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THE PHYLOGENY AND ONTOGENY OF INTELLIGENCE

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Phylogeny of Adaptive Behavior

Are there qualitative as well as quantitative differences in the behavior-adaptive capabilities of animals at different levels of the phyletic evolutionary sequence? That is to say, are there differences not only in the *speed* of learning but also in the complexity of what the organism can learn at all, given any amount of time and training? Are there discontinuities as well as continuities in capacities to perceive, to learn, and to manipulate the environment as we ascend the phyletic scale?

The answer to these questions is now empirically quite clear. There are indeed discontinuities and qualitative differences in learning (i.e., behaviorally adaptive) capabilities as we go from one phyletic level to another. Behaviorally, the phylogenetic hierarchy is best characterized in terms of an increasing complexity of adaptive capabilities and an increasing breadth of transfer and generalization of learning, as we move from lower to higher phyla. It is a fact that every animal, at least above the level of worms, has the capacity to learn, that is, to form stimulus-response associations or conditioned responses. But the degree of complexity and abstractness of what can be learned shows distinct "quantum jumps" going from lower to higher phyla. Simpler capacities, and their neural substrate, persist as we move from lower to higher levels, but new adaptive capacities emerge in hierarchical layers as we ascend the phyletic scale. Each phyletic level possesses all the learning capacities (although not necessarily the same sensory and motor capacities) of the levels below itself in addition to new emergent abilities, which can be broadly conceived as an increase in the complexity of information processing. For example, studies by Bitterman [1] of animals at various levels of

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the phyletic scale (earthworms, crabs, fishes, turtles, pigeons, rats, and monkeys) have clearly demonstrated discontinuities in learning ability among different species and the emergence of more complex abilities corresponding to the phylogenetic hierarchy. In the experimental procedure known as habit reversal, a form of learning to learn in which the animal is trained to make a discriminative response to a pair of stimuli and then has to learn the reverse discrimination and the two are alternated repeatedly, a fish does not show any sign of learning to learn (i.e., each reversal is like a completely new problem and takes as long to learn as the previous problems), while a rat improves markedly in its speed of learning from one reversal to the next. When portions of the rat's cerebral cortex are removed, thereby reducing the most prominent evolutionary feature of the mammalian brain, the learning ability of the decorticate rat is exactly like that of the turtle, an animal with little cortex, and would probably be like that of the fish if all the rat's cortex could be removed. Harlow and Harlow [2] have noted similar discontinuities at high levels of learning among rhesus monkeys, chimpanzees, and humans. Again, situations that involve some form of learning to learn are most sensitive to differences in capacity. No animals below primates have ever learned the so-called oddity–non-oddity problem no matter how much training they are given, and more complex variations of this type of problem similarly differentiate between rhesus monkeys and chimpanzees. The species' differences are not just in *speed* of learning but in whether the problem can be learned at all, given any amount of training. This is essentially what is meant by a hierarchical conception of learning ability. There is much evidence for this conception, which Jensen [3] has summarized more extensively elsewhere. The evolution of humans from more primitive forms is now believed to be intimately related to the use of tools and weapons [4]. The mental capabilities involved in the use of implements for gaining ever greater control of the environment, in lieu of sheer physical strength, were just as subject to the evolutionary effects of natural selection as are any genetically mutated organs. More specifically, according to Haskell [5, p. 475], "What primarily evolves in man is the nerve structure which confers the capacity to invent, to borrow, and to adapt culture traits."

Ontogeny of Human Mental Abilities

In humans does mental development of the individual occur in qualitatively different stages that are hierarchically related? Are there ontogenetic discontinuities in mental development just as there are phylogenetic discontinuities?

There is now much evidence, exemplified in the work of Piaget [6] and substantiated in numerous experiments by other child psychologists both here and abroad (for reviews, see Flavell [7], Kohlberg [8], and Phillips [9]), that individual cognitive development proceeds by distinct, qualitatively different stages in children's modes of thinking and problem solving at different ages. Piaget and others have demonstrated that children's thinking is not just a watered-down or inferior approximation to adult thinking; it is radically and qualitatively different. The stages of mental development form an invariant sequence or succession of individual development. Each stage of cognitive development is a structured whole; mental development thus does not consist of the mere accretion of specific stimulus-response associations. Cognitive stages are hierarchically integrated; higher stages reintegrate the cognitive structures found at lower stages. Also, as Kohlberg [8, p. 1021] points out, "There is a hierarchical preference within the individual . . . to prefer a solution of a problem at the highest level available to him." In reviewing the experimental literature on children's learning, Sheldon White [10] has amassed evidence for two broad stages of mental development, which he labels *associative* and *cognitive*. The transition from one to the other occurs for the vast majority of children between five and seven years of age. In the simplest terms, these stages correspond to *concrete-associative* thinking and *abstract-conceptual* thinking. The latter does not displace the former in the course of the child's mental development; in older children and adults the two modes co-exist as hierarchical layers.

Individual Differences in Mental Development

Are individual differences in the rate and the asymptotic level of mental development genetically conditioned?

Mental development, as indexed by a wide variety of tests, is known to take place at different rates among children, and the final level of ability attained can be viewed as a hierarchical composite of earlier developed abilities, each level of the hierarchy being necessary but not sufficient for development of the next higher level. At maturity, individuals differ with respect to the relative prepotence of different modes in the hierarchy of abilities and thus show differential capabilities for different kinds of learning and problem solving. The difficulty level of items in most standard intelligence tests (especially tests of the culture-fair variety, such as Raven's Progressive Matrices and Cattell's Culture-Fair Tests of *g*) reflects increasing dependence of the problem's solution upon higher mental processes.

Over the past half-century, numerous studies (for reviews, see Jensen [11–13] based on a wide variety of tests of mental ability administered to persons of varying degrees of genetic and environmental relatedness, sampled from European and North American Caucasian populations, lead to the now generally accepted conclusion that in these populations genetic factors are approximately twice as important as environmental factors in accounting for individual differences in mental ability. This means, among other things, that variations in mental abilities can be, have been, and still are subject to selective and assortative mating, just as is true of physical characteristics that display genetic variation.

Subpopulation Differences in Mental Development

Are there genetically conditioned differences among population *groups* both in the overall average level of mental development and in the pattern of relative strengths of various mental abilities?

Subgroups of the population which are relatively isolated geographically, culturally, or socially can be regarded as breeding populations to varying degrees (i.e., breeding within groups has a higher occurrence than breeding between groups). To the extent that breeding populations have been subjected to differential selective pressures from the environment, both physically and culturally, differences in gene frequencies can be expected to exist, especially for adaptive characteristics, physical and behavioral, but also for possibly non-adaptive pleitropic characters (i.e., seemingly unrelated phenotypic effects caused by the same gene). Racial groups and, to a lesser degree, social classes within a society can be regarded as breeding populations.

Social classes as defined largely in terms of educational and occupational status are subject to differential selection for mental abilities. Since these have genetic as well as environmental components, they are transmitted to the offspring, and because of a high degree of assortative mating for mental traits in Western cultures the gene pools for different social classes will differ in the genetic factors related to ability. The evidence for phenotypic mental ability differences among social classes, along with evidence for genotypic differences, has been reviewed extensively elsewhere [14–16]. It is now generally accepted by geneticists, psychologists, and sociologists who have reviewed the evidence that social class differences in mental abilities have a substantial genetic component. This genetic component should be expected to *increase* in an open society that permits and encourages social mobility. Phenotypically, of course, social class differences in patterns of mental ability are firmly established. Jensen [12] has found that lower-class and middle-class population samples differ much less in abilities that are lower in the ontogenetic hierarchy, such as associative learning and memory span, than in higher cognitive abilities, such as conceptual learning and abstract reasoning. A different pattern of correlations between lower and higher abilities also is found in lower-class and middle-class groups, implying abilities are necessary but not sufficient for the development or utilization of higher-level abilities.

Scientific knowledge concerning the genetic aspect of ability differences among racial groups, having been generally shunned as a subject of scientific study in modern genetics and psychology, is far more ambiguous and more in dispute than social class differences. The uncertainty in this area will be reduced only through further appropriate research using the most advanced techniques of behavior-genetic analysis. Phenotypically, racial differences in abilities are well established, both with respect to overall average level of performance and to the pattern of relative strengths of various abilities [17]. Both social class and racial (Caucasian, Negro, and Oriental) differences have been found in rates of cognitive development as assessed by Piagetian test procedures, such as ability to grasp concepts of conservation of number, quantity, and volume [18]. Some indication of the role of genetic factors in the Piagetian indices of level of cognitive development is shown in a study of Australian aboriginal children, the majority of whom, if full-blooded aborigines, do not show ability for grasping the concepts of conservation of quantity, weight, volume, number, and area, even by the time they have reached adolescence, while the majority of Caucasian children attain this level of mental development by seven years of age. However, aboriginal children having (on the average genetically) one Caucasian great-grandparent, but reared in the same circumstances as the full-blooded aborigines, performed significantly better (i.e., showed higher levels of cognitive development) than the full-blooded aborigines [19].

Personality Correlates of Ability

Do human behavioral traits other than ability have a genetic component, thereby also being subject to selection, and do such traits become associated, through genetic selection, with intellectual abilities?

Here the evidence is somewhat less well-established than that which was adduced in answer to the previous questions. Eysenck [20] has amassed extensive evidence for the existence of two broad dimensions or factors of personality, called extraversion-introversion (E-I) and neuroticism (N). The former (E-I) is related to outgoingness and carefreeness; the latter (N) is related to emotional and autonomic instability. Both dimensions have been shown to have physiological correlates and a substantial genetic component comparable to that found in mental abilities [20]. Together, these factors, E-I and N, account for most of the individual differences variance in a wide variety of personality assessments. Certain combinations of these traits appear to have socially important consequences. For example, high extraversion combined with high neuroticism is significantly associated with antisocial behavior [21].

In a social system such as ours, that tends to sort out people according to their abilities, it seems most likely that those traits of personality and temperament which complement and reinforce the development of intellectual skills requiring persistent application, practice, freedom from emotional distraction, and resistance to mental fatigue and to boredom in the absence of physical activity should become genetically assorted and segregated, and thereby correlated, with those mental abilities requiring the most education for their full development—those abilities most highly valued in a technological culture. Thus ability and personality traits will tend to work together in determining individuals' overall capability in the society. Cattell [22, p. 98–99] has, in fact, shown that certain personality variables are correlated to the extent of about .3–.5 with a general ability factor. Cattell concludes: "There is a moderate tendency . . . for the person gifted with higher general ability, to acquire a more integrated character, somewhat more emotional stability, and a more conscientious outlook. He tends to become 'morally intelligent' as well as 'abstractly intelligent.' "

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A HILDEBRAND EXCHANGE

EDITOR'S INTRODUCTORY NOTE.—One of the first families of scientists and teachers of science is that of Joel H. Hildebrand. We have been privileged to publish verse by him and an essay by his son, Roger. The following exchange of verse by the father[1] and son was in 1944. The progeny referred to was born in 1945, named Peter, and is now a scientist and father. Among the teachings of Joel Hildebrand which are accepted by his family is the philosophy that science does not have to be solemn to be serious.

(to be sung to the tune of Gilbert and Sullivan's "Modern Major General")

ROGER TO MOTHER AND DAD:

We are the very pedagogic bards of embryogeny;
We've information pertinent to generating progeny.
We know about the birds and bees, and know that
storks are much too dumb
To do what Gray's Anatomy describes for making
babies come.
There are other knowing families that think small
numbers wrong, and so,
Exploit unfair advantages of having married long
ago;
But we assail nativity with marvelous proclivity,
Indeed, next August, few will supersede our productivity;
In short, you'll see a profile that's increasingly
lugubrious,
And presages a Hildebrand addition most salubrious.

DAD TO ROGER AND JANE:

We are very much delighted with the news about your
progeny,
Which will surely be endowed with a superior philogeny.
We're glad the facts of life you know aren't limited
to botany,
For folks who try, with pollen, to get children haven't
got any.
Nor is it proper to rely upon parthenogenesis,
To racial continuity such futile hope
a menace is.

[1] Printed in *Chemical Bulletin,* December 1953.

We are grateful to our daughters for their talent so
obstetrical;
Our descendants are increasing in a series geometrical.
And so we 'wait with interest the appearance of
homunculus,
Convinced that, with such parents, he will surely be
quite spunkulous.

PHYSICIAN

Hands of skill
Wield with facile grace
The polymorphic weapons
That perpetuate the race to cheat
The Hands of Fate.

A. L. LIEBER