Prolegomena to Praxiology Redux:
The Psychology of Zing-Yang Kuo

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General Overview of Kuo's Ideas

As psychology enters the 21st century, this young scientific discipline finds itself at a watershed. Developments in molecular genetics, developmental and comparative embryology, and neuroscience over the last few decades have greatly enhanced our understanding of how biology is related to behavior. Furthermore, significant advances in conceptual and theoretical frameworks have allowed for the beginning of a synthesis of biological level factors with interpersonal and social ecological factors. Coupling these theoretical advances with increased computing power and powerful analytic methodologies, ranging from structural equation approaches to nonlinear dynamics and complex systems theory, has resulted in a psychology at the precipice of a major paradigmatic shift.

In reading the works of Zing-Yang Kuo in the context of such an auspicious time for psychology we hearken to the words of a learned professor to his young graduate student: "if you want new ideas, read old books," for Kuo's work in many instances presages the cutting edge advances in developmental and comparative psychology. Indeed, much of his writing is so contemporary and salient one may forget that much of it was written nearly a century ago. Kuo began his career at a time when sciences such as biology and psychology were in their infancy and flush with a superfluity of new and competing philosophical and theoretical ideas. In biology, the full force of Darwinian evolution by descent was taking shape and the rediscovery of Mendel's work was leading towards the neo-Darwinian modern synthesis. Prominent scientists such as Woodger (1929) and Needham (1929) were developing a uniquely biological philosophy. On the horizon were similar efforts by psychologists.

Kuo's writings fall into two distinct periods. The first ranges from the early 1920's to the late 1930's. During this time, most of Kuo's writings focused on general philoso-

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phical, theoretical, and methodological statements concerning the study of behavior. He also conducted his important studies of the prenatal development of chickens. The second period is between 1960 and 1967. During this latter period Kuo developed three general theoretical principles fully discussed in his book, *Dynamics of Behavior Development* (Kuo, 1967). The three theoretical principles outlined in this latter book are the theory of behavioral gradients, the theory of behavioral potentials, and his organizing framework of behavioral epigenesis.

Reading Kuo it is easy to get the impression that he was a behaviorist. Indeed, many of his criticisms of the psychology of his day were framed in a behaviorist framework. Thus, he argued forcefully for an objective science of behavior, he took strong positions against the introspection approach of structuralists, and he went so far as to point out that while he was a student of Tolman's he in no way adopted his cognitive way of thinking. Yet, even early in his career, Kuo became critical of behaviorism for not ridding itself of traditional psychological concepts and adhering to its objective ideals.

Praxiology

Kuo felt so strongly about the failure of psychology, particularly behaviorism, to mature into an appropriate scientific approach that he called for the formation of a distinct new discipline he labeled *praxiology* (Kuo, 1937b). The term was, according to Kuo, first coined by Mercier and Dunlap as an alternative to behaviorism as outlined by Watson and is actually a contraction of the Greek terms for physics and behavior (Epstein, 1984). Kuo defined praxiology as a specialized branch of biology, which was concerned with the ontogeny and physiology of behavior. In short, his prescriptions for praxiology are similar in nature to the contemporary applications of dynamic systems theory to behavior (e.g., Michel & Moore, 1995). The hallmark of praxiology was its consistency with physics and other exact sciences in methodological approach. In his paper on praxiology, Kuo articulated its five methodological principles:

1. Whenever possible, the scientific data must be stated in quantitative or mathematical terms.
2. In scientific observation the same phenomena reported by one investigator must be reproducible by his fellow workers.
3. For the sake of accuracy and refinement of observation the aid of scientific instruments is imperative.
4. Whenever possible, recording instruments should be employed in place of human observation. A photographic plate gives a better and more accurate picture of an object under microscope than a drawing made by hand while the eye is looking at the object. The motion of a star can be more reliably recorded by a camera than by the eye of the astronomer, even though both use the same telescope.
5. Control experiments are almost always necessary to secure data, which are scientifically acceptable.

(Kuo, 1937b, pp. 8-9)

In the summary of this paper, Kuo (1937b) used the metaphor of a miner, working long hours in the dirt and grit, to understand as thoroughly and as intimately as possible the subject at hand. This was very much the way Kuo foresaw the study of behavior: a difficult and exacting laboratory science, rich in information regarding the exact nature of stimulus conditions, organisms' capacities to respond to those stimulus conditions, and the dynamic relationship between the two. He frequently uses the analogy of a chemistry of be-

behavior. He even went so far as to suggest an algebraic expression where behavior is a function of specific biological features, the specific developmental history of an organism and the current stimulus conditions (Kuo, 1960b).

Epstein (1984) has more recently commented on the distinction between the philosophy of behaviorism and praxis. Epstein refers to praxis as simply the study of behavior independent of any philosophical underpinnings or conceptual organization, obviously a quite impossible undertaking. For Epstein, concepts such as mind, feeling, and free will were not really an issue in the study of behavior. Kuo would likely have taken strong exception to this position. For Kuo, the entire reason for developing praxiology was in reaction to what he deemed behaviorism's failure to rid itself of the concepts of traditional psychology. Like Epstein, Kuo believed that the behaviorism movement had largely failed. Epstein views behaviorism's failure as stemming from not being able to address such contemporary traditional concepts as mind and consciousness; Kuo found fault because it was corrupted by traditional psychological concepts extant in his day. Kuo claims that:

> In the early behaviorist revolt the purpose was to rescue psychology from philosophical speculation and to remodel its method of investigation on the pattern of the natural sciences. But the result has been tragic. Psychology has remodeled behaviorism. It still remains on a speculative level and continues to be most productive of schools, doctrines, and isms, all of which are purely verbalistic enunciations (1937b, p. 2).

Kuo was attempting to fashion praxiology as a branch of study to carry on where behaviorism had failed. In large part, this included a philosophical and conceptual overhaul. Indeed, "It [behaviorism] has failed to see that a successful revolt of behaviorism requires something far more fundamental than being objective. Negatively, it requires, first, a careful reexamination of every concept in both human and animal psychology to determine its usefulness and retainability in the new science, and secondly, a complete eradication of every teleological concept so that its basic principles can be compatible with those of the physical sciences" (Kuo, 1937b, p. 3). Thus, it can be concluded that Kuo saw praxiology as both a methodological and philosophical reaction not only to traditional psychology, but also to the failure of behaviorism to rid itself of this conceptual framework.

Selective Review of Kuo's Empirical Work

Kuo's writing spans some five decades (1921-1970), beginning with the very important stage setting paper of 1921, "Giving up instincts in psychology," and concluding with his equally important book of 1967, *Dynamics of behavior development*. All the remaining of his 33 papers can be seen as steps leading directly from proposals and ideas first presented in 1921 and elaborated into one of the few systematic theories of general psychology of the 20th century. The last paper he wrote in 1970 was fittingly included in a paean to T. C. Schneirla, the only other comparative psychologist of the 20th century who was devoted to developing a unified theoretical position for comparative psychology. Kuo, and the psychologists he influenced, worked from an anti-hereditarian, developmental-contextual perspective that is only now

being widely appreciated in the discipline.

Kuo's Anti-Instinct Position

Kuo began publishing in 1921 when psychology was a very different enterprise from what it is today. While scientific psychology was in its infancy in Kuo's day the exact nature of the scientific practices of the discipline had not been worked out with any consensus by 1920. Indeed, it is possible to argue that it is only at the end of our first 100 years, at the beginning of this new century, that this still young science has at last worked out the details of conducting psychology as a natural science. In 1920 psychology was very much influenced by the idea of instinct; that much of animal behavior was inherited, as was much of human behavior as well. Kuo's first paper (1921) argued forcefully against this idea. Though he was certainly not the only anti-instinct psychologist writing at the time, he was arguably the most strident. There are several reviews of the gestation of the instinct concept, among them reviews by Beach (1955) and Diamond (1974).

It comes as no surprise that Kuo could not find agreement on the definition of the concept of instinct in 1920. Psychology has been plagued with this problem of defining its terms and concepts for all of its 120 year existence – is there yet agreement about the meanings of intelligence, mental illness, aggression? However, for argument's sake, Kuo adopted a definition that seems to have persisted until the idea was formally described and defined by the Nobel laureates in ethology, Nikolas Tinbergen and Konrad Lorenz.

Citing Parmelee (no date), Kuo writes, "An instinct is an inherited combination of reflexes which have been integrated by the central nervous system so as to cause an external activity of the organism which usually characterizes a whole species and is usually adaptive" (1921, p. 646; cited from Parmelee, *The science of human behavior*, no date). That is, instincts are species specific, biologically adaptive, fixed and stereotyped, and triggered by specific stimuli only. Compare this to the definition of classical ethology of the mid 20th century, that instincts, as inherited behavior patterns, are: characteristic of the species they appear in; stereotyped and constant in form; behaviors which appear in animals isolated from conspecifics; and which appear without practice, fully formed when first triggered by appropriate sign stimuli (Hess, 1962).

Instinct theory, that behavior was inherited, was part of scientific psychology from its inception. Kuo tells us that though long relegated only to animals, it was William James who reintroduced the inheritance of behavior to human psychology. The impact of James' (1890) chapter on "Instincts" in the *Principles of psychology* was enormous and many of his contemporaries expanded James' ideas "with abandon," according to Harry Harlow (1969). References at the time to instincts were not to reflexes, but rather to complex coordinated behaviors: climbing by children, fear of strange men, pugnacity and anger (James; Harlow, 1969); human character and the human mind (Thorndike; Kuo, 1921); business acumen, religion, and "every other affair of life" (McDougal; Kuo, 1921, p. 646). As Kuo points out in a remarkably contemporary sounding paragraph, human behavior, our social institutions, religious motivations, social unrest, and the labor movement "are to be explained in terms of instinct" (1921, p. 645). Some currently ascribe to the genes such complex human behavior such as television watching, divorce, what we like in a mate, murder, religion (Horgan, 1993, 1995).

Given Kuo's conceptualization of psychology it is not surprising that his very first publication was an argument against instinct theory. It is noteworthy that he wrote his first

paper as a senior undergraduate at Berekely, as astonishing an accomplishment for an undergraduate in 1921 as it is today (Gottlieb, 1976). His first argument against instinct would be elaborated in three additional papers (Kuo, 1922a, 1924, 1929b). Of course, these criticisms of instinct theory have meaning only in the context of Kuo's definition of psychology as *"the science which deals with the physiology of bodily mechanisms involved in the organismic adjustments to environment with special emphasis on the functional aspect of the adjustment"* (1924, p. 427, italics in the original). The subject matter of psychology, behavior, what an animal does in response to a stimulus, "is solely physical and mechanical events." (1924, p. 427)

Kuo posited several criteria for rejecting the hereditarian view in psychology:

1. As we have already stated, there was no agreement in 1920 as to the precise definition of instinct.
2. The acquisition of so-called instincts. Kuo believed that a new born infant acquires its diverse behavioral repertoire gradually through its life. During development, if the psychologist looks carefully, he will discover that factors other than instinct are responsible for the acquisition of all behavior.
3. Instincts imply purpose and teleology. As discussed below, Kuo rejected these concepts.
4. Methodological limitations of the genetic method (not genetics as we understand the term today, but rather an observational approach to development) lead to labeling a behavior an instinct merely because we observe it to occur within a species. "But, a careful analysis will show that the members of a species have similar reactions, not because they have inherited the same instincts, but rather, because they have inherited the same action system and live in a similar environment" (Kuo, 1921, p. 652).
5. Instincts are biologically adaptive. This is still a fundamental principle of hereditarian psychology. Evolutionary psychologists today propose that *all* behavior is adaptive, it being the result of Darwinian evolution. Just as cogent arguments are made today against this position (e.g., Gould, 1997a,b), so did Kuo: "It will be very ridiculous to say that the young infant attempts to grasp the fire or a harmful snake, when presented to him, because such a reaction is useful to the organism.... To say that the so-called innate responses of the young human organism have biological value is to overlook the fact that from the moment that the child is born it is taken care of by society," that is, provided a stimulus world within which to develop (Kuo, 1921, p. 654).

What, then, was Kuo's alternative to the hereditarian approach? Crediting Watson for the idea, Kuo noted (1924) that the newborn comes into the world with a huge repertoire of individual motor reactions, the result of spontaneous neural and muscular activity and of random acts. These "units of reaction," are muscular movements of parts of the body which occur prenatally. Every movement prior to birth occurs in an environment rich with stimuli and these stimuli are responsible for new motor acts, each of which then stimulate subsequent acts, etc. The new born is extremely active and easily aroused, conditions which favor exploration and new stimulation, in turn leading to new behaviors. Except for vegetative acts (metabolic activities such as heart beat, gastric motility, breathing) no inborn behavior is adaptive or purposive. After birth these motor acts are constantly organized, reorganized, and integrated during the life history of the organism. Walking, for example, involves no new motor acts that the

infant has not already engaged in. Rather, walking requires the coordination and integration of the legs, feet, head, trunk, eyes, and more, as well as the maturation of the muscular and skeletal systems. All complex behavior can be understood this way as consisting of new organizations and integrations of old behavior units – organization upon organization upon organization. The new in a new habit is the new combination of old reaction units. "The development of human behavior is essentially the increase of complexity in the organization of reaction systems" (Kuo, 1921, p. 663).

There is much that contemporary critics of hereditarian psychology will recognize in the writing of Kuo more than half a century ago. To be sure, we have learned a great deal since then, but his prescriptions are still relevant. Little of what he had to say about the origins of behavior can be rejected today.

The Genesis of the Cat's Response to the Rat

Not content to merely make anti-hereditarian propositions about behavioral origins, Kuo went on to provide empirical verification of his views. The first series of experiments he reported (1930, 1938a) addressed the question, "Is a cat a rat killer or rat lover?" Rat killing by cats meets all the criteria of an instinct. It is characteristic of all cats, is adaptive, stereotyped, and specific to a particular stimulus – rats. It was not even denied by Kuo that some cats can do this without specific training. Thus, the purpose of his investigations was not to determine if training was necessary for rat killing, but, rather, to "manipulate the conditions in which the kitten is made to live so as to see what variations in its behavior toward the rat might be brought forth" (1930, p. 2).

Kittens were raised in nine conditions: 1. In isolation, kept from all animals after weaning; 2. In a rat-killing environment, with their rat-killing mothers; 3. In the same cage with different kinds of rats until 4 months of age; 4. As vegetarians and non-vegetarians; 5. Satiated or 12 hours food deprived at the rat-killing test; 6. Given specific rat killing training; 7. Participating in rat-killing with other cats; 8. Tested with three species of rat to determine species preferences in killing (It is curious that Kuo identified the three "rat" species as an albino rat, a wild gray rat, and a dancing mouse. This in no way impacts on the results of this research); and 9. Training kittens to fear rats.

It is of interest to note that in reporting the results of all his experiments Kuo used the simplest of statistical analyses, percentages and individual data; no inferential statistics, no null hypothesis testing. Kuo's conceptions of behavior and resulting hypotheses are as complex and sophisticated as any in contemporary studies of behavior and seemingly incapable of being tested without equally sophisticated analytic techniques. However, in science, method is more important than statistical technique. Indeed, much of the sophistication of current statistical analysis is designed to address deficiencies in method. Kuo's analysis of his results emphasize the fact that a clever experiment is often more valuable for answering a well thought out question, than it is for its complex statistics.

The main features of his results were:

1. In the first, isolation, experiment, 11 of 20 kittens did not kill rats when tested later. Kuo concluded, "Many psychologists believe that an instinct is universal in a species. But...11 kittens out of 20...did not seem to possess the rat-killing instinct" (1930, p. 8).
2. Kittens which watched their mothers kill rats, did so themselves and always killed the species they observed their mothers kill. Three of 18 kittens did not kill rats in this condition.
3. Of those kittens raised with rats only three of

18 killed rats at the test, and they did not kill the species or individual they were raised with.

4. Kittens reared in isolation can be later trained to kill rats (9 of 11), while those reared with rats apparently cannot be so trained (1 of 15). Some kittens in this experiment ate rats even having never seen that occur, suggesting that rat eating can develop without any *obvious* reinforcement. The key term here is *obvious*, since Kuo always believed that some stimulus or experiential condition was at the foundation of every behavior.
5. Being raised on a vegetarian diet reduced rat eating, but not rat killing.
6. The size of the rat affects the age at which rat killing appears. Young kittens kill smaller rats earlier than they do larger ones.
7. Kittens reared with albino rats killed the other two species but not albinos.
8. All species of rats were killed, showing no innate tendencies to kill a particular species of rat.
9. Kittens kill and eat what they see their mothers kill and eat.
10. Kittens do not kill the species of rat they are raised with.
11. Larger rats evoke different responses from the kittens than do smaller ones. More hostile and negative behaviors were displayed to the larger than to the smaller rats, whereas smaller rats evoked playing behavior from the kittens.
12. 66% of all rat killing was done by kittens raised in the rat-killing environment; only 5% by kittens raised with rats.
13. Three kittens protected the rats they were raised with; some kittens apparently learned to "love" their rats (Kuo's term).
14. Only 3 of 16 kittens could be conditioned to fear rats; 5 kittens ran from the box they were shocked in during fear conditioning, but not from the rats.
15. Kittens raised not only with a rat, but in social grouping with two or three other kittens, were tolerant of rats, though not as attracted as they had been in the earlier one kitten-one rat rearing situation. On the other hand, all of the kittens seemed to form attachments to the other kittens they were raised with.
16. Kittens killed and ate hairless and shaved rat pups, but not unshaven pups.
17. Kittens raised for 6 months with sparrows ignored them for the first two months. They subsequently followed, caught, played with, and killed flying sparrows.
18. These same kittens reacted with indifference to sparrows in a garden setting.

This is an impressive set of conclusions, even by today's standards! In one series of experiments Kuo was able to demonstrate the extreme malleability and plasticity of behavior that is characteristic of a species. The implication of this work is enormous. *It shows quite clearly that an animal comes into the world with the potential to behave, if a cat, in typical cat fashion, or, depending on its experiential and stimulus history, in extremely atypical fashion.* Can there be a stronger demonstration against the inheritance of behavior? In summing up this work, Kuo says:

> To me, the organismic pattern...or bodily makeup and the size should be sufficient to tell why the cat behaves like cat, the tiger like tiger or the monkey like monkey. The cat has a cat body and hence the rat-killing behavior; the tiger has a tiger body, and hence man-killing behavior. The chimpanzee has a chimpanzee body, and so uses sticks and does things almost human....But the cat is a living machine; it grows and changes; it has a life history. Its behavior is being modified from the moment of fertilization to the point of death, and is modified according to the resultant forces of environmental stimulation, intra-organic as well as extra-organic. In other words, the kinds and range of potential responses of an organism are determined by its

> bodily size, and especially its bodily make-up or organismic pattern, while its actual responses are determined by its life history. (1930, p. 33)

This is a crucial anticipatory statement of what Kuo will later refer to as the "principle of behavioral potentials" discussed in a later section of this paper.

Prenatal Behavioral Development

Kuo was a pioneer in the study of prenatal behavioral development which even 30 years after his work still was little studied (Gottlieb, 1970). His efforts paved the way for later researchers in this area such as Gilbert Gottlieb (1971, 1973, 1976) and William Smotherman (Smotherman & Robinson, 1988, 1998). His findings on chicken embryo development (Kuo, 1938b, 1939a, b, c) stand as an outstanding contribution to our understanding of the significance of prenatal events to later behavioral development. As we have pointed out in discussing Kuo's criticisms of instinct, he believed an organism was born with a repertoire of reaction units which would become components of complex behaviors and which could be reorganized and integrated repeatedly, to form new complex behaviors. The only thing new about behaviors developed after birth, then, was in the combination and the sequence of these reaction units acquired during embryonic development. It is in this series of experiments that Kuo attempted to provide empirical verification of this idea, of the prenatal origins of behavioral units which would be subsequently available to be utilized functionally at birth.

Kuo said several times that the work of the psychologist begins where that of the instinct theorist ends. The hereditarian psychologist begins to examine behavior after the animal is born. But Kuo understood the great significance of prenatal events in influencing postnatal behavior. If every behavior had an experiential history, then the reaction units present at birth must also. How, though, to study prenatal events? Kuo believed that since the procedures used by the embryologists of his day presented an extremely unnatural environment, i.e., an extracted and incompletely formed embryo in a dissecting pan, the behaviors studied must also be unnatural (Kuo, 1932c). Thus, Kuo commented that Coghill's (1930) studies of *Ambystoma* suffered from making no reference whatever to the organism's environment. And, of those studying mammals he said, "Those who have worked on the behavior of the mammalian fetus...removed the fetus from the uterus and gathered fragmentary information concerning its bodily movements...without noting the effect on behavior of the removal of the fetus from its normal fetal environment after the experimental delivery" (1932c, p. 245).

What was needed was a procedure which allowed observation and manipulation of the embryo without disturbing its normal environment (see also Gottlieb, this issue). After experimenting with several techniques Kuo settled on a procedure which not only did not kill the embryos but also provided the least interference with normal functioning. A window was carefully cut into the shell of chicken eggs which was carefully peeled away so as not to disturb the underlying membrane. The membrane was painted with a thin layer of melted petroleum jelly which made the ordinarily opaque membrane rather clear, much as the glass in a shower door becomes clear with moisture on it. This allowed Kuo to observe some 3000 (!) developing chicken embryos from fertilization to hatching. While he experimented on hens, pigeons, and ducks, he presents only data from chickens in these papers. He reported findings on ducks in a later collaboration with Gilbert

Gottlieb (Gottlieb & Kuo, 1965). Except for obvious species differences (e.g., size, developmental timing) results with ducks mirrored those reported for chickens. Embryonic observation windows are shown in Gottlieb's article in this issue (p. 6).

In selecting birds as a model for this series of experiments, Kuo noted that the environmental stimuli influencing the embryo's activities was complex and included extra embryonic membranes, shell membranes, the egg shell, yolk, and albumin, fluids in the extra-embryonic cavity. To study the development of the embryo outside the egg was to study it in an artificial environment completely devoid of these normally occurring environmental factors. The studies he conducted were laborious and the results extensive. He not only observed, he stimulated and measured reactions, some gross, some local and small, to compare his findings with those of others working with different species.

Prior to Kuo's work, one could safely say that pecking for food by newly hatched chicks was an instinct. It is characteristic of the species, since all chickens do it; it is constant and stereotyped in form because all chickens do it the same way – they raise and lower their heads, open and close their beaks, and swallow, in a coordinated fashion; it appears without practice – the first time the chicken sees the grains it pecks at them, the grains acting as a specific or sign stimulus for the pecking behavior; and it appears in animals isolated from conspecifics (in their shells) and thus deprived of any opportunity to imitate this behavior. But, as Kuo undoubtedly believed, things are not always as they seem and patient, careful observation will always reveal some other factors at work. In the case of observations of a developing chicken embryo, what is to be seen is non-obvious, and so new techniques are required.

In looking at the developmental sequence of the chick embryo Kuo made the following observations:

1. Because it is a bird developing in an egg, the head develops resting on the heart, a function of its phylogenetic standing as a bird;
2. When the heart begins to beat, as early as 13 hours into development, the head resting on the heart is forced to move up and down passively in response to the expansion and contraction of the beating heart; these head movements appear on days 3 and 4 of development.
3. Food getting activities, e.g., opening and closing of the bill, thrusting and clapping, etc., occur on the 6th or 7th developmental day. Of course, these are not actually pecking movements, since there is nothing present to peck at. "But who can deny that the opening and closing of the bill, bill thrusting and lifting and bending of the head which appear as early as the third or fourth day of incubation are primordial movements which after hatching become component parts of pecking reactions?" (1932d, p. 113)
4. Beak opening and closing is accompanied by swallowing of surrounding fluids.

To summarize, Kuo observed that long before the very life of a baby chick depends on its being able to lower and raise its head (in response to a grain of food), open and close its beak, and swallow, in a coordinated fashion, i.e., engage in food getting behavior, the baby chicken has already done those very same things. We fully agree with Kuo's assessment that, "The data ... cannot fail to show the tremendous influence of prenatal development upon postnatal behavior" (1932d, p. 120). It is important to underscore that this statement

was based strictly on observation, not on mere experimental manipulation.

Of course, one may question why the chicken initially pecks at the grains. T. C. Schneirla, a later proponent of Kuo's approach, provided a means of addressing this question in terms of his "approach-withdrawal hypothesis (AW)," which suggests that early in their lives, newly born animals make approach responses to weak stimulus sources and withdrawal responses to intense stimulus sources. To a baby chick, a kernel of grain is a small or weak visual stimulus (subtending a small retinal area); the chick thus approaches it, but lacking arms and hands can only explore it with its beak. It tastes good and the chicken is reinforced for subsequent grain pecking. The chick is also attracted visually to its own fecal matter, also a small round visual stimulus. These pecks are accompanied by obvious distaste reactions – the fecal matter is an intense chemical package – and the chick subsequently withdraws from its own feces. This analysis is lent weight by an experiment (Wallman, 1979) in which the feet of newly hatched chicks were fitted with "booties" which prevented them from seeing their own toes and claws, also small visual stimuli. These animals were poorer at pecking small mealworms than were undisturbed chicks. Apparently, experience with naturally occurring small visual stimuli (the chicks' own toes) is a prerequisite for successful food getting. It is worth noting that in his later writing, Kuo acknowledged the significance of Schneirla's AW formulation (Kuo, 1967, p. 125).

Is food getting by chickens an instinct? Unless one conducts observations such as these we are forced to conclude so. This is why Kuo referred to instinct psychology as a "lazy" science and why he said his work began where the instinct psychologists' ended. Rather than examine newly hatched chicks (the genetic method of his day) to determine the origins of pecking behavior, "The real nature of behavior cannot be understood unless its underlying physiology and *the entire developmental history* are known" (1932d, p. 120, emphasis added). Who today would deny the truth of this statement? What is often neglected, even by contemporary researchers, is that *self-stimulation*, such as that which occurs in the developing chicken or duck embryo is an important factor in the establishment of behavior patterns (Gottlieb & Kuo, 1965; see also Gottlieb's contribution in this issue regarding the background of self-stimulation). Kuo's work does not demonstrate that behaviors are learned in the egg. Rather, these activities in the egg are "non-obvious experiential precursors" of later behavior.

The Dynamics of Behavior Development

Kuo's career was exceptional in more ways than one. It appears to us that with his first anti-instinct paper of 1921 he specified clearly, though in preliminary form, all the principles he saw which applied to the development of behavior, a process he saw to be an extremely dynamic one. Then, his empirical work provided the support for those early ideas. Finally, he synthesized his research findings with his theoretical ideas and developed them fully in the culmination of his life's work in an extremely important book, *The dynamics of behavior development,* published originally in 1967 and then in a new edition by Gottlieb in 1976. Though now out of print, this book is a very rich resource for students of animal behavior today.

The book is essentially a revision of the most radical Watsonian behaviorism. It is interesting that Kuo became so radical in this approach given that he was a student of E. C. Tolman at Berkeley. Kuo informs us, how-

ever, that "I was never an adherent of his views" (1967, p. viii). The book is an extended statement of those ideas Kuo deemed crucial to a full understanding of behavior. While it is overflowing with ideas it develops three main principles: That behavior is an epigenetic phenomenon, that in any given behavior the whole organism is involved (behavioral gradients), and organisms have no inborn natures, they are behaviorally very plastic (behavioral potentials).

Epigenesis

> We shall define behavioral epigenesis as a continuous developmental process from fertilization through birth to death, involving proliferation, diversification, and modification of behavior patterns both in space and in time, as a result of the continuous dynamic exchange of energy between the developing organism and its environment, endogenous and exogenous. The ontogenesis of behavior is a continuous stream of activities whose patterns vary or are modified in response to changes in the effective stimulation by the environment. (Kuo, 1967, p. 11)

Behavior is understood here to be not predetermined by biology, but rather a result of the organism's past, present, and physiology, as stated in several of his earlier papers. Behavior continues to grow and develop from fertilization to death, and remains somewhat plastic or flexible throughout life. There are no guarantees as to how an organism will turn out behaviorally, since the interaction of the three sets of factors influencing organisms may change as a result of unknown and unpredictable factors. Development is thus "probabilistic" (Gottlieb, 1970), rather than predetermined to develop in one way or another. The organism-environment exists as a fused unit, the influences between them being bi-directional (Gottlieb, 1992, 1997).

But, each species lives in a unique environment, a result of its phylogentic standing. Each individual shares a unique physiology with all members of its species. Thus, we ought to expect extreme similarities among the behaviors of species members, since they tend to be similar biological and physiological packages developing in similar stimulus environments, having similar experiences. The more homogenized the environments of similar species, the more similar will their behavior be (Moltz, 1965). Compare ant behavior to that of birds, for example. Ant behavior, too, is under stimulus control, influenced by the three factors Kuo emphasized. The relatively stereotyped behavior of ants is not only variable, but task allocation among ants, i.e., whether one is a worker or forager, is a result of dynamic developmental factors. Tasks may change as a result of colony size, other social factors, and even climatic conditions (Gordon, 1988, 1997).

Behavioral Gradients

One of the prevailing positions of early twentieth century psychology was that complex behaviors were the result of chaining together simple reflexes. These reflexes were highly localized and thought to be directly inherited in the form of specific neural pathways. Even Watsonian behaviorism conceded the inheritance of simple reflexes and as a result could never fully rid itself of the concept of instinct. However, by the 1930's the reflex idea was coming under much criticism and the concept of total pattern development was gaining in popularity. However, as pointed out by Kuo (1939b), many of the arguments against the reflex concept were ideological rather than

empirical in nature. Kuo, a consummate laboratory researcher, preferred such debates to be settled empirically rather than logically. As such, Kuo points to Coghill and his work on the embryological development of *Ambystoma* (Coghill, 1930) as the first real step forward in the reflex debates (Kuo, 1939b; 1967). While Kuo is appreciative of Coghill's refining of the debate between local reflexes and total pattern development in the embryo, he concluded that under the given methodological constraints the debate could not be resolved. He ended his 1939 paper by stating that "Neither the reflex theory nor the total pattern theory gives us an adequate picture of the origin and development of behavior. The chief difficulty with both theories lies in their oversimplification of the developmental process" (p. 119). Presumably as a result of the methodological limitations for studying mammalian embryo development and the important role of prenatal development Kuo perceived for understanding the ontogeny of behavior, he subsequently perfected substantially improved methods for observing chick embryo development, as discussed above.

After careful observation of literally thousands of chick embryos undergoing development, Kuo concluded that, neither the concept of reflexes nor the concept of total pattern development fit empirical observation. As an alternative, Kuo proposed the concept of behavioral gradients, proposing that all responses of an organism to its environment involve the entire organism. In other words, the organism always behaves as an integrated complex whole. *"The most essential feature of the behavioral gradients concept is that, in any given response of the animal to its environment - internal or external - and in any given stage of development, the whole organism is involved"* (1967, p. 92, italics in the original). It is the *whole* organism which behaves, not just the brain, not just the neuro-muscular system, not just the endocrine system. He recognized the organism as an integrated and functional whole that could not respond in anyway as a set of independent units. "Behavior is not merely motor movement or glandular secretions; it includes every part and every organ of the whole animal as well as their feedbacks and interactions. It is the most complex and complicated biological phenomenon" (1967, p. 93).

However, while Kuo insisted that the entire organism was involved in all behaviors, the participation of the parts is not necessarily equal. This is what he means by the term gradient. In any given behavior the entire organism is behaving, but some features are more involved than others. Specifically, "At every level, from metabolic changes in the tissues to overt bodily movement, there are both qualitative and quantitative variations from moment to moment. These variations are what we mean by behavioral gradients." (Kuo, 1967, p. 93).

Some may view Kuo's concept of behavioral gradients as an attempt to both have and eat the proverbial cake. How can one say that the entire organism is involved in the production of any given behavior, yet some parts are more involved than others? Does this not beg the question and state that indeed, behavior is performed locally and that claims of organismic integration are just restating the obvious - that one can't have a part without a whole? However, there is a nontrivial distinction Kuo is making with the concept of behavioral gradients. Yes, indeed, the entire organism is involved in every behavior, and all aspects, at every level, of the organism's physiology are involved in the production of that behavior. The notion of gradients does not claim that some aspects of the organism's biology are more important to a given behavior than others. Rather, it is the entire pattern of involvement that is necessary, and that variation

across biological systems makes the involvement of some aspects more visible, rather than more important. Kuo saw the concept of behavioral gradients as a framework for integrating the various fields of physiology into the study of behavior. Thus, it was a synthesizing concept that would provide a framework for actualizing Kuo's firm belief that a precise knowledge of an organism's physiology and biology would allow for a "chemistry of behavior". It would give substance to the biology term of his conceptual equation of behavior.

Behavioral Potentials

The meaning of this epigenetic approach in psychology is that an animal develops its behavior as a result of the experiences it encounters during its developmental history, and this history is only likely, or probabilistic, not guaranteed to go in any predetermined direction. Thus, even two birds in the same nest, having similar, though, different environments, will develop individual behavior repertoires. "[E]very animal has its life history..." (Kuo, 1967, p. 29). What an animal is born with is a set of *behavioral potentials*, by which is meant "...the enormous possibilities or potentialities of behavior patterns that each neonate possesses within the limits or range of the normal morphological structure of its species" (Kuo, 1967, p. 125). Thus, being a cat endows the creature with cat-like behavioral "possibilities," or *potentials*. But actualizing these potentials depends on the life history of the animal. It is in this context that one sees the significance of the question we posed above, "Is a cat a rat killer or a rat lover?" As Kuo showed, the answer is "It depends." Here too, is the significance of the anthropologist Ashley Montagu's (1962) claim that humans have no inborn nature to be aggressive or to be nurturing, though surely both behavior patterns are within the realm of possibility for all humans. They have the potential to behave as human beings or monsters. "The most wonderful thing about a baby" said Montagu, "is its promise..." (p. 17).

The idea of species-specific behavior is critical to this discussion. If we accept the idea that behavior is genetically determined, then species behavior is indeed specific. But, no two animals ever behave exactly alike; their muscular and skeletal system differences would obviate that. As Kuo recognized early on, there is wide variability in all behaviors between individuals within a species. Even individual behavior is variable. No animal ever makes exactly the same response to the same stimulus. Behavior, then, is more accurately labeled *species-typical* (Haraway & Maples, 1998), or as Kuo said, it may be convenient at times to speak of the average, or the "characteristic" (1967, p. 18), behavior of a species.

However, every species is distinct biologically from every other one. These phylogenetic, or in Kuo's terms, "morphologic" differences, constrain behavioral possibilities. While it may be possible to rear a cat to become a rat killer or a rat lover, a cat can never be induced to fly. The idea of behavioral potentials was seen by Kuo to be a resolution of the nature-nurture issue, a problem that has plagued psychology from its inception and which seems impossible to do away with (Lerner, 1993).

There is much to be gleaned from Kuo's book and we cannot do it full justice in the space allowed us. Perhaps a listing of what Kuo himself identified as his major points will illustrate how rich in ideas this slim volume

is.

1. Behavior is an enormously complex phenomenon and is extremely variable within an individual and a species;
2. There are identifiable factors which influence behavior: morphology and anatomy; biophysics and biochemistry; developmental history; the nature of the stimulus; and the environmental context;
3. These factors do not act alone, but rather as a *system*;
4. The distinction between innate or learned is a false dichotomy since one cannot separate the relative contributions of each;
5. The significance of his "theories" of behavioral gradients and potentials;
6. That psychology is a real science, a natural science, a synthetic science of morphology, comparative physiology, and comparative embryology. Psychology is concerned with both pre- and post-natal periods and with the relationship of the organism to its environment;
7. Once psychology develops its procedures so that it may take its place among the other natural sciences, we will see how unnecessary it is for us to maintain allegiance to concepts such as "consciousness, memory, intelligence; insight; instinct,...motivation, emotion..." (Kuo, 1967, p. 198);
8. The nervous system enters into behavior primarily as a center for excitation, inhibition, coordination of behavior;
9. The concept of epigenesis applied to behavior;
10. A new role for psychology is to examine the limits of behavioral neo-phenotypes, those behaviors not typically found in an organism, but which the organism has the potential to develop (e.g., rat loving by cats).

This is a powerful set of conclusions which lays out a set of guidelines for the science of psychology to follow.

Uniformity of Science

Nearly all of Kuo's recommendations for the study of behavior can be derived from his fundamental assumption of an ontological uniformity of science. For him, the differences between physics, chemistry, biology, and psychology were a matter of content rather than method. For Kuo, each branch of science has a unique set of principles, laws, and concepts appropriate to the phenomena of interest. However, these principles, laws, and concepts must be consistent across disciplines; principles of one discipline can not contradict those of another discipline. Further, the methodological and analytic framework used to describe, measure, and predict was, according to Kuo, to be invariant in principle across all disciplines.

Thus, Kuo implicitly recognized that the relationship among various scientific disciplines is artificially disparate, due only to the fact that each discipline concentrates its studies on just one aspect of nature. But, fundamentally nature is a unified, coherent whole and thus, cannot be contradictory. This distinction between unique phenomenological description and philosophical and methodological uniformity is essential to understanding several aspects of Kuo's work. First, it explains the seeming contradictions between much of his theoretical work, which is decidedly non-reductionistic, and his seeming support for reducing behavior to biology, and ultimately physics. Secondly, much of Kuo's contentiousness toward much of early twentieth century psychology stems from the fact that many of the concepts and methods of his time were in direct opposition to physics and were openly ignorant of physiology.

In the early twentieth century, physics was indeed the vanguard scientific discipline. Recent discoveries, by eminent physicists such as Einstein, Bohr, and Heisenberg were ushering in changes in our understanding of such seemingly self-evident concepts of time,

matter, and empirical certainty. Not since Copernicus proposed a heliocentric cosmos had our fundamental understandings been so shaken. Outside of pure mathematics, physics remains, even today, the most quantified and precise of scientific disciplines. As a result, physics is often the gold standard by which "younger" sciences are evaluated.

However, Kuo seemed to understand something much deeper about the relationship between physics and other sciences. Physics has as its primary aim the description of the physical universe. Thus, physics, by default, defines the ontology of the universe. Since all objects of study, whether they are in the domain of chemistry, biology, or psychology, are elements of the physical universe, they are bounded by the limits placed on them by physics. In short, physics defines the boundary conditions of all explanatory frameworks. If a concept or explanation is inconsistent with physics, it is inconsistent with what can "exist" in the universe, and thus, not admissible.

In addition to ontological consistency of psychology with physics, Kuo was also a strong proponent of methodological uniformity as well. Again, the appeal was largely to physics, as the "gold standard." Yet, Kuo also pointed out the extensive advancements of other disciplines, such as chemistry, biology, and medicine, which adopted the methodological approaches of physics, whereas the science of behavior had made very little progress on quite fundamental issues. He emphasized the methodology of physics, not primarily because of its status and reputation among the scientific disciplines, but rather because it produced highly accurate, yet distinctly counter-intuitive results. Indeed, the two stalwarts of physics, general relativity and quantum quantum electromagnetic dynamics (QED), provide predictions that fit empirical observations to imperceptible degrees of accuracy. Yet, they are so counter to human perceptions and intuition that at times they seem irrational (e.g., Davies & Gribbin, 1992). Indeed, Einstein himself could never come to grips with quantum uncertainties, and the eminent developer of QED, Richard Feynman, is reported to have stated that anyone who claims to intuitively understand quantum theory is either a fool or a liar (Green, 1999). It is precisely the counter-intuitive aspects of physical theory that are of paramount importance to understanding Kuo's insistence on adopting this methodological stance. We should note, however, that Kuo's apparent attraction to physics was characteristic of his early thinking, and reflects his being caught up in the *zeitgeist* of his day. By the time he wrote his 1967 book, he had seemingly abandoned efforts to physicalize psychology. However, he did retain his insistence on many of the scientific principles to which he had earlier equated with physics. Most notably the conjoint principles of conceptual and methodological objectivity.

Against Introspection and Teleology

Kuo clearly understood the profound implications of the fallibility of a subjective methodology in the study of behavior, especially introspective methods. Kuo was vehemently opposed to the method of introspection. He believed that there was absolutely no place in the study of behavior for such a subjective methodology. Although, traditional forms of introspection, such as that discussed by William James, were waning, attempts were being made to rescue the method. Titchener for example, had formulated a method of objectifying introspective approaches. This did not

escape the fundamental flaw as Kuo saw it, namely that the observation of the data was still subjective and impossible of either replication or refutation. On this same reasoning, Kuo was critical of Watson's use of verbal report as an objective measure.

Those who saw that Kuo's main argument against introspective methods was that they were not objective, often pointed to the fact that even physicists were not entirely without subjectivity. In response, Kuo rightly pointed out the faultiness of this logic. A bad habit is a bad habit independently of the number or stature of people engaging in it. It is reminiscent of jumping off the proverbial bridge because all the best people are doing it. In short, according to Kuo, subjectivism is bad science, period. Further, the physicist is subjective in what data he chooses to observe and by what conceptual categorization he chooses to refer to that observation. However, the observation process itself is objective, and as pointed out above, is capable of dislodging even the most ingrained of human notions about their world.

Kuo's dissent from many of the approaches to the study of behavior common in the early part of this century rest on his coupling these methodological prescriptions with his insistence on a consistent conceptual ontology with physics. Psychology at this time was teeming with competing theories of behavior. However, in all of these schools of thought there was a set of a priori assumptions, largely derived from Aristotlian and folk psychology, and were in direct conflict with his unified approach to study.

Kuo was highly critical of many psychological concepts, widely accepted at the time, because they were teleological. The commonplace usage of teleological thinking in psychology at the turn of the century can be derived from two primary sources. First, Aristotlian influences on behavior, particularly human adult behavior, were still quite strong. One of these influences was Aristotle's notion of final or ultimate causality (Peters, 1951). This notion of causality was explicitly teleological in that the cause of some attribute of an object was for the purpose that attribute served. Related to this, and perhaps resulting from it, was the common misunderstanding of Darwin's theory of evolution by natural selection. According to Darwin's theory, the mechanism of evolution was natural selection, in that attributes which increased the probability of an organism successfully reproducing tended to be conserved in subsequent generations, whereas traits which decreased the likelihood that an organism would successfully reproduce tended to disappear from the species. The misunderstanding comes from interpreting natural selection as an active process rather than a passive process. Applying Aristotle's notion of ultimate causation to this situation one gets the axiom, "the cause of a behavior, ultimately, is to assist the organism in adapting to its environment." This reasoning is, again, explicitly teleological, and thus violates one of the central tenets of science, namely, that causes cannot precede effects. The physicist, for instance, does not explain gravity by stating that the cause of gravity is to maintain the organization of planetary bodies in their respective orbits. This is no different than stating that a behavior's cause is to be adaptive to the environment. On these grounds, Kuo rejected all teleological concepts.

Ways of Confessing Ignorance

For quite similar reasons, Kuo was also highly critical of a wide array of concepts that can be included under the umbrella term of *purpose*. He frequently argued that terms such as motivation, drive, goal-seeking, and trial and error, were but semantic substitutions for the concept of purpose. Thus, if purpose was disal-

lowable, then, by extension, so too were these concepts. Further, more rigorous methods, characteristic of Kuo's approach, would reveal these concepts to be baseless. Kuo was fond of stating that use of concepts such as instinct, purpose, motivation, etc. were merely convenient ways of "confessing ignorance." Indeed, he went so far as to suggest that purposive and teleological concepts such as instinct were "substitutes for Divinity" (Kuo, 1922a, p. 345).

This attitude was most thoroughly discussed in his 1928 paper "The fundamental error of the concept of purpose and the trial and error fallacy." In this article Kuo argued that the "attempts to retain in the behavioristic system such unscientific concepts as consciousness, heredity, emotion, personality, habit, trial and error, purpose and the like by giving them objective interpretations..." (Kuo, 1928, p. 414) was a serious threat to behaviorism. He extended this list to include emotion, consciousness, heredity, habit, and thinking. Indeed, he went on to state that, "the fact that the methods and concepts of the traditional psychology are capable of objective treatment is no justification for their retention, which is based on a premise radically different from that of traditional psychology."(p. 414). Evidentiary of his unified view of science, this perspective is a system of behavioral science which is "founded on the fundamental principles of the physical sciences" (p. 414).

Indeed, it is this consistency of science that underlies one of his more complex criticisms, that of trial and error. In his first paper, in illustrating the development of habits, Kuo relates the following example: "A new-born babe, when stimulated by a certain object, displays a number of random acts. If some of these acts incidentally result in satisfaction, it is likely to be repeated on similar occasions. If, on the other hand, it results in pain, it is likely to be avoided. Through a number of trials and errors the ill-adaptive acts are eliminated, perhaps inhibited by the emphasis on the favorable reaction, and the adaptive ones selected." (Kuo, 1921, p. 649). This seems to suggest that Kuo is favorable toward the notion of trial and error. In fact, he reports a quite rigorous study on the elimination of unsuccessful acts (Kuo, 1922b), which is quite suggestive of trial and error learning.

The issue Kuo had with trial and error, as it was being used, was the purposive notion inherent in it. For an organism to make an "error" it had to have a purpose or a goal. As far as Kuo was concerned trying to objectify such a statement by stating that the animal was motivated or was trying to reduce a drive was simply a semantic replacement and did not remove the purposive nature of the statement. The only purpose in any experiment, he said, was that of the experimenter. As far as the organism is concerned, there is no error. All behaviors are complete and performed exactly as would be predicted given the organisms developmental history, present physiological state, and environmental conditions. What Kuo argued, is that some behaviors lead to changes in the way the organism's physiological state relates to the environmental conditions, and this leads to either increased or decreased probabilities for the initial behavior to be performed on subsequent occasions. Such an explanation requires no intent, purpose, goal, drive, motivation, or insight on the behalf of the organism. Indeed, Kuo referred to the actions of the organism as "forced movements."

This is cogently summarized in the following passage:

> The difference between the action of a man and the movement of a stone is merely a difference in complexity, primarily due to the differences in the complexity of structure. The basic principles that have been employed to explain the behavior of a stone should be sufficient to explain human behavior. The behaviorist need not assume an inner motive in the case of human behavior any more than the physicist needs to assume spiritual influence in the case of stone movement. (Kuo, 1928, p. 417)

Psychology as a Branch of Biology

Psychology is still struggling with the role of biology in behavior. At the time Kuo was working the essence of this debate centered on two mutually exclusive positions: behavior was either determined by biology or biology was completely irrelevant to the understanding of behavior. Over the course of the few decades this debate certainly has not been resolved, but it has matured (e.g., Lerner, 1993). Certainly no serious student of behavior today would make the argument for strict biological determinism or strict environmental determinism. Most psychologists would agree that both the environment and biology are important factors in the development of behavior. However, the discussion has now shifted to addressing the question of how biology and environment influence behavior.

On one end of this spectrum, biology is the primary determinant of behavior, with environmental factors acting to either facilitate or inhibit the "natural course" of development. On the other end is the assertion that biological and environmental factors can not be separated. In essence they become fused in an integrated system, such that questions about the relative contribution of each is nonsensical. Kuo was one of the first to recognize this and was one of the earliest proponents of the integrationist camp. Indeed his work has directly influenced many of the leading researchers from this perspective, including T. C. Schneirla, D. S. Lehrman, Howard Moltz, Gilbert Gottlieb, Robert Cairns, Gerald Turkewitz, and Richard Lerner.

Kuo's stance against a strict biological determinism is quite clear in his arguments against instincts. Indeed, the repudiation of instinct theory formed the foundation of the majority of his theoretical and empirical work. Unlike other anti-instinct theorists, however, Kuo posited that behavior could not be understood independent of an organism's biology. Indeed, Kuo frequently defined psychology as a biological sub-discipline, as "the science which deals with the physiology of bodily mechanisms involved in the organismic adjustment to environment with special emphasis on the functional aspect of the adjustment" (1921, p. 427). Further, in reaction to his perceived failure of behaviorism to rid itself of traditional psychology's short-comings, Kuo was a strong proponent of a new field of behavioral science referred to as praxiology. He defined praxiology as "a branch of biology, which deals with the behavior of animals (including man) with special emphasis on its ontogenetic and physiological aspects as the chief channels through which causal factors of behavior may be discovered" (1937b, p. 5).

As such, praxiology can be seen as an alternative to ethology with an emphasis on ontogenetic control rather than phylogenetic control of behavior. Kuo recognized that, in their disregard for the biology of the organism, Watsonian behaviorists could ultimately not rid themselves of traditional psychological concepts, especially those of heredity and instinct. He understood that, while behavior is not inherent in an organism's biology, it was through its biology that the organism interfaced with the environment. Thus, organisms behave in specific ways under specific envi-

ronmental conditions, because that is what their biology allows them to do. A tiger behaves as a tiger, because it has a tiger body; a chimpanzee behaves as a chimpanzee because it has a chimpanzee body. If one does not understand the specific means in which environmental conditions interact with the organisms physiological capabilities to produce behavior, then one is likely to resort to metaphysical conceptions such as "insight, purpose, goal-seeking, or instinct."

Behaviorism could ultimately not explain seemingly unlearned behaviors as non-instinctual, because they were unaware that the behavior was a simple physical function of the manner in which an organism's biology would respond under certain physical conditions. Although Kuo in many cases professed his own ignorance to the actual mechanism and offered up explanations that by late twentieth century standards seem simplistic or errant, he confessed this was a temporary situation resulting from a lack of appropriate methodology and data. In the end, he was sure that his physical-systems approach would be empirically supported. And by and large it has been, as Robert Lickliter so clearly demonstrates in his contribution in this issue.

Units of Reaction

There are two key concepts utilized by Kuo which are important in understanding his sophisticated and prescient views on behavior and biology. The first of these is the concept of units of reaction. He first introduced this in his 1921 anti-instinct paper and defined them as "elementary acts out of which various coordinated activities of later life are organized" (p. 658). On the surface this concept sounds much like that of an instinct. Apparently readers at the time found it confusing as well leading Kuo to elaborate his views in another paper (1922a) in which he attempted to refine and clarify his position with respect to what he called the *reaction-unit hypothesis*. In this paper Kuo uses the concept of an action-system to make his point clearer. He lays his position out quite cogently in the following citation taken from a footnote in this paper

> By action system I mean the gross bodily architecture of the organism in general and the structure of the sense organs and the response organs. I do not by any means refer to the pre-established nervous arrangements, which have long been regarded by the instinct psychologists as the physiological basis of instincts. The number and types of activities, which a given organism can perform, are largely determined and conditioned by its physiological structure, the action system. It is obvious that no organism can fly without wings, nor can it use tools without hands. This is no assumption of the existence of instincts in any sense of the term as it is commonly understood by the instinct psychologist. On the other hand, by reaction system I mean organized habitual response which has been integrated directly or indirectly from the units of reaction. (p.344)

The functional structure of the organism simply has a range of response capabilities with which it can respond to the environment, but there is nothing predetermined in its response. It is a very different thing to state that a bird flies because it has wings, and that a bird *can* fly because it has wings. Outside of making it possible, the presence of wings have little to do with flying behavior.

Kuo later refined these notions of action system and reaction system into his theory of behavioral potentials. According to this theo-

retical proposition, an organism has a given morphological structure which is capable of engaging in a large array of behaviors. This array is so vast that it is impossible for any given organism to actualize the full range of behaviors it is capable of producing (Kuo, 1967). Accordingly, he stated that it is the task of the psychologist to take an organism with a given morphological structure and work out the full range of behavioral responses such an organism could potentially display. Among the ways this could be accomplished would be by establishing behavioral neophenotypes, e.g., rat loving cats.

In summary, Kuo argued that knowledge of an organism's physiology was essential to understanding the behavior of that organism. Without such knowledge, psychology would be left to the mercy of such metaphysical and vacuous explanations as purpose, drive, motivation, instinct, and heredity. Although he did state that many "mental" concepts such as intelligence or consciousness, would ultimately have to be reduced to bio-physical terms, he did not imply that such behaviors were determined by the underlying physiology, but rather allowed for by that physiology under the appropriate environmental history and conditions. His understanding of the role of biology in the production of behavior was not exemplified by biologically deterministic theories, but rather was much more sophisticated and a forerunner of contemporary integrationist and systems theory conceptualizations.

Concluding Comments

In constructing a complete empirical science of behavior, Kuo took pains to ensure that this science would be built upon a solid philosophical base and be theoretically, conceptually, and methodologically consistent with that base. Thus, in order to appreciate much of Kuo's prescriptions for the conduct of behavioral science one must fully grasp his philosophical base. One of the more subtle yet sublime philosophical positions was his stance on reductionism.

In reading Kuo's work one can get easily confused about his position on reductionism and at a surface level it appears often that Kuo may be contradicting himself. On the one hand he clearly states that the study of behavior should be considered a special branch of biology, *Praxiology* (Kuo, 1937a). Indeed, in nearly all of his writings, Kuo comments on the need to understand behavior from a biological perspective and that ultimately, if we are to fully elucidate the causes of behavior, those causes must include the physiological and biochemical levels of description. Yet conversely, he discusses extensively the role of context and developmental history as essential causes of behavior. Here he frequently uses the analogy of a chemistry of behavior. He even goes so far as to suggest an algebraic expression where behavior is a function of specific biological features and the specific developmental history of an organism. Further, both the biological and ontogenetic aspects of this relationship can be decomposed into species-level and organism-level effects.

Kuo also waged into the debate on the organization of behavioral development with a decidedly non-reductionistic position, by proposing -- based on careful empirical observations -- that motoric behavioral development proceeded from gross global and undifferentiated behaviors toward more refined, localized and specialized behaviors. This stands in stark contrast to the behaviorally reductionistic position that motoric behavior develops through the accumulation of local-

ized and specialized reflexive movements. Finally, in his 1967 book, Kuo's most fundamental theoretical constructs, behavioral gradients, behavioral potentials, and behavioral epigenesis, are presented in an integrationist formulation of the relationship between biology and behavior.

Kuo's views may on the surface seem contradictory and paradoxical. Yet a careful reading reveals a sophisticated and sound perspective that is thoroughly integrationist and holistic. There are five general propositions that provide the essential foundation to Kuo's position:

1. The laws and principles of behavior can not be contradictory of the principles and laws of the physical sciences;
2. Since biology is the medium through which an organism behaves, a deep understanding of the physiology and biology of an organism is necessary for a complete understanding of its behavior;
3. The behavior of organisms is complete in that all behavior involves the entire organism at all biological levels as a unit;
4. Behavior can not be understood in an ahistorical context, the developmental history of the organism is essential in understanding its behavior;
5. The immediate context is crucial to understanding behavior.

Given these five propositions one can clearly deduce all of Kuo's published positions on instincts, contentions with rival psychological schools of thought, the nature of his experiments, and the methodology he employed.

His final paper (1970) is in many respects a lament (see Gottlieb's contribution in this issue). In it, Kuo identifies several areas of developmental study in need of progress. He suggests a plan for the future. He regrets that save for only a small handful of behavioral scientists, the hereditarian view is still in vogue. One can only wonder what he would have thought of "the decade of the brain," of the Human Genome Project, and of the successes of sociobiology and evolutionary psychology. At the conclusion of his paper on praxiology he relates a poignant ancient Chinese fable about an old farmer. It seems a fitting way to end this review of his work:

> The farmer was known among his neighbors by his nickname, "Mr. Fool." He lived in a house which was right behind a hill. Displeased by the obstruction in front of his house, he started to remove the hill. All his neighbors laughed at him most heartily and called him "Mr. Fool." But despite the laughter and ridicule, Mr. Fool carried on. Once he told his neighbors, "I believe we shall be able to remove this hill. If I cannot finish it in my lifetime, I will make my children, grandchildren, and great grand-children do it." When he died he stated in his will that he had buried all his fortune under the hill and the only way to get it out was to remove the entire hill. So generation after generation all his children worked feverishly on the hill. And in less than four generations, the old house had gained a clear view of the field. Perhaps this is a true story about some modern fools in science. Be it fact or fable, and fool or no fool, the praxiologist has planned to remove something much larger than a hill. (Kuo, 1937b, pp. 21-22)

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