in adapting (responding) that might otherwise have gone to feeding, mating, caring for young, and so forth. The ultimate cost, however, is death, for when there is no more *time* for organisms to respond to environmental perturbations, adaptation proceeds on the basis of natural selection of mutations and recombinations alone. These are slow and only potentially flexible or adaptive ways of responding

to the environment—nor are they available to the individual. A successful response at the level of the genotype depends on having just the right mutation occur or on there already existing in the gene pool just the right set of alleles for recombination to bring into play.

Preserving the Successful Response

In order for adaptation to occur, there must be a mechanism for preserving the successful response in the behavioral repertoire of individuals. The process of evolution is the way that natural selection makes it easier for organisms to behave in the ways that have worked best in the past; the process of adaptation includes the development of mechanisms for the preservation of these behaviors. Before some of these mechanisms are outlined, it must be stressed that it does not matter for the process of adaptation *how* a successful response is preserved—only that it *is* preserved. Further, the preservation need not be absolute but can be probabilistic.

There seem to be four general categories of preservation mechanisms. The first is well known: successful responses can be preserved directly in the genotype as, for example, innate releasing mechanisms or fixed action patterns. Responses preserved directly in the genotype are those that have been successful in removing the stress associated with perturbations that have been the most constant and widespread over many generations. The second set of preservation mechanisms would include the complex genetic and epigenetic mechanisms underlying cognition, learning, and memory. Closely related to this, but not isomorphic with it, are the third and fourth mechanisms: the third includes those factors underlying the capacity of individuals to elicit from *others* a successful response to their own perturbations and the fourth is the capacity of social organizations and cultures to store information necessary for a successful response by any member of the group.

These four broad categories of mechanisms for preserving successful responses to environmental perturbations will be dealt with in more detail in the concluding chapter, but it may be useful here to give examples of the third and fourth mechanisms. Consider an infant crying because of the stress (pain) associated with, say, a toothache. The infant's social environment will ordinarily include his or her mother, and the infant's pain cry will ordinarily elicit from her a successful response to the infant's perturbation. Her initial response will probably include cuddling and carrying and perhaps nursing—responses which are more functional in alleviating the pain than the specific problems associated with an erupting tooth but which are at least *momentarily* successful in removing the stress of the particular dental per-

turbation. It the toothache persists and the mother's responses to the infant's cries no longer serve to alleviate the child's pain, the mother might then take her child to a pediatrician, who would then respond to the child's perturbation, perhaps by prescribing some medication. In this case, the infant's social environment provided the agents of his or her successful response, and the infant's culture provided both the role of the pediatrician and the specific storehouse of pharmacologic information used to finally remove the perturbation.

A more general example can be seen in an infant growing up and learning the language of his or her cultural group. With the acquisition of this language there is now access not only to all who speak that language and from whom he or she may elicit responses, but there is also access to all information about the environment and its workings that the culture has stored. Phenotypical plasticity of response has been uniquely selected for in humans partially to the extent that the capacity to learn information stored in the environment has made possible our major adaptive mechanism—culture. According to one important interpretation, culture is a means of storing information in an individual's environment in a strikingly systematic and easily retrieved form (Goodenough, 1978).

Environmental Tracking

Regardless of how adaptive culture may be, however, it is not enough to say that humankind is unique simply because culture is biologically adaptive. One must describe the natural selective processes that produced the phenotypical, behavioral plasticity which so characterizes man and has made it possible for man to so uniquely specialize in the extragenotypical preservation of successful responses to the environment; it is necessary to outline the evolutionary theoretical reasons why there should be natural selection (in the sense of ultimate causation) for an adaptive "essential indeterminancy" in the ontogenetic effect of the genotype on the phenotype.

Slobodkin and Rapoport's notion that the process of adaptation starts with behavior is not unique. Theirs is a notion that is common to all theories of "environmental tracking." The special value of the general concept of environmental tracking here is that it provides the most basic evolutionary theoretical rationale for natural selection for behavioral flexibility or adaptability. Environmental tracking is the process whereby natural selection produces the ubiquitous "good fit" between organism and environment. In this process, organisms are seen as responding to environmental changes or perturbations in terms of mulitple, hierarchically interconnected response

systems, beginning with bio- and electrochemical responses at the level of individual cells, proceeding through the range of reflexive and instinctual responses, on to slightly slower but more pervasive or long-lasting hormonal responses, then learning responses, and on ultimately, when large numbers of individuals are involved in the same perturbation, to population responses in demographic and gene pool characteristics. The immediate and quick responses, when called into play frequently and/or for long periods of time, serve to trigger the slower responses, which in turn may reset the response thresholds of the quicker responses (helping the higher responses to alleviate the stress) and/or which may themselves change. The slowest responses are the most costly to the organism because they have such far-reaching effects on the potential flexibility of all the faster responses above them in the response hierarchy.

Behavior, perhaps especially social behavior, is the best example of an environmental tracking device. Behavioral responses to environmental perturbations have been selected for in evolution because they tended to provide a high degree of response flexibility that protected the slower, deeper, and only potentially flexible response capacity latent in the gene pool. The principle of natural selection for behavioral response flexibility (the "adaptive indeterminancy") can be illustrated with the game theory analog of the process of adaptation envisioned by Slobodkin and Rapoport. The game is called Gambler's Ruin and is a bizarre card game in which all players have a

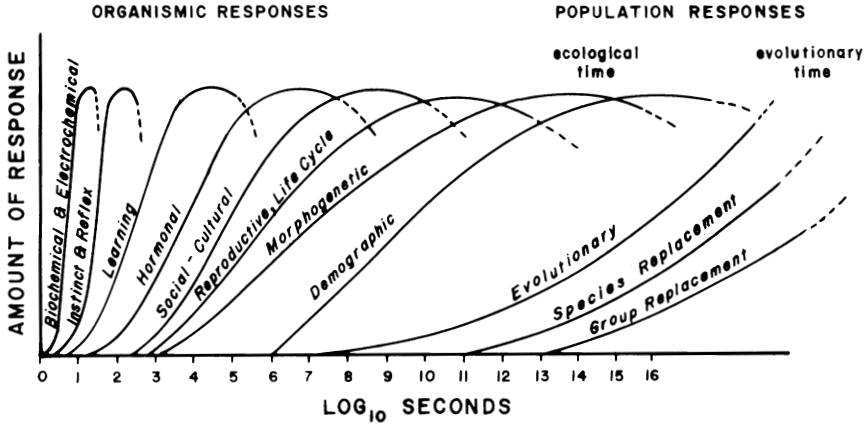

Fig. 1.1 A hierarchy of responses to environmental perturbations (adapted from Wilson, 1975:145).