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3 The mutual definition of culture and biology in development

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The classical debate concerning nature and nurture implies a single relationship between biology and environment, even when the issue is resolved as an interaction between both forces. However, contrary to this perspective, my thesis is that there are not one but many relations between cultural environment and biological nature in human development. These relations constitute ways in which culture and biology mutually define and influence each other in development. I am going to illustrate this thesis with six relationships, taken one at a time. These relationships are tentative, meant to stimulate further research and thinking.

The relationships are not alternative perspectives, but complementary principles. By illustrating many principles with examples from the same community, I can present a clear case for complementarity. My research site is the Zinacantec Maya hamlet of Nabenchauk in Chiapas, Mexico. Examples from there and elsewhere show that all six principles are required to understand the roles of culture and biology in the developing human being. They will also illustrate the value of the theoretical principles for understanding real-world phenomena.

While complementarity is highlighted by utilizing material from a single community, at the same time generality is compromised. In addition, the examples are by-products of research designed for other purposes. The principles require not only further investigation in other settings, but also research that is designed to test these particular relationships. In this way, the principles can transcend the research of a few investigators. Finally, it is important to note that the examples presented involve proximal processes and explanations. However, I have also included more speculative interpretations concerning distal processes of adaptation and mutual constituted processes of cultural and biological evolution.

Culture reinforces biology

Zinacantec infants are born with long visual attention spans and restrained motor behaviour, relative to Euro-American newborns in the United States (Brazelton, Robey and Collier, 1969). Beginning with attention, Zinacantec newborns were notable for being more alert than Caucasian babies in the United States. They attentively observed their surroundings for much longer periods than Caucasian babies in the United States, laying the foundation for later observational learning (Brazelton et al., 1969). They did not cry intensely or flail about, demanding that someone react to them.

Given the Asian roots of indigenous groups throughout the Americas, there would be a closer genetic link of Maya peoples with Asian groups such as the Chinese than with Euro-Americans. Indeed, Zinacantec newborns shared this behavioural quality with genetically related but environmentally unrelated groups (Freedman, 1979; Freedman and Freedman, 1969). For example, prenatal nutrition and the general pregnancy experience of Chinese-American and Euro-American mothers (both groups born in the United States) had to be much more similar to each other than to that of pregnant Zinacantec mothers, who (a) relied on a staple diet of corn and beans, supplemented by small quantities of vegetables and fruit, with extra meat, eggs and beans during pregnancy (Anschuetz, 1966) and (b) continued their subsistence work during pregnancy. Yet the Chinese-American newborns differed in their attentional qualities from the Euro-American newborns, with whom they shared important features of the prenatal environment; instead they resembled the Zinacantec newborns, with whom they shared an Asian ancestry.

Without forgetting the crucial role of the environment in epigenesis, we are led to the conclusion that there is a genetic component to this newborn behaviour of attentiveness. This conclusion is buttressed by the results of behaviour genetics studies that, in finding greater correlations for attention in monozygotic than in dizygotic infant twin pairs, conclude that attention has a significant component of heritability (Freedman, 1965; Freedman and Keller, 1963; Goldsmith and Gottesman, 1981).

Newborn visual attention becomes intense observation and imitation as infancy progresses. Indeed, in the infant tests carried out by Brazelton, Robey and Collier (1969), infants showed interest in imitating object manipulations, but little interest in initiating object play. Later, when we studied how Zinacantec girls learn how to weave, we found that learners showed a remarkable ability to observe an adult teacher attentively for long periods of time (Greenfield, Brazelton and Childs, 1989). The culturally defined way in which weaving apprenticeship progressed provided practice and further reinforcement for the newborn attention span.

Zinacantec newborns also showed a lower level of physical activity, which was in turn reinforced by the cultural environment. Their distinctive level of motor activity seemed to be at least partly a function of genetic factors. This conclusion stems from prior empirical evidence concerning the behaviour of newborns from other ethnic groups. Chinese-American, Navajo and Japanese (Goto Island) babies differed from Euro-American babies in many of the same ways that Zinacantec babies did – for example in their relatively low rate of motor activity (Brazelton et al., 1969; Brazelton, personal communication, 1988; Freedman, 1979; Freedman and Freedman, 1969). Although the Chinese-American sample studied by the Freedmans *shared* critical elements affecting the prenatal environment with the Euro-American sample (e.g. prenatal care, middle-class means to obtain good nutrition), the behaviour of the newborns *differed* in the two groups. On the other hand, Zinacantecs, Navajos, Chinese-Americans, and Goto Islanders, sharing almost nothing relevant to the prenatal environment (e.g. nutrition, prenatal care) did share a common pattern of newborn behaviour. Given the absence of a distinctive aspect of prenatal environment in common, the distinctive shared behaviour must, logically have some genetic basis. Indeed, these groups may have common genetic roots. It is now thought that Navajos have been part of a migration from Asia (Freedman, 1979); Maya Indians also have Asian roots. This conclusion concerning a genetic basis for the shared neonatal motor style is in accord with data from well-controlled behaviour genetics studies in the United States that show infant activity level to have a significant heritable component (Goldsmith and Campos, 1982; Goldsmith and Gottesman, 1981).

I am not arguing against the important role of prenatal environment in development. For example, Zinacantec women themselves used controlled motor movements; thus, pregnant mothers provided their unborn babies with a restrained style of prenatal movement environment that itself was culturally mandated (Haviland, 1978); this environment, according to my first principle, should have *reinforced* an epigenetic pathway toward quiet motor patterns.

Outside the womb, the newborn's relatively low motor activity was immediately reinforced by the Zinacantec culture. The cultural practice of swaddling, itself an adaptive protection against the cold of unheated Zinacantec houses in highland Chiapas, restricted the infants' movements (Brazelton et al., 1969; Greenfield, 1972). Nursing at the slightest sign of movement further lessened motor activity (Brazelton et al., 1969).

These cultural norms for infant care thus *reinforced* newborn motor behaviour, enhancing differences between the activity level of Zinacantec newborns and newborns in the United States. Reinforced by different infant-care practices in the two cultures, this group difference in level of physical activity increased during the first week (when a Euro-American baby at that period would have typically been unrestricted in a crib, free to flail about at will).

Lesser Zinacantec motor activity manifested itself in other ways as development proceeded. Children tested in the first year of life, when compared with United States norms, showed a slower rate in the development of motor milestones. This group difference was greater in the area of motor than mental skills (Brazelton et al., 1969). There was evidence of low motoric activity in older children who sat observing for long periods of time when learning to weave (Childs and Greenfield, 1980; Greenfield, 1984). Less use of an active motoric strategy was also noticed in adults instructing babies in a nesting cup task:

Mothers used the more physically aggressive teaching strategy of 'shoving' the baby's hand less frequently than mothers in the United States in a parallel situation (Greenfield et al., 1989; Kaye, 1977).

A low level of physical activity continued into adulthood. Restricted motion was adaptively reinforced for the Zinacantec mother, who nearly always had a baby on her back and, during her childbearing years, had to perform work under this condition (Haviland, 1978). 'Never a people given to wild gesticulation even at their most excited, Zinacanteco physical restraint is most marked in the behaviour of women' (Haviland, 1978, p. 243). Quite astonishingly, Leslie Haviland's description of female body movement is remarkably reminiscent of Brazelton, Robey and Collier's (1969) observations of Zinacantec newborns:

Feminine body movement is highly controlled and carried out in a narrow circumference. 'Women keep their upper arms tight to their bodies and rarely raise their hands or arms over their heads . . . In short, Zinacanteco women never engage in sweeping, expansive gestures, nor do they allow their limbs to stray outward from their bodies, whether in work or in fun' (Haviland, 1978, p. 243).

Culture appropriates biology

Haviland's description is not merely the way Zinacantec women *actually* moved; this is also the way they *were supposed* to move. The 'is' of biology had become the 'ought' of culture. Although less extreme than for women, the aesthetic value for Zinacantec men involved movement patterns that were equally constrained, in comparison with typical movement patterns in the United States (Devereaux (formerly L. Haviland), personal communication, July, 1989). An innate newborn behaviour ultimately becomes a valued adult behaviour.

The adult woman's restrained style of motor movements, itself a product of epigenetic development, created a prenatal motor environment for her own unborn child. The restrained style of movement of Zinacantec females continued to provide a postnatal motor environment during the baby's first two years of life, when he or she was carried most of the time. In this way, the epigenesis of movement patterns in one generation has the potential to influence the epigenesis of movement patterns in the next. In sum, restrained motor activity was a part of the developing Zinacantec from birth to adulthood, at which point, in pregnant females, it provided a restrained movement environment for the unborn Zinacantec baby, most likely helping to preserve this stylistic feature of body culture into the next generation.

Culture and biology are mutually adapted for survival

The area of motor development is also a good arena for illustrating the mutual adaptation of culture and biology for survival, as well as cultural context as interpretive framework. Sophie, the daughter of American social scientists living in Nabenchauk, walked at nine months of age, about five months earlier than the Zinacantec norms. According to her mother, sociologist/anthropologist Leslie Devereaux, in Zinacantec eyes, her precocious walking made her a 'monster' because, in their particular environment, it was dangerous for a child to walk before understanding language (Devereaux, personal communication, July, 1989). For example, Zinacantec houses always have an open fire in the centre. Because Sophie could propel herself motorically, yet lacked the understanding to stay away from the fire, there was a constant danger that she would fall in. Walking before the development of rational sense and understanding also was considered disruptive to others, as when Sophie would stagger into somebody's weaving.

Zinacantecs were horrified at the problems that resulted from Sophie's early walking. They were amused that her parents, unlike the typical Zinacantec family, had to be on guard all the time to keep her from hurting herself or inadvertently causing some kind of damage (Devereaux, pers. comm., July, 1989).

Breaking cultural norms often reveals most dramatically what the norms are. The cultural context goes unnoticed until it is disrupted. In the case of motor development, Zinacantec reactions to Sophie's deviation from the normal walking age make it clear that Zinacantecs do not merely *tolerate*, but actually *value* late walking. In their cultural context, unlike that of the West, relatively late motor development had a positive social value. Even more important from a theoretical perspective is the fact that this norm was much more adaptive for survival in the Zinacantec environment than the Western norm of *accelerating* motor development would be. If we consider late walking to be related to the typically restrained motor activity that is innate from birth in Zinacantec babies, then we see how this characteristic is well adapted to features of Zinacantec cultural norms such as having a fire on the ground in the centre of the house. At the same time, note that early walking can also be adaptive to environmental conditions, as in the USA, with its technology of cribs, playpens, etc.

Culture selects from biology

The operation of this relationship can, in principle, be distinguished from the operation of the first relationship, 'Culture reinforces biology', in which the biology provides the substrate for one particular behavioural outcome, which can either be reinforced by the environment or not. When 'Culture selects from biology', the relationship under discussion here, the biological substrate provides the foundation for more than one capacity and the environment can reinforce one capacity more than another. My example, drawn from the work of Heidi Keller, comes from the newborn period.

From a biological perspective, neonates all over the world are equipped with special propensities for relating to primary caregivers (Keller and Greenfield, 2000). In order to receive the physical and psychological care required by such immature and helpless creatures, infants are able to attract their caregivers' attention and elicit caregiving motivation reliably with a special repertoire of inborn characteristics such as their facial configuration ('Kindchenschema' or 'babyness'; Lorenz, 1969) and attachment behaviours, signalling distress like crying or fussing, as well as communicative cues like looking, smiling and vocalizing (Bowlby, 1969). They are equipped with a perceptual system that prefers the human face over other visual displays (Fantz, 1963) to facilitate the familiarizing of significant others. Their social orientation is expressed in their preference for company over being alone; they behave differently towards persons as compared with objects (Trevarthen, 1980). They are able to detect contingencies and expect social responsiveness from their interactional partners (Brazelton, Koslowski and Main, 1974). They want to be held and carried and are consoled by body contact (Keller and Greenfield, 2000). Parents are equipped with complementary behavioural propensities to meet the special characteristics of infant behaviours in terms of intuitive parenting programmes: they nurse and carry infants in response to distress, they look and smile at them and approach when they cry.

Infant capacities, as well as the basic components of parenting behaviour, have been identified across a remarkable range of cultures; thus they would appear to have their origin in the evolutionary history that is universal across the human species (Keller et al., 1999). Basically, four systems of parenting can be differentiated which address different infant needs and prompt relevant socialization experiences at the same time. The primary care system (especially nursing) provides infants with a reliable response to distress, thus promoting the infant's trust in his or her social partners. The body contact system (especially carrying) relates the infants to the caregiving environment. The body stimulation system promotes an early motor self, and the face-to-face system induces a sense of agency (Keller, 2000). Caregiving usually consists of contextually shaped mixtures of these parenting systems which reflect cultural variability.

Individualism/independence and collectivism/interdependence: two idealized pathways through universal developmental stages

However, some combinations can be found more reliably than others. The prevalence of the face-to-face system, for example, has been described as a typically Western (Keller and Eckensberger, 1998) or pedagogical (LeVine, 1994) parenting style. The body contact system is described as a non-Western (Keller and Eckensberger, 1998) or paediatric style (LeVine, 1974, 1994), prevalent in farming or pastoral communities. These early experiences lay the ground for developmental trajectories, which, as cultural ideals, require corresponding socialization scripts across developmental stages.

Keller and Eckensberger (1998), as well as Greenfield and Suzuki (1998), have identified idealized pathways that can be termed individualism and collectivism, independence and interdependence, or autonomy and relatedness (Greenfield, 1994; Kagitcibasi, 1996; Markus and Kitayama, 1991). Each path involves selective cultural interpretations of the same maturationally grounded stages. These paths are not binary opposites, but relative emphases and systems of prioritization. They represent life strategies that have proved adaptive in addressing specific environmental problems. Each pathway is a mode around which variation can occur.

First we turn to the developmental path of *individualism* or *independence*. This scenario, most common in European-derived and industrial or commercial societies, consists of an impact of exclusive dyadic attention between caregiver, mainly mother, and infant, plus a special emphasis on face-to-face exchange, especially promoting face-to-face contingency experiences in the infant. In other words, it selectively emphasizes the universal face-to-face system. The mother orients the child from early on to the material world, often mediating the interaction with toys. This pathway also selectively elaborates the infants' innate reactions to objects, providing socialization for the development of technological intelligence – knowledge of how to manipulate the world of objects.

These experiences allow the baby to develop expectancies, predictability and control and thus foster the development of the self as a causal agent. The cultural value of early independence is also supported, for example, with independent sleeping arrangements (cf. Morelli et al., 1992) and the use of baby technology, such as infant seats, to provide precocious physical independence for young babies.

The early conceptions of self and relationships, both to people and to things, that are acquired during these early socialization situations may set the stage for specific ways of developing competence in childhood, e.g. with active exploration, asking questions and formal instructions. The development of an independent or individualistic adult, as described by Markus and Kitayama (1991) or Triandis (1989) might represent the 'better adult' in these environments.

Next we turn to the pathway of *collectivism* or *interdependence*, a developmental trajectory that is more common in rural environments in Africa, Asia, and Latin America. This pathway mainly relies on the prevalence of the body contact system in multiple caretaking environments with childcare as a co-occurring activity. The main socialization context is established through bodily proximity, thus promoting warmth and interrelatedness.

The resulting conception of self as 'co-agent' is based on feelings of interrelatedness. This developmental pathway continues in socializing skills through observation and participation, finally leading to an interdependent (Markus and

Kitayama, 1991) or collectivistic (Triandis, 1989) adult. Thus, a developmental approach identifies mechanisms across lifespan trajectories leading up to the culturally diverse adult forms of development.

Each path involves different cultural interpretations and selective emphases of the same maturationally grounded stage. The cultural environment selects components of the universal inborn repertoire – e.g. the differentiation between object behaviour and person behaviour identified by Trevarthen (1980) for newborns – and shapes the behavioural expressions accordingly. Either object behaviour or person-oriented behaviour can be emphasized by those around the infant. The infant who is given toys to play with on his or her own learns experientially the cultural value of independence and technological intelligence, as described by Mundy-Castle (1974, 1991). Innate reactions to objects are enhanced by the individualistic socializing environment more than the collectivistic one.

In contrast, the infant who has other people to play with and is in constant contact with others learns through experience the cultural value of interdependence and social intelligence, also described by Mundy-Castle (1974, 1991).

Caregiving arrangements carry cultural meanings, and these meanings are reconstructed by infants through implicit messages that may become explicit at maturity, or may rest implicit. Thus, the early biologically predisposed development results in basic cultural learning; the foundation for a selective emphasis on independence or interdependence is laid. These early conceptions of relationship and self are the basis for divergent pathways through childhood and adolescence (Greenfield, 1994; Greenfield and Suzuki, 1998; Keller and Eckensberger, 1998). For example, in middle childhood the collectivistic model can be expressed in unconditional in-group helpfulness, while the individualistic model leads to conditional or negotiated helpfulness – as in the research of Mundy-Castle and Bundy (1988). The collectivistic model can be expressed in an emphasis on socially shared knowledge, while the individualistic model leads to an emphasis on individually possessed knowledge (Greenfield, 1997a, 1997b; Keller and Eckensberger, 1998). The collectivistic model leads to an emphasis on fitting into a group, while the individualistic model leads to an emphasis on individuality and uniqueness (Greenfield et al., 2002; Keller, 1998; Markus and Kitayama, 1991). Adolescence is contingent upon these preceding experiences as a short transition in the collectivistic model, from childhood to adulthood, with early marriage and childbearing and responsibilities for the economic support of the family. In the individualistic model, adolescence is a period of moratorium reserved for education and other forms of self-development.

In adulthood, these early experiences also lay the ground for one's own parenting style, so that intergenerational continuity and transformation are

established. Thus, each cultural environment selects different components of the universal infant repertoire and the basis for differentiated cultural socialization is laid.

Culture respects biology

Developmentally gradated tools

My theme here is that *cultures have sets of artefacts and practices that respect and stimulate sensitive periods for cognitive and neural development.* I would like to make the argument that the *developmental timing* and *order* in which Zinacantec girls are exposed to various weaving tools show implicit knowledge of and respect for cognitive development. Specifically, these tools show implicit knowledge of the progression from the preoperational to the concrete operational stage and the timing of this progression. Vygotsky noted how much cognitive history is contained in cultural artefacts and that these artefacts function, in turn, as tools for the stimulation of current cognitive development (Scribner, 1985). I would like to take this line of thinking a step further: not only cognitive history but also cognitive development can be contained in cultural artefacts. To provide evidence for this point, I analyse the cognitive requirements of a developmentally gradated set of Zinacantec weaving artefacts: the toy loom, the warping frame, and the real loom.

Play weaving on the toy loom, illustrated in figure 3.1, is widespread in Nabenchauk. It begins at age 3 or 4, in Piaget's preoperational period. The toy loom is used several years earlier than the real loom and warping frame, which are not used before age 6 or 7, the beginning of the concrete operational period. Preparing the real loom to weave is a concrete operational task, as I shall demonstrate in a moment. Because the toy loom is just slightly different from the real loom, it does not require concrete operational thinking to set up. The difference lies in the ropes between the two sticks, on each side (figure 3.2).

By holding together the two endsticks (top and bottom of the loom in figures 3.1 and 3.2), these ropes permit the warp or frame threads (the white threads in figure 3.2) to be wound directly on the loom. Figure 3.1 shows how the sticks that constitute the loom are connected by a loop of ribbon that goes around the weaver's back (hence the name backstrap) to the post; the tension necessary to keep the loom from collapsing is provided by the weaver, who leans back against the strap. Note that, unlike the real loom (figure 3.3), the top and bottom weaving sticks are connected by the ribbon looped around them.

The real loom (shown in figure 3.3) does not have the side ropes (figure 3.2) or ribbons (figure 3.1) holding the loom frame (top and bottom sticks) together. Note that only the warp threads (multicoloured in figure 3.3) hold the two sticks

Figure 3.1 Play weaving on the toy loom.

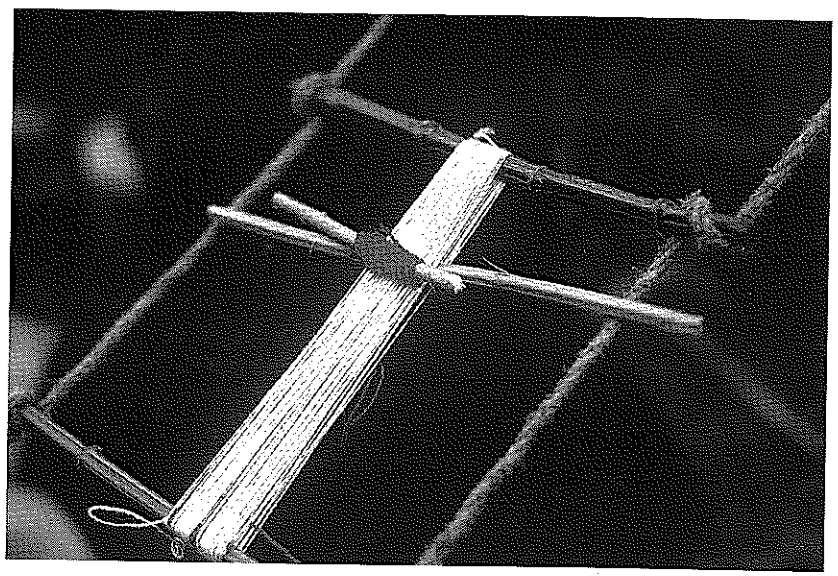

Figure 3.2 The difference between a toy loom, shown here, and a real loom (figure 3.3) lies in the ropes between the two sticks.

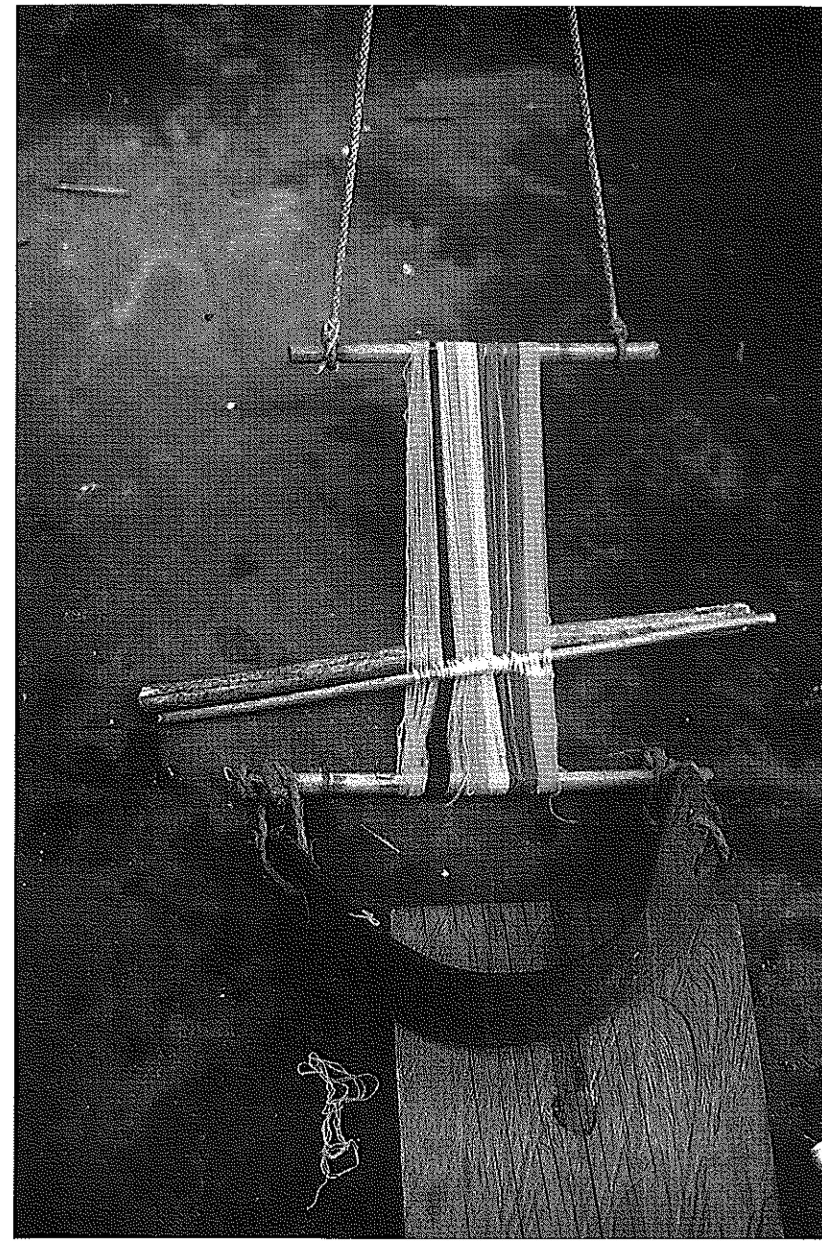

Figure 3.3 The real loom, without the side ropes.

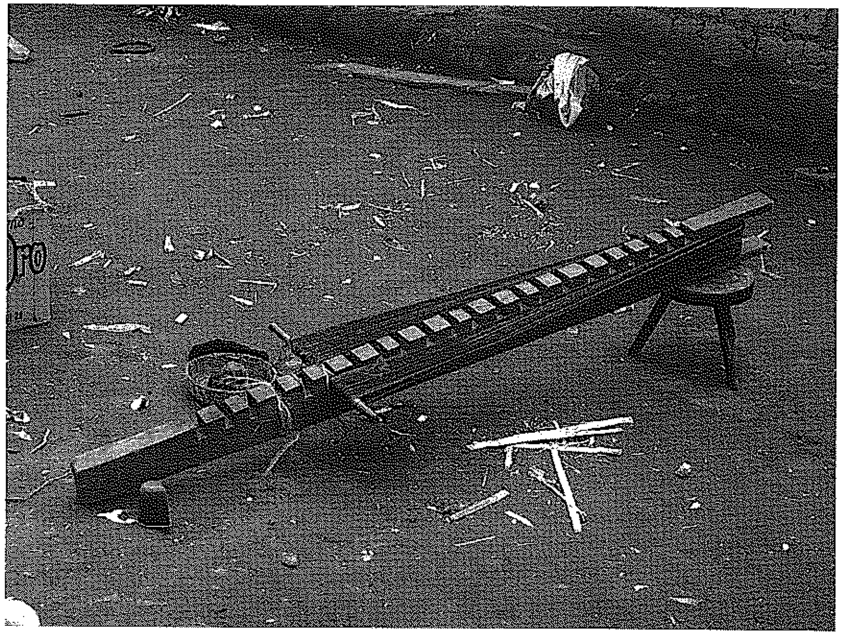

Figure 3.4 The *komen* or warping frame has a warp already wound on it.

together. However, these threads cannot be wound directly on to the loom (the two end sticks) because if the threads were not there, the loom would collapse; the loom has nothing to hold the two sticks together before the winding of the warp threads begins.

Therefore, a real loom must have the warp prewound on a separate apparatus, the *komen* or warping frame shown (with a warp already wound on it) in figure 3.4.

My thesis is that winding the warp on a *komen* intrinsically involves concrete operational thinking. This is the case because winding on the *komen* requires mental transformation, the essence of concrete operations (e.g. Piaget, [1963]1977). The form of the warp threads wound on the *komen* (figure 3.4) is quite different from the form of the threads on the final loom (figure 3.3). Complex topological transformation is required to understand the connection between how you wind the warp and how the warp looks and functions on the loom. Let me illustrate this point with the sequence in figure 3.5.

Figure 3.5a shows a *komen* or warping frame, ready to begin winding. In figure 3.5b, a girl has begun to wind the threads on the warping frame; in figure 3.5c she has gotten a bit further. Compare this image with figure 3.3. Figure 3.3 shows how the warp turns out (after more of the same with additional

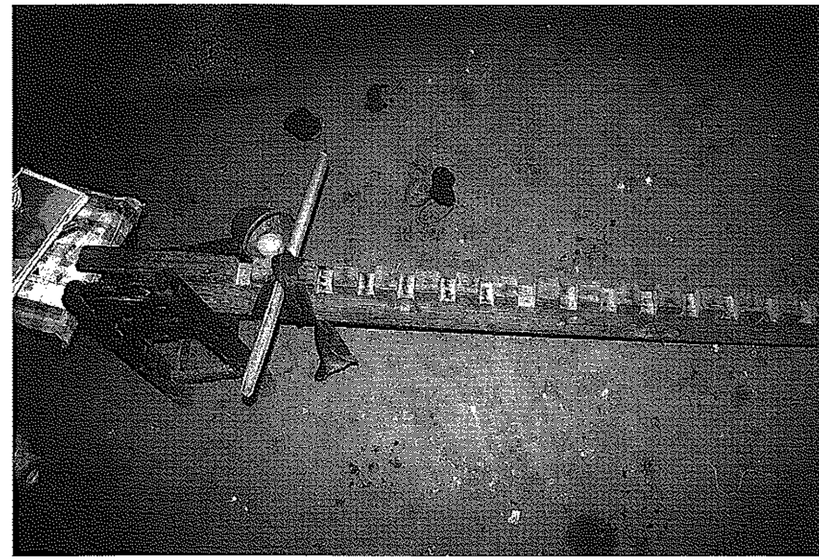

Figure 3.5a The *komen* or warping frame is ready to begin winding.

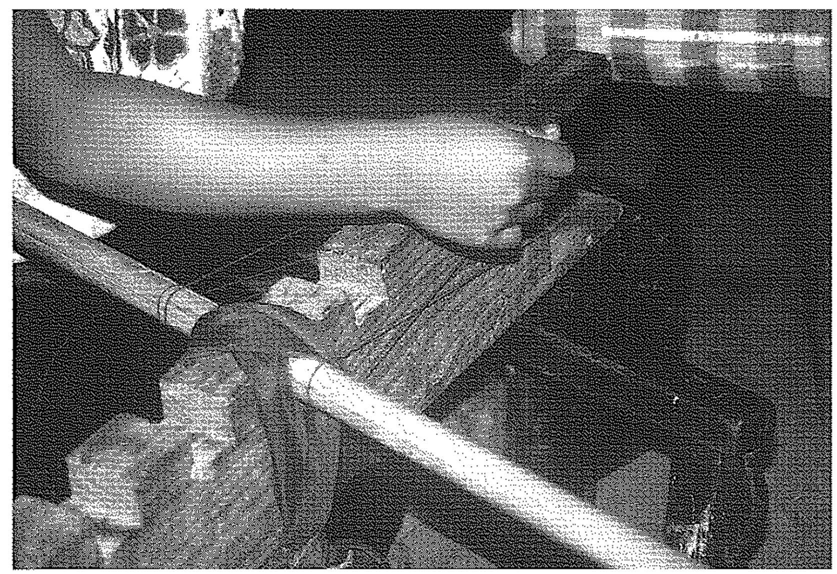

Figure 3.5b A girl has begun to wind the threads on the warping frame.

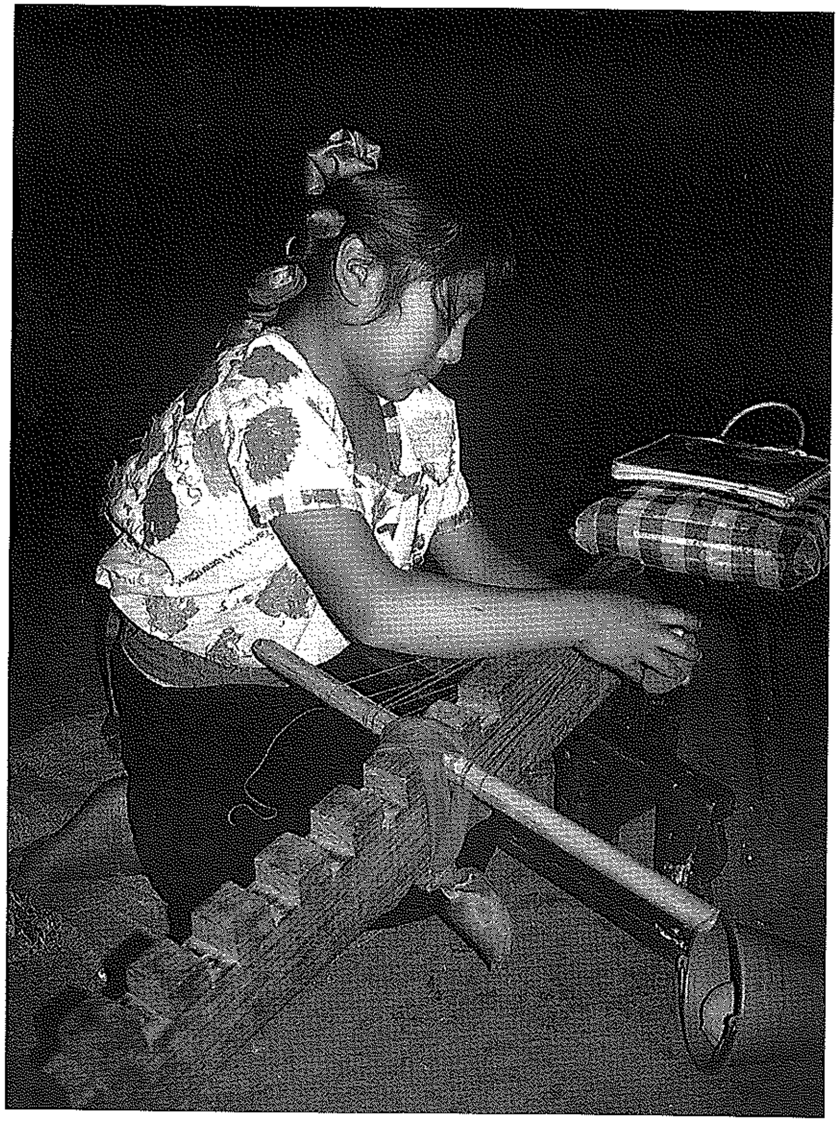

Figure 3.5c The girl has further succeeded in winding the threads.

colours) after being transferred to the loom. Note the difference between the U-shaped configuration of threads in figure 3.5c, where the warp threads are still on the warping frame, and figure 3.3, where the warp threads have been straightened out and transferred to the loom. Threads on the left side of the stick

Figure 3.6a A girl has started winding the warp directly on to the toy loom.

in 3.5c go to one end of the loom (e.g. the top in figure 3.3), while threads on the right side go to the other end (e.g. the bottom in figure 3.3).

This sequence illustrates the important cognitive point: that a complex series of mental transformations is required for a weaver to understand the connection between how the threads are wound on the warping frame and how they end up in the configuration visible on the loom in figure 3.3. Because mental transformations characterize the Piagetian stage of concrete operations, winding a warp on the warping frame in order to set up a backstrap loom is a culture-specific concrete operational task.

I now compare the cognitive level required to set up a 'real' loom with that required to set up a toy loom. Whereas to set up a real loom demands the mental transformations of concrete operations, mental transformations are not required for the toy loom. Because of the extra supporting ropes on the side (figures 3.1 and 3.2), the warp can be wound directly on the loom. The sequence in figure 3.6 illustrates this central point.

In figure 3.6a, a young girl has just started winding the warp directly on to the toy loom, which is already set up. The top and bottom loom sticks (left and right in the photo) are held in place by white string connecting the sticks; one of the two side strings is shown clearly at the top of figures 3.6a and 3.6b.

In figure 3.6b, the young girl continues winding, making repeated figure eights between the end sticks, seen in the photograph. This process of winding figure

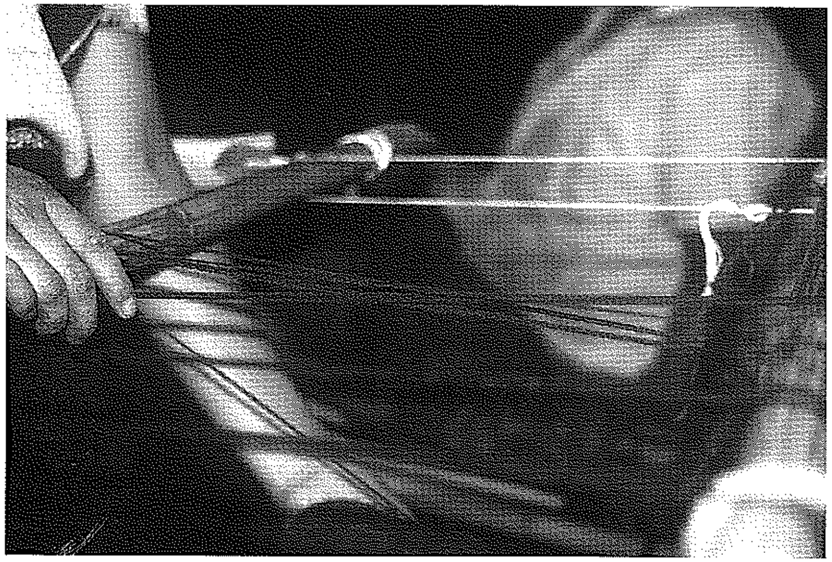

Figure 3.6b The girl continues winding, making repeated figure eights between the end sticks.

eights makes the cross-configuration we see on the *komen* in figure 3.5b. In this process, there is no mental transformation required to go from the winding process to the set-up loom.

The important conclusion from this analysis is that Piagetian theory is part of the Zinacantecs' implicit ethnotheory of development. Whereas Zinacantec girls start on the toy loom from age 3, they do not set up a real loom before age 6 at the earliest, the normal age range of concrete operations. So, most interestingly, Piagetian theory is implicitly (but not explicitly) built into the developmental progression of Zinacantec weaving tools.

Culture shapes and actualizes biological potential

If we think of Piagetian stages as age-dependent sensitive periods, then learning how to set up a real loom can be seen as an activity that actualizes concrete operations in a culture-specific form.

Cognitive stages as age-dependent sensitive periods for cultural learning

What is the evidence for Piagetian stages as age-dependent sensitive periods and how does play weaving fit into this picture? I should like to draw upon a new theory of primate play by Fairbanks (2000) and propose that it applies both to human play in general and to play weaving in particular. Fairbanks has developed a theory of monkey play that posits its role in stimulating neuromuscular pathways that underlie a particular adult monkey skill. She contrasts her theory with the theory that play functions as direct practice of an adult behavioural skill. She observes that because the peak of each monkey play form occurs years before the adult behaviour, it would not be very useful as practice for the adult behaviour. However, the playful form is most frequent just at the time the relevant neural substrate for that particular activity is developing. For example, play fighting in monkeys reaches its maximum just as the neural circuitry for adult aggression is developing – but years before aggression is required in adult monkey social life.

Could this analysis apply to human play in general and to play weaving in particular? There are several parallels with Fairbanks' theory and data: First, there is the behavioural parallel: just as play fighting occurs in monkeys several years before the real thing, so does play weaving on the toy loom occur several years before weaving utilitarian items on the real loom. Second, Thatcher (1994) presents EEG evidence for spurts in neural development. These spurts are periods of neural instability that serve as developmental transition points in the nervous system. One of these transition points or spurts is at age 4 (Fischer and Rose, 1994), in the age range when play weaving begins.

My theoretical interpretation of these transition points in neural development is that they are sensitive periods – developmental windows – when stimulation, often in the form of culture-specific practices, actualizes maturationally specific neural circuits. It follows from this that play weaving could stimulate neural and neuromuscular pathways that provide a foundation for the later cognitive development required to weave on a real loom.

Fischer and Rose (1994) identify a second spurt in neural development that occurs between ages 6 and 10. This is precisely the period in which weaving on a real loom begins for most Zinacantec girls. It is also Piaget's period of concrete operations, which, as I have tried to illustrate, are indeed required for setting up a real loom. But looking at these matters across cultures, we would not necessarily expect concrete operational children in the United States to be able to set up a loom, beginning with the *komen*. Nor would we necessarily expect Zinacantec children to be able to do Western concrete operational tasks, for example two-way classification. Indeed, we found, through an experiment, that they could not do this task.

In conclusion, the cultural environment *shapes* and *actualizes* the biological potential for concrete operations. Thus my hypothesis is that the concrete operational potential of Zinacantec girls has been actualized by and in the form of weaving-related tasks. In the United States, concrete operations are actualized by different experiences and in different forms; for example, conservation of weight might be actualized by the experience of weighing.

Conclusion

These are the various ways in which I suggest that culture and biology mutually define and influence each other in development. These relationships make it clear that it is much too simple to think of biology on the inside and culture on the outside. The external culture depends on the internal biological capacity for cultural learning. To realize this biological capacity for cultural learning in turn requires an external culture that results from the cultural learning of earlier generations. I hope that this discussion can lead to systematic investigation of these six relationships in a wide variety of cultural settings.

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Part II

Perspectives on development informed by culture