

# A developmental model for the evolution of language and intelligence in early hominids

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**Abstract:** This paper presents a model for the nature and adaptive significance of intelligence and language in early hominids based on comparative developmental, ecological, and neurological data. We propose that the common ancestor of the great apes and man displayed rudimentary forms of late sensorimotor and early preoperational intelligence similar to that of one- to four-year-old children. These abilities arose as adaptations for extractive foraging with tools, which requires a long postweaning apprenticeship. They were elaborated in the first hominids with the shift to primary dependence on this feeding strategy. These first hominids evolved a protolanguage, similar to that of two-year-old human children, with which they could describe the nature and location of food and request help in obtaining it. The descendants of the first hominids displayed intuitive intelligence, similar to that of four- to seven-year-old children, which arose as an adaptation for complex hunting involving aimed-missile throwing, stone-tool manufacture, animal butchery, food division, and shelter construction. The comparative developmental and paleontological data are consistent with the hypothesis that the stages of development of intelligence and language and their neural substrates in our species recapitulate the stages of their evolution.

**Keywords:** brain; development; evolution; hominids; intelligence; language; Piaget; play; recapitulation

One major obstacle to attempts to reconstruct the evolution of intelligence is a failure to distinguish different types and levels of intellectual achievement. We can hardly determine the stages of the evolution of intelligence before we know which achievements are more advanced than others, which are prerequisites for others, which are correlated with others, and most basically, which imply intelligence. A Piagetian model for human cognitive development (Cowan 1978) is useful in such a reconstruction because it provides a taxonomy for the various kinds of intellectual achievement and their interrelations, as well as a stage system indicating their structural prerequisites and the sequence in which they tend to emerge [see also: Brainerd: "The Stage Question in Cognitive-Developmental Theory" *BBS* 1(2) 1978].

Intellectual development in human children occurs in three major domains: (1) the physical domain, including object concepts (permanence, identity, and quantity), space, time, and causality; (2) the interpersonal domain, including imitation, the symbolic functions of drawing, language, and symbolic play, and moral judgment; (3) the intrapersonal domain, including imagery, memory, consciousness, and dreams. The earliest period of intellectual development is called the *sensorimotor period*, spanning from birth to 18 or 24 months of age. During this period the human infant achieves the ability to remember the spatial location of a hidden object, to retrieve it, and finally to search for an invisibly displaced object in a series of locations (object permanence). He also achieves the ability to place objects inside, outside, before, behind, underneath, and on top of each other, and to understand simple means-end relationships as revealed, for example, by using a stick as a tool to rake in an out-of-reach object. He also achieves the ability to imitate novel actions long after he has seen them, and to mentally represent actions and images. The achievements of this period can be divided into six sequential stages occurring in six series: sensorimotor intelligence, space, time, causality, imitation, and object concept.

The subsequent period of intellectual development is the *preoperations period*, spanning from 18 to 24 months to 6 or 7 years of age. During this period children extend their new symbolic capacities in language, drawing, and make-believe play, constructing precepts (interiorized actions) concerning object relations and causal relations between events (Piaget & Inhelder 1967; Inhelder & Piaget 1964). During the early part of this period (the symbolic subperiod) they are preoccupied with simple topological relations between objects (such as proximity and enclosure). During the later part (the intuitive subperiod) they are emancipated from this preoccupation and begin to construct simple Euclidean spatial notions such as angularity and straightness. They also begin to construct simple classes of objects based on a single criterion. In subsequent periods they develop true concepts based on reversible mental operations, and finally they develop hypothetical-deductive reasoning.

Intellectual development occurs through the differentiation and coordination of actions (and interiorized mental representations of actions) on objects: Intelligence arises from action rather than from perception (Piaget & Inhelder 1971). These coordinations create classes of objects (classification) and relations between objects (seriation), revealing properties (quantity) that did not exist before; they also reveal the nature of physical causality (gravity, inertia, equal and opposite forces, transmission of forces, etc.). The coordinations create feedback, which the agent tries to assimilate to his sensorimotor and mental "schemes" (repeatable action patterns). When the feedback does not fit his schemes, he accommodates his schemes to the phenomena as best he can. Mismatches between his schemes and the world create disequilibrium and give rise to attempts to re-equilibrate on a higher level. Feedback from other people in the form of disagreement also plays an important role in creating disequilibrium (Piaget 1977).

Recent research on the course of intellectual development in monozygotic versus dizygotic twins reveals a strong genetic canaliza-

Table 1. *Piaget's model of cognitive development*

Periods of development	Types of logic	Domains of cognition		
		Physical	Interpersonal	Intrapersonal
<i>Sensorimotor period</i> (birth to 2 yrs.)	sensorimotor trial-and-error, experimentation; discovery of new means	object permanence; externalized time, space, & causality	deferred imitation of novel schemes; sensorimotor games	first evoked images
<i>Preoperations period</i> Symbolic subperiod (2 to 4 yrs.)	nonreversible interiorized action schemes, i.e., preconcepts with transductive reasoning	object identity; topological space; graphic collections	make-believe games; language; drawing	static evoked images
Intuitive subperiod (4 to 7 yrs.)		incipient projective and Euclidean space; nongraphic collections	construction games	—
<i>Concrete operations period</i> (7 to 12 yrs.)	reversible interiorized action schemes, i.e., true concepts with deductive reasoning about concrete phenomenon	object quantity; true classification with inclusion	games with rules	dynamic evoked images
<i>Formal operations period</i> (12 yrs. on)	abstract reasoning	true measurement; systematic hypothesis formation and testing of causality	universal rules	

tion of intellectual development analogous to the genetic canalization of morphological development in the embryo (Wilson 1978). This research supports the notion that the sequences of intellectual development in human children are products of a species-specific constructive propensity that produces a standard schedule of development, given appropriate environmental stimulation. Comparative data from studies of intellectual development in other societies confirm the existence of an invariant sequence of human cognitive development (Cowan 1978; Piaget 1976; Dasen 1972). Although there are conflicting data as to specific ages of development and highest levels of achievement in different societies (Cowan 1978; Piaget 1972), research based on naturalistic tasks administered by native speakers reveals a more consistent pattern (Cole & Scribner 1974; Nyiti 1976; Deavilla & Pulos 1977; Ogbu 1978; Kamara & Easley 1977).

A developmental model is useful for cross-species as well as cross-cultural comparisons (Jolly, 1972; Parker, 1977). Piagetian analysis of primate behavior allows us to compare the numbers and types of schemes (manual, locomotor, etc.), their coordinations, and the scope and nature of their applications. Finally, it allows us to compare species- or family-specific sequences, types, and levels of achievement. This model extends the domain of comparative studies to include complex nonstereotyped behavior, which is not amenable to traditional ethological analysis.

### The intelligence of prosimians, monkeys, and lesser apes

Intellectual achievements have been studied from a Piagetian perspective in stump-tail macaque monkeys (Parker 1973, 1977), chimpanzees (Mathieu 1978; Chevalier-Skolnikoff 1977), gorillas (Gibson & Parker 1976; Chevalier-Skolnikoff 1977; Redshaw 1978), and cebus monkeys (Chevalier-Skolnikoff 1978; Gibson & Parker 1976; Parker & Gibson 1977). Although we know of no developmental studies of prosimians, lesser ape species, or other old- or new-world monkeys, some conclusions can be drawn from published reports and casual observation of object-manipulation in these

groups.

Studies of problem-solving and object manipulation in lemurs and lorises (Jolly 1964) suggest that prosimians display neither the object permanence characteristic of the fourth and fifth stages of the object concept series, nor the object manipulation schemes characteristic of stages three through six in various other series in the sensorimotor period. They do seem to display reflex grasping and the simple prehensive adaptations characteristic of the first and second stages of the sensorimotor period. This pattern correlates with their heavy reliance on olfaction and their use of their mouths rather than hands as primary foraging and grooming organs. Reflex grasping occurs in insect catching, and simple prehensive adaptations occur in climbing and bringing food objects to the mouth.

Stump-tail macaques display a mosaic of sensorimotor period abilities more advanced than those of prosimians and less advanced than those of the great apes. They complete stage five or six of the object concept series, searching for an invisibly-displaced object when it is hidden in the hand or inside a small cup and then emptied under a cloth (Wise et al. 1974). They do not, however, display the behaviors of stage five or six in the other series of the sensorimotor period, such as tool-use or the imitation of novel schemes. And although they display the coordination of vision and prehension characteristic of stage three of the sensorimotor intelligence series, they do not display the "secondary circular reaction" (repeating actions that create an interesting spectacle, such as the movement or noise of a toy), which is also characteristic of stage three in that series in human infants. They do display most of the coordinations and object manipulation schemes of stage four of the sensorimotor intelligence series, including hand-to-hand exchange, rotation, pulling apart, and rubbing, and they investigate the properties of objects through serial application of these schemes. They do not, however, display the object-object manipulations (such as placing objects inside other objects and removing them, rolling balls, raking in out-of-reach objects with sticks, etc.) of stage five in the spatial and causality series. They also fail to display the "tertiary circular reaction" (varying the intensity and orientation of schemes on objects in order to discover novel reactions) and they do not experiment with new

to solve problems, both characteristic of stage five in the sensorimotor intelligence series. The only circular reactions they display are stage-two "primary circular reactions" of hand-mouth and hand-foot coordination, and circular body reactions in play (Parker 1973, 1977).

Although other old-world monkey species have not been studied from this developmental perspective, published reports and casual observations on other species in this group suggest that the stump-tail macaque pattern is common to old-world monkeys.<sup>1</sup> It seems likely that object permanence (stages four to six of the object concept series), the coordination of vision and prehension (stage three of the sensorimotor intelligence series), and simple manipulation of single objects through the coordination of schemes (stage four of the sensorimotor intelligence series) arose in the common ancestor of old-world monkeys and apes some time in the Oligocene, about 35 million years B.P. (before present), as an adaptation for hand-foraging and feeding on a variety of vegetable foods. This pattern of sensorimotor period development in monkeys correlates with enhanced hand-eye reliance (as opposed to the mouth-nose dominance of prosimians). The coordination of object rotation, pulling-apart, hand-to-hand exchange, and rubbing is highly adaptive for picking and cleaning foods. It is possible, of course, that some old-world monkey species may have evolved elaborations on this basic pattern.

Like great apes, cebus monkeys display the intellectual abilities of the fifth and sixth stages of the sensorimotor intelligence, space, and causality series (Parker & Gibson 1977), as well as the object concept series (Mathieu et al. 1976). Specifically, they display the "secondary" and "tertiary circular reactions" and the discovery of new means, which are characteristic of the sensorimotor intelligence series, and the object-object manipulations of stage five of the spatial and causality series. They do not, however, display imitation of novel gestures and vocalizations. Judging from published reports and personal observation of object manipulation in other new-world species, this pattern is unique among ceboid monkeys.

Although they have not been studied from a developmental perspective, the lesser apes (gibbons and siamangs) do display some of the intellectual abilities of stage five of the sensorimotor intelligence and spatial series. A young siamang at the San Francisco Zoo was observed repeatedly dropping a leaf and catching it in the air, suggesting "tertiary circular reaction" (Lacie, personal communication). Siamangs at the Gladys Porter Zoo, Brownsville, rolled coconuts on the floor and launched them off walls repeatedly (Gibson, personal observation). Rumbaugh (1970) reported a gibbon weaving a rope in and out of the links of a chain-link fence, suggesting an early preoperational understanding of topological relations of enclosure. Reynolds (1971) reports a gibbon raking in food with a stick when the food was placed directly in front of the stick but not when it was further away, suggesting a poorly-canalized capacity to discover new means for solving problems.

### The intelligence of great apes

Gorillas and chimpanzees pass through the six stages of the sensorimotor period in the same sequence and at almost the same rate as human infants, and they display most of the abilities characteristic of human infants in most of the series: They complete the object concept series earlier than human children and the sensorimotor intelligence series somewhat later than human infants. They display the "tertiary circular reaction" and "discovery of new means," but somewhat less frequently and in fewer contexts. They complete most but not all aspects of the space and causality series. They complete the imitation series in object use and in the gestural but not the vocal modality (Parker 1976, 1977; Chevalier-Skolnikoff 1976, 1977; Redshaw 1978; Mathieu 1978). Different investigators have reported slightly different rates of development in the same species, perhaps as a result of differences in methodology; investigators studying sign-using animals report the development of causality

schemes that are not reported in group-living animals (Mathieu, personal communication).

Although there are no published reports of developmental studies on the preoperations period in great apes, there are reports of tests for specific abilities; and there are other reports on great ape intelligence from which much can be inferred about the abilities characteristic of this period (Jolly 1974). Taken together, these reports suggest that great apes display the abilities characteristic of human children in the symbolic subperiod of preoperations (two to four years of age), such as language (see below), drawing of simple topological forms, and symbolic play (see below). They also display evidence of this subperiod's topological-perceptual dominance. This is revealed, for example, in the phenomenon of "optical realism" described by Köhler (1927), wherein chimpanzees focus on the apparent proximity of objects rather than their causal relations—as in standing a ladder on edge against a wall rather than leaning its two ends against the wall.

Observations and experiments on chimpanzees and gorillas at the San Francisco Zoo have revealed the prominence of the topological preconcepts of enclosure and open versus closed form. Like two- to four-year-old children, these apes engaged in repeated tactile and visual exploration of the hole in doughnut-shaped objects but did not systematically explore their surfaces, or those of cubes, cylinders or eggs. (Davenport & Rogers, 1970, report that chimpanzees have much greater difficulty than children in recognizing the shape of objects from tactile exploration alone.) The chimpanzees also displayed a strong interest in the containing or enclosing aspects of hollow plastic cubes, doughnuts, and detachable "pop" beads, peering into the small holes in the beads, pushing the nipples into the holes, purposefully enlarging tooth marks in the toys with their teeth and hands, and placing small objects and water into the holes (Pulos & Parker 1979). These observations are consistent with Premack's (1976) observation of the high salience of the "in" scheme in chimpanzees and human children. (This scheme is less salient in gorillas; Pulos & Parker 1979, Redshaw 1978). The focus on topological relations is also suggested by reports that chimpanzees and gorillas, like two- to four-year-old human children, draw closed figures resembling circles, and open figures resembling crosses (Rensch 1973; Temerlin 1975; Premack 1976; Reynolds 1971; Patterson 1978b) but are unable to copy triangles (and other geometric figures), even with a mechanical guide (Rensch 1973). According to Piaget & Inhelder (1967), in human children this phenomenon results from the fact that they abstract from geometric figures only the topological features of openness and closedness.

Knot tying is another expression of the development of topological notions during the symbolic subperiod in human children. We know of no reports of knot tying in great apes, but Köhler (1927) reported that his chimpanzees removed a knot from a hook and unwound rope looped around a beam. They could not, however, untie a knot. A three-year-old gorilla at the San Francisco Zoo repeatedly looped burlap around his cage bars and hung by the end of it (Bent, personal communication; Parker, personal observation). Schiller (1949) reported similar "weaving" of sticks through bars by his captive chimpanzees. These reports suggest that the great apes are slightly less advanced in this regard than two- to four-year-old human children.

The classification and seriation abilities of great apes have not been systematically studied. Like two- to four-year-old human children, chimpanzees in zoos construct "graphic collections" of geometric blocks: a series of pairs of related forms, with similarity criteria shifting from pair to pair (e.g., choosing a green square and a red square and then shifting to color and choosing a red circle; Pulos & Parker 1979). Premack (1976) reports, however, that his sign-using chimpanzees group geometric forms by shape and color; Hayes & Nissen (1971) also report object grouping by color and form (Jolly 1974). These reports suggest some classification abilities like those of human children in the intuitive substage of preoperations. Premack (1976) reports that his chimpanzees could not seriate objects by size—an ability that emerges at a trial-and-error level in the intuitive substage of preoperations in human children (Inhelder & Piaget

1964). Jolly (1974) interprets chimpanzees' serial choice of symbols for graded sizes of food as seriation. It seems likely, however, that this behavior is based on perceptual recognition of seriation rather than on construction.

The contrasting patterns of prosimians, macaques, great apes, and man constitute four levels of intellectual achievement, suggesting a phyletic series of stages in the evolution of intelligence. Insofar as the contemporary representatives of each group retain their respective ancestral characteristics, we can infer the following stages in the evolution of intellectual abilities:

First, *the prosimian stage*: stage-one and -two sensorimotor period grasping and coordination of hand and mouth without object permanence.

Second, *the old-world monkey stage*: the accretion of stage-three coordinations of vision and prehension without "secondary circular reactions," stage-four coordination of simple prehensive schemes, stage-five or -six object permanence.

Third, *the great ape stage*: an elaboration of stage three with the addition of "secondary circular reactions," addition of stage-five "tertiary circular reactions" and "discovery of new means," stage-five spatial and causal object manipulation schemes, stages-five and -six deferred imitation of novel object manipulation and gestural schemes, symbolic play, and spatial precepts.

Fourth, *the hominid stage*: elaboration of the "secondary" and the "tertiary circular reactions" and "discovery of new means," imitation of novel vocal schemes, preoperational spatial notions, and classification and seriation notions.

We can infer that the addition of all the subsequent stages of preoperational, concrete operational, and formal operational intelligence must have occurred subsequent to hominid differentiation.

It is important to emphasize in this context that the comparison of living species can only provide an approximation to a phyletic series. Living prosimians and monkeys do not necessarily retain the adaptations of the ancestor that they share with us. They are all products of adaptive radiation into different feeding niches, and some have evolved new specializations.

Although we are focusing almost exclusively on intelligence in this paper, we do not mean to imply that any primate species, including our own, relies exclusively on intelligence. Each species has its own total adaptive pattern, based on a unique interdependent mixture of innate and learned elements (Lorenz 1965). This pattern includes reproductive, defensive, and maintenance strategies. Intelligent problem-solving is one adaptive mechanism that has been selected in a few species. Most successful species, however, survive with very little intelligence. It would be wrong to conclude that an adult animal with the intelligence of a two-month-old human infant could not survive in the wild because a two-month-old human infant could not. Whatever level and degree of intelligence a species displays is part of a total adaptive pattern and must be analyzed in that context. A basal great ape, a chimpanzee, or a protohominid adult with the intelligence of a one- to five-year-old human child are not equivalent to such a child in all other respects. Their locomotor skills and their defensive strategies, for example, are those of adult animals adapted to a particular niche. It is interesting, however, to reverse the perspective and ask at what age a human child could survive on his own in a benign environment. A three-year-old child is quite competent to move about on his own and to feed himself, given the availability of appropriate foods that do not require special preparation. The phenomenon of feral children suggests that human children of tender years can survive on their own for extended periods (Lane 1977).

#### Extractive foraging in apes and hominids

Feeding strategies are the behaviors involved in locating, extracting, preparing, distributing, storing, and eating foods. These strategies are adaptations to the temporal and spatial distribution of food sources in a given habitat, and, like all other behavioral systems, they involve both learned and instinctive elements. Feeding strategies are



Figure 1. Chimpanzee extracting termites from mound with stick.

primary determinants of mating and parental care and, hence, of social structure (Wilson 1975; Klein & Klein 1975; Trivers 1972; Orians 1969; Daly & Wilson 1978). (There is, of course, a feedback relationship, whereby the reproductive strategies of ancestors also constrain the feeding strategies of the descendants, as, for example in lactation.) We suggest that feeding strategies are also primary determinants of intelligence (Parker & Gibson 1977) and that intellectual adaptations for social life are probably secondary to those for feeding (*contra* Humphries 1976).

Chimpanzees live in a wide variety of habitats, including continuous forests (Reynolds 1971; Jones & Sabater-Pi 1971) and a mosaic of riverine forests and savanna woodlands (van Lawick-Goodall 1968b; Suzuki 1969). They are omnivorous seasonal feeders who eat fruits, leaves, shoots, and flowers of more than 80 plants; birds' eggs; many small mammals, including four species of monkeys at the



Figure 2. Chimpanzee extracting water from tree bowl with leaf sponge.

Stream Reserve alone; many insects, including galls, caterpillars, several species of ants and termites, grubs, and insect eggs (van Vleet-Goodall 1968b; Teleki 1975; Suzuki 1969). Chimpanzees employ a locally variable "subsistence technology" throughout their geographic range, including: pounding open nuts and hard-shelled fruits with sticks and stones (reported in Liberia and Ivory Coast); working with twigs for termites, ants, and honey (reported in two locations in Rio Muni and four locations in Tanzania); sponging up water and brain tissue with crumpled leaves (reported in Tanzania); and wiping the body off with leaves (Teleki 1974). All but the last of these techniques are associated with extractive foraging for embedded or encased foods.

In the wild, both gorillas and orangutans engage in extractive foraging without tools; on account of their great strength they are able to extract foods with their hands and teeth (Schaller 1963; MacKinnon 1974; Brindamour 1976).

The common ancestor of the great apes and hominids was a small species of Dryopithecoid or Sivapithecoid ape living in the middle or late Miocene (fifteen to eight million years B.P.) somewhere in Africa, Asia, or Europe (Pilbeam et al. 1977). Although the particular species giving rise to the adaptive radiation of great apes and hominids is unknown, it seems likely that they were locomotor generalists, equally capable of movement on the ground or in the trees. Like chimpanzees, they were opportunistic omnivorous ground and tree feeders who ate a variety of seasonally-variable embedded high-energy foods present in the seasonal forest-edge savanna habitats. Their ability to use tools allowed them to exploit embedded foods that were relatively inaccessible to competitors. Foraging with tools to extract embedded foods was a small but important part of a general feeding strategy, including heavy seasonal consumption of fruit, young leaves and small vertebrates. Hominid differentiation from the apes was based on a shift from secondary seasonal dependence (as in the case of chimpanzees) to primary year-round dependence on such tool-aided extractive foraging. All the target foods shared the property of being encased in a shell or being embedded in a solid matrix such as the earth, which had to be penetrated or excavated in order to free it. Because of their small body size (probably comparable to that of pygmy chimpanzees) hominids could not open these foods with their hands and teeth (as gorillas and orangutans do). Tool use is an efficient use of energy for species lacking the relevant anatomical equipment. (Alcock 1972, 1975).

The first hominids had a basic tool kit consisting of perishable wooden and other organic tools and unmodified stones; pounding stones for breaking open hard-shelled fruits and nuts, for cracking open scavenged long-bones for marrow, for smashing open turtle shells, and so forth; digging sticks, for excavating deep roots, tubers, and bulbs, and for digging for water; stabbing sticks for stabbing excavated fossorial animals; hitting sticks for knocking nuts, fruits, and seeds off bushes and trees; probes for termite fishing and ant dipping; leaves for cleaning and wiping grit from food, natural shell dippers for scooping up and drinking fluids from holes such as water, blood, and honey; and perhaps natural containers for collecting and transporting small extracted and gathered items such as grubs and nuts (Gibson & Parker 1979). Most of these extractive foraging techniques are still used by contemporary hunters and gatherers.

### The first hominids

Although the Plio-pleistocene (from 2.5 million years on) hominids *Australopithecus* and *Homo habilis* are well known, the age and specific identity of the first hominid is unknown. Until recently there were no ape or hominid fossils representing the late Miocene and early Pliocene epochs (from about 8 to 2.5 million years B.P.) preceding the time of *Australopithecus* and *Homo habilis*.

Part of this gap has been filled with the discovery of the new Pliocene (3.8 to 3 million years B.P.) hominid, *Australopithecus afarensis*, which is almost certainly the common ancestor of the Plio-pleistocene *Australopithecus* species and early *Homo* (Johanson & White 1979). *A. afarensis* is a small (three- to four-foot tall)

bipedal creature with reduced canines and a chimpanzee-sized brain. No archeological remains are associated with this creature. The mixture of ape-like and hominid-like characteristics in *A. afarensis* suggests that this species was the direct descendant of the common ancestor of the great apes and hominids. It is impossible to be certain that *A. afarensis* was indeed the first hominid, but this interpretation is supported by the dating of hominid-ape divergence as 5 million years ago on the basis of immunological comparisons of living primate species (Sarich & Wilson 1967).

An earlier hominoid, *Ramapithecus*, may have been the first hominid (Leakey & Lewin 1977; Simons 1976, 1977; Grantt & Pilbeam 1977; Tattersall 1975; Pilbeam et al. 1977), a collateral line of apes that died without issue, or the common ancestor of the great apes and the hominids (Zihlman et al. 1978). The latter interpretation is attractive, because *Ramapithecus* was a small pygmy chimpanzee-sized creature inhabiting a variety of late Miocene mosaic biomes (Isaac 1976a), which offered a diversity of embedded foods. In other words, *Ramapithecus* is an appropriate candidate for the first extractive-foraging adaptation (Gibson & Parker 1979).

Even though the identity of the first hominid is unknown, the idea of a pre-archeological phase of hominid evolution has brought in its wake a de-emphasis on the hunting hypothesis and a compensatory emphasis on seed-eating (Jolly 1970) and gathering of vegetable foods (Teleki 1975; Tanner & Zihlman 1976; Lancaster 1978). The emphasis on vegetable gathering has also focused interest on the digging stick (Washburn 1960; Robinson 1963; Bartholomew & Birdsell 1953; Mann 1972; Tanner & Zihlman 1976; Lancaster 1978) and on containers (Tanner & Zihlman 1976; Lancaster 1978).

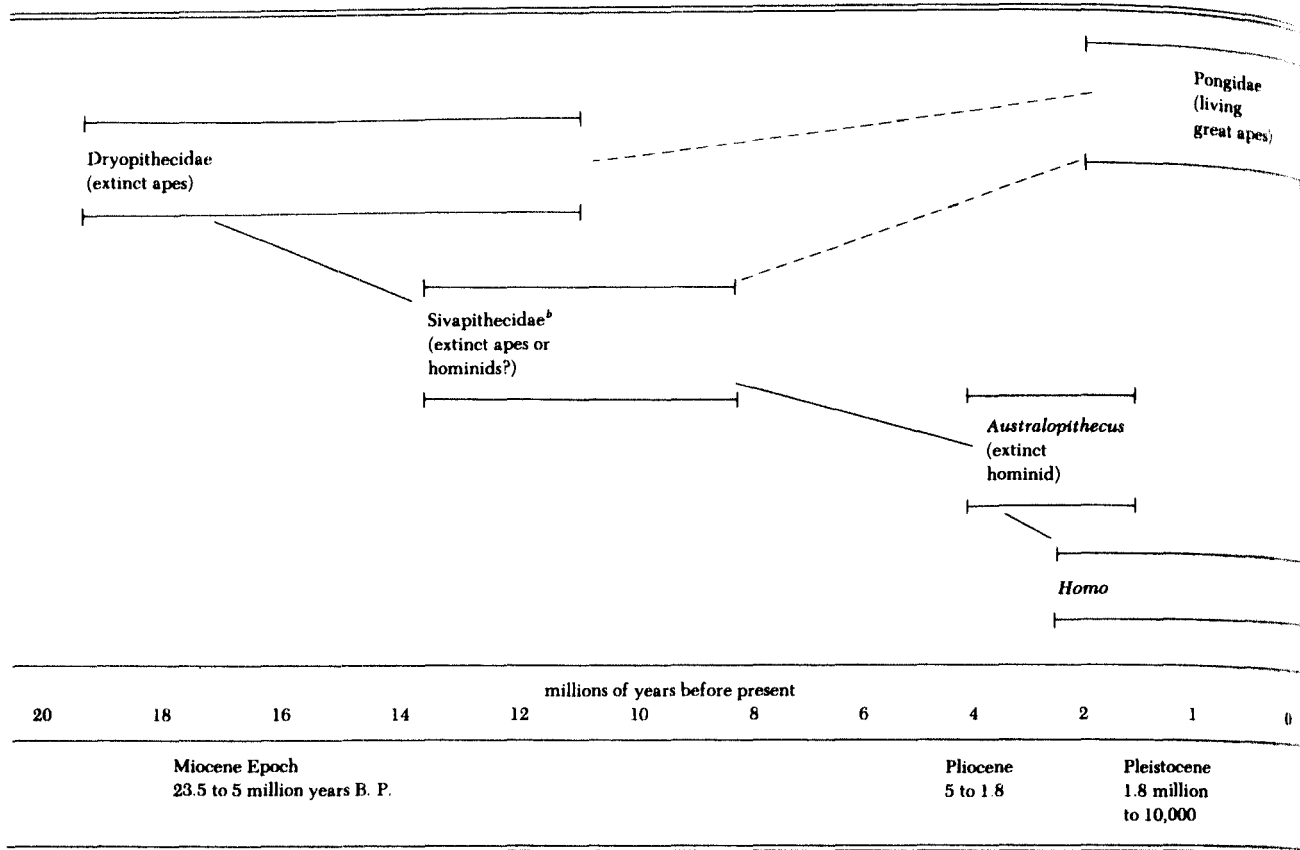
The present extractive-foraging model of hominid differentiation, derived from Hamilton's (1973) "scavenge-hunting" model, is not inconsistent with the gathering and seed-eating hypothesis, but it has several advantages: it provides (1) a central organizing principle embracing a larger range of behavior and technology, (2) a smooth transition from protoape to protohominid behavior and technology, (3) a smooth transition from early hominid subsistence and technology to later hominid subsistence and technology, and (4) a basis for understanding the adaptive significance of language and intelligence in hominid life. The seed-eating and vegetable-gathering models, by contrast, do not provide an adequate challenge for the selection of intelligence and language, nor do they provide preadaptations for hunting and construction.<sup>2</sup>

### Sensorimotor and symbolic intelligence as adaptations for extractive foraging

True tool use (as opposed to simpler forms of prototool use) involves using one detached object (not a part of the animal's anatomy) to change the state of another object - that is, tool use requires a tool. The activity can be stereotyped and context-specific, as it is in some birds, such as the Galapagos woodpecker finch, or it can be more or less intelligent and generalized, as it is in man and great apes. Tool use in animal species tends to correlate with extractive foraging on embedded foods. Stereotyped tool use is associated with context-specific foraging on a single nonseasonal food source; intelligent tool use is associated with extractive foraging on a variety of seasonally- and locally-variable encased foods. Intelligent tool use results from trial-and-error and insightful invention of new means to solve a problem. Once a tool-using technique is invented, it may spread through imitation and observational learning in a local population. Intelligent tool use allows species to invent new technology to exploit locally and seasonally variable resources (Parker & Gibson 1977).

Intelligent trial-and-error tool use is based on certain achievements characteristic of the fifth stage of the sensorimotor period in human infants, which occurs at about one year of age (Piaget 1962, 1963, 1971a). Specifically, it requires a practical understanding of object-object relations in space such as relations of before-behind, near-far, above-underneath, inside-outside (fifth stage of the spatial series); a practical understanding of simple means-ends relations of force and movement (fifth stage of the causality series); variable experimenta-

Table 2. Living and fossil apes and hominids<sup>a</sup>



<sup>a</sup>Based on Table from Pilbeam et al. (1977)  
<sup>b</sup>Family including genus *Ramapithecus*

———— established phylogeny  
 - - - - - uncertain phylogeny

tion to discover the properties of objects and force fields such as dropping objects from different heights (the "tertiary circular reaction") and goal-directed trial-and-error coordination and application of schemes to solve problems ("discovery of new means", the fifth stage of the sensorimotor intelligence series); but not object permanence (fifth stage of the object concept series).<sup>3</sup> Insightful tool use without prior trial-and-error groping is based on the achievement of deferred imitation of new schemes and on the mental representation of schemes characteristic of the sixth stage of the sensorimotor period in human infants, which occurs at about one year to eighteen months of age.

The discovery of new sources of embedded foods and the anticipation of tool use to extract and gather them in containers is based on topological precepts, mental imagery, and the formation of "graphic collections," characteristic of the symbolic subperiod of the preoperations period in human infants, which occurs between two and four years of age (Piaget & Inhelder 1967; Inhelder & Piaget 1969). The discovery or recognition of new potential embedded foods requires mental imagery of the topological relationships of enclosure, proximity, and separation of elements in space, combined with a strong propensity to focus on these relationships in the environment. Anticipation of tool use requires interiorized schemes of trial-and-error groping for means of penetrating enclosures with implements; anticipation of container use requires interiorized schemes of placing objects in other objects.

Tool and container selection, and transportation to the site for extractive foraging requires mental imagery of enclosing relations and the propensity to create small ("graphic") collections of functionally related objects (e.g., digging stick, wiping leaves, and a natural container that can be used to excavate, clean, and store extracted foods).

Searching for new foods involves a propensity to see the world in

terms of the potential topological relationships of enclosure and proximity - that is, suspecting that objects such as shells contain fruits and nuts, that substrates such as earth contain objects such as tubers, roots, bulbs (especially in proximity to plants), and small fossorial animals such as moles and gophers (especially in the proximity of holes).

Foraging with digging sticks for deep tubers, roots, or bulbs, for example, requires: (1) an image of the embedded food and its proximity to surface plants; (2) a grasp of the enclosure relation between earth and the food; (3) a mental representation of the scheme for penetrating the enclosure with a stick through trial-and-error manipulation of the tool in space relative to the earth and to the surface plant; (4) an image of the position of the agent's body; and, finally, (5) a mental representation of the scheme for cleaning the food with leaves and placing it in a container. Foraging with tools also requires a propensity to see the potential of objects such as rocks, branches, leaves, and shells as tools, wipers, and containers, as well as a tendency to collect and transport them to the sites of embedded foods - that is, a propensity to create small functional collections of objects.

The importance of fifth and sixth stage sensorimotor period and symbolic subperiod abilities for tool use and food location suggest that these abilities, which are present in great apes and man, arose in the common ancestor.<sup>4</sup> Elaborations of these abilities must have occurred in the first hominids as the latter increased their dependence on this subsistence mode.

**The food-sharing hypothesis of language origin**

We suggest that food sharing first arose as a secondary adaptation for extractive foraging with tools, rather than as an adaptation for

feeding and gathering (Isaac 1978). During a long apprenticeship period, juvenile protohominids depended on their mothers and other kin to share food with them, to help them open embedded foods, and to act as models for extractive foraging. Data on the behavior of contemporary chimpanzees support this view. Chimpanzee juveniles develop slowly and depend on their mothers to nurse them, share food with them, and act as models for observational learning of local subsistence technology. Silk (1978) reports that chimpanzee mothers at the Gombe Stream Reserve share hard-to-process foods such as *Strychnos* fruits with their offspring during the transition from suckling to independent foraging, which occurs between four and five years of age in this species. She emphasizes the energetic efficiency of food sharing as opposed to continued lactation. Teleki (1974) and McGrew (1976) report that efficient termite eating and ant dipping with probes require several years' apprenticeship by juvenile chimpanzees at the Gombe Stream Reserve.

Food sharing must have been more frequent and adaptively significant in a species relying primarily on hard-to-process foods that had to be extracted with tools. The energetic savings from a behavioral food-sharing strategy, as compared to a physiological lactation strategy, would have been even greater in a species requiring five or six years' apprenticeship for efficient independent foraging.

The importance of food sharing in hominid adaptation is indicated by its apparently universal occurrence among human children as young as one year of age. In their second year children begin feeding their parents with real and imaginary food and greeting strangers with food and other objects (Parker, personal observation). These food-sharing behaviors persist into nursery school, where greetings with food are common (Garvey 1977). Eibl-Eibesfeldt (1974) witnessed this food-sharing complex in young children in several primitive societies and suggests that it is an innate human pattern [see also Eibl-Eibesfeldt: "Human Ethology" *BBS* 2(1) 1979]. Food sharing also plays a vital role in adult human social behavior. The existence of these patterns, of course, does not necessarily imply that food sharing began with extractive foraging, but their appearance during the sensorimotor period does.

In human children language emerges during the period from 9 to 24 months, between the fourth and sixth stages of the sensorimotor period. The language of this period is called prelanguage or protolanguage, because it precedes the mastery of grammar and entry into the adult language system (Halliday 1975). Protolanguage has content and expression. The content is the meaning within a given social and material context. By eighteen months (the sixth stage of the sensorimotor period) these meanings serve the following functions: the *instrumental function* of getting goods and services (the "I want" function); the *regulatory function* of controlling the behavior of others (the "do as I tell you" function); the *interactional function* of initiating and responding to interactions (the "you and me" function); the *personal function* of expressing emotional states (the "here I come" function); the *heuristic function* of gaining information about the environment (the "tell me why" function); and the *imaginative function* of creating make-believe (the "let's pretend" function). The last function, the *informative function* (the "I've got something to tell you" function), appears later.

An "expression" is the particular form that meanings take. While the meanings of protolanguage and their functions remain relatively constant (with the gradual addition of new functions), the expressions of these meanings change radically from phase I to phase II of protolanguage development. Phase I, from nine to sixteen months of age, is characterized by instrumental, regulatory, personal, and imaginative functions. The meanings subserving these functions are expressed in idiosyncratic personal utterances (which are usually not imitations of adult words) and by ritualized referential gestures. During phase I the meaning of an utterance is synonymous with its use in the immediate situation. In other words, each utterance specifies both meaning and context and has only one function.

Meanings in phase II of protolanguage, from 16 months to 24 months of age, are expressed in the words of the adult language. These utterances have more generalized, less context-specific mean-

ings and can hence refer to objects and events outside the immediate situation. During phase II children's utterances begin to display the heuristic function (tell my why) and to differentiate into pragmatic and descriptive functions. Pragmatic utterances have a rising intonation, indicating that they require a response, while descriptive utterances have a falling intonation, indicating that they do not. Children in phase II engage in dialogues (which require the ability to adopt, assign, and reverse social roles), asking and answering yes, no, and "wh?" (who, where, when, why) questions, as well as lying, joking, rhyming, and analogizing (Halliday 1975).

Protolanguage involves gestures that express all or part of a particular meaning. In fact, the emergence of a "gestural complex" between nine and thirteen months predicts and precedes the emergence of the first words (Bates et al. 1977). This gestural complex is comprised of referential pointing, object showing, object giving, and a gestural request for objects (the "gimme" gesture of rapidly opening and closing the fists, with hands extended; Bates, personal communication). The emergence of this gestural complex correlates with the achievement of the fourth and fifth stages of the causality series (involving the realization that other people can act on objects, as revealed by nonverbal requests to reach objects and wind up toys, etc.) and with the achievement of the fifth stage in the imitation series (involving the ability to imitate novel schemes), but not with the stages of the object concept series (Bates et al. 1977).<sup>5</sup>

Neither this gestural complex, nor the use of adults to act on objects, were displayed by gorilla infants living in a social group at the San Francisco Zoo (Parker, personal observation). The complex has not been described in wild chimpanzees and gorillas (van Lawick-Goodall 1968a; Schaller 1963), and its absence in interactions between animals in undisturbed social groups of apes contrasts with its occurrence in interactions between apes and their human keepers. In the presence of their keepers chimpanzees proffer objects, engage in referential pointing at objects that they want (Alcaez, personal communication), and use people to activate toys for them (Mathieu, personal communication; Pulos, personal communication). This suggests that while apes do not use these gestures in undisturbed social groups because under these conditions gestures fail to elicit helping responses, gestures are available to them, and apes will use them, given the appropriate context and incentives. Chimpanzees and gorillas are also able to learn, and use productively, several hundred arbitrary and iconic signs in the hand/eye modality - that is, hand sign language (Gardner & Gardner 1969), plastic form language (Premack 1971), and typewriter language (Rumbaugh et al. 1973), although it is important to emphasize in this context that ape language learning has only occurred as a result of "arduous, carefully-planned instruction" by human keepers (Rumbaugh, personal communication); whether the offspring of hand-signing apes will learn signs from their mothers is an unanswered question.

Setting aside this crucial difference in spontaneity, we can ask what level of language ability apes display relative to human children. Gorillas and chimpanzees can engage in dialogues with each other and with their human keepers, (interactional function), asking yes, no, and perhaps "wh?" questions (heuristic function), issuing and responding to requests and commands (instrumental and regulatory functions), labeling and describing objects (by shape, color, and class of function), referring to past and future events (mathetic functions), expressing emotional states (personal function), lying, joking, and rhyming (imaginative function) (Gardner & Gardner 1969, 1975; Premack 1971, 1976; Fouts 1973, 1975; Rumbaugh et al. 1973; Gill & Rumbaugh 1975; Rumbaugh & Savage-Rumbaugh 1978; Savage-Rumbaugh et al. 1978, 1979; Patterson 1978a and b). [See also "Cognition and Consciousness in Nonhuman Species" *BBS* 1(4) 1978.] With these protolanguage functions, meanings are expressed in signs and words that are used in a variety of contexts for a variety of functions. (Like human children, chimpanzees first associate meaning with a specific context, and only later, under the pressure of multifunctional uses of a word by their keepers, do they develop more generalizable and less context-specific meanings; Savage-Rumbaugh et al. 1979.)

The pragmatic functions of referential communication are well

illustrated in the dialogues between two language-using chimpanzees at Yerkes. Two sign-using animals were placed in adjacent rooms connected by a window and a pass-through; each had a typewriter and a screen displaying the messages typed on the keyboard. When they were placed in a situation where one animal had access to food (which had been hidden by the experimenter while both animals watched) and the other did not, the one without access requested food items by name from his partner, and his partner gave the requested items to him (Savage-Rumbaugh et al. 1978). When the animal without access to the food had access to the tools his partner needed to get at encased foods (but to which he did not himself have access), he responded to requests for specific tools by giving them to his partner. His partner used the tools to get at the encased foods and then shared the bounty with his partner (Savage-Rumbaugh et al. 1979).

In other words, when placed in a situation of enforced dependency, with a language system at their disposal, these animals used language to request foods and tools that they could not get for themselves. The authors interpret these data as indicating that chimpanzees are capable of intraspecific referential communication, with intentional message transmission and reception as well as reversible roles.

On the basis of the close phylogenetic relationship between great apes and hominids, we assume that the common ancestor displayed a capacity for referential communication at least as great as that of chimpanzees and gorillas, and that the first hominids displayed a language capacity at least as great as that of the common ancestor, and probably greater. The similarities between great ape language and human infant phase II protolanguage, as well as the correlation between protolanguage and fifth and sixth stage sensorimotor intelligence imitation and causality series abilities, suggest that the common ancestor of great apes and man displayed language-learning abilities similar to those of two-year-old human infants. From the absence of spontaneous language acquisition in great apes, we conclude that these abilities were not specifically canalized into language learning in this common ancestor as they are in human infants (Fishbein 1976), but were side-effects of the sensorimotor intellectual capacities that arose as adaptations for extractive foraging with tools. The shift to primary dependence on extractive foraging with tools, and the attendant food sharing that characterized hominid differentiation, favored canalization of language-learning abilities and resulted in a strong propensity to acquire protolanguage. The first hominids displayed a form of protolanguage similar to the phase II protolanguage of human infants. Comparative data suggest that the common ancestor had a greater degree of voluntary control in the gestural modality than the vocal modality. These data support the idea that the first language was primarily gestural (Hewes 1973). The evolution of a propensity to acquire a gestural protolanguage only required an increased tendency for voluntary combination and coordination of gestures (including the gestural complex and gestural imitations) and their use to refer to objects and events. The intellectual prerequisites for this sort of problem-solving already existed in connection with object manipulation for tool use and only needed to be extended into the arena of gestures.

The subsequent evolution of language in the vocal modality was slightly more complex, since it required a shift from involuntary subcortical control of vocalization to voluntary cortical control (Campbell 1974). This shift also involves increased neurological control of the lips and tongue, permitting rapid and precise articulatory coordinations and combinations (Gibson, 1977). As vocalizations came under voluntary control, they could be used as "means" to refer to objects and events. Language in the vocal modality probably first arose as an imitational supplement to gestural language, then gradually replaced it due to the two advantages of vocal/auditory communication over gestural/visual communication: First, vocal communication is multidirectional and therefore does not require visual attention from the receiver (Marler 1965). Second, the vocal channel is more energy-efficient than the gestural/locomotor channel - that is, moving the vocal chords requires substantially less effort

than moving the hands, arms and legs. Vocal communication was advantageous for animals engaged in extractive foraging with tools an activity that requires sustained visual attention. There was an advantage for individuals who were able to convey requests, commands and other information over short distances without expending the extra energy required to go to the receiver and get his visual attention.

The functions of protolanguage are well suited for communicating requests for tools and help in opening embedded food sources and for issuing commands to accompany a scout to distant food sources. These messages were expressed by referential pointing and ritualized "display walking" in the direction of stationary or distant foods, by showing an object and imitating the tool-using schemes associated with extracting it; and by object-giving plus ritualized "gimme" gestures to indicate the need for help in opening a food. (It is interesting to note in this context that "display locomotion" toward a distant food source has referential value. Captive chimpanzees communicate to their fellows the location and relative size of hidden food caches through the direction and speed of their locomotion [Menzel & Halperin 1975]. Honey bees too communicate the location of distant food sources through a highly ritualized form of "display locomotion" [Brown 1975].)

Our confidence in a theory of adaptive function is increased if there is evidence of analogous function in other animal taxa. The honey bees are the only other animal taxon known to display referential communication [See Griffin: "Prospects for a Cognitive Ethology" BBS 1(4) 1979]. Theories of language origin have tended to ignore the analogies between human and bee language, however, because of the great phylogenetic distance between the two taxa. Obvious differences in the proximal mechanisms of human and bee language have also discouraged comparisons. This is unfortunate, because analogies between the most distantly related taxa may be very instructive if they are made at the appropriate level (Gibson & Parker 1979; Hockett 1960).

In fact, the analogies between human and bee language function are very instructive: Honey bees communicate the nature of a distant food through olfactory cues, and its location through a dance involving "display locomotion," indicating the direction and distance from the hive (Brown 1975). Early hominids communicated the nature and location of embedded or distant food through ritualized "display locomotion" toward the food and through a referential and imitational gestural system. Despite the differences in the mechanisms of expression, both languages involve directed communication, to close kin, as to the location of food. It seems likely that directed forms of referential communication are favored in situations where kin groups are competing for scarce, dispersed, seasonal foods.

This directed, referential communication contrasts with the nondirected, nonreferential communication of chimpanzees, which occurs when they advertise fruit bonanzas by loud calling and drumming. The latter communication system is apparently an adaptation for sharing abundant, dispersed, seasonal food. It is also worth mentioning that the hunting hypothesis for language origin is not supported by functional analogies. Hunting animals who share food do not use referential communication systems.

#### Symbolic play and imitation as extractive-foraging adaptations

Human children begin to display symbolic play during the sixth stage of the sensorimotor period when they become capable of deferred imitation of novel schemes. During the symbolic subperiod they extend and elaborate this ability, creating and enacting small dramas of daily activities such as eating, preparing and serving food, traveling, dressing, sleeping, and so forth (Piaget 1962). Make-believe feeding is an especially important theme in symbolic play. Symbolic play (imitative make-believe play), like play fighting and play chasing (Symons 1978), is important for the rehearsal of subsistence roles. Specifically, imitative tool use is important in practicing extractive foraging. Bushman children as young as fifteen months of



for example, play at digging with digging sticks (DeVore & Hammer 1974).

Consistent with their other symbolic subperiod abilities, captive great apes display symbolic play. Koko, the signing gorilla, for example, plays dolls and has make-believe tea parties with her keeper (Patterson 1978b). Both she and Lucy, a signing chimpanzee, enjoy dressing up and making up (Patterson 1978b; Temerlin 1975). Vicki, another human-reared chimpanzee, played with an imaginary stick, pulling it along behind her by an imaginary pull string, even chopping to unloop it (Hayes 1976). These apes also display the descriptive function of language in their make-believe play - they comment to themselves on what they are doing.

This similarity between great ape and human children in terms of symbolic play suggests, by homology, that early hominid children displayed symbolic play, and that this form of play arose as an adaptation for learning tool use in extractive foraging, and perhaps secondarily for symbol use.

### Intuitive intelligence as an adaptation for aimed throwing, tool manufacturing, animal butchery, and shelter construction in *Homo habilis*

Sometime in the Pliocene epoch (about 2.5 to 3 million years B.P.) the first hominid species or its direct descendent split into two lineages. *Australopithecus* and *Homo* (Leakey & Lewin 1977). *Australopithecus*, the more primitive of the two, maintained an extractive-foraging adaptation; *Homo habilis*, the ancestor of *Homo erectus*, evolved hunting as an additional subsistence strategy. This new strategy was based on several new technologies: aimed-throwing of missiles to drive or stun game; stone tool manufacture for aimed throwing and for butchering large animals; shelter construction (Gibson & Parker 1979).

*Homo habilis* was a larger-bodied, larger-brained (600 to 700 cc) bipedal creature who apparently preferred lake margins, while his cousin, the Australopithecine species, preferred river margins (Behrensmeyer 1975). During the Plio-Pleistocene Epoch, East Africa was a mosaic of lakes, marshes, rivers, narrow strips of riverine forest, deciduous woodland, and grassland. The climate was drier and more seasonal than that of the Miocene, and the amount of forest was reduced. During the dry season, surface water was available only at lakes and permanent rivers. Lakes were desirable locations for *Homo habilis* because they provided water as well as plant and animal food. Large mammals congregated near rivers and lakes during the dry season, providing a source of game. Fossil evidence from Omo, Olduvai, and East Turkana indicates that by 2.5 million years ago *Homo habilis* was eating big game (more than 30 pounds), including antelope, porcupine, waterbuck, horse, pig, giraffe, elephant, and hippopotamus (Isaac 1978).

**Aimed throwing of missiles by *Homo habilis*.** Driving large animals into bogs or traps, or stunning small animals, are impossible for a relatively slow-running animal without the aimed throwing of missiles: Man sprints at about 22 mph and runs for sustained periods at about 13 mph, while antelope sprint at 61 mph, horses at 43 mph, hippopotamuses at 30 mph, and elephants at 25 mph (Hamilton 1973). Therefore we can conclude that hunting by *Homo habilis* involved missile throwing. This possibility is also suggested by the presence of spheroid stone tools at Olduvai Gorge; because of their shape, these tools are particularly well suited for aimed throwing. Mary Leakey suggests that they were used in bolas (M. Leakey 1971).

Aimed missile throwing was a significant innovation, and a much more complex and difficult one than it appears. It requires the construction of a straight line between the thrower and the target through line-of-sight aiming. This ability does not emerge until four to six years of age in human children - before that time the child is unable to draw or construct with sticks a straight line between two points unless he does so along the edge of a table or another guide (Piaget & Inhelder 1967) - and it does not seem to occur at all in

great apes. The emergence of aimed-throwing games at four to six years of age (Dennis 1940; Fortes 1976; Hartley & Goldenson 1963) is consistent with the notion that aimed throwing is dependent on line-of-sight straight line construction emerging in the intuitive subperiod.

The adaptive importance of aimed throwing in hominids is also suggested by the ubiquity of aimed-throwing games among human males. Since play is generally recognized as a mechanism for practicing skills (particularly fight and flight skills; [Dolhinow 1971; Aldis 1975; Symons 1978]), it is likely that aimed-throwing games have a practice function for hunting and warfare. By analogy with wrestling and chasing games, there may be an innate tendency to play aimed-throwing games in our species, a tendency that is especially strong in males. This is particularly likely because efficient aimed-throwing is difficult and requires extensive practice.

Although great apes occasionally throw missiles, they rarely hit their targets (Kortlandt & Kooij 1963; Albrecht & Dunnett 1974; van Lawick-Goodall 1978; Eaton 1978). Missile-throwing in apes seems to be primarily a threat display aimed at increasing the apparent size and ferocity of the displayer (von Lawick-Goodall 1971). Although chimpanzees use tools in extractive foraging, until recently there has been no evidence that they use tools in hunting (Teleki 1973). Now there is a report of unaimed missile-throwing at adult animals to isolate immature prey for seizure (Plooij 1978). This is apparently an intelligent application of social tool use. It is very likely that the first hominids regularly engaged in this practice, and that this behavior was a pre-adaptation for the practice of aimed missile-throwing to drive and stun game. Very few animals have evolved aimed throwing as an adaptation for predation (or any other function). Bolas spiders fling silk bolas at insect prey (Gertsch 1947); worm lions and ant lions fell insect prey with hurled grains of sand (Wheeler 1930). In all of these species, aimed missile throwing is context-specific and almost certainly relies on a simple innate releasing mechanism and fixed action pattern similar to that involved in the aimed tongue-flicking of frogs.

On the basis of the importance and complexity of aimed throwing for hunting game, and its association with the development of line-of-sight aiming during the intuitive subperiod between four and six years of age in human children, we suggest that the projective and Euclidean preconcept of the straight line constructed through line-of-sight aiming arose in *Homo habilis* as an adaptation for aimed missile-throwing at prey.

**Stone tool manufacture by *Homo habilis*.** By two million years ago at Omo, Olduvai, and East Turkana, *Homo habilis* was using a variety of simple stone tools including spheroids, hammerstones, choppers, scrapers, and small flakes. Some of these tools (e.g., choppers, spheroids, scrapers, and flakes) were manufactured by chipping flakes off with a hammerstone (they were tools made by tools; M. Leakey 1971). This new extension was more complicated than simply pounding open a hard-shelled fruit or nut with a stone, however. Each artifact implies a set of intellectual operations (Deetz 1967; Holloway 1969; Isaac 1976b). Creating a sharp-edged stone tool requires the notions of sharpness or angle and of sectioning solids, which emerge only during the intuitive subperiod. These notions of angle and section emerge in conjunction with the construction of the straight line as a part of a complex of emerging projective and Euclidean spatial preconcepts (Piaget & Inhelder 1967). Using percussion to create a geometric section requires a notion of the transmission of forces through object contact, which begins to emerge at this time<sup>6</sup> (Piaget 1974).

On the basis of the stone tools associated with *Homo habilis* and their intellectual prerequisites, we suggest that certain projective and Euclidean preconcepts, including sharpness (angle) and geometric sectioning, arose as adaptations for stone-tool manufacture.

**Food preparation and animal butchery.** *Homo habilis* butchered large animal carcasses with stone tools and distributed the meat to adult and juvenile members of their group. They almost certainly transported meat and other foods to a home base and

distributed and exchanged it there (Isaac 1978). This form of food sharing is unique among animals. Although chimpanzees hunt, divide and share their prey, they do so in a manner entirely different from hominids. Division of carcasses occurs through manual ripping and pulling apart by one or several animals, rather than through butchery with sharp tools (Teleki 1973). The absence of tool use in division of prey is hardly surprising, however, because chimpanzees hunt small prey (under 20 pounds) that are easily dismembered by hand, and because meat does not play an important role in their diet. Sharing of carcasses by chimpanzees is opportunistic rather than systematic and occurs through passive permission ("tolerated scrounging"; Isaac 1978), rather than through active distribution (Teleki 1973). Active food sharing only occurs in the case of mothers giving hard-to-prepare foods to their own offspring during the period between weaning and self-sufficient feeding (Silk 1978). These hard-to-prepare foods are small vegetables that do not require division into pieces and subsequent distribution among several animals, as large animal carcasses do. Even food sharing by the first hominids was primarily among parent, offspring and siblings. It did not require division of a whole carcass or exchanges between adults.

The food sharing of *Homo habilis* was obviously much more extensive and elaborate than that of contemporary chimpanzees or of the first hominids. It involved butchery and transportation of carcasses for delayed distribution and consumption as well as the exchange of meat for other kinds of food between adults, probably mates. Use of containers to gather and transport collected and extracted foods for later distribution was also an important part of the food-sharing complex in *Homo habilis*.

Butchering large animal carcasses requires the use of sharp-edged tools to penetrate tough hides and hence calls for the intellectual abilities subserving stone-tool production. Cutting animals open is a new extension of extractive foraging with tools. Cutting substances into equal parts is an ability that emerges in human children during the intuitive subperiod; before that time, when children are asked to cut a substance into two parts, they will cut off a small piece or two and ignore the rest (Piaget & Inhelder 1967). Distributing pieces of a divided whole requires an ability to construct one-to-one correspondences, which emerges during the intuitive subperiod. Exchanging food on a systematic basis requires an understanding of one-to-one exchanges, which also emerges at this time (Piaget 1965). The entire procedure requires some degree of planning, which begins to emerge in the intuitive subperiod.

Although they can engage in one-to-one exchanges and matching (Pulos & Parker 1979), chimpanzees apparently cannot construct one-to-one correspondences (Premack & Kennell 1978). The data on chimpanzee notions of number and quantity are somewhat confusing. In human children one-to-one correspondences are constructed but not conserved during the intuitive subperiod (that is, the numerical correspondence between two sets of objects is forgotten when they are no longer laid out side by side). The emergence of numerical concepts of conservation of quantity (including conservation of one-to-one correspondence of discrete items, and conservation of the quantity of continuous substances such as liquid and plastic) first occurs at the onset of concrete operations at seven or eight years of age (Piaget 1965). Therefore the report of conservation of quantity of liquid and plastic substances by a chimpanzee (Premack & Kennell 1978) is surprising. It seems more likely that the animal is conserving the *identity* of the substance (understanding that it is the same substance, despite its transformations in shape) and not the quantity. Conservation of identity in human children occurs during the symbolic subperiod (Piaget 1968).

Despite the ambiguity of the data on chimpanzee notions of number, we suggest that the ability to divide a whole into equal parts and the ability to construct one-to-one correspondences arose as adaptations for butchering large carcasses and distributing foods.

**Shelter construction.** The importance of shelter construction in hominid evolution has not been widely appreciated. This may be because this behavior is not common among primates and carnivores,

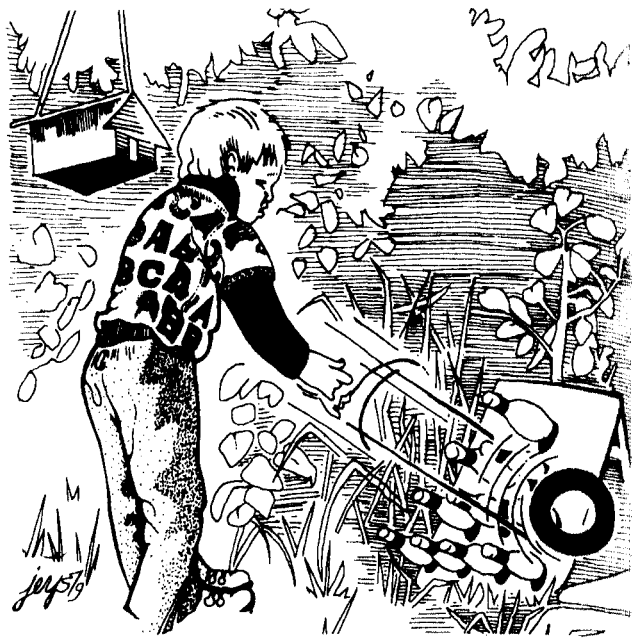


Figure 3. Inaccurate throwing by 4 1/2-year-old boy (aimed-throwing games - symbolic subperiod).

which have been the sources of most hominid analogies. Such construction by other taxa, however, suggests interesting analogies concerning the adaptive functions of shelters. Shelters, like tools, are "artificial organs" (Hass 1970) serving many adaptive functions that are served by natural organs in other species. They are partial or complete enclosures constructed, excavated, or appropriated by animals for various purposes. Among other functions, such enclosures protect an animal from predators and from temperature extremes; they shelter its young, and its food. Shelter construction is common among insects, birds, and rodents.

Construction is a technique that is distinguished from other types of manufacture by the conjoining of two or more separate objects to form a new composite object. Conjoining can occur in a variety of ways: for example, by weaving or intertwining flexible materials, by cementing materials, by nesting, or by juxtaposing or interlocking



Figure 4. Block construction by 4 1/2-year-old boy (construction games - symbolic subperiod).

materials (often with stacking). Shelter construction generally occurs on top of or suspended from some sort of substrate. Like tool use, shelter construction can be stereotyped and context-specific, as it is among insects and birds, or generalized and intelligent, as it is in our species. Great apes construct sleeping nests every night on the ground or in the trees. Nest building by apes is a rapid and simple process of bending over and stepping on small branches to create a body-sized concave structure. Insertion and intertwining occur sporadically in nest construction.

As early hominids became bipedal and moved further from the trees, they became more dependent on shelter construction as a defense against predators and as a protection against wind and rain. The first hominids probably constructed simple shelters of branches piled against natural barriers such as scrubs and small hillocks. They may have slept inside these piles rather than on top of them. Even

simple sleeping-pile construction requires sensorimotor schemes of stacking objects on top of other objects (characteristic of the fifth stage of the spatial series) and an understanding of the topological relationship of enclosure - enclosure of the body in the sleeping pile. Shelter construction in early hominids favored sensorimotor and symbolic spatial intelligence and led to more elaborate shelter construction in *Homo habilis*.

There are many factors suggesting that *Homo habilis* constructed shelters. These creatures lived in open areas around lakes, where they were more vulnerable to predators, wind, and rain. The butchery, transport, delayed consumption, and meat distribution called for by subsistence on large animals brought increased vulnerability to predators and scavengers. These factors combined to favor more elaborate shelter construction. Archeological evidence from East Africa suggests that *Homo habilis* had home bases and lived in

Table 3. Primary adaptive functions of primate intelligence, by grade levels

Kind of intelligence	Prosimian	Old-world monkey	Great ape	Early hominid
<i>Sensorimotor intelligence</i>				
Stages 1 & 2				
Simple prehension, hand-mouth coordination	manual prey catching, branch-clinging, climbing-by-grasping			
Stage 3				
Hand-eye coordination		manual foraging		
Secondary circular reactions*			object play for tool use	same
Stage 4				
Coordination and application of manual schemes on single objects		manual food preparation and cleaning, manual grooming		
Stage 5				
Object permanence		food location, memory (?)	same	same
Object-object coordinations, trial-and-error investigation of object prop. (tertiary circular reactions), discovery of new means (tool use)			trial-and-error discovery of tool use for extractive foraging on embedded foods	same
Stage 6				
Deferred imitation of novel schemes			imitative learning of tool-use traditions	same
Mental representation of images of actions			search for new embedded foods, insightful tool-use	same
<i>Preoperational intelligence</i>				
Symbolic subperiod				
Topological precepts of enclosure and proximity			search for rare embedded foods	same, plus shelter-construction
Make-believe games				
				practice of subsistence roles
Intuitive subperiod				
Euclidean and projective precepts of straight line and angle				tool manufacture, tool use in butchery, shelter-construction
Classification and seriation				
				shelter-construction
1 to 1 correspondence				
				food division
Construction games				
				practice in shelter-construction and tool manufacture
Aimed-throwing games				
				practice for aimed-throwing in hunting and defense

\*Not present in Macaques - arose as retrospective elaboration in great apes

groups of nine to twenty animals. There is also evidence of a walled enclosure or windbreak at Olduvai Gorge (M. Leakey 1971; Leakey & Lewin 1977; Isaac 1978).

Shelter construction by *Homo habilis* required some degree of planning to collect and transport building materials; a propensity to form collections of similar materials (leaves, stones, branches, etc.) and seriate them by size; a propensity to construct straight lines and simple geometric figures; and the ability to tie knots and intertwine materials. Construction also required hierarchical organization of elements (Greenfield 1975). All these abilities emerge during the intuitive subperiod of the preoperations in human children. Shelter construction favored the evolution of tying and intertwining, construction of collections, seriation of objects, and angle and straight-line construction. It also favored construction games as an adaptation for practicing construction.

**Selection for specific abilities.** If our model for the adaptive significance of intelligence seems overly specific, this is because there are compelling reasons for specificity in evolutionary models. The study of organic evolution suggests that specific abilities and characteristics have been selected for specific functions in one or a few contexts. Once selected, these abilities may take on new secondary and tertiary functions in other contexts. The subsequent multiplication of functions tends to obscure the original primary function, which can only be inferred through comparative study of closely-related species and of distantly-related species displaying analogous adaptations (Daly & Wilson 1978).

The ability to grasp objects with the hand, for example, serves many functions in living apes: they use their hands to cling to their mothers, climb trees, pick food, catch prey, make nests, use tools, and so forth. The variety of grasping functions in apes, however, does not suggest that grasping arose as a general adaptation for nonspecific functions. Comparative studies of grasping in monkeys and prosimians and more primitive mammals suggest that this ability arose in primitive primates as an adaptation for small-branch clinging while hand-catching prey insects (Cartmill 1976). Likewise, the variety of functions of intelligence in modern man does not suggest that intelligence arose as a general adaptation for nonspecific functions. Mutation and natural selection work very specifically: they generate specific adaptations that may turn out in the future to be pre-adaptations for new functions. If this occurs, these new functions may obscure the original function. We proceed now to a consideration of the comparative neurology of the species that have been discussed.

### The brain and intelligence

Intelligence differences between primates correlate with differences in brain size and organization. The most obvious neuroanatomical differences among primate species are in terms of total brain size, a measure that probably reflects the total information-processing capacity of the brain. Brain size and total information-processing capacity reflect more than intelligence, of course. They also reflect the entire perceptual, sensorimotor, and emotional organization of the organism. Nevertheless, brain size can be used as a rough index of intelligence when corrected for allometric variations in the brain/body size ratio (Jerison 1973).

Several investigators have found that indices of brain size correlate with performance on psychological tests (Rensch 1956; Riddell & Corl 1977; Passingham 1975a and b). The use of brain size statistics in comparative studies of behavior has been criticized, however, on the grounds that species differences in behavior result not from increases in brain size but from internal structural reorganization of the brain (Holloway 1966, 1968). The reorganization hypothesis is supported, for example, by the fact that microcephalics of our species, who have brains the size of great apes, speak and display other typically human behaviors. This implies that speech depends on neural organization and not solely on brain size. Despite their species-specific abilities in some domains, however, microcephalic men are mentally-retarded.

This suggests that while brain organization determines species-specific behaviors, brain size (in the case of two organisms with the same basic neural organization) determines intelligence.

Modern human brains are both absolutely and relatively larger than great-ape brains. Modern human brains average 1300 to 1400 cc, while great-ape brains average 383 to 594 cc (383 to 393 cc in chimpanzees, 400 to 411 cc in orangutans, 497 to 504 cc in gorillas [Tobias 1971]). When differences in body size and surface-to-volume ratios are taken into account, the size of the human brain exceeds the size of great-ape brains even more markedly than it does in absolute terms (Jerison 1973; Stephan 1972).

Assuming that the common ancestor of great apes and man had a brain size in the range of modern apes, we infer that the first major increase in brain size occurred in Plio-Pleistocene hominids. Brain sizes in *Australopithecus* and early *Homo* range from 506 to 775 cc (McHenry 1975). (Brain size in the newly-named *Australopithecus afarensis* is nearer that of great apes.) The larger-brained hominids at this time probably were members of the genus *Homo* (Leakey & Leakey 1978). Brain sizes increased significantly in the middle Pleistocene: *Homo erectus* in Java averaged 880 cc, in Asia, 1075 cc (Tobias 1971). The total information-processing capacity of the hominid brain apparently increased gradually from about two million years ago until 35,000 to 100,000 years ago and then stabilized at about 1300 to 1400 cc.

Among mammals, species with the largest brains usually have the largest neocortices (Elias & Schwartz 1969; Jerison 1973). This rule holds true in our order as well. In fact, the human brain has a larger neocortex in relation to the rest of the brain than the ape brain does. The human neocortex is 3.2 times larger than it would be in a nonhuman primate of our body size. Within the neocortex the motor cortex and the association areas are proportionately larger than the neocortex as a whole (Passingham 1973, 1975b). In other words, man has much more neocortex, and particularly association cortex, than any other primate.

Histological reorganization as well as expansion of the neocortex apparently occurred during the evolution of the hominid brain. The human neocortex has a lower neuronal density than that of any other primate species. Consequently, even though the human brain is more than three times as large as the chimpanzee brain, it contains only 1.25 times as many neurons (Holloway 1968; Shariff 1953). In animals, low neuronal density in the neocortex is associated with increased dendritic branching, increased numbers of axons, and increased numbers of glial cells (Bok 1959; Holloway 1968; Sholl 1959). Although these data were not obtained from primate species and must be interpreted with caution, they suggest that the human neocortex processes information differently from the ape neocortex. Specifically, the greater number of dendrites and axons suggests that the human neocortex is designed for greater intercellular communication and integrated information processing than that of the ape brain. In other words, the lower neuronal density of the human cortex is associated with increased information-processing capacity and increased synthesis of data and behavior.

The cortex provides flexibility and mobility of behavior, fine differentiation of sensory and motor data, and simultaneous and sequential synthesis of data and behavior (Gibson 1977, 1978). These neurological functions may be the basis for the combination and coordination of schemes, their trial-and-error application in new contexts, and the varieties of mental construction discussed in the preceding developmental sections.

Brain development correlates with intellectual development. At birth the human brain weighs approximately 350 to 400 g; by six months, approximately 600 to 650 g; by 1 year, 900 to 1000 g; subsequently it slowly increases in size until puberty (Blinkov & Glezer 1968, Tables). At birth, then, the human brain is already within the size range of that of adult apes; by six months of age it has clearly surpassed the size norms for any ape species. This should not be interpreted to mean that the human neonate has as much functioning nervous tissue as the adult ape. Neurons do not immediately become functional but may remain dormant for long periods of time prior to interacting in neuronal circuits (Jacobson 1978). Much

of the human neocortex is still extremely immature at birth (Conel 1939-1967), and much of the existing nervous tissue must be considered non-functional at that age. It is not possible on the basis of present data to state the age at which the human child surpasses the adult ape in functioning nervous tissue. The important point is that the size of the human nervous system information-processing network increases dramatically after birth, from a starting point possibly equal to, but probably less than, that of the adult ape.

Just as the major factor producing the differences in brain size between man and apes is not the increase in numbers of neurons (Shariff 1953; Holloway 1968), the major postnatal size-increases in

human brains are not the result of neurogenesis. Human neonates have virtually their full complement of neurons at birth. The major factors influencing size are changes in histological parameters. The ontogeny of the human brain is characterized by decreasing neuronal density in the neocortex accompanied by increasing numbers of glial cells, increasing differentiation of dendrites, and increasing numbers of axons per unit cortical volume. In addition, neurons increase in size and axons grow in width and acquire myelin sheaths (Conel 1939-1967). These changes are particularly marked within the first year or two of life but continue well into childhood. Myelin may continue to increase even into early adulthood (Yakovlev & Lecours 1967). These changes serve to increase the functional capacities and efficiencies of individual neurons. The increased dendritic differentiation and axonal proliferation also increase synaptic interconnections, which are substrates for increasingly-advanced intellectual construction.

The majority of existing data on ontogeny of the brain concern myelination. Myelination is the deposition of the myelin sheath around a nerve fiber during ontogeny. This lipoprotein sheath surrounds the fibers of most peripheral and central nerves above a critical diameter in size: 1 micron in the peripheral nervous system, .2 microns in the central nervous system. Myelin contributes to the functional efficiency of neurons because myelinated fibers transmit impulses more quickly, have shorter refractory periods, lower thresholds to stimulation, and greater functional specificity than nonmyelinated fibers (Bishop & Smith 1964; Duncan 1934; Kingsley et al. 1970; Martinez & Friede 1970; Matthews 1968).

From the standpoint of intelligence, the maturation of the neocortex is of the greatest interest. This is the last region of the brain to myelinate in all species in which myelination has been studied. Detailed studies of patterns of cortical myelination exist for three species: rat (Jacobson 1963); rhesus monkey (Gibson 1970, 1977, 1979); and human (Flechsig 1927; Conel 1939-1967). All three follow the same general pattern. Primary sensory and motor areas myelinate first, followed by secondary sensory and motor areas. The association areas myelinate last. At any given age the sensory and motor areas are the most mature regions of the cortex; the association regions are the least mature.

In the rhesus monkey some myelin is found in the cortical layers of the primary and secondary sensory and motor areas at birth, and myelin is found in all layers of these regions by six months. In contrast, most of the association areas do not possess any myelin at all until three months. Myelin is not found in all layers of the association regions until two years of age. In our species the first myelin is found in the cortical layers of primary sensory and motor areas by one to three months, and in the association areas by six to fifteen months. All layers of the primary sensory and motor areas contain myelin by 15 to 24 months, while some layers of the association areas remain unmyelinated at six years. Since the general direction of morphological differentiation in man, apes, and monkeys is the same in other morphological traits (Schultz 1950), it is likely that, although the myelination of great-ape brains has not been studied, it does not deviate in a significant way from the general pattern of brain maturation exhibited by other primates and other vertebrates.

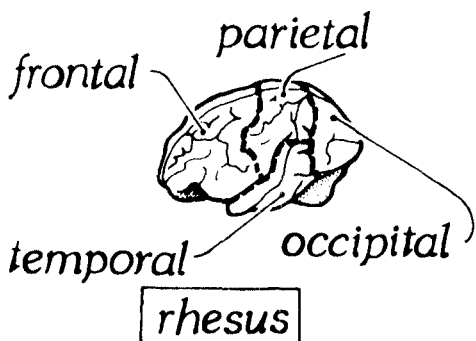
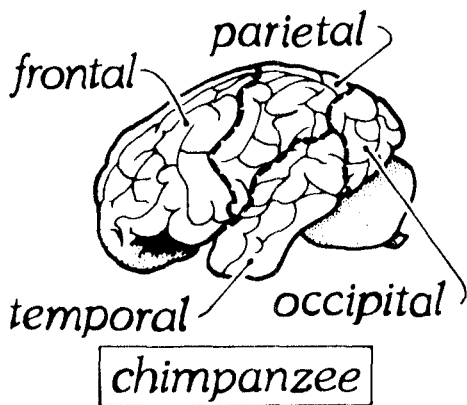
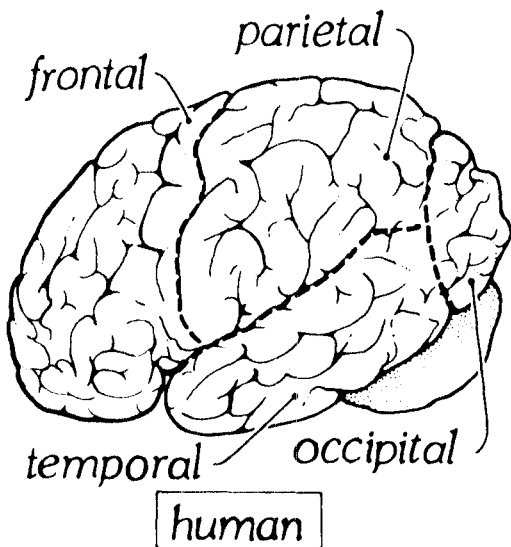


Figure 5. Human, chimpanzee, and rhesus monkey brains drawn to scale. Note the greater size of the human cerebral cortex as a whole and the expansion of the posterior parietal and inferior frontal association areas. [Adapted from Rosen (1974) p. 141.]

### The evolution of ontogeny

Developmental rates are part of a larger pattern known as a life-history strategy. A life-history strategy refers to the relative and absolute length of different parts of the life span. Large, long-lived animals such as man, great apes, elephants, and whales are the products of selection for repeated reproductive effort with low fecundity, long gestation, slow development, and late sexual maturity. Selection favors extended life-history strategies in animals feeding on relatively stable and dependable food sources who can increase their efficiency in exploiting resources through individual and social learning, thereby increasing the carrying capacity (K) of their environment (Gould 1977). Iteroparity (repeated reproductive bouts by the same individual) is advantageous because it reduces vulnera-

bility of the group to extinction by increasing the number of age classes reproducing at the same time (Demetrius 1975). Hence patterns of development, like morphological and behavioral traits, are adaptations. Our strategy of extended life-history with slow maturation and increased number and length of developmental stages resulted from selection for retardation of developmental rates and terminal addition of new traits resulting in neoteny and recapitulation.

There has been considerable controversy over the legitimacy of the concept of recapitulation. A recent reexamination of recapitulation theory, however, places this phenomenon squarely in the context of evolutionary biology: "... recapitulation was not 'disproved'; it could not be, for too many well established cases fit its expectations. It was instead abandoned as a universal proposition and displayed as but one possible result of a more general process... evolutionary alteration of times and rates to produce acceleration and retardation of development of specific characters" (Gould, p. 206, 1977).

Neoteny and recapitulation are two results of the alteration of ontogeny by natural selection. "Evolution occurs when ontogeny is altered in one of two ways: When new characters are introduced at any stage of development... or when characters already present undergo changes in developmental timing" (Gould, p. 4, 1977). Neoteny refers to the retention, in the adult-life stages of the descendants, of what were fetal or juvenile traits of the ancestors. Recapitulation is the repetition of the stages of phylogeny during ontogeny. Recapitulation is due to two processes: the first process is the extension of ancestral ontogeny, involving "terminal addition" of new features at the end of ancestral ontogenies; the second process is the acceleration of the development of the new features. The second process, however, is not universal. Although recapitulation often involves acceleration of development, it need not; "If ontogeny is simply extended without being compressed, the adult characters of the ancestors appear at the same time as in the descendants, but at intermediate stages of ontogeny" (Gould, p. 237, 1977).

Given the fact that in human children the abilities of each stage of intellectual development (within a given area) are logical and structural prerequisites for the emergence of the abilities of the succeeding stage [cf. Brainerd: "The Stage Question in Cognitive-Developmental Theory" *BBS* 1(2) 1978], and given the fact that the abilities of each ancestral species were logical and structural prerequisites for the evolution of new abilities in descendent species, we must conclude that intellectual abilities develop in the same sequence in which they evolved. In other words, in the case of human intelligence, ontogeny recapitulates phylogeny (Stenhouse 1974). Ontogenetic recapitulation of the stages of evolution of traits in a functional complex results from a series of "terminal additions" of new traits at the end of the developmental sequence in a series of descendent species. Terminal addition, like neoteny, is a product of natural selection (Gould 1977).

Comparative data on primate development are consistent with the hypothesis that hominid intelligence evolved through a series of terminal additions of new abilities and a series of retrospective elaborations of abilities already present in rudimentary form in ancestral species. The stages of evolution by terminal additional and retrospective elaboration correspond roughly to the grades of primate intelligence outlined in the earlier part of this paper, and to the grades of hominid intelligence proposed on the basis of homology. Judging from the time of human and great-ape intellectual development, it seems likely that new abilities appeared in our ancestors at roughly the same ages at which they appear in human children today. In other words, the evolution of hominid intelligence probably involved terminal addition and retrospective elaboration without changes in developmental timing.

Although the comparative method gives fewer clues for reconstructing the evolution of language, there is evidence to support the hypothesis that the stages of language development recapitulate the stages of language evolution (Lamendella 1976). The fact that great apes don't acquire language spontaneously but have the mental capacity to learn it, and the fact that the stages of language development are correlated with the emergence of certain intellec-

tual abilities (Slobin 1973; Edmonds 1976; Bates et al. 1977), suggests that the evolution of intelligence was a necessary but not a sufficient condition for the evolution of language. The invariant sequential nature of the acquisition of language implies that each stage is dependent on the preceding stage. All these factors indicate that language could not have evolved in any other sequence than that in which it develops.

Not only do the stages of intellectual and language development seem to recapitulate evolutionary stages, but so do the stages of brain development. Recapitulation in nervous-system development has been reported by so many investigators that a leading textbook on developmental neurobiology (Jacobson 1978, p. 60) states "... the parallels between ontogeny of the nervous system and its presumed phylogeny are often so striking as to demand explanations. It is the general rule that parts of the nervous system that appeared first in phylogeny have a tendency to appear early in ontogeny and structures that arose later in evolution also arise late in ontogeny."

Not all aspects of brain maturation recapitulate the phylogenetic sequence, however, and not all those that do are relevant to the evolution of human intelligence. Only those aspects that differentiate man and other primate species, that mediate intelligence, and that develop in synchrony with intellectual development are relevant to reconstructing the evolution of intelligence in hominids. The following parameters apparently do qualify: increasing total brain size, increasing dominance of the neocortex and its association areas, and decreasing neuronal density with its correlated increase in connectivity.

The data on human brain maturation and brain evolution are consistent with the hypothesis that the ontogeny of the human brain recapitulates phylogeny in these parameters. Specifically, neuronal density decreases during development as dendrites differentiate and axons grow; the neocortex matures last during human development, and within the neocortex the areas that have undergone the greatest size increases are the last to mature. This conclusion is contrary to the theory that the development of the human brain is neotenic (Gould 1977). The neoteny model was proposed because the total morphological pattern of the human face and brain case is neotenic with respect to that of apes, and because the rate of brain maturation is retarded in human infants as compared to ape infants. Human infant brain growth continues at what is the fetal growth rate for apes (and hence probably the fetal growth rate in the common ancestor). The neoteny model is also based on the observation that we do not display the retardation of sexual maturation usually associated with terminal addition.

Although the human brain does grow at a rapid rate for a longer period of time than the brains of other primates, thus prolonging the high fetal growth rate into postnatal life (Count 1947; Gould 1977; Passingham 1975a), the result is that the brain assumes new shapes and enlarged size. The adult human brain does not resemble the brain of a juvenile ancestor; it has added new tissue and connections in the neocortex and its association areas. The human infant brain resembles the ancestral juvenile state of a relatively small neocortex in which sensory and motor areas predominate. During ontogeny the brain goes on to achieve functional predominance of the later-evolving association areas.

The neoteny model for brain evolution is based on a classification by process; the recapitulation model is based on a classification by result. The latter criterion is preferable (Gould 1977). The recapitulation model for the development of human intelligence, language, and neocortex does not imply purposiveness in evolution. The new abilities and tissues characteristic of each stage arose through mutation (and/or recombination) of genes programming brain growth and the coordination and application of schemes; new genes increased in frequency through natural selection because they increased the reproductive success of their bearers. Each new trait, of course, arose through modification of pre-existing structures and was therefore dependent on the latter's prior existence for its emergence. This phenomenon is sometimes referred to as preadaptation or phylogenetic inertia (Wilson 1972; Daly & Wilson 1978). Phylogenetic inertia, mutation, and natural selection are responsible for the

emergence of epigenetic stages of development, just as they are for all other adaptive complexes. The purposive nature of the result of natural selection should not be confused with the nonpurposive nature of the process by which it evolved (Mayr 1976).

Conclusions

*Homo sapiens* is the "cultural animal" (Fox 1971), and culture is the product of language and intelligence; intelligence and language are products of the brain. The human mind and brain, like all other biological characteristics, are the result of natural selection (Humphrey 1976). The stages of intellectual, linguistic, and neocortical development in modern human children recapitulate the stages of the long evolutionary journey, leading from simple object manipulation in monkeys to simple tool use in Miocene apes, to engineering, science, religion, and literature in modern man.

At each stage of this journey specific abilities were selected because they facilitated particular technological and social adaptations; elaborated fifth and sixth-stage sensorimotor and symbolic intelligence were selected in the first hominids because they facilitated expanded tool use in extractive foraging. Protolanguage was selected as an adaptation for food sharing, necessitated by the long apprenticeship for extractive foraging with tools. Symbolic (imitative) play was selected because it facilitated social learning of tool technology and language. Intuitive intelligence was selected in *Homo habilis* because it facilitated hunting by aimed missile throwing, stone tool manufacture for missile throwing and butchery, and shelter construction for food sharing and defense. The evolution of language and intelligence has made us adaptive imperialists who display virtually every technological adaptation discoverable in the animal kingdom, from tool use (as in Galapagos finches), to shelter construction (as in weaver birds), to interior decoration (as in bower birds), to food processing and storing (as in honey bees), to domestication (as in aphids by ants), to dam building (as in beavers), to use of organic poisons (as in hedgehogs), to referential communication (as in honey bees). We are adaptive imperialists because we can do all these things and many more. We can do all these things because of our intelligence and language. Unlike other animals, we do not have to wait for natural selection to fashion new organs or new fixed action patterns in order to create new technology.

Ultimately language and intelligence were favored in our lineage because they increased the carrying capacity of our environment in the most efficient manner. Given the absence of specialized organs and fixed action patterns, and the intelligence and manipulative ability of our ancestors, selection for increased intelligence was highly efficient; in a small fangless naked ape, tool use is more efficient than organ use for extractive foraging; aimed throwing of missiles is more efficient for hunting than running and biting; shelter construction is a more efficient defense against predators than tree-sleeping; language is more efficient than begging gestures in stimulating food sharing. From an energetic perspective, language and intelligence are a bargain.

NOTES

1. Although tool use has been reported in old world monkeys (Beck, 1975), judging from field and colony reports, this behavior is rare. Tool use may occur spontaneously in some animals of unusual intelligence or it may be evoked through prolonged training. It is evidently not canalized.
2. The specialized seed- or tough-object-eating adaptation does not seem to be associated with tool use or intelligence in other taxa and, judging from the species exhibiting it, it is apparently susceptible to extinction; giant pandas, *Haplorhina* (an extinct, giant ground-living lemur from Madagascar), *Gigantopithecus* (an extinct ape from Asia); gelada baboons (once widespread in Southern and Eastern Africa; now limited to the Ethiopian Highlands); *Australopithecus* (an extinct hominid); and gorillas (Jolly 1970; Groves 1970; Tattersall 1975; Dunbar 1976).
3. Unlike the abilities characteristic of the fifth stages in other series, object permanence (fifth stage of the object concept series) is displayed by macaque monkeys (Parker 1973, 1977; Wise et al 1974). It has also been reported in squirrel monkeys (Vaughter et al. 1972) and cats (Gruber et al. 1971). The

taxonomic distribution of object permanence suggests, by homology, that this ability evolved earlier than the abilities characteristic of the fifth stage in the sensorimotor intelligence, imitation, space and causality series. The independent evolution of different abilities is an example of mosaic evolution - that is, independent evolution of different characteristics influenced by different selective agents (Parker 1977).

4. The existence of homologous structures or behaviors in two or more species implies common ancestry (Brown 1975; Eibl-Eibesfeldt 1975; Mayr 1976). Although homology can never be proven (Brown 1975), its existence is indicated by the following phenomena: 1) common position of a structure in the anatomical, behavioral or developmental pattern of the species; 2) common details of structure in the species; 3) linkage by intermediate forms, in terms of either ontogeny or taxonomy; 4) presence of the same structure in a large number of closely-related species (Eibl-Eibesfeldt 1975). Cognitive development and language in great apes and man is characterized by all these similarities. By the same token, firm evidence of common ancestry based on homology in one set of characters suggests homology in other sets of characters. Therefore by reversing the principle of homology we can reconstruct the characteristics of the common ancestor [see Eibl-Eibesfeldt: "Human Ethology" *BBS* 2(1) 1979].

5. While great apes complete the fifth and sixth stages in all the sensorimotor period series except the vocal modality in the imitation series (Parker 1976; Chevalier-Skolnikoff 1976, 1977; Redshaw 1978; Mathieu 1978), stump-tail macaques do not complete the fifth and sixth stages in any but the object concept series (Parker 1973, 1977). This suggests mosaic evolution of the abilities characteristic of different series in the sensorimotor period, with object permanence preceding other abilities. It also suggests that great-ape language abilities are dependent on the fifth and sixth-stage abilities in the sensorimotor intelligence, causality and imitation series (Parker 1973, 1976, 1977; Chevalier-Skolnikoff 1976, 1977). Bates et al. (1977) comment on the apparent confirmation of this hypothesis implicit in their discovery that the achievements of the object concept series do not correlate with the emergence of the prelanguage "gestural complex" in human children. (Bates et al. used Uzgris & Hunt's [1975] sensorimotor-period scales rather than Piaget's stages to assay the intellectual achievements of the children in their study; we have translated these scales back into Piaget's stages.)

6. A captive orangutan learned through imitation to hammer a flake off a rock with another rock and to use the flake as a cutting tool (Wright, 1972). This performance implies a rudimentary notion of pointedness.

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**Recapitulationism, Piaget, and the evolution of intelligence: déjà vu.** Attempts to devise evolutionary explanations for the emergence of intelligence, language, or any other behavioral trait are bedeviled by the fact that behavior, unlike physical structures, leaves no fossil record. Consequently, interpretations of behavioral evolution are bound to be speculative and, more often than not, out of the reach of direct experimentation. But we need such interpretations, especially in the case of socially valued traits such as intelligence and language. So the difficulties attendant upon producing compelling empirical support should not dissuade us, and Parker & Gibson (P&G) are to be applauded for their efforts. However, I think that neither the need for models in this area nor the traditional difficulty of empirical verification can entirely excuse a failure to learn from history or a failure to consider contradictory evidence. The first point refers to P&G's reliance on the outmoded doctrine of recapitulation. The second point refers to their failure to consider either conceptual or empirical

criticisms of Piaget's theory. Although these points are not unrelated, they will be discussed separately.

1. *Recapitulationism* The recapitulation doctrine says that the order of appearance of traits (physical or behavioral) in the individual is the same as their order of evolutionary emergence. This parallelism is said to result from a "bionomic law," according to which an evolutionary change has its date of ontogenetic appearance (if any) so fixed as to precede the ontogenetic appearance of subsequent evolutionary changes. It is obvious that P&G's analysis presupposes the validity of *some* form of recapitulationism; otherwise, it makes no sense to invoke an ontogenetic model (Piaget's) to interpret the evolution of intelligence and language. The authors' reliance on recapitulationism overlooks the insuperable difficulties posed by this doctrine. Interestingly, these difficulties are especially severe when it comes to traits whose ontogenesis is closely connected to brain maturation (e.g., intelligence and language).

Thanks to our history, we developmental psychologists are probably more familiar with the dangers of recapitulationism than any other single group of scientists. As a field of research, developmental psychology was more or less invented by Granville Stanley Hall. Hall and his circle at Clark University (which included Franz Boaz, William Burnham, and Edmund Sanford) thought that the proper way to study behavioral ontogenesis was from an evolutionary point of view. They were firmly committed to explaining the facts of behavioral ontogenesis in phylogenetic terms. Fashionable evolutionary concepts of the day, particularly recapitulationism, were routinely invoked. There were many serious discussions of fish stages, reptile stages, and monkey stages, discussions that in retrospect seem to revolve around an epicenter of utter irrelevance. The high-water mark for recapitulationism was Hall's two-volume opus *Adolescence* (1904), wherein, for example, are found fish-stage interpretations of gross motor behavior: "In children and adults . . . we find swaying from side to side or forward or backward, not infrequent. This suggests the slow oscillatory movements used by fish" (vol. 1, p. 192). It was not long thereafter that E. L. Thorndike (1913) summarized the main flaws in recapitulationism. His observations are still instructive today.

For our purposes, Thorndike's two most important objections are these: (a) traits that violate the rule seem to be almost as numerous as those that obey it and (b) the maturation of the human brain seems especially nonrecapitulative. The first objection refers to the fact that it is very easy to identify behaviors whose ontogenesis reverses their order of phylogenetic emergence. Thorndike gave several examples in chapter 16 of his book *Educational Psychology*. However, since P&G's paper deals with intelligence and language, it seems more appropriate to consider some linguistic examples. Ontogenetically, the ability to understand and to utter speech appears long before sexual behavior, the ability to throw missiles accurately, and the ability to run either rapidly or for sustained distances. Yet the phylogenetic sequence must have been the opposite in each case. The exceptions to the rule are so numerous and the explanations for them so ad hoc that one is led to wonder with Thorndike whether "little more is left of the theory than a useless general scheme for explaining facts whose existence has to be proved by direct observation entirely apart from the theory" (quoted in Grinder 1967, p. 244).

Thorndike's second objection poses serious problems for any recapitulationistic theory whose principal ontogenetic medium is brain maturation. Thorndike noted that there is very little correspondence between human brain maturation and what we know about brain evolution from either the fossil record or from the comparative study of extant species. One of the most obvious anomalies concerns the ratio of brain mass to body mass. This ratio steadily *decreases* from birth to physical maturity in humans, whereas the opposite is true phylogenetically. The ontogenetic-phylogenetic disparities in the brain are so pronounced that authors of neurology textbooks sometimes warn the reader against assigning phylogenetic significance to certain ontogenetic events. I would add that there are also important trends in brain evolution that seem to have no counterparts in brain maturation. Perhaps the most important of these is neurotaxis, the migration of neurons toward their sources of stimulation — a phylogenetic event of major significance. As nervous systems evolve, neurons seem to get

closer and closer to their sources of stimulation. However, these migrations are not observed during human brain maturation; the change seems to be purely intergenerational.

P&G seem to be aware that all is not well with recapitulationism. Near the end of their paper, they observe that "there has been considerable controversy over the legitimacy of the concept of recapitulation." However, their response consists of citing a 1977 book by Gould [q.v.] in which it is claimed that recapitulationism cannot be disproved because one can find examples that are consistent with its predictions. This is rather like saying that one cannot disprove the conjecture that a coin is biased because if you flip it enough times, you will find some runs of outcomes that depart significantly from chance expectations. The crucial point about recapitulationism is that the exceptions are so numerous that it seems necessary to establish the *fact* of recapitulation in any individual case. This would seem to rule out the *assumption* of recapitulation in the P&G model.

2. *Piaget*. The authors state at the outset that they wish to use Piaget's theory to clarify evolutionary questions. Forgetting the recapitulation problem for the moment, this strategy obviously requires that one be willing to assume the theory's conceptual and empirical validity, at least in broad outline. Given the many criticisms lodged by various authors in an earlier BBS treatment (Brainerd 1978a), this seems a dubious strategy with regard to something as important as interpreting the evolution of intelligence and language. Although P&G believe that Piaget's theory is useful "because it provides a taxonomy for the various kinds of intellectual achievement and their interrelations, as well as a stage system indicating their structural prerequisites and the sequence in which they tend to emerge," they do not say how such basic criticisms as circularity, measurement sequences, and plain old obscurity are to be blunted. These criticisms, it will be recalled, bear directly on the key theoretical notions of stage, structure, and culturally universal invariant sequences. Some of them also have implications for aspects of P&G's paper. The measurement sequence and measurement error criticisms, for example, raise questions about the evolutionary significance of the authors' interspecies comparisons of sensorimotor intelligence.

Some readers will undoubtedly argue that it is not the job of would-be appliers of Piaget to sort out and deal with criticisms of the theory's validity. This view, which is especially prevalent among devotees of Piaget-based curricula (e.g., Kamii 1973; Bingham-Newman 1974), strikes me as both frivolous and intemperate. It is frivolous because it avoids serious intellectual questions merely for the sake of getting on with the business of application. It is intemperate because it can lead to conclusions that are dead wrong. The uncritical acceptance of the theory by Piaget-inspired curriculum developers provides a rich source of illustrations. For example, Piaget-inspired curriculum developers all agree that a Piagetian curriculum is truly child centered. The most effective curriculum, according to the theory, is one that introduces new material very slowly and in lock step with the child's ongoing sequence of spontaneous cognitive acquisitions. These ideas are derived primarily from the Piagetian concepts of stage and structure (e.g., see Brainerd 1978b). The facts, however, tell a different story. Contrary to the tenets of the theory, it seems that the crucial element in curriculum effectiveness is the teacher rather than the child or the content of the curriculum. The best curriculum effects seem to accrue from hard-working and highly motivated teachers, regardless of the type of children they teach or the curriculum they have to work with.

Even in areas of application where it is relatively easy to generate disconfirmatory data (e.g., curriculum effects), we must beware of uncritical acceptance of any theory. Theories, after all, have a way of resisting falsification by the facts. We should be still more circumspect when contemplating areas of application where disconfirmatory data are usually hard to come by.

by Suzanne Chevalier-Skolnikoff

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*The gestural abilities of apes.* Until recently, research on the



evolution of behavior has been hampered by the absence of a theoretical framework, or measuring tool, for making systematic comparisons between species. Piaget's model of human development, with its ontogenetic sequence of increasingly complex behavioral levels, offers such a measuring tool. P&G's paper is a welcome attempt to apply Piaget's model to the evolution of intelligent behavior, and to reconstruct the behavior of early hominids. It will no doubt stimulate further research in this area.

I am in general agreement with P&G's proposal, but disagree on some details. For instance, they have presumed that great apes living in undisturbed social groups do not use gestures to communicate with conspecifics. Group-living great apes do display a "gestural complex" similar to that shown by human infants between nine and twenty-four months. During my observation of a captive gorilla group, I noted gestures similar to those described for human infants (Bates, Benigni, Bretherton, Camioni, and Volterra 1977; Bruner 1977). They made "begging" gestures, with hands stretched palm up toward the individual from whom they were begging. One infant learned the gesture from an adult through stage-five imitative matching. The same infant also made frequent "let's go" gestures to his mother. He slowly motioned with his hand and gazed in the direction in which he wanted to travel, and his mother then picked him up and carried him there. Occasionally, the gorillas gave each other food. In one instance, an infant fed a leaf to his mother, putting it into her mouth. Adults were seen trading objects. In gorillas, as in human infants, these gestures appeared during the fourth, fifth, and sixth stages of development of the sensorimotor intelligence, causality, and imitation series (Chevalier-Skolnikoff 1975, film).

Chimpanzees also display a gesture complex. Their use of gesture is more salient than that of gorillas. A number of chimpanzee gestures occur repeatedly in the films of wild chimpanzees taken at the Gombe Stream Reserve (e.g. Goodall 1966; Van Lawick, Marler, and Lawick-Goodall 1971). Among these are "begging" with upturned palm held out; an "away" gesture, with arm swung briskly forward as in under-hand throwing; a "reassurance" gesture, with hand - generally palm down - held out; and what is probably a gesture of "impatience," with both arms held out to the sides and shaken rapidly. Chimpanzees also give each other food.

These gestural abilities in apes require only minor modifications of P&G's model. However, I think we should keep in mind that the model presented here is based on scant data. Cognitive ability has been studied systematically from a Piagetian perspective in only ten of the two hundred or so living primate species: squirrel monkeys (Vaughter, Smotherman, and Ordy 1972), howler and spider monkeys (Chevalier-Skolnikoff 1978), woolly monkeys (Mathieu, Bouchard, Granger, and Herscovitch 1976) cebus monkeys (Chevalier-Skolnikoff 1978; Mathieu et al. 1976), stumptail macaques (Parker 1973, 1976), rhesus macaques (Wise, Wise, and Zimmerman 1974), gorillas (Chevalier-Skolnikoff 1976, 1977; Hughes and Redshaw 1973; Redshaw 1978), chimpanzees (Chevalier-Skolnikoff 1977; Mathieu et al. 1976) and orangutans (Chevalier-Skolnikoff 1979b). The study of even these few species has just begun; only the object concept series has been investigated in squirrel monkeys, woolly, and rhesus monkeys; only howler, spider, and cebus monkeys have been studied in the wild where the adaptive significance of their abilities can be examined. It will be interesting to see how data collected in the future will support or require modifications of P&G's model.

by William Orr Dingwall

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**Reconstruction of the Parker/Gibson "model" for the evolution of intelligence.** A model is nothing more than one of the possible interpretations within some data domain of a mathematical theory.

Such a theory typically covers a much broader range than deductive calculae in that it need only involve the names of relations, the names of variables, and the properties of the relations (see Dingwall 1978, ch. 6, for a discussion of such concepts in relation to linguistic theory). I begin with this somewhat esoteric statement simply to highlight the fact that seldom, if ever, do "models" within the social or biological

sciences even begin to approximate this degree of formalization. Usually the term *model* is used to convince readers of a degree of rigor that is invariably lacking; indeed, the term has been used in the literature in such a multitude of ways as to have become virtually devoid of content (Chao 1962).

While P&G have clearly failed to develop a model characterized by the degree of explicitness demanded by current philosophy of science, they have, I believe, made a positive contribution, in this and other papers they have written, to the understanding of the evolutionary history of complex behaviors. By attempting to reconstruct the general approach - we cannot as yet (if ever) speak of a model in the sense outlined above - the authors appear to be employing, I hope to be able to demonstrate the nature of their contribution as well as some of the transgressions they have committed along the way.

The general approach to which I am alluding was probably first set forth by Darwin (1872) in his monograph on the expression of emotions in man and animals. In this work he sought to demonstrate how one might glean insights into the origins and development of human emotional expressions via the study of closely related species, particularly nonhuman primates. He, in effect, extended the methods of comparative anatomy to behavior, retaining the insight that behaviors require structural correlates. This program for the establishment of behavioral homologies has been clarified and extended recently in a number of papers (see, e.g., Hodos 1976). Basically, what is being proposed is that behaviors (BEH) that are similar in closely related species, that can be related to structures showing a high degree of concordance in a number of parameters, and that could - together with their structural correlates - be traced back to a common ancestor, may be considered homologous. Structural correlates refer, as they did in Darwin's work, to peripheral structures (PS) such as nerves, muscles, bones, and structures of the central nervous system (CNS). Some of the possible relationships that have been documented among these variables are illustrated in Figure 1.

A number of guidelines (heuristics) have been proposed by Hodos and others for the investigation of behavioral homologies. Let us examine a few of these in relation to the paper under review:

1. *The most convincing examples of behavioral homologies involve behaviors uniquely observed in closely related species.* While it is true that some striking instances of convergence, such as vocal learning in birds, may be of heuristic value in determining the phylogeny of behaviors in humans, I am doubtful that such behaviors as "display locomotion" in bees, aimed throwing in ant lions, shelter construction by weaver birds, and others cited by the authors have any relevance.

2. *Behaviors, in order to be considered homologous, must be mediated by both peripheral and CNS structures that can be shown to be homologous.* P&G have by and large followed this guideline, in that they mainly discuss behaviors mediated by the hands of nonhuman primates and man. At least two questions can be raised, however, in

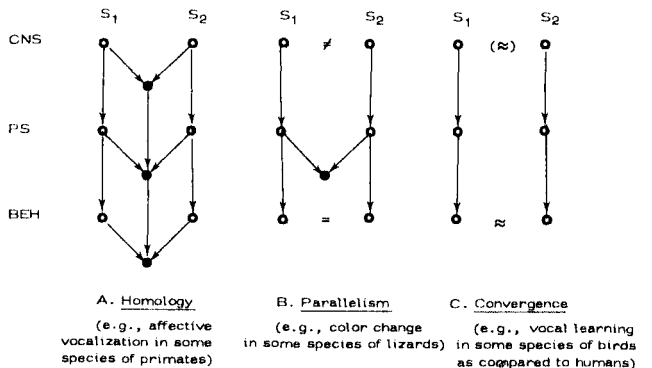


Figure 1 (Dingwall). Three instances of similar or identical behaviors only one of which can be traced back to a stipulated common ancestor. (S = species; white circles refer to structures or behaviors in extant forms; black circles refer to reconstructed structures or behaviors in common ancestors.) For further discussion of the processes illustrated in this figure, see Dingwall 1979, Hodos 1976, and Nottebohm 1975.

connection with their discussion of the brain. (a) It is not clear that microcephalics really constitute support for the reorganization hypothesis as is so often claimed (Passingham and Ettlinger 1974). I should hasten to add that there is no doubt that such reorganization has occurred within the order of primates (for example, as regards vocal learning). (b) I am certain that many commentators will point out that myelination cannot be assumed without qualification to be tied with functional maturation of the brain (Jacobson 1978, p. 179). Further, the ties between the ontogeny of the nervous system and phylogeny have recently been called into question, particularly as regards myelination (Sanides 1975, pp. 402-3).

3. *One must avoid the circularity of employing behavior to establish taxonomies and then using such similarity in behavior as evidence for behavioral homology.* This type of circularity has, I believe, crept into the discussion of homology in P&G's footnote 3.

4. *In comparing acquired behavior across species, the maximum ability to perform the behavior should be the common reference point.* An animal's behavioral potential for dealing with new or unusual situations is important in the struggle for existence. I am thus not particularly worried, as are P&G and others, by the absence of spontaneous gestural language acquisition by the great apes in the wild.

5. *The ontogeny of behaviors, together with their mediating structures, can be an important clue in establishing behavioral homologies.* It is, of course, in connection with this heuristic that P&G have made their major contribution. In order to apply the approach we have been discussing to complex capacities such as language or intelligence, these need to be analyzed into their constituent functions, not only to establish valid comparisons at the level of behavior but also to establish correlations with peripheral and CNS structures. Despite recent criticisms of Piaget (Siegel and Brainerd 1978; Brainerd 1978a; Donaldson 1978), P&G have, I believe, made a case for how something as amorphous as intelligence can be investigated in a systematic manner employing Piaget's "model" of human cognitive development. While I tend to agree with their conclusions concerning exceptions to Gould's [q.v.] neoteny "model" (the development of the human vocal tract is an additional exception), I cannot bring myself to embrace their resuscitation of Haeckel's Law. Would that it were true, how simple things would be! But then again, that would take all the fun out of what Washburn (1973) has termed "the evolution game."

#### by G. Ettlinger

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*Does development tell us about evolution?* This paper raises certain wide-ranging questions, perhaps unanswerable ones at the present time, as well as some more limited problems. To what extent do developmental stages after birth recapitulate evolutionary stages? Is a developmental model useful for cross-species comparisons? Some will be impressed by the similarities of behaviour between stages of human development and presumed ancestors of man or living nonhuman species. But in what respects are the factors determining the optimal development from birth to maturity within a species likely to be the same as those determining the evolution of a new species? The former relate to survival of an immature individual for a short period in a protected setting until the adult potential can be realised; the latter relate to survival of a changed (adapted) individual over long periods in a competitive setting. (Or can it be argued that the neonate, like the foetus, is relatively protected from evolutionary pressures? A difficulty then arises from the finding of, for example, Gianvile, Best, and Levenson 1977, that lateral asymmetries of cerebral function already exist early in human infancy, and at a time when neocortex may not yet have become functional, so that phylogenetically "old" noncortical structures may have evolved to subservise specifically human behaviour.)

Several important questions are raised in regard to language and cognitive skills, but I remain uncomfortable with the answers given. Why do present-day apes have a capacity for language that is not spontaneously realised in normal settings? Why has this discrepancy survived if the common ancestors of great apes and man already possessed

such capacities? Is the assumed early protolanguage, based on gestures, *functionally* a genuine precursor of human vocal language? Can we conclude, despite the absence of clearly negative findings, that monkeys lack the capacities possessed by chimpanzees for trained language and other cognitive skills (e.g. conservation)? A few recent studies (e.g. Lenneberg, and Ettlinger 1978; Jarvis and Ettlinger 1977; Brown and Pasnak 1979) have failed to find substantial differences between apes and monkeys. If some monkeys were able to learn the skills shown by communicating apes, would we infer that they too can be taught "language," or that such performance is not as closely analogous to human language as has been suggested?

Discussion of neuronal density in relation to cognitive attainment is to be welcomed. (I have been surprised to find little reference to densities in studies of anatomical asymmetries in man and apes.) But do changes during the ontogeny of neuronal density (or of the dominance of the neocortex and its association areas) correlate with the appearance of specifically human behaviour? I fear that the identification of the neural correlate(s) of uniquely human behaviour will prove elusive.

#### by Harold D. Fishbein

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*An evolutionary perspective of the family.* This commentary consists of two caveats, one concerning a central assumption in the Parker & Gibson paper, and the other, longer one, concerning the intellectual context of the paper itself. The latter takes the form of an outline dealing with the social context of human evolution. In a concluding passage I will attempt to make some explicit links between the outline and P&G's thesis.

The paper by P&G is well written, well conceived, and stimulating. As someone who has traveled along the same intellectual road as these authors but arrived at a different destination (Fishbein 1976), I'm positively impressed by their integration of the human and nonhuman primate psychological data. In my book I eschewed such an integration because I thought it would add little to the human evolutionary story. The present paper has forced me to reevaluate that conclusion.

My one serious reservation about this paper concerns P&G's reliance on Piaget's stage theory. My reading of the contemporary psychological literature indicates that the sequences he noted for the sensorimotor stage have been pretty well substantiated. (This is not a universally held opinion; see, e.g. Bower 1974.) However, once you move into the preoperational and concrete operational stages, the sequence and ages at which they are attained often bear little resemblance to Piaget's reported results. For example, in the realm of spatial understanding, for the coordination of perspectives task, Piaget and Inhelder (1967) report that it is not until children are 9-11 years old (upper stage of concrete operations) that they can master this task, which they state is accomplished in part by the near complete dropping out of egocentric errors. Fishbein, Lewis, and Kieffer (1972) found that, when given a simplified task, children as young as 3 (lower stage of preoperational thought) can perform without error. With more difficult tasks they and older children perform at an above-chance level; moreover, the ratio of egocentric to total errors remains relatively constant across all ages.

I don't think that P&G have built a Piagetian house of cards. However, they will have to find ways to strengthen the foundation of their arguments, taking into account the research carried out by students of psychological development other than Piaget and his collaborators.

Moving from the specific to the general, the essence of P&G's paper (and my book) is the notion that evolutionary processes designed the human species such that individuals would acquire certain intellectual characteristics in specified developmental sequences.

Although I still adhere to this position, I have recently been rethinking the social context in which these intellectual characteristics may have emerged. My conclusion thus far is that it is premature to indicate lists of intellectual capacities and sequences until we have a fuller understanding of the evolutionary social context. When we attain a clearer understanding we will be in a better position to identify and elaborate the most relevant features of both social and intellectual development.

What follows, then, is an outline (literally) of what I consider to be many of the essentials of the social context of human evolution. I place primary emphasis on the family and hence believe that future evolutionary/development constructions should view psychological development in that context.

Man's evolutionary design is that of a placental mammal, an Old World primate, and a gatherer and hunter. These adaptations probably form a sequence from stronger to weaker degrees of canalization.

A. For the mammals, the long-range goal of genetic survival is accomplished through at least four shorter-range survival goals: (1) attaining food; (2) reproducing; (3) protecting oneself and one's offspring; (4) socializing the young (this refers primarily to interindividual behaviors).

1. Intensive and long-term maternal care of young is characteristic of the placentals. This places constraints on protection and socialization especially, but also on the attainment of food and on reproduction.

2. At a minimum, long-term maternal care requires mother-infant bonding and the inhibition of aggression by adults of the same species toward infants [see Rajecki et al.: "Toward a General Theory of Infantile Attachment" *BBS* 1(3) 1978].

B. The following are characteristics shared by nearly all Old World primates.

1. They form long-lasting subsistence groups whose members are all well known to one another.

a. Short-range survival goals are accomplished by the subsistence group.

b. There is substantial cohesiveness within the subsistence group.

2. Mother-infant dyads are the core of the subsistence group.

a. Mother-infant involvement is very long, relative to other mammals, which produces strong bonding between the mother and her offspring, and often between siblings (sibling rivalry is a concomitant).

b. Adult males typically have little interaction with infants, including their own offspring.

3. Socialization occurs primarily by play, observation, and imitation.

C. Man's ancestors about 3-5 million years ago evolved in environments in which relative food scarcity was a regularly occurring event. This periodic scarcity had at least two effects on the social organization of the prehuman subsistence group.

1. Adult male - adult female - offspring subunits (families) formed, which periodically (in times of food scarcity) left the main group to fend for themselves.

2. Reciprocal obligations between the adults in these family subunits started to emerge.

D. About 1-1.5 million years ago, man's male ancestors started to engage in the hunting of large game. This had several major effects on the social organization of the subsistence group.

1. Large-game hunting requires cooperation among the hunters.

a. Cooperation required increased attraction between the males.

b. Cooperation required decreased aggressiveness between the males.

2. Male/female role differentiation in food-seeking activities, tool-making activities, and tool use, markedly increased.

3. The sharing of resources - food in particular, and of obligations between members of the subsistence group, was in general markedly strengthened.

4. Paternal involvement in the offspring, especially the males, markedly increased (e.g., the future hunters had to be "trained").

5. Cross-generational collaborative activities were markedly strengthened. Thus, parent/child reciprocities emerged such that parents were responsible for their young children, and children were responsible for their old parents.

6. The ability to form temporary hierarchically organized groups to carry out short-term tasks emerged. The family was probably the model for these activities.

7. In general, the family was strengthened as the basic subunit of the subsistence group. The family was special in that greater bonding and reciprocity among its members occurred, relative to others in the group.

When the P&G paper and the above outline are considered together, several salient observations can be made. We agree that at each evolutionary stage of social development, as with intellectual development, the earlier stages "are logical and structural prerequisites for the emergence of the abilities of the succeeding stage." It is not clear, however, that the stages of social development of individuals recapitulate the evolution of the human species. For example, the development of reciprocity is a key attribute of human evolution. Do infants and children proceed through stages of reciprocity that parallel those of prosimians, Old World monkeys, great apes, and early hominids? The same question can be asked of sex-role differentiation, cooperation, sharing, and male involvement in child care. Finally, P&G link the evolution of language and food sharing to extractive foraging with tools, whereas I would place primary emphasis on their social consequences, for example, strengthening familial bonds.

This last point goes to the heart of the matter. P&G focus on the development of intelligence as the essence of human evolution, and they trace roots to our primate ancestors. If the development of the family is considered to be the essence of human evolution this causes us to ask different kinds of questions about individual social and intellectual development. Some of the questions asked by P&G may be highly relevant to this different context, but with the present level of analysis, we don't know.

#### by Stephen Jay Gould

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**Panselectionist pitfalls in Parker & Gibson's model for the evolution of intelligence.** I admire very much both the boldness and range of the model proposed by P&G for the evolution of intelligence. I have read many weaker attempts constructed only from the data of paleontology, or from comparative psychology, or from little more than sheer guesswork. The synthetic approach followed here is a great improvement over previous attempts; as an old devotee of the neglected subject of relationships between ontogeny and phylogeny, I was especially intrigued by the comparison of Piagetian stages in human children, possible phyletic pathways of human evolution, and the attainments of modern primates - the "threefold parallel" of the old recapitulationists.

However (and there must always be a however), as an evolutionary theorist, I did locate what I regard as two serious problems, one very general, the other more specific.

1. *The construction of adaptive scenarios and the problem of adaptation.* P&G base their evolutionary speculations on the notion that highly specific adaptation, via natural selection acting directly for its attainment, is the cause of nearly every organic structure and behavior - an attitude that I call panselectionism. Such panselectionism was a feature, almost a defining feature, of mainline evolutionary thought under the so-called modern synthesis, or neo-Darwinism. But this attitude is now fast fading, particularly as the accumulating data of molecular evolution continue to challenge the idea that virtually all changes in gene frequency are adaptive within populations. (Natural populations generally contain more genetic variation than models based on selection allow. Genetic change seems to accumulate at too clocklike a rate to be attributed to the workings of selection alone - for selection pressures should vary greatly through time.) We are returning to a pluralism of causes (with natural selection prominent, even predominant, among them to be sure) - a position rather close to Darwin's own. In this climate, I believe it is no longer permissible to build a speculative model on the premise that nearly all bits of morphology and behavior are direct results of natural selection working specifically for them. We must take more seriously the issues of developmental and design constraints (limits imposed by the delicate orchestration of ontogeny and by the nature of biological materials), and the importance of nonfunctional correlation (since the body is an integrated structure, every adaptive change imposes a host of other alterations, some potentially major in scope and nonadaptive). The panselection-

ists never denied constraint and correlation, but they paid little more than lip service to these ideas and constructed their speculations with adaptive stories alone.

In thinking about the evolutionary path of human mental abilities, I fully admit that a large dollop of speculation cannot be avoided – the evidence is too scrappy, indeed in some cases probably unobtainable, for anything else. Thus, I do not criticize the highly speculative character of many statements in this work per se. But I do feel that the confinement of speculation to strictly adaptive arguments (this behavior "for" this highly specific action) represents a limited view inconsistent with our best reading of evolutionary theory.

P&G remark, for example: "There are compelling reasons for specificity in evolutionary models. The study of organic evolution suggests that specific abilities and characteristics have been selected for specific functions in one or a few contexts." Leading evolutionists did speak this way during the heyday of the modern synthesis; but an abandonment of such panselectionism has been among the healthiest of recent trends in our science.

As an example of what I regard as an overly specific adaptive story, consider the following: "We suggest that the ability to divide a whole into equal parts and the ability to construct one-to-one correspondences arose as adaptations for butchering larger carcasses and distributing food." I doubt very much if any mental ability so broad, complex, and multifarious arose "for" any specific action. And, on the subject of pluralism, in the absence of direct evidence I would avoid such definite assertions as: "Hominid differentiation from the apes was based on a shift from secondary seasonal dependence (as in the case of chimpanzees) to primary year-round dependence on such tool-aided extractive foraging."

I don't doubt for a moment that the brain's enlargement in human evolution had an adaptive basis mediated by selection. But I would be more than mildly surprised if many of the specific things it now can do are the products of direct selection "for" that particular behavior. Once you build a complex machine, it can perform so many unanticipated tasks. Build a computer "for" processing monthly checks at the plant, and it can also perform factor analyses on human skeletal measures, play Rogerian analyst, and whip anyone's ass (or at least tie them perpetually) in tic-tac-toe. The fact that some people write great operas and that all of us can write at all is just one obvious and quintessentially important ability that could not have arisen by direct selection.

Scientists overly tempted by panselectionist models should remember Wallace's dilemma. Wallace, not Darwin, was the real nineteenth-century panselectionist, but he made a single exception for the human brain as a result of the following curious argument: "savages" and civilized folks have the same mental capacities (Wallace was one of the very few nineteenth-century egalitarians); but savages do not use all these capacities; since natural selection is evolution's only force and since it makes each part, no matter how small and seemingly insignificant, for a specific use, it cannot be the artificer of unused potential. The capacities of the human brain must, therefore, not be the product of selection (or of evolution at all). Clearly Wallace, blinded by his panselectionism, did not realize that a brain, evolved "for" some set of functions to be sure, could also (as a result of its complexity) do a variety of other "unanticipated" things as well.

2. *Ontogeny and phylogeny.* P&G provide a recapitulationist interpretation, based on the principle of terminal addition, for human intellectual evolution. I do not contest this interesting hypothesis (though I do wonder whether mental evolution could really proceed by simple addition to the end of ancestral ontogenies without any correlative modification or reconstruction of earlier ontogenetic stages). But I do reject P&G's assertion that this hypothesis contravenes the theory of neoteny, which argues that our bodies evolved by a retardation of somatic development with retention, as adults, of many features representing juvenile stages of ancestral primates. As De Beer and others have argued since 1930, neoteny and the other categories of heterochrony are "morphological modes." Not even the most devout neotenyist has ever argued that our mental capacities regressed down an ontogenetic scale because our bodies retained youthful characters. (E.D. Cope, in the 1880s, first pointed out that mental advance had

accompanied morphological neoteny.) Mental evolution has been a process of addition, perhaps in the recapitulationist mode advocated by P&G. But we must still explain the morphological basis of this capacity for addition. I suggest that the somatic delays associated with neoteny – particularly the prolongation of rapid fetal brain growth rate, into postnatal stages of ontogeny (a process admitted by P&G) – provide the morphological basis for increased mental capacity. We do not have here, as P&G claim, a conflict between classification processes and result (I advocate classification by process in *Ontogeny and Phylogeny*, Gould 1977, not by result as P&G state). We have, rather, the possibility of a unified (and interesting) explanation – morphological neoteny permitting increased mental capacity by terminal addition in a larger brain.

by Howard E. Gruber

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*Protocultural factors in a constructionist approach to intellectual evolution.* In a recent episode in the evolution of intelligence, two distinct currents may be discerned. In the field of artificial intelligence, progress in the invention of computer hardware, which can be likened to organic evolution, has been almost exclusively aimed at very general increases in computing power. In contrast, conceptual progress – computer languages, programming strategies, ways of representing knowledge – has been both general and specific. This evolution of software can be likened to cultural or protocultural evolution. Both kinds of evolution occur in nature. They are governed by quite different laws, and they occur at very different rates, on entirely different time scales.

P&G present an admirable synthesis of information and ideas suggesting a synergistic relation among anatomical, behavioral, cognitive, and protocultural forms of evolution. But this relationship can be considered within different theoretical frameworks. P&G are wedded to a certain variant of the family of neo-Darwinian models, in which genetic changes beget anatomical changes which beget specific cognitive-behavioral changes. As they develop this theme, a sequence of proposed cognitive changes permits a corresponding sequence of behavioral changes:

$$C_1 \rightarrow B_1; \quad C_2 \rightarrow B_2; \quad C_3 \rightarrow B_3 \dots$$

It is furthermore proposed that each such cognitive change results from a highly specific genetic change, which is then favored by natural selection:

$$G_1 \rightarrow C_1 \rightarrow B_1; \quad G_2 \rightarrow C_2 \rightarrow B_2; \dots$$

It seems to me that the same synthesis can be thought of in another way. At the psychological level, cognitive changes open the way for behavioral changes, which in turn open the way for new cognitive changes. Neither level of functioning has any evolutionary priority over the other. Within each evolutionary episode, a given cognitive-behavioral complex can be thought of as a culture or protoculture. Each protoculture is made possible by the general neurological level the group of organisms has achieved, that is, the total information processing capacity of the brain as it has evolved.

$$\text{protoculture \# 1} \rightarrow \text{protoculture \# 2} \rightarrow \text{protoculture \# 3} \dots$$

$$C_1 \rightleftharpoons B_1 \qquad C_2 \rightleftharpoons B_2 \qquad C_3 \rightleftharpoons B_3$$

It is noteworthy that the major part of P&G's paper, that describing the relation between cognition and behavior, applies equally well to the whole of human history, operating over considerable reaches of cultural time, but negligible spans of evolutionary time.

We now know that protocultural transmission of innovations can at least occasionally occur *between* species (as in the case of humans teaching other primates language). The same kind of transmission of information also occurs *within* species, as among the members of a culturally and organically evolving species. Suppose that we are dealing with a species that produces some members who occasionally make adaptive behavioral innovations that might be called "inventions." Selection would operate to favor individuals capable of profiting from these novelties, of emulating the inventors. There is no need to think that a specific invention is governed by a specific genetic change.

We need only suppose some capacity within the species for invention (which might even remain quite constant) and some capacity for emulation. This coupling would produce protocultural evolution, just as it produces whatever we may call progress on the time scale of human history.

Selection favors neural organizations (and that of other organs) permitting higher levels of information processing. There is no need to suppose selection for specific cognitive structures or behavioral patterns. Indeed, such specificity is at odds with the *general* nature of intelligence, as must be the case if the outcome is to be intelligent. In Piagetian theory, cognitive structures – such as object permanence, conservation, seriation, spatial coordinate systems – do not and never were intended to specify the cognitive strategies and procedures by which they are attained. They serve more as criteria that any intelligent system must satisfy if it is to be capable of highly general understanding and problem solving.

Moreover, at the primate level that concerns us, the possession of a given neurological endowment by no means guarantees the emergence of any particular behavior pattern that can be called intelligent (cf. the accumulated observations at assorted faculty meetings). Each such cognitive structure and corresponding behavior must first be constructed and invented by some individual or group; it must then be reconstructed by offspring generations who have the advantage of protocultural transmission. There is ample evidence of such transmission at the primate level. Natural selection can operate to favor individuals (or groups) more capable of participating in this protocultural process because of their general neurological development, rather than because of any highly specific, inherited cognitive or behavioral patterns.

Although P&G rely heavily on Piagetian theory, there are two relatively new developments that their model does not reflect. First, it is now quite widely recognized that a distinction must be made between cognitive structures and the strategies and procedures employed in embodying them in action. For example, *seriation* is not a single behavior pattern but a very general structure that can be achieved in a variety of ways; Gilliéron (1977) has shown that there are some eight strategies, each executed by several more detailed procedures: which approach is most suitable depends both on the individual's developmental level and on the task situation. This puts a premium, not on specificity, but on the generality and flexibility of cognitive-behavioral complexes of the Piagetian kind.

Second, Piaget has recently published an emphatic treatise arguing that behavioral changes necessarily precede and set the stage for genetic changes. This is almost the exact opposite of P&G's thesis. It is unfortunate that Piaget's work has been translated under the title of "Behavior and Evolution," since its original title was *Le Comportement Moteur de l'Evolution* (Piaget 1978).

Piaget's central argument is that every individual must construct and reconstruct cognitive complexes of strategies, procedures, and structures in his or her own lifetime. What has happened over evolutionary time is that intelligent systems capable of these constructive processes have appeared. A constructionist approach to evolution corresponds admirably to the problem of understanding the construction of individual intelligence. The latter must be capable of transforming itself with every migration or other environmental change (often initiated by the organism's own actions), and of reconstructing itself in every generation.

by Gordon W. Hewes

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*Some complexities in the evolution of language.* It is refreshing to encounter a frank (rather than covert) recapitulationist scenario for some very important features of hominid phylogeny. Although the Piagetian schema, based on studies of Swiss children, will probably have to be refined and modified further if it is to be fully applicable to problems in the comparative cognitive psychology of primates, up to now it has provided the most completely worked out system for dealing with the complex array of facts and hypotheses constituting this field of investigation. The evidence for the sequential myelination of nerve fibers in the brain points generally in a similar direction.

The most impressive thing in the P&G model is the use of "extractive foraging with tools" as a substitute (I would prefer, as an important supplement) to the by now overworked hunting model for hominid emergence. That a switch from seasonal to year-round dependence on tool-based extractive foraging was a major hominizing step is a plausible suggestion, as is the parallel between Piagetian "graphic collections" and Lower Paleolithic tool kits. On the other hand, I am not impressed with the possibility that Ramapithecus used tools to a significant extent, nor that we need to continue thinking of Ramapithecus as a particularly hominid precursor.

Despite the promise implied in the title of their paper, the topic of language is not very fully explored. To begin with, I do not think that recent language-origin theorists have ignored the work on honeybee "language." Thanks to C. F. Hockett's well-known presentation of the design features of language, with which almost all would-be glottogenic theory-builders are familiar, bee language has not been overlooked. Unfortunately, one can only go so far with the bees, when it comes to attempting to understand how human language might have originated. Similar limitations with respect to apian analogies apply in the area of human reproductive behavior. Social communication in taxa far closer to the primates, notably in the Cetacea, has also failed so far to yield much of direct bearing on early hominid linguistics [see *Cognition and Consciousness in Nonhuman Species*, *BBS* 1(4) 1978].

That tool using and subsistence probably had much to do with the origin of language I would certainly accept. Some time ago I explored relations between tool using and language (Hewes 1973a). It seems likely that food sharing also played some part in glottogenesis, but I am not dismayed by the absence of referential communication in food-sharing carnivores such as the African wild hunting dog. Early hominid adaptations to predation and carnivory seem to me much more adventitious and "jury rigged," compared to the 60-odd million years during which the Carnivora perfected their ways of life, under conditions rather different from those confronting the Australopithecines.

P&G suggest that the hypothesized transformation of an initial gestural language system into a vocal one was only "slightly more complex" as a process. If by "complex" it is meant that many factors were involved, whose interrelations are by no means clear to us, I disagree. Although I happen to regard the gestural beginnings of human language as highly plausible, the problem of explaining how spoken language arose out of gesture has never seemed simple to me. Several neurological changes were probably required before a sound-based language could become more efficient than a visual-gestural one, both in the productive (speech-output) and receptive (speech-input) channels.

The authors suppose that *Homo habilis* possessed the ability to hunt with well-aimed missiles – rough-hewn stone spheroids, perhaps, or sharpened sticks. I do not see that we have any evidence for this, despite the modern prevalence of aimed-throwing pastimes practiced chiefly by male children and adults. Our ancestors clearly acquired aimed-throwing skills, which we now learn with little difficulty, but I am not yet ready to subscribe to the notion that modern baseball or basketball, or even darts as hurled in British public houses, rests on a genetically based propensity. Rock throwing was probably never a very efficient hunting technique, although it probably served to drive off troublesome animals, predatory or otherwise. Of all the rocks still hurled at offensive dogs, I suspect that few result in mortal wounds; squirrels are another matter.

I am equally skeptical of the notion that *Homo habilis* used containers for carrying food or water. To be sure, containers would have been very useful, just as digging sticks would be useful for baboons (I believe the suggestion comes from Sherwood Washburn), but that is not the same as direct evidence. Cordage, too, would have been useful for transporting butchered meat back to camp, but archaeological evidence for its use comes quite late in the prehistoric record. Early hominids may have survived without either containers or cordage, just as they seem to have survived without fire.

P&G are more willing than I am to accept the validity of the reported cases of feral children. Fascinating as the few "documented" cases are – the Wild Boy, Victor, of Aveyron, and the two "wolf-girls" of Midnapore – I think a hearty skepticism is still called for. I suspect that

not only would human infants fail to survive on their own from age three or so, even with the kindly support of a maternal wolf or dhole, but pongid infants too would probably succumb. We do have evidence that pongid infants can survive under the care of human surrogate mothers, and the reverse is at least possible in principle, but I think the odds for feral survival would decline rapidly with taxonomically more distant foster mothers.

In their conclusion, P&G suggest that "engineering, science, religion, and literature in modern man" are part of the long continuum from object manipulation in monkeys and simple tool using in Miocene apes. I cannot disagree with the continuum, but wish to suggest that ever since language arose, the "continuum" has been shifting into a superorganic mode, in which genetically programmed behavioral tendencies, while never totally overcome, have been increasingly subordinated to learned, cultural programs. For the latter, we are not going to find Piagetian stages or anticipations. It is probably no accident that most of the world's formal educational systems are planned to start at about age six or seven, when all but the last two Piagetian stages have been completed in most individuals.

by Glynn L. Isaac

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**Evolutionary hypotheses.** As E. O. Wilson (1975) has pointed out, the study of human evolution has until very recently tended to involve passionate advocacy of a particular interpretation as being "the truth." However, during the past decade there has been a healthy shift towards the recognition of the need to work with multiple rival hypotheses, thereby minimising the propensity for emotional commitment to one particular interpretation. As I see it, the paper by P&G makes a very valuable contribution by adding to the stock of worthwhile hypotheses to be scrutinised and tested. In point of fact, the paper does not so much introduce an entirely new hypothesis as clarify and make far more explicit (and therefore most testable) an old idea; namely, the notion that tool use was *the* prime mover in the establishment of the evolutionary trend that produced the human brain and its associated intellect (see Washburn 1960, Tobias 1967, and many other authors).

In the search for potential explanations of how the evolutionary trend to brain enlargement got underway, P&G's "tool-aided extractive foraging hypothesis" joins two other major rival hypotheses that have been clearly formulated and currently remain under particularly serious consideration. One of these is the "hunting hypothesis" first vigorously enunciated by Raymond Dart (1949) and then widely promulgated by Robert Ardrey (1961). Variants of this view have been incorporated into anthropological literature (e.g. Morris 1967, Tiger and Fox 1971, Campbell 1966, and others). The other is the "food-sharing hypothesis" which was recently clarified by myself (Isaac 1978, 1978a) and which incorporates elements of the tool-using and the hunting hypothesis. It should be noted that three other important hypotheses concerned with the early stages in human evolution deal only indirectly with selection pressure for expanded intellect. Jolly's seed-eating hypothesis suggests a preadaptive shift to a vertical body posture and changed dental configuration as the starting point for other behavioural developments (Jolly 1970). Tanner and Zihlman's (1976) "gathering hypothesis" and Lovejoy's (forthcoming) "shortened birth-space hypothesis" both deal with mechanisms by which food-sharing or hunting got underway rather than with new direct selection pressures on the evolution of the brain.

As several philosophers of science have shown (e.g. Karl Popper and Peter Medawar), there are, in general, numerous potential hypotheses that can be enunciated to cover a particular problem. Science commonly progresses by picking what seem to be the most useful ones and testing them. This process can lead to the rejection of hypotheses that are inconsistent with the evidence, and to the modification and elaboration of others for which at least partially consistent evidence is found. In the investigation of processes of great complexity by simple means, rejection more commonly amounts to the recognition of a much lesser degree of plausibility than to outright elimination.

Given the plenitude of potential hypotheses, how does one evaluate a new one such as that advanced by P&G? I would recognise two

criteria: first, the value of a new hypothesis is perhaps in proportion to its potential for demonstrating interconnections between previously unconnected data sets. By suggesting connections between disparate fields as ecology and diet, tool-use skills, and the ontogeny of cognition in modern higher primates, P&G's hypothesis is clearly of value. Second, the hypothesis must be testable and should stimulate new lines of research. Many predictions or test implications involving many different lines of research do follow from P&G's proposal. (Of this, more below.)

It should be apparent that the hypotheses mentioned earlier were not necessarily mutually exclusive, and the explication of human evolution may well turn out to involve not so much elimination as assessing the interaction of the various factors and the determination of the sequence in which they came into play. Let me illustrate this with reference to my own work. I have been working since 1970 to enunciate and start testing the hypothesis that by about two million years ago, a novel adaptive complex had come into existence involving food sharing, tool making, meat eating, gathering, division of labour, and operation out of a home base. I have argued that this adaptive complex might well have been operated by nonhunting hominids and that it would have put selection pressure on the development of the mental capabilities needed for language-like communication and the calculation of advantage in long-term chains of reciprocal social interaction (Isaac 1969, 1978a). The evidence with which I have been concerned tests for the existence of this complex at an early stage (i.e. about two million years ago) and cannot therefore deal with the mechanisms whereby the complex itself came into existence. Herein lies an important part of the interest for me of P&G's hypothesis incorporating observations of their own, and new information from Sully (1978) and McGrew (1976) regarding mother-infant food sharing among chimpanzees, P&G have boldly suggested a sequence of possible preadaptations that could have culminated in the aforementioned food-sharing, tool-making, hunting, gathering complex. Furthermore, the suggested sequence has interesting looking cross ties with observations on the ontogeny of modern human mental capabilities (which potential cross ties I am not qualified to judge specifically).

I also share P&G's sense that the precision throwing of modern humans is an ability with very ancient evolutionary beginnings, and that it was an important part of the initial hominid adaptive complex. We are already seeking to investigate this in archaeology and ethnography.

In summary, it seems to me that P&G's specific hypothesis is at least as useful and promising as any other in confronting the problem of mechanisms by which early hominid behaviour came to acquire evolutionary trends not shared with other hominoids. It could also help to explain selection pressure towards bipedal locomotion, though that is not a line to be pursued here.

To turn now to testability and stimulus: the hypothesis has clear test implications in several fields. It leads to predictions about the diet, feeding modes, and ecology of early hominids which might well be testable against the evidence of tooth wear and paleoenvironments. These are lines of work that are already being pursued, and specific questions can be formulated. It should also stimulate studies of the feeding opportunities and problems in environments analogous to those occupied by very early hominids. Were there important food sources to which tool use gave improved access? Clearly this paper should also stimulate increased activity and rigor in the comparative study of human and other primate behavioural ontogeny. I look forward to seeing the implications of this important paper being followed up.

by V. V. Ivanov

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**On the development of sign systems in primates.** 1. There is an evident parallel between the communication systems of great apes and early hominids and the sensorimotor period and gestural complexes of a child's sign systems (Ivanov 1978b, p. 82). As far as the Piagetian idea of the priority of action (particularly in the third sensorimotor period) is concerned, it seems important to use the homological facts bearing on the sign systems of the deaf-mute

sighted, and blind. As has been shown by Sokolyansky (1959), blind deaf-mute children manipulate objects before producing tactile "hieroglyphic" signs consisting of the schemes for these preoperations. The "physic" signs describing different methods of fishing and other operations known to all the members of the community are typical of the sign system invented by the only deaf-mute of Renell Island (Kushel 1974, Ivanov 1978b, pp. 53-61). Since symbolic play and some other ritualized forms of primate behavior (see Tikh 1970) might have their origin in ancient everyday routine operations, it seems possible to reconstruct some of the latter (e.g. flower gathering by early hominids) by studying such rituals [cf. Eibl-Eibesfeldt: "Human Ethology" *BBS* 2(1) 1979].

2. The hypothesis of strong genetic canalization of intellectual development with a result close to the Chomskian concept of the innate language universals [see Chomsky: "Rules and Representations" *BBS*, forthcoming] might lead to another step in the search for the roots of symbolic behavior. Some of the gestures found in the gorilla's natural system of communication, such as tongue showing, are common to great apes and man (Smith, Chase, and Lieblch 1974). The grooming described as a social custom in wild chimpanzees has exact homologues in different cultural traditions (Paleosiberian, Amerindian); there are grounds to suppose that the roots of the motif of the "chercheuses de poux" (to use Rimbaud's image relating to the grooming of a child) may be typical of a common ancestor (Ivanov 1977, p. 33; 1978b).

According to this commentator's personal observations, the inactivation of a left (speech dominant) hemisphere (under a unilateral electrical shock therapy) can lead (especially in the first minutes after the shock) to some (minor hemisphere-controlled) gestures homologous to the visual communication of great apes. Some of these gestures can be compared to the Piagetian egocentric speech of a child as well as to the homologous behavior of the trained chimpanzee Washoe while manipulating an illustrated magazine (Hewes 1973).

The use of a tree branch as a sign of social rank (especially by the troop leader) in monkeys (Kawamura 1967; Neville 1968, p. 23) has homologues in the symbolic function of a tree or of the branch of a tree as a universal sign of the sacral king. It would be particularly important to find out whether the open figures resembling crosses drawn by great apes might be compared to the universal tree drawing characteristic of a normal human child ("l'arbre de Koch," Bouvard 1961, p. 51). It seems possible that the complex of activities directed toward twin children and their mothers in human societies has homologues in monkey troops (Tikh 1970, pp. 126-127, Ivanov 1978a). The symbolic ("sublimiert," in the Freudian sense) social use of sexual symbols is found in monkeys (Tikh 1970) and continues through Paleolithic art up to the subconscious (right hemisphere) layers of symbols in modern man (Ivanov 1978b).

3. Among the important datable human and anthropoid visual symbolic systems one should first mention the difference between the evidently innate three-colour triad, black-white-red, found in all the linguistic and cross-cultural studies of man and the great apes' systems including black as the most important color (Firsov 1972, pp. 164-65). The early date of the symbolic use of red in *Homo erectus*'s culture is evident in the archeological remains, such as archaic shelters, that were associated with seasonal activity more than 250,000 years ago (according to the new methods of thermoluminescence dating), the burials and artifacts of the period are understood as the earliest evidence of consciousness (Eccles 1977, p. 172). In modern man (and in the modern child) the growth of the symbolic function of blue is found only in pathological and specific (e.g. artistic) cases of activity (Novalis's "blue flower" etc.).

4. The experiments on electrically elicited vocalization in monkeys and lesser apes make it possible to study the subcortical mechanism of vocal control reorganized in more complicated cortical systems not later than in *Homo erectus*. Particularly important are the data according to which the monkey's vocal communication consists of very short signals. Their temporal characteristics (Gershuni, Bogdanov, Vakarcuk, and Malts'ev 1977) as well as the average number of signals (Wilson 1975) are quite similar to those of human phonological systems. The difference lies neither in the shortness of the elementary

signals nor in their number but in their use as the elements to be combined in morphemes and words (Ivanov 1977).

5. The selective causes of brain evolution, particularly in *Homo habilis* and *Homo erectus*, are clearly connected with the evolution of gestural and vocal communication (see also Eccles 1977). The causal link between methods of food sharing and language and brain development does not seem so clear to the present commentator, although some data on archaic mythologies and rituals might be interpreted as showing the importance of food sharing (e.g. the magical number of the parts of the sacrificial animal such as the bear or horse). It is by no means evident that this single factor, although energetically important, should be chosen as the only decisive one in brain and language development. On the other hand, much data can be cited in support of the suggestion that the formation of semantic spaces (including pre-Euclidean and possibly pre-non-Euclidean in the right hemisphere) was partly conditioned by man-animal relations in hunting (see Thom 1974).

by Allison Jolly

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**Feeding versus social factors in cognitive evolution: can't we have it both ways?** Sue Parker and Kathleen Gibson have given us a rich and illuminating article. They make at least three major propositions - two that apparently contradict much current thinking, and another that will surely stimulate research to contradict it. I believe that the contradictions are more apparent (or didactic) than real. P & G have thrown new light on the evolution of intelligence, but by adding to previous speculations, rather than refuting them.

**Recapitulation versus neoteny.** To begin at the end, P & G conclude that human intelligence is a terminal addition, tacked on at the end of a brain growth and growth in intelligence that largely parallel those of great apes. They say: "this conclusion is contrary to the theory that development of the human brain is neotenuous, [retaining juvenile characters into adulthood]."

However Gould (1978), championing neoteny, says that "juvenile features are a storehouse of potential adaptations. Retardation provides a mechanism for the easy retention of any juvenile feature that suits the adult life style of the descendants" (p. 68.) Gould [q.v.] thus argues for mosaic evolution of human neotenuous traits, in the anatomical sphere. Gould, Parker, or Gibson could each argue for mosaic cognitive evolution. We would then have neotenuous playfulness and curiosity as adults, and perhaps our willingness to pay attention to others' opinions, even if we do grow crustier with age. Meanwhile, we would have achieved our logical and linguistic powers by terminal addition, even if we achieved them through a slowing as well as a prolongation of relative growth rates.

**Phylogenetic grades and Piagetian stages.** P & G have given clear evidence that apes and macaques seem to mature through the same stages, in the same order, as human children, though with "decalage" or mosaic evolution of various capacities within each stage. However, P & G might qualify phrases like "language could not have evolved in any other sequence" or "the abilities of each ancestral species were logical and structural prerequisites for the evolution of new abilities in the descendent species." These statements hold if they are restricted to "within the human line," or "within the constraints of the primate line" - they then become empirical accounts of higher primate natural history. However, Piagetian stages are not universal - the logic does not apply to bees or to machines.

Further, P & G need not assume that the common ancestor of apes and men "displayed a capacity for referential communication at least as great as that of chimpanzees and gorillas." The common ancestor probably had less capacity than any of its descendants. If sensorimotor intelligence toward food is not logically bound so tightly to language stages as P&G imply, then the modern apes' language capacity could, indeed, be a mere byproduct of intelligence as apes evolved it. Human language, on the other hand, might have evolved as a far more integral part of the differing hominid style. In fact, I am inclined to accept that ape and human language evolved in perfect parallel. This, however, is because so few empirical differences have appeared between free

utterances of chimpanzees and young children (Gardner and Gardner 1978), not because of "logical" necessity.

Finally, P&G's Table 3, and the list of prosimian stage, old-world monkey stage, and great ape stage intelligences, are a fundamental step forward - but due to be instantly superseded. Like Crook and Gartlan's (1966) seminal classification of primate social structure, P&G's will inspire research, and then research attention will focus on all the ways their classification breaks down. After all, every species has its own cognitive style: it might have been safer for them to say "our macaques," rather than "old-world monkeys." And they themselves point out the mosaic qualities of each "stage's" achievements in their notes and footnotes.

*Embedded foods versus social life or hunting as selective pressures for intelligence.* P&G make a beautiful case throughout - but why must we choose either/or? Are not two or three good reasons for evolving a trait better than one?

What P&G's target article does, it seems to me, is to bridge a time gap rather than a logical gap. Suppose the first advances from prosimian to simian intelligence took place primarily in the social sphere (Humphries 1976, Jolly 1966). Suppose, then, that ape-level intelligence did evolve primarily through the search for food, and ape-level memory in order to recall the distribution of widely spaced, seasonal food. The two hypotheses are compatible, unless you take the second as far as MacKinnon (1978), and argue that apes evolved as large-bodied, solitary animals, such that individual wit and knowledge were at a premium long before they committed themselves to social groups.

Then the ancestral hominids' social communications could have been refined, as P&G suggest, to communicate about the getting and sharing of food. Meanwhile, tool use grew in the same context. (One further advantage of the food-gathering context over the hunting one is that there is time for worrying over a problem, for second thoughts and delayed inspiration before the quarry escapes. Even a protohominid may have protothought, "What I *should* have said was...").

Surely, though, in deciphering this undervalued aspect of human evolution, there is no need to see it as the only aspect. Emerging man with millennia at his disposal might well have invented linguistic symbols for food extraction *and* food sharing *and* plans for hunting distant animals *and* mystic sing-songs that linked an apelike sense of rhythm with the growing human need to conjure cause and effect.

by J. Kitahara-Frisch

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*The evolution of intelligence: making assumptions explicit and hypotheses testable.* As J. P. Scott observes in a recent review (Scott 1979), there are two possible approaches to the evolutionary study of behavior. The first is to discover *how* the evolution of behavior occurs, the second to explain behavior on the basis of evolutionary history. The model presented in P&G's target article obviously belongs to the second kind of approach: it attempts to visualize how human behavior *might* have developed, and in so doing it provides numerous helpful hints for anthropologists and archeologists who choose to undertake the discovery of how the evolution of human behavior *did* occur.

For this sort of model to perform its heuristic function fully it is important to make clear the major assumptions that underlie it. These may best be brought out by somewhat oversimplifying the pattern of reasoning that runs through P&G's article: (1) a certain behavior appears at a given stage of hominisation; (2) rudiments of this behavior are observed in chimpanzees; (3) a similar behavior also appears at a given stage in the sensorimotor development of the human child; (4) therefore, it can be assumed to have been present in the hypothetical dryopithecine ancestor of man.

This line of reasoning assumes, in the first place, that the behaviors compared are truly homologous; that is, that they reflect a common phylogenetic origin. As noted by P&G, homology may be difficult to prove. The issue is, nonetheless, far from trivial, since the behavioral similarities on which homology is predicted may turn out, upon examination, to be superficial. Territoriality, for instance, in species such as vervets and langurs, is found to be, in some populations, an adaptation

to local ecological conditions, while in other species it appears to be genetic heritage that permits no alternative (Kummer 1971). In other words, outwardly similar behaviors may result from entirely different mechanisms - here an adaptation to a particular habitat, there an inherited pattern of behavior. Obviously, the implications of such behavioral similarities for a reconstruction of phylogeny differ considerably from those due to homology.

There are reasons to suspect that some of the similarities on which the argument presented in P&G's article rests may just as well cover a diversity of meanings. Take, for instance, the sharing of food observed in meat-eating chimpanzees and the sharing taking place between mother and child during the sensorimotor period, both in chimpanzees and humans. Are these truly comparable? As stressed by Isaac (1977) in an article quoted by the authors, sharing by adult chimpanzees has been observed only in the case of meat-eating, and, even then, it is best described as "tolerated scrounging." Vegetable foods, the great apes' principal diet, are not shared and are almost invariably consumed by each individual on the spot. Neither is it clear that the so-called food sharing reported by Silk (1978) as taking place between mother-infant pairs amounts to anything more than the Isaac's "tolerated scrounging" (observe, for instance, that Silk considers snatching or stealing food as instances of sharing).

Observations by Japanese workers in Kasoge support Isaac's comments as they report that "meat-owners at Mahale were reluctant to share and apt to monopolize carcasses in all cases when consumption was observed" (Nishida, Uehara, and Nyundo 1979, p. 16). Observation of chimpanzees in captivity likewise points to the absence of active sharing between mother and offspring, although, here too, in the wild, some "scrounging" appears to be tolerated (Nicolson 1977, p. 336).

In contrast, the food giving observed by Parker in children during their second year probably represents the imitation by the child of the body schemata of the mother: the child imitates the pattern "giving to another," whether it deals with food, toys, or other objects. The comparison raises a number of questions, such as: do passive tolerated scrounging (the involuntary yielding of food in response to persistent solicitation) and active imitation of giving have enough elements in common to justify the assumption of homology between them? Can the tolerance shown by the mother chimpanzee to her offspring be regarded as a step in the direction of bringing food back to the basecamp envisaged by Isaac as a determining factor in the process that made hominids human? Should not the tolerance rather be regarded as a form of parental-care behavior, whose like is perhaps more readily found in birds than in human food sharing among adult males?

The above questions are not meant to invalidate the interpretation offered in P&G's article, but rather to stress that the amount of evidence at hand is still far from sufficient to allow more than the roughest of guesses as to the meaning of the observed behaviors for the reconstruction of hominid phylogeny.

A second assumption in P&G's model concerns the legitimacy of the concept of recapitulation. As acknowledged by the authors, the explanatory value of this concept has been the object of much controversy. That the case for recapitulation as an explanatory concept has been recently reexamined and masterfully presented by Gould (1977) does not terminate the controversy (witness the mixed reviews received by the book). Yet, much in P&G's article appears to depend on the soundness of the recapitulation concept. Among others, the correlation assumed to obtain among the grades of primate intelligence, the stages in the development of the human infant, and the grades in the development of hominid intelligence raises the question of the *extent* to which phylogeny can be assumed to be recapitulated in ontogeny.

In the final pages of their article, P&G clearly state the hypothetical character of their attempt. One would have wished the assumptions on which the reconstruction rests to have been clearly formulated earlier in the article. Also, would it be mischievous to suggest that the conclusion tends to present as *verified fact* what had been correctly presented, during the exposition, as a hypothesis? Let the reader beware!



Despite these criticisms, the endeavor that this article represents is a valuable one. It deals with a subject of paramount interest to anthropologists and psychologists alike. The model proposed suggests a number of avenues for research. It could be considerably improved by making its assumptions and hypotheses more explicit and, thereby, rendering the model susceptible of proof or disproof. This ought to be done if the scenarios proposed are to be more than just So Stories à la Rudyard Kipling.

By Melvin Konner

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**Origins of language: a proposed moratorium.** P&G have provided perhaps the most comprehensive and original account of the origins of language in many years. Its scope extends from great ape language to protohominid neurology, from infantile problem solving to Australopithecine taphonomy, from Piagetian developmental sequences to the behavior of wild chimpanzees; and it covers all these areas informally. Its great original contribution is in the revival, in an up-to-date, measured, and, I think, acceptable form, of the notion of Haeckelian recapitulation. This revival rests largely on previous work of the present authors on comparative neurobehavioral ontogeny (which I much admire) as well as on the excellent recent work of Stephen Gould. It therefore became quite a challenge for me to discover why, in the end, I found their attempt so unsatisfying.

Though I doubt their central importance, there are significant omissions. Considering Gibson's great experience in neuroanatomy, it is a pity that the section on "The brain and intelligence" is not more substantive. It tantalizes us with a prospect of structure-function relationships in the recapitulation model, rather than really describing them in detail. Gibson's own excellent previous work is given too short shrift. More significant, possibly, is the rather skimpy account of present knowledge of brain evolution. No reference is made to the work of LeMay on the phylogeny of lateralization, and scant reference to the most recent and relevant work of Holloway and Radinsky. No reference is made to the major contribution of Kotchetkova, recently made available in English.

On the functional side, it seems difficult to understand the omission of any treatment of sources on modern gathering-hunting populations. Surely some attention to the cognitive challenges faced by people in such populations, and, perhaps more important, their uses of language and other forms of symbolic and nonsymbolic communication, would illuminate somewhat the more shadowy regions of protohominid taphonomy.

Perhaps this last omission is an important one. P&G offer an account of language-related cognitive functions presumed to exist in protohominids. It has some interesting original elements, such as the stress on aimed throwing and shelter construction, and, again, the very intriguing recapitulationist parallels. But, finally, it seems quite conventional and also quite thin beside the cognitive and linguistic complexities of gatherer-hunter life. What, for instance, of the capacity to store mentally a map of the location of vegetable food sources, three-fourths of the diet by weight in tropical foragers [See *BBS* multiple book review of O'Keefe & Nadel's *The Hippocampus as a Cognitive Map*, *BBS* 3(1) 1980]? What of the capacity to care for increasingly altricial, increasingly vulnerable young [See Rajecki et al.: "Toward a General Theory of Infantile Attachment," *BBS* 1(3) 1978]? What of the possible value of language in maintaining and equilibrating the infant's social bonds after weaning, a period of great vulnerability to mortality among higher primates? What of the possibility of sexual selection - females exercising choice in favor of more verbal, less aggressive males? It appears that P&G have fallen prey, alas, to the conventional male emphasis on the central role of hunting in human brain evolution.

"Ultimately," they write near the end, "language and intelligence were favored in our lineage because they increased the carrying capacity of our environment in the most efficient manner." It is difficult for me to gloss this sentence in any way that makes sense in relation to my understanding of how evolution works, and the remarks about comparative bioenergetics, given without evidence in the next two sentences, do not really help. Is it a group-selectionist argument? If so,

I must demur, language and intelligence were favored in certain individuals and kin groups because of reproductive advantage conferred on them *relative* to conspecific competitors. Fitness, by definition, is always relative.

We can, if we wish, continue to speculate on just what functions conferred these fitness increments. However, I wonder if we are not making rather a spectacle of ourselves for the nonanthropological scientific community - at least for that segment of it that realizes how little we have to go on. David Pilbeam has been calling for a moratorium on the "human family tree" question as, for the moment at least, a paleontological red herring. I would like to see a similar moratorium - a sort of epistemological quietus - on the question of the origins of language. There is much related work to be done. Thanks to the ape language studies, we are on the verge of understanding for the first time the mutual interdependence of language and other cognitive functions [See *Cognition and Consciousness in Nonhuman Species*, *BBS* 1(4) 1978]; these studies will probably lead, in the not too distant future, to the first solid foundation for the neurophysiology of language. The current work of Holloway, LeMay, and others on cerebral cortex phylogeny should soon lead to a conception of hominid brain evolution that goes far beyond cranial capacity. Not least in this picture will be a comparative neurobehavioral ontogeny of primates such as that initiated by P&G in previous writings. Perhaps we can take their present paper as a sort of manifesto of future research directions; and if rewritten in twenty years, it should be substantially more than that.

by John T. Lamendella

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**Assumptions about hominid "intelligence" and "language."** I would like to comment on two aspects of P&G's very interesting paper. First of all, I find inappropriate the tone of sure conviction with which the authors state their conclusions. Given the paucity of direct evidence and the impossibility of performing crucial observations on extinct hominids, the answers P&G provide in such detail lie squarely within the realm of speculation and plausible inference. There is nothing wrong with well-reasoned speculation, particularly in an area for which conclusive answers may never be attainable. Still, I feel that P&G might have exercised a greater degree of rhetorical caution in stating their hypotheses, if only to remind the reader that, at best, these conclusions have the status of probabilistic inferences with widely varying degrees of certitude associated with them.

P&G claim that extractive foraging with tools was the primary factor responsible for hominid preadaptations for "intelligence" and "language," rather than any of the several other factors that have already been proposed as "the" answer. I am not sure on what basis they feel able to affirm this answer so categorically. Surely every aspect of hominid evolution involved the complex interaction of a multiplicity of factors operating in different domains. At this point, neither the extant evidence, nor Occam's razor, nor logical necessity allows us to decide which factor was primary, or even the relative weight a given factor really had for a given hominid species; these are empirical questions with little likelihood for certain resolution. In itself, extractive foraging is neither a necessary nor a sufficient condition for explaining the selective value of cognitive and communicative functions. This aspect of the hominid adaptation may actually have played the central role P&G assign it, but there is no way to know this for sure. Moreover, there is no a priori reason to assume that human cognition and communication developed only once and in only one manner. Both individual and group variability in cognitive makeup and cultural norms (even for members of the same hominid species) may well have played a determining role in the actual course of evolution.

The second aspect of this paper I would like to comment on concerns P&G's focus on the adaptive significance and selective basis for early hominid *intelligence*. They invoke the notion of different "types," "levels," and "degrees" of intelligence. They seem to view intelligence as an independent quality which can be "acquired" in phylogeny, but which is distinct from either overt behavior or "brain organization." Neither do they identify it as one of the "mental structures" posited by Piaget. At one point they conclude that brain organization determines "species-specific behaviors," while brain size

(for two organisms with the same basic brain organization) determines intelligence (but note, for normal human adults, a range in brain size from approximately 600–2,200 cc.).

It is not at all obvious what the empirical counterpart or ontological status of P&G's notion of "intelligence" is supposed to be. Within the Piagetian tradition, some observed behaviors are labeled as "intelligent," and the progressive manifestation of such behaviors is called "intellectual development." In this context, Piagetians use the derived nominalization "intelligence." Once reified, it becomes quite tempting to talk about the development or evolution of an intelligence that transcends both the individual and the species. Most psychologists have given up on the notion of a "nonspecific intelligence" which species possess in varying degrees. P&G imply that great apes and human children of some age have the same intelligence, even while differing drastically on so many other behavioral and cognitive parameters. This conclusion derives from the observed ability of apes and children to perform successfully some subset of Piagetian tasks. That is, the cognitive information-processing systems that are responsible for producing behavior in great apes and the cognitive systems underlying the behavior of children are both able to muster "equivalent" behaviors in these instances. This conclusion does not carry with it an entailment that the internal functional organization of the relevant cognitive systems in apes and children is ipso facto structurally or functionally homologous, much less that they are equivalent in all significant respects. Given our general lack of information about the internal functional basis for such behaviors, it is gratuitous to attribute the same intelligence to apes and children merely on the basis of their ability to perform some equivalent behaviors. To extrapolate this same intelligence backward in time as a hypothetical attribute of the first hominids accomplishes little. In my opinion, intelligence is a classic example of a name without a coherent referent. As such, it is not the most useful focus for investigations into the origins of human cognition and communication.

In a similar fashion, the notion of "language" that P&G adopt is a vague nominalization covering a wide variety of radically different types of communication and, like intelligence, is treated as an independent entity transcending individual and species. Their willingness to label the various nonverbal and verbal communication systems of 9 to 24-month-old children as a type of "language" called "prelanguage or protolanguage" suggests that, according to their use of the term, the hominoid ancestors of the first hominids already possessed "language." What they call the "adult language system" is presumably what a linguist would call language – that is, a specialized type of verbal communication system with particular phonological, morphological, lexical, syntactic, semantic, and pragmatic properties.

P&G assume that the hominoid ancestors of the first hominids possessed at least the same "language capacity" as chimps and gorillas have shown under laboratory conditions. In their view, already existing "language-learning capabilities" were selected for in relation to the sharing of food associated with extractive foraging, thus resulting in a strong propensity to acquire "protolanguage." Leaving aside the questionable force of their argument, this account ignores the prior need for some hominid or hominids unknown to have first created "protolanguage." For many people, it is precisely the origin of verbal communication systems (and especially the "adult language system") that is of interest, and up to this point at least, no contemporary ape has exhibited a capacity to create even the most rudimentary verbal system.

Comparative studies of nonhuman primates simply cease to be of direct relevance when one is concerned with the culturally conditioned cognitive and communicative capacities that make human beings human. Neither "formal operations" nor language in the linguist's sense seem to be within the scope of the nonhuman primates' information-processing potential. It is at this point that the maturational stages of the human child become of special import on the (probabilistic) assumption that the neurofunctional systems characteristic of modern *Homo sapiens* arose during hominid evolution in a process of "terminal addition." I have argued (Lamendella 1976) that a modified recapitulationist view could in principle provide a useful framework for considering the origins of human speech and language. To the degree

that we understand the internal functional organization of the hierarchically structured neural systems responsible for maturational stages of the development of nonverbal and verbal communication, we have another possible evidential basis for drawing inferences about the series of evolutionary stages that led from the limbic communication of our hominoid ancestors to the type of language system that exists today. However, I do not share P&G's conviction that evidence already exists that demonstrates that any particular stage of prelanguage or language acquisition, much less the entire sequence, is in fact recapitulative. There are simply too many variables that could have acted to modify either the sequential or substantive character of the genetically specified neurofunctional systems underlying cognition and communication for this conjectural leap to be made on general principle alone (see Lamendella 1976 for discussion). Once again, P&G might have adopted a more cautious stance with regard to the certainty of their conclusions.

by Liliane Lurçat

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**Graphic skills, posture, and the evolution of intelligence.** The hypothesis underlying P&G's article is the following: (1) intelligence is defined according to Piaget's model with progression through a series of stages and substages; (2) the model has a universal value that can be projected back onto the development of humanity to the extent of being extrapolated into a phyletic model.

Piaget's model, insofar as it concerns the intellectual development of the child, is of course debatable. His theory is enjoying an enormous popularity in psychological and pedagogical circles at the present time to the extent that many writers do not hesitate to identify the model with the actual processes that it claims to describe. Certainly this is the case with the article under consideration. Recent French critiques (F. Lurçat 1976; Thom, 1976) as yet untranslated into English, suggest, however, that the Piagetian model is historically dated and thus has limitations that must be taken into account. Piaget has borrowed many of the concepts that he uses to describe intellectual development from physics and mathematics. It is not surprising therefore, that some of the criticisms should come from physicists and mathematicians who are not afraid of attacking Piaget when he trespasses into areas of their disciplines where most psychologists would fear to tread.

According to René Thom (1976) what Piaget defines as topological relations between objects are in fact only semantic relations between concepts. In addition, Thom argues that Piaget has misused axiomatic exigencies of mathematical systems for describing fundamental psychological structures. François Lurçat (1976) suggests that Piaget's ideas on the role of mathematics are closely tied to the theses of the logicist school, ideas that for modern contemporary mathematicians have become museum pieces. For Piaget, adds F. Lurçat, mathematics is supposed to say what are, from the psychological point of view, the fundamental notions of space. Intellectually this is dangerously seductive. Order in the psychological development of notions of space has nothing to do with the fact that the corresponding mathematical objects are more or less complex, or with the order of difficulty in which they appear in mathematical text books.

Piaget adopts the concepts of intellectual realism and visual realism developed by Luquet in his study of children's drawings (Luquet 1977). The analysis of children's drawings is basic to the theory (Piaget and Inhelder 1948). Drawings are used to verify whether the construction of representative space goes through the same phases as did the construction of perceptual space several years before. In the case of intellectual realism, the elementary topological relations are respected. In visual realism, a method of drawing taking perspective and proportion into account appears in the eighth or ninth year. One wonders when looking at the distortion in these drawings how much is due to the child's possible representation of what is real, and how much to the phenomena associated with the evolution of graphic skills. Piaget observes that certain children, although quite capable of placing a tree vertically in a pile of sand representing a mountain, will nevertheless persist in drawing it as being perpendicular to the side of the mountain. He interprets these graphic distortions solely as evidence for a stage of spatial representation. It appears difficult at this point to misperceive the properties of graphic space (L. Lurçat, 1979).

Taking the Piagetian model literally, P&G are brought to the position of identifying the beginning of Euclidean and projective relations with the manufacture of certain objects and tools. Such a perspective eliminates from our ancestors' activities the sense of positioning and the spatial locating skills indispensable for the satisfaction of the most fundamental of needs, entailing the search for food and the appropriation of places to live. Moreover, what does it mean to attribute a human intelligence level of two months in our current world to a monkey who has to solve his own survival problems in his specific environment? The Piagetian model appears to be irrelevant.

In addition, the legitimacy of an evolutionary approach from monkey to man is questionable. Leroi-Gourhan (1964, 1965) considers that to say that man evolves from the monkey has as much validity as to say that the tapir evolves from the rhinoceros. He argues that human characteristics are not reducible to those of monkeys — that the history of evolutionary theory, from fish to gorilla, shows posture to be fundamental. Monkeys have one particular set of postures: quadrupedal and seated; hominids have another: bipedal and seated. This difference means that the hominids not only have the hands free while moving, but also have a shortened face, weak canines, and a brain freed from the mechanical constraints caused by suspended position. The transition from the primates to the first toolmakers is not a question of technological skills: apes grasp, touch, forage, crush, peel, and manipulate; they tear with their fingers and teeth, crush with their molars, cut with their incisors, pierce with their canines, hammer with their fists, and scratch and dig with their nails. This inventory comprises all the varieties of tool-using activities that one might wish to distinguish in archanthropes and paleanthropes. What is valuable for humans is not the nature of the hand, but the vertical walk and the paleontological consequences of this for the development of the cerebral mechanism.

What we are contesting here is not so much the posing of the problem of the evolution of intelligence, but of using an inadequate model that eliminates the entire social dimension from that evolution.

#### ACKNOWLEDGMENT

I thank T. Greacen for the help he gave me in writing these comments in English.

by W. C. McGrew

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**Habitat and the adaptiveness of primate intelligence.** P&G are to be congratulated for their latest and most comprehensive effort to integrate the insights afforded by Piagetian developmental psychology and recent findings on the behaviour of human and nonhuman primates. They provide one of the most heuristically useful frameworks yet advanced for dealing with the adaptive significance (and therefore the evolution) of higher intelligence. Such a synthesis is long overdue.

As a field primatologist, I shall address myself to several pervasive implications arising from P&G's formulation of the phyletic stages of intellectual achievement. These relate to what I see as their underemphasis on the contributions of the environment to adaptation and their overemphasis on phylogenetic position. Since the crux of the authors' model is extractive foraging, I shall concentrate on it whenever possible. These points are:

1. Reliance upon laboratory findings may result in a misleading picture, as is the case with the gorilla;
2. Findings of recent ecological field studies may provide a more representative and accurate picture, as with the baboons;
3. Consideration of (1) suggests that a recapitulationist approach without taking account of phenotypic adaptation may be simplistic;
4. Consideration of (2) in terms of intra- and interpopulational (cross-cultural?) comparisons suggests that, at least with some catarrhines, P&G's grade-levels (see Table 3) underestimate cognitive capacity.

Most of P&G's generalizations and specific examples concerning the great apes are based upon the chimpanzee. The species has been well studied in field and laboratory and during home rearing, and its intellectual performance is impressive in all circumstances. Comparable scrutiny of the other two pongid species (orangutan, gorilla), however, yields perplexing results. All evidence from captive studies

seems to indicate that few if any differences exist in the intellectual capacities of the three species. However, field studies of subsistence behaviours indicate that gorillas show little intelligence beyond basic stage five of sensorimotor intelligence, that is, the authors' Old World monkey grade level. Once it could be argued that the disparity might be an artifact of limited knowledge of the gorilla in nature, but recent detailed studies refute this (Fossey and Harcourt 1977; Goodall 1977).

In P&G's model, the baboons (*Papio spp.*), as representative Old World monkeys, should be consigned only to the second grade of intelligence. Others might agree, both on the basis of field (Beck 1974) and laboratory (Benhar, Carlton, and Samuel 1975) data. But even taking the (overly?) stringent criteria of tool use as an example, this is unjustified, as tool-using baboons in captivity would seem to show most if not all of the sensorimotor series (Beck 1973a). Furthermore, wild baboons regularly use tools in some circumstances (Hamilton, Buskirk, and Buskirk 1975). If one looks at object manipulation in a broader sense, naturally exhibited baboon intelligence satisfies all stages of the sensorimotor series and perhaps even extends into the preoperational series. To cite a few suggestive examples: baboons detect hidden corms and show individually different techniques in excavating them (Rhine and Westlund 1978). They dig water holes in dry riverbeds and rub fish in the sand to remove the surface mucous layer; infants play "games" focused on objects (toys?) such as palm nuts (Hamilton, Buskirk, and Buskirk 1978).

In light of the above, it would seem insufficient to characterise grades of primate intelligence on the basis of phylogenetic position, even given exciting new knowledge of the interactive ontogeny of the brain's morphology and function. The fact remains that in the real world, baboons appear to be much more intelligent than gorillas. The solution to this paradox, I submit, lies in the adaptive interchange between organism and environment. Put more specifically, baboons show more intelligence because they are opportunistic, omnivorous generalists subsisting in the widest range of marginal habitats. Gorillas are conservative, herbivorous specialists restricted to certain suitable habitats. Any assessment of intellectual performance (as opposed to potential) should take these differences into account. Neither recapitulation (nor neoteny) as presently formulated can explain adequately the observed disparities between baboon and gorilla. This calls for caution in extrapolating along the same lines to the early hominids.

The authors stress the cross-cultural robustness of the Piagetian sequence of human cognitive development. This may unwittingly give the impression that intelligence is somehow expressed even more invariantly in infrahuman species. Comparative studies of nonhuman primate groups, both within and across natural populations, are showing just the opposite, namely, greater and more frequent differences. Hamilton et al.'s (1978) careful study of object manipulation in five troops of chacma baboons shows more differences than similarities, many of which are directly attributable to the demands and limitations of the physical environment. In other words, adaptive (intelligent) behaviour stems primarily from habitat features, not cognitive capacity, which is assumed to be constant across all populations of the same species. Furthermore, wild chimpanzees show interpopulational contrasts that are presently inexplicable in environmentally dictated terms. They appear to be cross-cultural differences in social customs (McGrew and Tutin 1978; McGrew, Tutin, and Baldwin 1979). Regardless of the relative contributions of environmental and social factors to such emergent differences, their origins and persistence imply that at some time novel solutions were applied to subsistence problems and that these solutions have been transmitted socially through cultural tradition. Innovation and dissemination require more than basic sensorimotor intelligence. The capacity for cultural evolution in baboons, at least, shows them to be underestimated in P&G's gradings, since such a process would seem to require (among other things) inventiveness and imitation.

by John Macnamara

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**Doubts about the form of development.** What would be needed to construct an interesting model for the evolution of language and

intelligence in early hominids? In addition, what would be needed to persuade us that the language and intelligence of early hominids led on to our own? The least we would need would be a satisfactory characterization of the following: human intelligence: hominid intelligence; human language: hominid language. Having none of them, we are scarcely in a position wisely to undertake the project, or wisely to evaluate any model set before us.

I will say little about hominids because I am unmoved by arguments about brain size, eating habits, shelter building, tools, or the signing of chimpanzees. The trouble is double edged. We do not know whether P&G underrate or overrate hominids. They point out that much of what nonhuman species do looks intelligent, but may not require an intelligence directing the behavior. It follows that we do not know what to take as evidence of intelligence in hominids, or what as lack of intelligence. The language of early hominids is best passed over in complete silence.

P&G have a strong faith in Piaget, in the validity of his stages of cognitive growth, in the belief that the stages "provide a taxonomy of intellectual achievement," and that intelligence and language in the human species evolved through those stages in that order. I see no grounds, intuitive or otherwise, for assuming that the child's learning which words refer to which objects in the second year of life is intellectually a lesser achievement than learning that volume is conserved under certain transformations in the sixth year. Though I cannot here elaborate on it (see Macnamara, 1976, 1978, and in preparation), I see no grounds for believing that the structure of intelligence changes with age. The null hypothesis of developmental psychology, hitherto unfalsified in any particular, is that it does not - though there surely is learning. If the structure of mind does not change, there is no reason to suppose that manifestations of intelligence over time follow an order that ascends on any scale except that of age. I have no idea how to assess the claim that the succession of accomplishments through childhood recapitulates the succession of accomplishments in the race. I have nothing against it; and alas I have nothing for it.

What about the fact, invoked by P&G, that there is physiological development of the human brain after birth? The trouble is that we do not know what that means in terms of intelligence and language. And even when we do know, there is no guarantee that the development of brain function will follow some interesting scale of intellectual advance. Neither, unfortunately, is there any guarantee or, as far as I can see, any probability that it reveals the path of evolution.

A word about loquacious chimpanzees! They are more impressive than fifteen years ago I believed they could ever be. But have they human language in any sense of that word? I am at a loss to judge. A minimal requirement for language is that some of their signs *refer* to objects in the same sense as some of our words refer. The problem is that *refer* resists analysis. It has never so far been defined, say, in terms of truth (an equally prickly notion). Tarski succeeded in eliminating the notion of reference for certain purposes in certain formal languages. But he succeeded only because he was able to presuppose reference both in setting up the formal language and in making statements in it. To make a long story (see Macnamara, in preparation ch. 2) short, we seem obliged to take referring as a primitive of cognitive psychology. Intuitively we recognize acts of referring in ourselves and in other people. Should we allow our intuition to tell us whether a Washoe or Sarah refers? I would argue against those who say yes, and also against those who say no. As for hominids!

My feeling about P&G's whole project can be summed up in Belloc's cautionary lines:

O, never, never let us doubt  
What nobody is sure about.

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**Data for a theory of language origins.** Parker and Gibson deal with data and subjects that have come increasingly under interdisciplinary discussion in the last decade. Unfortunately, in a subject of extraordi-

nary biological and cultural complexity, much relevant research and data are omitted, and the theories used are, in large part, accepted uncritically and without evaluation. There is no mention of studies of brain function and dysfunction, brain lateralization and hemispheric specialization, or the affective and limbic components in human language in primate communication and sharing, and in recent primate language studies. There is no mention of the important non-tool-oriented aspects of primate language use, of the ways in which language is actually used by hunter-gatherers during tool making, hunting, gathering, butchering, or food sharing, or of the use of language by hunter-gatherers while subsistence skills are being taught. Nor is there any consideration of the way in which language is used by hunter-gatherers in "nonsubsistence" cultural activity. Similarly, there is no mention of the use or adaptive role of cognitive and symbolizing skills in nonsubsistence activities, either by chimpanzees or children except as play preparatory to subsistence activity; and there is no discussion of how nonsubsistence activities may have played a part in hominization and in hominid adaptive success. There is no awareness of the inherent limitations of the early archaeological evidence, whether of tool kits or measurements of brain volume, in documenting anything valid about cultural or behavioral complexity.

The crux of the P&G model is the statement that the "stages of intellectual, linguistic, and neocortical development in modern human children recapitulate the stages of the long evolutionary journey." I will not comment on the heuristic use of the concept of ontogeny repeating phylogeny when it refers not to biological structures but to complex behavior. I will discuss only the validity of certain basic referential data used by P&G to structure their model.

The paper assumes that Piagetian sequences of cognitive development in the human child (and to a degree in the great apes) represent the fundamental measure of "intellectual" development and therefore comprise the basic adaptive capacity that evolved in the hominid line. These observable, measurable, and testable skills and capacities are viewed as primarily subserving subsistence survival, that is, food getting and eventually food sharing. It is assumed that the development of the human language capacity, which biologically occurs in tandem with the development of the above cognitive skills, is dependent on and primarily related to this fundamental subsistence activity.

But the developing skills of the child are not the developed skills of the adult, or even those of the still-developing adolescent. In the evolution of the protohominids and then of the hominids it was the adaptive capacity of adults or near adults, both in the natural phenomenological world and in the cultural, social, *relational* world, that represented the functional matrix and the operational arena within which success, failure, reproduction, rearing, survival, and selection occurred. As recognized by P&G, the cognitive skills of the child are not in and of themselves adaptive, nor are they adequate for subsistence survival. In terms of adaptive success, they are minimally functional without the presence of other relational, social skills. The child's skills are preparatory for the successful strategies and constructs of adults, and the latter are far more complex intellectually, affectively, hormonally, sexually, socially, culturally, and neurologically than the developing cognitive, operational, or linguistic skills measured by Piaget in the child.

What human and monkey or primate infants begin to learn, before the development of stage four, five, or six cognitive skills, are the relational equations of the species. Harlow's mother-deprived and (relationally) feedback-starved rhesus infants, though they can later score comparatively well on Piagetian cognitive tests, will fail totally in adult survival, adult relations, or adult reproduction. Long before the child begins language production, he is involved in complex relational modeling, involving intelligence, symboling, structuring, cognitive mapping, and other relational strategies [see *BBS* multiple book review of O'Keefe & Nadel's *The hippocampus as a cognitive map*. *BBS* 2(4) 1979]. Food-getting is only one part, and not the most important part, of this learning process. When language production does begin, it is the rapidly developing relational domain, and the child's role and increasing competence in it, that is used, tested, and talked about. The objects and relations named and tested in language are essentially marked and culturally relevant aspects and cues. "Naming" is itself a

test of relational as well as linguistic competence. The child, then, is not only learning language production, but relational modes mediated by language. This is a complex and non-Piagetian aspect of the ontogeny of human language. It is also the central problem for understanding communication as such and the evolution of the human language capacity. One small part of this problem is today being discussed and studied in terms of "context" in child language development (Keller-Cohen 1978). The "contexts" are not essentially related to food getting or subsistence activity.

I stress that food getting and food sharing in all possible cultural variants are neither the central nor the crucial sets of relations involved, either in the ontogeny of Piagetian skills in the child or in the development of language competence. A human child will, in fact, survive with or without developing its cognitive or linguistic skills. The feral child will survive by developing some, at least, of its cognitive skills, but like Harlow's monkeys (Harlow, Schitz, and Harlow 1969) or like chimpanzees (Menzel, Davenport, and Rogers 1963 a, b), he is automatically excluded from the evolutionary process. Cognitive and linguistic or communicative skills are ultimately adaptive and will serve in species survival only to the extent that they are successfully used in adult social, relational, and cultural contexts.

Primary "sharing" in the hominid or human line depends on the capacity for structuring complex relational modes, a capacity that is apparent in varying degrees among the great apes and was probably increasingly developed in the hominids. Now, one way or another, relational modes, whether they involve rearing, teaching, learning, ritual or role playing, sexual acts, cultural specialization, or cooperation and group subsistence activity, all have a strong limbic, affective component. Language itself, a relational mode, has such a component.

The above comments do not mean that I underestimate the importance of Piaget's data or his developmental sequence. I think, in fact, that I was the first to use Piagetian data and concepts in an attempt to explain the cognitive contents and complexities of early *Homo sapiens* symbolic materials (1969, 1972a, 1972b, 1974, 1976, 1977, 1979). But it was adult cultural material and the adult use of these basic skills in nonsubsistence cultural activity that I was studying, and it was the adaptive significance of these adult activities that I was seeking.

I present an example of the theoretical problem from the archaeology of early man. At the *Homo erectus* shelter of Bečov in Czechoslovakia, c. 250,000 B.P., archaeologist J. Fridrich (1976) excavated a piece of red ochre that was striated on two faces with the marks of abrasion and one flat rubbing stone with a granular crystalline surface that had been abraded in the center, clearly in the preparation of ochre powder. On the floor of the shelter, at the side where the piece of ochre was found, there was a wide area of ochre powder. Seating himself on a rock against the wall of the shelter to study the ochre, Fridrich found that his feet accidentally fitted the only two areas without ochre powder. *Homo erectus* had sat on this stone, away from other activities in the site, while he made his red powder.

The manipulative, "extractive" skill involved was perhaps not much different from that of New World cebus monkeys who take pods or beans with an uncomfortable fuzz to another location to rub them against a hard surface before beginning extraction (Chevalier-Skolnikoff 1978), nor was it much different from the skills used by chimpanzees in idiosyncratic acts of curiosity and experimentation on the nature of materials. The difference lies in the adult human use and context of these skills.

Pieces of red, brown, and yellow ochre have been found in the *Homo erectus* site of Terra Amata, France, c. 380,000 B.P., by H. de Lumley (1966), indicating that what we have here is an early and widespread cultural tradition. The ochre powders would also have had to be contained in a holder of sorts. Leaving out any discussion of possible meaning or usage, it is clear that what we have at the simplest level of discussion are cognitive skills not much beyond Piaget stages four, five, and six of the human child, but which were here used in an adult, nonsubsistence context, one that involved an adult semantic. One part of the meaning and viability of this symbolic activity, one part of its deep structure, would have involved an affective, limbic component.

In sum, the generalized cross-modal capacities evolving in the

hominid line, including the cross-modal cognitive and communicative capacities, were potentially effective and adaptive in areas that went significantly beyond subsistence activity, extraction, and food sharing. Symbolically structured relations were perhaps as significant as cutting edges, extractive strategies, or carrying vessels, certainly in the evolution of language. These relational, social activities and contexts involved all the evolving parts of the neocortex as well as the older parts of the brain and the limbic centers.

Finally, subsistence activities requiring cognitive and manipulative capacities at the level of stages five and six do not require a complex use of language and, in fact, in normal day-to-day success do not require directed language at all. Tool making and tool use are not learned through language, and the skills of the hunt are learned by example and participation, not by linguistic description. Even directional references do not necessarily lead toward the complexities of human language. The most effective "linguistic" or protolinguistic component of subsistence activity (whether vocalized or gestural) is often simple "affect marking," indicating approval, affirmation, support, negation, warning, request for cooperation or delay, none of which requires a complex use of language or any significant increase in evolved linguistic capacity. Such affect marking forms a large part of communication during human subsistence activity even today.

Protolinguistic affect marking, with perhaps a minimum of gestural or vocalized nominative marking, would have been utilitarian and effective long before the development of syntactic modes of language because the nonlinguistic contexts in adult life were understood and shared. In an early volume (Marshack 1972a, p. 115) I indicated how such communication in a shared context can signal completed action, future action, role, status, and even nominative specification, in essentially non-food-oriented activity. If human language is cross-modal and associative, involving, in its evolution, the use of the spectrum of available communicative and marking modes, then what evolved was cross-modal and associative and probably simultaneously involved gestural, facial, vocal, behavioral, and relational aspects. This formulation implies an inadequacy in all simple, unitary, one-dimensional explanations for the origin of language.

I might here suggest that the selective advantage in hominid evolution was not with those who "talked" a lot when they worked, either gesturally or vocally, but with those who "talked" most relevantly when they were not engaged in direct subsistence activity, that is, before, after, and in between. Those who had to "talk" a lot about the subsistence activities in which they were engaged would probably have been selected out for eventual extinction.

These problems and suggestions, which I have been investigating and writing about for more than a decade, are perhaps to some degree validated by recent archaeological findings and chimpanzee studies. If the evidence reported by Johanson (Johanson and White 1979) and Mary Leakey (1979) is correct, and hominids or protohominids were walking upright with freed hands and forward vision three to four million years ago, before the archaeological presence of a cultural tool kit and before the presence of a brain significantly larger than that of the great apes, then we have in the anatomical evidence the theoretical possibility of laryngeal vocalization at some nonphonemic level, present in the species before major brain enlargement and artifactual innovation. Such a potential vocalizing capacity would have existed with or slightly above the protolinguistic capacity that has been determined for the chimpanzee and gorilla. Protolinguistic potential of hands and throat were then contemporary. Simply posing the question and problem in these terms puts the recent chimpanzee research in a different perspective.

Clearly, in the case of the chimpanzee, the potential capacity for protolinguistic behavior in the laboratory is not dependent on a change in either brain volume or brain structure, but is elicited by a change in context - in cultural, relational, and behavioral contexts that contain periodic, culturally maintained feedback and reinforcement. The contexts are supplied and maintained by man. As a result, at least part of the question relating to the inherent potential for language present at the protohominid stage must be discussed in terms of the changing cultural contexts within which the early brain functioned. Natural selection would have then operated for the development of those

potentially variable capacities that were present or incipient in varying degrees among different individuals and that were becoming increasingly adaptive with the increasing complexity of adult cultural behavior and structures.

by Sue Savage-Rumbaugh, Duane M. Rumbaugh, and Sally Boysen

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**Chimpanzees and protolanguage.** P&G offer important perspectives on the evolution of intelligence. Their basic postulate – that the stages of intellectual and linguistic development in the human infant recapitulate the stages of the evolution of intelligence experienced within the order Primates – is both intriguing and, at least in part, testable. However, as P&G point out, at birth the brain of the human infant is very different from that of its nearest primate relative, the great ape. The brain of a human infant contains more neurons and by six months – long before the onset of language – it completely surpasses in size even the brain of adult apes. The richness of associative connections permitted by such a large brain would suggest that the progress of the modern human infant through the sensorimotor stages may be very different from that of the apes or the now extinct human ancestor.

While an ape infant may display object-permanence understanding earlier than a human infant – because of the ape's more rapid maturation (and thus earlier myelination) – we should not conclude that the intellectual achievements of the two species at the end of the object-concept period are equivalent. The larger brain of the human infant will have allowed him to store more information and perceive more associative relations than the smaller brain of the ape – even if both have arrived at the concept of object permanence. P&G note this difference themselves when they point out that although apes give evidence of engaging in "tertiary circular reactions" and "discovery of new means," they do so less frequently and in fewer contexts than human infants. This implies that, at any stage, the brain of the human infant permits a wider variety of behaviors than the brain of the ape infant, and therefore is recapitulating the levels of intelligence of smaller brained creatures only in a general way. Thus one could expect to find in all domains of modern human development a richness of behavior that simply did not exist in our ancestors. The problem with a recapitulation approach is to separate those behaviors that do reflect important developmental stages in ancestral intelligence from behaviors that are peculiar to the human species by virtue of its large and associatively rich brain.

Although the P&G view of the origin of hominid intelligence and language is, as the authors suggest, more versatile than the hunter-scavenger model, it leaves many questions unanswered. First, the authors do not clearly state why food-sharing "arose as a secondary adaptation for extraction with tools." They point out that it would be more efficient (physiologically) for mothers to share hard-to-process foods with offspring than to continue lactating for the lengthy rearing periods required by hominoid-hominid infants. They then note, however, that human infants have a strong tendency to feed their parents and strangers with real and imagined foods. The implied premise here is that mother-to-offspring food sharing and offspring-to-parent (or other individual) food-sharing are equivalent behaviors – that infants share because their mothers share. However, mother-infant food sharing is widespread within the other Primates, yet is only human infants who have been reported regularly to use imagined or real food in greeting behaviors [see Eibl-Eibesfeldt: "Human Ethology" *BBS* 2 (1) 1979]. This would suggest that mother-offspring sharing of food is not itself a sufficient explanatory mechanism for the appearance of the hominid group pattern of food sharing.

The proposed relationship between the evolution of "protolanguage" and that of extractive foraging and food sharing is intriguing, but the way in which the appearance of a protolanguage enhanced these abilities is not clearly specified. Moreover, although present-day apes engage in both extractive foraging and food sharing, P&G offer no explanation for their lack of a protolanguage.

The chimpanzees Sherman and Austin have employed symbols to

identify hidden foods to one another and to request tools from one another (Savage-Rumbaugh et al. 1978). Moreover these tools were requested because they were needed to open an embedded food source. The linguistic, cooperative-social, and motor skills that have emerged in Sherman and Austin are atypical for apes and have appeared as we structured the laboratory environment in a way that stressed cooperative tool use for extracting embedded food sources. This was not done with the intention of testing the P&G model (of which we were unaware), but arose from trial and error. In an effort to find ways to induce interanimal cooperation and to teach object referential we tried many approaches that failed. The use of tools to extract embedded foods emerged as a successful way of initially inculcating these skills and was therefore intentionally elaborated upon. This method has also proved successful with retarded children who show similar deficiencies in cooperation and referential capacity.

Thus while we were unable to begin language training with names of colors or objects, we were able to begin by designing the environment so that the animals had to request foods and tools. Furthermore, while we have only rarely been able to achieve spontaneous interanimal communication regarding tickling, playing, hugging, and the like (our animals seem to prefer to communicate about these things nonverbally) we have achieved spontaneous interanimal communication about hidden foods and needed tools. This would strongly imply that when apes are placed in an environment in which communication about food and implements is placed at a premium, they are able to encode and use symbols in the protolanguage fashion proposed by P&G.

Have we, without intending, created a laboratory environment that bears significant similarities in terms of environmental pressures to the natural environment encountered by our ancestors? We feel that the answer is yes – we have done this, in part. However, in the laboratory, Sherman and Austin knew the symbols and used food and tool symbols to communicate with human instructors long before they used them to communicate with one another. The human instructors, in fact, taught these symbols by making tools and foods available only if requested symbolically. Nonverbal requests such as pointing and whimpering were acknowledged, but not honored. It seems unlikely that protolanguage would have emerged because parents suddenly began insisting that their offspring use a symbolic mode to communicate requests for tools and embedded foods. Surely, if such requests could be communicated by whimpering and gestural begging (as is presently the case in apes) they would be – and they would be understood and honored. Why then did our ancestors need a protolanguage to share food and to use tools when present-day apes do not need a protolanguage to accomplish these things?

Based on our observations of interanimal symbol use, we suggest that protolanguage arose to facilitate the structuring of cooperative interindividual endeavors. In present-day apes most object-linked activities are of an individual nature. Chimpanzees, for example, work singly at termite mounds; if sharing of food occurs at all, the individual who has received food moves away after getting the food and eats it alone. The only social game involving an object is that of "keep away," and here again only one individual has the object at a time.

In contrast human beings cooperate in tool use, with two or more individuals working together to accomplish the task. Human beings eat facing one another and repeatedly take food from the same pot. They engage in object games that involve passing objects from one individual to another or cooperatively constructing forms from a variety of objects. Object giving and showing develop in association with food giving, and both occur before the human has completed the final sensorimotor stage. This high level of cooperative behavior, revolving around the joint use of and action upon objects (as opposed to the non-object-oriented interaction found in social behaviors such as tickling and grooming) requires a more elaborate means of coordinating and structuring interindividual behavior.

For example, when faced with a fixed amount of food, human beings will divide it into portions. All individuals in the group will receive some portion, and the size of the portions will be determined in advance according to some standard shared by the group. Division of this sort requires a coordination of group actions. Turns must be taken, and the distribution itself requires a concept of one-to-one correspondence

Who gets what food when must be determined in advance of action or the grab and beg situation ensues, as occurs with present-day apes.

P&G view food division as an important adaptation for butchering and dividing large carcasses. We suggest that food division and regulation occurred much earlier. Any embedded food whose extraction required cooperative effort would be subject to division. The cooperative extraction might initially have been as simple as one individual keeping watch while a second extracted the food, or as complex as two individuals using two levers to jointly lift a heavy rock away from food. In any case, wherever joint effort is required to obtain food, division is encouraged, and to be successful the joint actions of obtaining and dividing must be structured and regulated.

While facial expressions and nonverbal vocalizations readily serve as communicative mediators during a social bout of tickling or grooming, they are poor coordinators of object-linked interindividual interaction because they are contextually bound. They can communicate messages such as "tickle me," "groom me," or "stay away from me," but they cannot communicate specific messages such as "from the set of objects around you select the lever," or "from the group of foods in front of you give me the orange and take the apple." The interindividual structuring of actions upon or with objects therefore requires a level of communication not required by simple social exchanges. Coordinated food distribution and the coordinated use of implements to obtain embedded foods require a protolanguage that permits the coordination of joint attention toward and action upon objects.

We suggest that it was not the requesting itself, but rather the need for coordinating joint action toward objects. This view is supported by observations of symbol use by Sherman and Austin. Although we initially structured their environment to force interanimal communication, the two chimpanzees now coordinate and structure their interactions symbolically when working together. They use symbols during food division, they regulate turn-taking with gestures, and they use symbols to regulate object exchange. These gestural role- and attention-regulating behaviors have emerged without specified environmental structuring or training. As they have appeared the iconic gestural repertoire has also become increasingly elaborate. Both symbols and gestures function in this context to permit a degree of inter-individual object-related behavioral coordination and cooperation that was not previously present.

In linking Piagetian developmental stages to ancestral evolutionary landmarks, the P&G comparative approach to the evolution of intelligence is important because it offers a broader perspective and more testable framework than were heretofore available. Although we have suggested some conceptual modifications based on our work and although we feel that more are needed, we applaud in general the efforts of P&G.

#### ACKNOWLEDGMENT

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by Euclid O. Smith

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**An alternative model for language acquisition.** P&G offer some interesting ideas on the evolution of language and intelligence. They see the roots of language acquisition in the events surrounding extractive foraging and food sharing. With this perspective in mind, it might be useful to examine the cases of extractive tool use across the primates to see if there are other species that might serve as a useful model besides the chimpanzee, gorilla, and orangutan. Often it is tempting to look only at the pongids if we are trying to develop a model for language acquisition, but it is clear that other species may exhibit adaptations of some considerable interest and importance.

If we look at other primate species that practice extractive foraging or have a substantial amount of animal protein in their diet, we might find a form that would provide additional information for building a suitable model for the acquisition of language and the development of

higher cognitive abilities. In addition to the numerous references that P&G have presented for extractive foraging in nonhuman primates, we find among the neotropical primates one form that is reported to rely on animal protein for part of its diet and to practice extractive foraging, at least in a rudimentary sense. *Cebus* monkeys have been reported to open oysters with rocks on Gorgonia Island (Hernandez-Camacho and Cooper 1976), as well as to open *Astrocaryum chambira* nuts by smashing them together (Struhsaker and Leland 1977). Chevalier-Skolnikoff (1978, 1979a) and Parker and Gibson (1977) have also noted the manipulative and cognitive abilities of *Cebus* in the wild.

Numerous researchers have noted the omnivorous dietary propensities of *Cebus*, and particularly their reliance on animal protein - for example, lizards (Hernandez-Camacho and Cooper 1976; Izawa 1978; Watts 1977), baby squirrels (Oppenheimer 1969; Watts 1977), frogs (Izawa 1978), crabs (Milton and Mittermeier 1977), and other small vertebrates (Klein and Klein 1975). Furthermore, *Cebus* are reported to be found frequently in polyspecific associations with *Saimiri* which Klein and Klein (1973) feel increases their foraging efficiency for insects. By traveling in larger groups, they stir insects into flight, making them much easier to catch.

Taken together, these observations suggest that the neotropical primates should be investigated more fully to document their feeding patterns and overall foraging strategies. It is clear that the *Cebus* are interesting primates with some considerable potential for cognitive tasks. Although not rivaling chimpanzees, they might provide additional data on the possible alternative pathways to the evolution of persistent food sharing and, ultimately, language acquisition. Interestingly, however, food sharing has not been observed in *Cebus*, even in the consumption of animal prey, although it has been observed in *Ateles geoffroyi* on Barro Colorado Island (Dare 1974a, 1974b). *Ateles*, however, have not been observed to practice extractive foraging.

Overall, it seems that P&G are on the right path to developing a model for the evolution of language and intelligence, but it is necessary to keep in mind all the possible alternatives to the particular evolutionary end. Investigation of the cognitive abilities of other species should provide additional insight that may force some reevaluation of the model, but may not render it invalid.

by Charles T. Snowdon and Jeffrey A. French

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**Ontogeny does not always recapitulate phylogeny.** The idea that the ontogeny within an individual represents a recapitulation of the individual's phylogenetic history was most strongly developed in comparative embryology. It was used by Jolly (1972) as a device for organizing a diverse literature on the cognitive abilities of primates. While the idea is useful for organizing a body of diverse data for a textbook presentation, it is not clear that it is as useful as an explanatory principle for the evolution of language and intelligence. A model or explanatory principle must, if it is to be useful, account for a large amount of existing data with few exceptions. If there are numerous exceptions, then the specific nature of these exceptions should be predictable from the model.

While the recapitulation model presented by P&G may seem compelling given the supporting data in the text, there are many other data that we can cite that fail to fit the model or to be predictable from the model in a straightforward way.

For example, in the description of the Piagetian paradigm, lemurs, stump-tail macaques, cebus monkeys, and great apes are discussed as though they provided a uniform phylogenetic sequence. However, cebus monkeys which "like great apes . . . display the intellectual abilities of the fifth and sixth stages of the sensorimotor intelligence" are actually more primitive phylogenetically than the stump-tail macaques, which do not show this "ape-like intelligence." No explanation is given for this anomaly nor is an anomaly even acknowledged to exist.

Furthermore, while the inability of the stump-tail macaque to demonstrate tool use or to imitate novel schemes is used to define the cognitive levels of the macaques and indeed of all Old World primates, a recent study has shown that the closely related Japanese macaque (*Macaca fuscata*) shows complex object-object manipulations and imitation (Candland, French, and Johnson 1978). One juvenile ma-

caque learned to take a steel bar, insert it between the bars of the enclosure, and bend it into a hook. The subadult male who performed the manipulations rarely used the objects as swings at the site where he modified them but carried them from the floor of the enclosure to the walls or the roof. All the infants in the enclosure intently observed the subadult male using the swing objects and subsequently played on the swing, both alone and with peers. These observations, as well as others cited in Candland et al. (see Table II), suggest that tool use, object modification, and the imitation of novel schemes of behavior are not unique to great apes, protohominids, and man.

Classification is cited as an ability unique to great apes and man. However, there are numerous exceptions. As one example, Tinbergen (1938) showed that the digger wasp (*Philanthus triangulum*) could classify geometric shapes. If when leaving her nest the wasp saw a circular array of pine cones around the nest, she would, upon returning, fly to the center of a circular array rather than some other geometric shape. When pine cones were rearranged in some other geometric shape and a totally different set of objects was placed in a circular array, the wasp would fly to the center of the circle, demonstrating a classification of geometric shapes. There are a host of species intermediate between wasps and apes, which apparently do not show this sort of classificatory behavior.

Similar examples can be raised with each of the remaining behaviors used to define the evolution of language and intelligence. Pygmy marmosets engage in extractive feeding by digging holes in the bark of trees and extracting sap. A variety of different animals feed from the same hole, suggesting that food sharing is occurring: not only the animal who excavates the hole uses its sap. Almost all passerine birds engage in food sharing, both adults with mates and adults with offspring. Canids also display extensive food sharing. The imitation of novel vocal schemes has been demonstrated in several studies of bird vocalizations. White-crowned sparrows will learn the particular dialect to which they are exposed during the early months of life (Marler 1970) and goldfinches, upon mating, imitate unique characteristics of their mate's songs (Mundinger 1970). Finally, shelter construction has appeared several times in evolution, from social bees and termites, to the elaborate nests of weaver finches such as *Oropendula*, the nests of wood rats, and the burrows of prairie dogs. If any conclusion were to be drawn about shelter construction it would have to be that the closest ancestors of man are noticeably poorer constructors than his more primitive ancestors.

These examples all indicate that there is no simple relation between phylogenetic level, ontogenetic level, and intelligence or language. Behaviors that we human beings consider "intelligent" or "protolinguistic" have appeared at several points in evolution and failed to appear at other points. A more sophisticated biological theory of the evolution of intelligence or language would take into consideration the different types of adaptations that are suitable to different ecological habitats. Since each biological species has adapted to a unique habitat, one would expect not just quantitative differences in behavior or cognition between any pair of species, however closely related, but also qualitative differences reflecting the qualitative differences in habitat.

An example of these qualitative differences in behavior was given in a study by Jolly (1964) on seven closely related species of prosimians. All were presented with objects, either baited with food or unbaited. The insectivorous species paid attention to objects for long periods, but displayed little object manipulation, while the herbivorous species only paid attention to the object for brief periods, but displayed extensive manipulation of both baited and unbaited objects. The omnivorous species were intermediate. These responses to objects are similar to the responses needed to obtain each type of food efficiently. This example illustrates the importance of a model for the evolution of intelligence that focuses on the specific adaptations of the members of each species to their habitat.

From this type of model one would not expect to find simple correlations between phylogeny and intelligence. One would expect to find anomalies, and one can develop predictive hypotheses about the circumstances in which different anomalies should appear. On the

other hand the recapitulation theory presented by P&G does not lead to the prediction of anomalies.

One final comment must be made about the argument that brain size and intelligence are correlated. This notion is quite oversimplified. Many species have larger brains than ours, yet it is not clear that they are more "intelligent" than we. Human females have, on the average, lighter brains than human males yet most of us do not consider females to be less intelligent. It seems a mistake to raise the brain-size/intelligence issue, when it is likely that the complexity of neuronal connections is more correlated with what we call intelligence. The authors have opened a Pandora's box.

by Jan Wind

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**The evolution of intelligence: rehabilitation of recapitulation?** In general I found P&G's approach quite interesting, refreshing, and convincing. It deals with a fascinating though difficult problem: the origin (rather than just the evolution, as suggested by the title) of language and intelligence. The road to the solution of the problem has many pitfalls, most of which the authors seem to have ably bypassed. Their basic methodology is sound: comparing phylogeny with ontogeny rather than assuming a priori that the former can be reconstructed with the latter as has traditionally been propagated by the "biogenetic law." Departing from the axiomatic point that all selective pressures that shaped a series of adult ancestors were the same as those that shaped the individual development of the modern human cannot reasonably be accepted by modern evolutionary biology. On the other hand, it might well apply to some of the selective forces that have shaped human intelligence and language, as when a comparison of the behavior of ancestral primates with that of modern children would indicate analogies or even similarities. Though the previously published attempts - of which I am aware - to use Piagetian cognitive (Bruner 1972; Stenhouse 1974) and moral (Wilson 1978) development models for reconstructing phylogeny seem to have been less thorough, a (short) discussion of them might have been useful for BBS readers. And thorough as P&G's approach may be, it impresses me as having left some questions not clearly answered.

There is a pitfall in recognizing a similarity between the behavioral processes of ancestral species and modern children. Because of convergent selective pressures two comparable behaviors may very well be the net result of two completely different sequences of causes and effects in two different species, for example, the type of environmental stimulus acting as a releaser for the behavior, the sensory and afferent neural pathways, the cerebral processing centres, the mediating enzymes, or the efferent neural pathways may be different.

Second, P&G's target article's central argument seems to me to hinge upon six hypotheses mentioned in the section "Extractive foraging in apes and hominids" which, unfortunately, are not clearly discernible as such, and which, in addition, are largely interdependent.

Hypothesis 1: "Feeding strategies are primary determinants of mating and parental care and, hence, of social structure. . . . We suggest that feeding strategies are also primary determinants of intelligence." It would have been helpful for the reader - at least for me - if P&G had discussed some evidence for these suppositions instead of referring to previous publications. (In any case, I could not find this topic in Trivers 1972.) All these types of behavior form a complicated, mosaic like network (Wind 1970, 1976), both during evolutionary processes and during ontogeny, in which it is hard to point to one type as a primary determinant. For example, why could tool use not have started as a antipredator strategy (Kortlandt, in press) or during shelter construction?

Hypothesis 2: "Like chimpanzees, [the Dryopithecines or Sivapithecines] were opportunistic omnivorous ground and tree feeders." Mentioning some paleontological, paleoclimatological, or paleobotanical evidence would have been helpful in providing a basis for this hypothesis.

Hypothesis 3: "Their ability to use tools allowed them to exploit embedded food." I am unaware of any paleoscientific evidence for tool



use in Dryopithecines. In addition, are not embedded foods exploited by dogs, pigs, birds, and moles digging up bones, truffles, and invertebrates? Or, for that matter, by many carnivores opening the skin of the bones to get to the flesh, brains, or marrow?

Hypothesis 4: "Foraging with tools to extract embedded foods was a small but important part of a general feeding strategy." See my remark under Hypothesis 2. In addition, some more ecological data would have been helpful here, that is, which niches contain which embedded foods and which do not.

Hypothesis 5: "Hominid differentiation from the apes was based on a shift from seasonal dependence . . . to primary year-round dependence on such tool-aided extractive foraging. All the target foods shared the property of being encased in a shell or being embedded." The first sentence provides a hypothesis that can only be viable after the previous three have been supported, and it forms the central idea on which P&G's arguments on language origins are based. The second one impresses me as circular reasoning. The authors continue: "Because of their small body size (probably comparable to that of pygmy chimpanzees) hominids could not open these foods with their hands and teeth." Why did and do not the various other similarly sized primates, like the pygmy chimpanzees themselves, or at least the smaller ones, show the hypothesized tool use?

Hypothesis 6: "The first hominids had a basic tool kit." I would have welcomed some more evidence for the series of techniques mentioned than the statement that most of them are still used by contemporary hunters and gatherers. The latter belong to the species *Homo sapiens sapiens* which is quite different from the earliest hominids, and whose use of simpler techniques, next to more complicated ones, does not provide any evidence for dating the origin of such techniques in their ancestors. Second, to be sure, it is probable that the hypothesized "tool and container selection, and transportation to the site for extractive foraging requires mental imagery." However, here we run into another food question, namely, the chicken-egg problem: what came first, the mental capacities or the tool use? Most elegantly, such reconstructions are made by finding an ecological change acting as a selective pressure and triggering the origin and the evolution of such new morphological and behavioral properties rather than by assuming an elaborate series of mutations accidentally leading to it.

The food-sharing hypothesis for language origin leaves me with some unanswered questions. Food sharing occurs in many taxa that use beaks, crops, stomachs, mammary glands, limbs (or, as in some arthropods, even whole bodies). Why did these taxa not develop language? Again, this hypothesis is dependent upon the chain of previous ones and on a new one: that food sharing evolves in species using tool-mediated food extracting. P&G suggest that numerical concepts arose as adaptations for butchering large carcasses and distributing foods. Isn't this another chicken-egg question? And what part of the early hominids' diet was actually meat, and what part of the meat actually originated from large carcasses? Doesn't the nonhominid food sharing and transportation mentioned above often involve division into equal parts?

Some miscellaneous remarks: P&G repeatedly use the term intelligence when referring to nonhuman species; for readers, like me, unfamiliar with comparative psychology, some definition might have been useful to avoid anthropomorphic projections. Vocal communication may require less effort (I would have said *physical* effort), than gestural communications, but its disadvantages include prey and predator arousal and interference with breathing and swallowing. "Vocal communication was advantageous for animals engaged in extractive foraging with tools, an activity that requires sustained visual attention," was it not so for those species that foraged extractively with beaks, like birds feeding on molluscs, or, for that matter, any other vocalizing species? Shelter construction cannot be explained only by bipedality and nonaboreality as it is not always found in other species showing this combination.

I had some problems with "The evolution of ontogeny," especially its fourth paragraph, where it is concluded that "in the case of human intelligence, human evolution recapitulates phylogeny." Apart from the fact that Stenhouse (1974) did not make such a statement (see his p. 201),

I wondered whether there is really only one and the same sequence of causes and effects constituting (i) the ontogeny of intelligence in modern humans, as indicated by the Piagetian model, for example; and (ii) the phylogeny of human intelligence. But what is really meant here by phylogeny? This is a fragile concept with an admittedly great heuristic value, but here it presumably means a comparison of some loosely defined properties of an artificial, imaginative series of adult (male? female? unicellular? amphibian? reptilian?) ancestors. And what, exactly, are the parameters to be compared (see Wind 1970, 1976, and again my second paragraph)? Though the end results may at best be comparable, the underlying causes, and therefore phylogeny and ontogeny themselves, are not. The pleonastic – if not tautological – statement the authors adduce for basing their conclusion that the abilities of each stage are logical and structural prerequisites for those of the succeeding stage during ontogeny as well as during phylogeny does not elucidate the problem since this applies to almost any sequence of biological events once it has been investigated and described.

In conclusion, I think that the question mentioned in my comment's title cannot yet be confirmed. However, there is still hope for fervent recapitulationists. For the fact that – at least in my copy – "neotony" was typed nine times instead of neoteny and "language" twice instead of language, indicates that the latter has sufficient embedded food for modern scientific hominids to keep them foraging for the time being.

## Authors' Response

by S.T. Parker and K.R. Gibson

### How the child got his stages

We are happy for the opportunity to receive and respond to a wide variety of commentaries on our model. We were pleased to discover that commentators from a variety of disciplines found heuristic value in our hypotheses. We are particularly grateful to ISAAC and DINGWALL for outlining criteria for judging hypotheses and for finding ours useful and testable.

Many commentaries revolve around the scope and focus of our paper, and in some cases they are based on misinterpretations of our assertions. Because the number and breadth of issues raised preclude a detailed response to each point, we will respond on the most general level whenever possible. Before addressing general issues, we want to explain that our "tone of sure conviction" which disturbed LAMENDELLA, KITAHARA-FRISCH, and JOLLY was a rhetorical device meant to save the reader from frequent reiteration of the conjectural nature of the presentation.

**Recapitulation: a sometimes thing.** Our recapitulation model was the most controversial aspect of the article. BRAINERD, DINGWALL, KITAHARA-FRISCH, MACNAMARA, and LURÇAT all saw us as resurrecting Haeckel's biogenetic law. Some of them argued that we are inferring phylogenetic sequences from ontogenetic data.

These interpretations are based on misreadings. We note specifically that recapitulation is only one possible result of the evolution of ontogeny, and furthermore, as WIND notes, we explicitly limit our recapitulation model to the stages of intellectual development, language development, and certain selected aspects of neocortical development in human children. Moreover, we do not derive our model from a doctrine as Brainerd asserts, but from comparative data on highest achievement and developmental sequences in prosimians, old world monkeys, and great apes. We interpret these data in the light of well-established phyletic relationships and evolutionary principles.

Since no universal law of recapitulation is proposed, BRAINERD's arguments based on "exceptions" have no force. Because of this, and because of space limitations, we will not respond specifically to

"exceptions" falling outside the scope of our model. Without digressing into larger issues in the history of science, we cannot resist responding to Brainerd's comment on our historical ignorance - past rejection of a theory does not constitute a valid argument against it. Past rejection of Wegener's theory of continental drift, for example, was no index of its validity. Continental drift was accepted when the mechanism of sea floor spreading was documented, and recapitulation will be accepted if the mechanism of terminal addition and neurological development of behavior are better documented.

**Piaget's evolutionary and developmental models.** LURÇAT and GRUBER both chide us for relying on a strictly Piagetian interpretation of development and for ignoring neo- and anti-Piagetian research.<sup>1</sup> Gruber also chides us for ignoring Piaget's constructionist model of evolution. Lest it seem that we are uncritical disciples of Piaget, we want to indicate that we completely reject Piaget's extension of his ontological model into the domain of phylogeny (Piaget 1971, 1978). His evolutionary model is Lamarckian and vitalistic and hence in conflict with well-demonstrated mechanisms of evolution. Distinguishing the mechanisms of phylogenetic and ontogenetic change and the relation between them has been one of the great achievements of biology.<sup>2</sup> Piaget's stand on this issue is particularly unfortunate because it will alienate many biologists who might otherwise find his developmental model useful.

On the other hand, we rely on a strictly Piagetian developmental model because it is the only powerful, comprehensive, and coherent model for development that currently exists, and because neo- and anti-Piagetian research is plagued by serious conceptual and methodological problems [see Brainerd: "The Stage Question in Cognitive-Developmental Theory," *BBS* 1 (2) 1978].

First of all, many investigators are unfamiliar with the original theory and research, having taken their model for Piaget's theory from secondary sources, which are often incomplete and inaccurate. Investigators often take a single issue out of context and set up experiments that eliminate the critical complexities Piaget included. On the basis of their simplified research design, they claim disconfirming results (Groen 1978; Cowan 1978; Kamara and Easley 1977). This is true, for example, of the Fishbein, Lewis, and Kieffer (1972) study cited by FISHBEIN.

Second, most experiments cited as evidence against Piaget's model focus on performance rather than mechanism. This creates considerable confusion because in some cases the same problem can be solved with different structures (Cowan 1978; Gilliéron 1977). There are particularly serious problems in translating Piagetian tasks into learning-set experiments. This process is based on the unstated and untested assumption that structures and transformations produced through learning sets are equivalent to those produced by spontaneous activities and ontogenetic transformations in human children (Pulos, personal communication). The experiments cited by ETTLINGER suffer from these problems. There is no reason to believe, for example, that the conditioned responses described by Brown, Lenneberg, and Ettlinger (1978) have any similarity to hierarchical classification by concrete operational children.<sup>3</sup> (Similarly, there is no reason to believe that the structures responsible for pattern recognition in digger wasps have any similarity with classification, as suggested by SNOWDEN & FRENCH.)

In our opinion, the most telling criticism of our model is that we focus primarily on the descriptive aspects of intellectual and linguistic development rather than explicating the underlying cognitive structures involved (GRUBER, LURÇAT, KITAHARA-FRISCH, LAMENDELLA). Although such a presentation would be much more difficult, it would allow a more thorough analysis of the relation between performance and structure and would facilitate the analysis of homology and nonhomology of mechanism behind similar performances (raised by Lamendella and Kitahara-Frisch).

**Organism-environment interactions.** SMITH, GOULD, MCGREW, MARSHACK, and SNOWDEN & FRENCH raise the issue of the interaction between learning and intelligence and the environment. A brief

theoretical analysis of organism-environment interactions will help clarify this issue.

Animals experience at least two types of environmental influences: *autogenic* or self-generated inputs arising from their own actions on social and physical objects, and *allogenic* or other-generated inputs from biotic and abiotic objects in their environment. Both types of input have didactic consequences. While some of these consequences are fortuitous, others are evolutionarily shaped through developmental algorithms which have been selected to respond to "provenient" inputs with progressive and irreversible reorganization of the nervous system. Exposure to these convenient inputs then becomes a prerequisite for normal ontogeny.

By analogy with deprivation experiments, we think of training experiments (including learning-set experiments) as "augmentation experiments," exposing animals to (nonprovenient) inputs that do not constitute part of their normal developmental environment. Whereas deprivation experiments reveal which convenient elements are critical to normal development, augmentation experiments reveal the response range of preexisting structures to nonprovenient inputs, and hence suggest new functions of old structures which might be canalized in changing environments. In other words, they reveal the serendipitous potential of existing behaviors and structures. Training experiments, including learning-set experiments on monkeys, and language-training experiments on great apes, can best be understood in this light.

It is important to emphasize, however, that the potential response of organisms to changed environments is always shaped and limited by their current adaptation, that is, by phylogenetic inertia. This means that there are definite limits to the serendipitous response to new situations. Generally speaking, we expect the descendants of an adaptive radiation to share the complexes inherited from their common ancestor, except where adaptations are superimposed as a result of entry into a new niche.

As we have indicated in another article (Parker and Gibson 1977), the parallel evolution of fifth and sixth stage sensorimotor intelligence in two distantly related primate taxa with similar feeding strategies is a good example of adaptations arising as a result of entry into a new niche (specifically an extractive foraging niche). Far from vitiating our model, as SMITH and MARSHACK suggest, the similarity in intelligence of cebus monkeys and great apes strongly supports our extractive foraging model. (Since this similarity could only have arisen through parallel evolution, the cebus data also support our underlying assumption - "panselctionist" as it may be - that natural selection rather than genetic drift was the primary factor shaping primate intelligence.) To the extent that omnivorous extractive foraging with tools favors fifth and sixth stage sensorimotor intelligence, we expect monkey species exhibiting this complex to display this level of intelligence.

It is possible that this level of intelligence is present to some degree in both baboons and Japanese macaques, but we know of no well documented cases of true tool use in wild baboons or Japanese macaques. (As Hamilton, Buskirk, and Buskirk 1978 point out, stone-dropping behavior and other object manipulation schemes in baboons do not qualify as tool use by the rigorous definition that a separate object must be used as a means of changing the state of another object.) While it is true that a few individual baboons (Beck 1973 a, b) and macaques (Candland, French, and Johnson 1978) have displayed stage five means-end schemes in captivity, these are probably the products of rare genotypes which have had no special advantage in wild populations. The existence of these rare genotypes is significant, however, because it indicates that mutations for higher intelligence must be available for selection to favor, should conditions change.

MCGREW's argument that baboons are more intelligent than gorillas "in the wild" is based on equating object manipulation with intelligence. Object manipulation per se cannot be equated with advanced sensorimotor intelligence: many forms of object manipulation displayed by baboons and macaques in food preparation and other activities (e.g., pushing and pulling, twisting, pulling apart, and rubbing), are characteristic of the fourth stage of

sensorimotor intelligence rather than the fifth and sixth stages. Piaget's model is valuable for comparative studies of intelligence precisely because it makes such significant but nonobvious distinctions (Parker 1977; Parker and Gibson 1977). Even though gorillas may engage in less object manipulation in the wild and feed on a more restricted diet than baboons, they are more intelligent because their ancestors were tool-using extractive foragers and they retain the intellectual legacy of that basal great ape adaptation.

**Feeding strategies, social life, and primate intelligence.** LURCAT, MARSHACK, FISHBEIN, and KONNER argue that we neglect social factors in hominid evolution. In fact we simply emphasize that social behavior and organization (specifically mating and rearing strategies, Trivers 1972; Clutton-Brock and Harvey 1978; Emlen and Oring 1977) are adaptive responses to the dispersion of resources, particularly food resources, and hence depend on feeding strategies. In fact, feeding strategies are the centerpiece of all the major models of hominid evolution.<sup>4</sup>

Although we stick by our assertion that feeding strategies were important in early hominid evolution, we agree with FISHBEIN and KONNER that we have given short shift to sex differences in subsistence activities. A recent report by McGrew (1978) indicates that chimpanzees show a significant division of labor between females, who search for termites, and males, who hunt. A similar situation probably existed in early hominids.<sup>5</sup>

We also appreciate KONNER's remarks on the pertinence of data on living hunters and gatherers. We do believe, however, the data on apes are more important for reconstructing the earliest stages of hominid evolution, and that ethnographic data are more important for reconstructing later stages.

We do not, as MARSHACK and LURCAT imply, address the nature and adaptive significance of higher forms of intelligence in *Homo erectus* and *Homo sapiens*, nor the retrospective elaboration of sensorimotor and preoperational intelligence in these forms.<sup>6</sup> In particular, we do not claim that intellectual capacities characteristic of these later hominids arose as feeding adaptations. In fact, we agree with Marshack that nonfeeding social contexts became increasingly significant in later stages of hominid evolution as man relied on cooperative technologies in a growing number of contexts.

We do claim that sensorimotor and preoperational intelligence were adaptations for adult as well as infant and juvenile subsistence activities in early hominids, and not just for the infant and juvenile stages as MARSHACK implies. Selection operates at all stages of the life cycle, and there is good reason to believe that it operates on intelligence as well as other characteristics. The general importance of selection in shaping early stages in the life cycle is clear from the myriad of behavioral and structural adaptations specific to infancy and juvenility (e.g., egg tooth in snakes, suckling adaptations in mammals, and natal coats in primates and carnivores). Although no studies have explored the adaptive significance of sensorimotor and preoperational cognitive structures, it is easy to imagine the survival value of tool use, symbolic communication, and imitation in the infant postweaning period among hunters and gatherers where infant and juvenile mortality is extremely high (Howell 1976).

LURCAT is also dismayed at our neglect of bipedalism as a factor in the evolution of hominid intelligence. She attributes several traits, including the freeing of the hands, the shortening of the face, and the canine teeth and enlarged brain to bipedal locomotion. This is a very peculiar argument, which fails to address the issue of the adaptive significance of bipedalism itself. In fact, far from being the prime mover in the evolution of any of these traits, bipedalism was itself probably a secondary adaptation for food and tool transport (Lancaster 1978). Lurcat also expresses the peculiar notion that the simple hand-mouth object manipulation of monkeys (?) is equivalent to "all the varieties of tool using activities that one might wish to distinguish in archanthropes and paleoanthropes." The confused formulation demonstrates the need for a clear definition of tool use, object manipulation, and intelligence (Parker and Gibson 1977).

The origins of language. Our food-sharing hypothesis for

language origin was the second most controversial aspect of our model. LAMENDELLA and MACNAMARA, rejecting the theoretical bases of our reconstruction, see no virtue in our hypothesis. KONNER even calls for a moratorium on language origin models. Other commentators such as SAVAGE-RUMBAUGH ET AL. and HEWES see important virtues in our hypothesis.

HEWES, MARSHACK, KONNER, and IVANOV correctly remark on omissions in our treatment of the data and suggest a variety of directions for future research, including the sign systems of deaf mutes, the sign and language use of hunter-gatherers, and the affective aspects of language use.

We were particularly pleased by the elaboration and extension of our language origin model suggested by SAVAGE-RUMBAUGH ET AL. Our model differs from theirs primarily in its emphasis on the casual role of extractive foraging as a selection pressure generating the initial conditions favoring cooperative tool use and food sharing.<sup>7</sup> Their elaboration has the virtue of emphasizing cooperation and of suggesting an evolutionary path by which cooperative tool use expanded into new arenas creating cultural innovations which in turn carried new didactic consequences, thereby increasing the tempo of hominid evolution.<sup>8</sup>

The begging gestures and occasional trading behavior of gorillas described by CHEVALIER-SKOLNIKOFF do show close parallels with the object-showing and object-giving gestures described in human children by Bates, Benigni, Bretherton, Canioni, and Volterra (1977). If these gestures were present in the common ancestor of great apes and hominids, they may have been the basis for the elaboration of this element of the gestural complex.

MARSHACK disputes our food-sharing model for language origin on grounds that "food getting and food sharing... are neither the central nor the crucial sets of relations involved... in the development of language competence." He stresses the importance of "relational modes." Of course we are not arguing that food sharing is the major focus of language use in modern human children, but rather that it was so in the earliest hominids. We do suspect, however, that the instrumental and regulatory functions of prelanguage continue to play an important role in that context in addition to the role they play in other contexts. Our evolutionary reconstruction focuses on primary functions which become obscured with subsequent elaborations of secondary and tertiary functions. If we took all the current functions of a complex as primary, no coherent evolutionary model would be possible.

WIND asks why other food-sharing species have not evolved language. It is important to emphasize that all food sharing is not equivalent in its effects on communication. As we indicate in our paper, only food sharing requiring directed transmission of information about the location and nature of hidden foods, or about the nature of the tools necessary for food extraction favors referential communication. The only other taxon displaying referential communication has this kind of food sharing.

**The evolution of the brain.** The short section on the brain was intended to suggest something of the structural basis for the evolution of hominid intelligence and to indicate that the neocortex of the human brain and the stages of human intellectual development both recapitulate the stages of their evolution. This section was not intended to trace the evolution of the brain or to describe in detail parallels between the ontogeny of brain and behavior. We agree with KONNER, IVANOV, and MARSHACK that thorough discussion of brain evolution demands treatment of brain function and dysfunction, lateralization and hemispheric specialization, limbic components, and paleontological data.

Comments on our treatment of the brain revolve around the issues of recapitulation versus neoteny, the validity of myelination as an index of maturation, brain size as an index of intelligence, brain size versus brain reorganization, and selection pressures for increased brain size.

GOULD argues that the human brain is neotenuous because increased brain size resulted from the prolonging of fetal growth rates. We agree that longer fetal growth rates provided the mechanism for the

production of new neural substrates for the terminal addition of new intellectual abilities. We disagree with the designation of this phenomenon as neotenus because the adult human brain does not resemble the brain of the ancestral juvenile. (Gould 1977, p. 387, defines neoteny as a form of paedomorphosis produced by the retardation of somatic development, and argues that "the best measure of paedomorphosis is the extent to which an adult descendant resembles an ancestral juvenile.")

DINGWALL implies that we use myelinization as an index of brain maturation "without qualification." We suggested the use of myelinization as an index of the increasing functional efficiency that prevails during maturation provided it is used within and not between neuroanatomical systems (Gibson 1970, 1977). The validity of myelinization as a measure of neocortical maturation is also supported by the fact that it provides exactly the same picture as data from other measures of neocortical maturation including Nissl substance, cell size, neuronal density, and number of axonic and dendritic processes (Conel 1939-67).

LAMENDELLA and SNOWDEN & FRENCH imply that we use absolute brain size as an index of intellectual differences. In fact, we use the allometric relation between brain and body size, which, although far from ideal, is the best existing measure of brain capacity relative to intelligence. The validity of this index is supported by its high correlation with neocortical size, neocortical association layer size, and neuronal density. We do say that brain size correlates with information-processing aspects of intelligence, but not with species-specific repertoires of schemes, and presumably each parameter can change independently. Parenthetically, the idea that normal human brains can be as small as 600 cc is highly questionable because it is based on anecdotal data and fails to account for the fact that disease and trauma can increase and decrease brain size, and that brain size varies with the length of time since death as well as with the preservative used (Tobias 1970; Passingham and Etlinger 1974).

ETTLINGER's comment that phylogenetically older structures have evolved to subservise specifically human behaviors is undoubtedly correct; moreover, there is evidence, for example, that subcortical structures that mature early in ontogeny have changed significantly during hominid evolution (Stephan 1972). Our limited model in no way contradicts or is contradicted by this phenomenon. Etlinger also raises the interesting question of whether the decreasing neuronal density and increasing neocortical dominance during ontogeny correlate with the appearance of species-specific human behaviors. Our best guess is that they correlate with the appearance of the increasing combination and hierarchical coordination of schemes rather than with specific motor patterns, many of which are shared by other primate species or have a subcortical component (Gibson 1970, 1977).

SAVAGE-RUMBAUGH ET AL. note that the human infant's brain has greater cortical capacity than the ape's brain at all ages. As they suggest, this greater capacity is undoubtedly instrumental in the greater elaboration of each stage of sensorimotor and preoperational development in human infants and children. It is important to note, however, that much of this brain capacity is afunctional during early stages of development. (Because neurons do not divide after birth, the total number are present at birth and only ramify and connect over many years; in this respect, as in many others, the ontogeny of the brain does not parallel its phylogeny.)

#### NOTES

1. MACNAMARA and LAMENDELLA make much more radical criticisms: Macnamara asserts that no satisfactory characterization of human intelligence or language exists. If he is right, our entire exercise is futile; Lamendella doubts the "empirical counterpart of ontological status" of the Piagetian concept of intelligence. He argues that it and our Halliday-like concept of prelanguage are "vague nominalizations" and "independent entities transcending individuals and species." It is unclear whether this is a criticism of any comparative models of intelligence and language or if it is specific to ours.

2. It should be clear that we do not mean to imply, as WIND and ETLINGER suggest, that there is any parallel between the mechanisms involved in producing ontogenetic and phylogenetic change, but only that there can be a parallel in their sequences.

3. Even if this experiment reveals significant cognitive structures, contrary to ETLINGER's implication, its results are consistent with our model: because the concept of "some," which chimpanzees and macaques both fail to learn, is characteristic of concrete operations, we would not expect to see it in either monkeys or apes.

4. Indeed, this emphasis goes back at least as far as Darwin: "We can see that in the rudest state of society, the individuals who were the most sagacious, who invented and used the best weapons or traps, and who were best able to defend themselves, would rear the greatest number of offspring. . . . Numbers depend primarily on the means of subsistence, and this depends partly on the physical nature of the country, but in a much higher degree on the arts which are practiced" (Darwin 1930, p. 130).

5. Clearly sexual selection and kin selection have played a major role in the evolution of social behavior and the generation of social structure. We disclaim KONNER's interpretation of group selection. No such implication was intended in the statement he cites or in any other statement we made. Selection of individuals and kin groups with greater intelligence increased the carrying capacity of the environment for those genotypes. Directional selection over many generations shifted the population norm so that the carrying capacity of the environment increased for the whole species.

6. Much of the sexual symbolism in Paleolithic art and sculpture can be interpreted as a retrospective elaboration of preoperational topological notions of enclosure and penetration expressed in a new context (albeit embedded in higher level structures). Marshack would be mistaken, however, if he inferred from his reconstruction of the use of fifth and sixth stage sensorimotor schemes in the ochre production of *Homo erectus*, that these sensorimotor abilities were the highest level of achievement of this species. As we point out in our article, individuals typically continue to use structures characteristic of all the stages below their highest level.

7. We did not imply, as SAVAGE-RUMBAUGH ET AL. suggest, that parents suddenly insisted on a symbolic mode to communicate requests for tools and embedded foods. Rather, we implied that children and adults who spontaneously engaged in this mode of communication contributed more genes to subsequent generations. Presumably parents with genes for symbolic abilities would have children with symbolic abilities and hence would respond to requests in that mode. (As Savage-Rumbaugh et al. emphasize, symbolic communication involves alternating reciprocal roles.)

8. We do not claim as DINGWALL implies, that bee language (or bird nest construction, etc.) are homologous to human language (or technology) but rather that they are analogous (i.e., convergent and based on different mechanisms).

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