The psychobiology of early attachment

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Abstract

New laboratory research has begun to reveal a network of simple behavioral, physiological and neural processes that underlie the psychological constructs of attachment theory. It has become apparent that the unique features of early infant attachment reflect certain unique features of early infant sensory and motor integration, early learning, communication, motivation and the regulation of biobehavioral systems by the mother–infant interaction. This chapter will undertake to answer three major questions that have remained unsettled in our understanding of early human attachment: How does the infant find its own mother and stay close to her? Why does separation of the infant from its mother produce such severe physiologic and behavioral responses? How can individual differences in adult offspring and especially in their maternal behavior toward their own infants be related to the patterns of early life with their parents? In each of these cases, I will review the recent research that has given us new answers to these questions at the level of early behavioral, affective and cognitive processes and their neurobiological substrates. Attachment remains useful as a concept, like hunger, that describes the operation of subprocesses that work together within the frame of a vital biological function.

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1. Introduction

“Everything in the sphere of this first attachment to the mother seemed to me so difficult to grasp … so gray with age, shadowy and almost impossible to revivify … in analysis” Sigmund Freud, 1931 [1].

This early stage in human development—prior to language and beyond the reach of memory—continues to be ‘difficult to grasp’ and therefore controversial within psychoanalysis and psychodynamic psychotherapy. Despite these difficulties, clinicians have become increasingly aware of the importance of this ‘preoedipal’ period for understanding the problems of certain child and adult patients. Similarly, the therapeutic and reconstructive effect of the patient–therapist encounter has been increasingly compared to the formative effects of the early parent–infant relationship. Most recently, observational studies of infants by clinicians and a growing interest in the psychology of mother–infant attachment, stimulated by John Bowlby’s work [2], have resulted in a flowering of systematic research by clinicians and the formation of parent–infant programs in many clinical training institutes within the last few years. This growing appreciation of the importance of the early parent–infant relationship has been fueled by a growing body of public health and epidemiological research documenting the frequency of childhood abuse and neglect in this country and the greatly increased risk for the development of borderline personality disorders, depression, attention deficit hyperactivity disorder and drug abuse in individuals with an early history of parental maltreatment.

Bowlby’s great accomplishment was to dispel the misconception that existed among professionals in the first half of the century, that the only functions of the mother for the infant were to provide nutrition and protection. But it was Harlow’s experiments [3] carried out under controlled conditions in the laboratory, that compelled the skeptics to take Bowlby’s revolutionary ideas seriously. The problem with Bowlby’s conceptual structure was not its limitations, but that it explained too much. This was of course also a
strength (and still is) in that it allowed a great many observations in both humans and other animals to be grouped together and integrated within a single powerful idea. But for the psychoanalysts, it attempted to take over much that was better understood within existing concepts of early appetite, sex and aggression. For many behavioral scientists studying early development experimentally, evidence from their research did not fit Bowlby’s concept of a unitary attachment system at work within the mother–infant interaction. Instead they found a number of relatively independent systems (e.g. for orientation, for early learning and memory, for thermal regulation, or for early affect expression), each with its own regulatory principles. In addition, Bowlby’s concept did not generate research questions but rather seemed to answer questions with a frustrating form of circular reasoning. For example, the strength of an infant’s attachment was assessed through the intensity of the response to separation, which itself was explained as the consequence of disruption of the attachment bond.

Evolutionary principles give us a conceptual common ground that can be shared by both neuroscience and psychoanalysis, providing answers to questions about how the human mind and brain have come into being and why they have their present form. The historical nature of both development and evolution bridges the gap that exists between the ‘reductionist’ emphasis of the molecular/cellular neurosciences and the ‘holistic’ emphasis on meaning that is the central focus of psychoanalytically oriented clinicians. Early human development traverses a series of levels of scale and organization from the multicellular interactions of the embryo, to the integrated systems and behavior of the fetus, to the emerging cognitive and affective capacities of the child. The biological, behavioral and psychological processes at work at those levels of organization seem very different. But the new properties that emerge at each level arise from the combined operation of simpler processes taking place at the previous level. Understanding those transitions, and the emergence of new properties at higher levels, is one of the central questions for research in early human development as well as for attempts to integrate neuroscience and psychoanalysis in general.

In this paper, I will outline how a strategy of attempting to understand the component processes underlying the psychological constructs we have created in studying early human attachment, can give us new and potentially useful ways of thinking about patients and undertaking to help them. The idea of ‘early attachment’ exists in a number of forms in our ways of speaking and thinking. In its most general sense the phrase refers to a set of behaviors we observe in infants and the feelings and thought processes (conscious and/or unconscious) that we suppose infants have, based on our own experiences, memories and psychological concepts we have formed for ourselves or learned from others. Within this range of usage of the word ‘attachment’, several different schools of thought have coalesced, some within psychoanalysis and others within different schools of psychodynamic psychotherapy. Common to all, however, are three themes: (1) some sort of emotional tie or bond that is inferred to develop between the infant and its caretaker that keeps the infant physically close; (2) a series of responses to separation that constitute the infant’s emotional response to interruption or rupture of that bond; and (3) the existence of different patterns or qualities of the interactions between infants and mothers that persist over time, as mental representations that lead to corresponding differences in later close relationships throughout life, even extending to a repetition of given patterns of mothering by daughters in the next generation.

These observations and concepts of attachment have been extremely useful clinically, but they leave a number of observations unexplained and questions unanswered. Furthermore, when we found close similarities in the behavioral separation responses of a far less evolved mammal, the laboratory rat pup, this suggested that we were missing a deeper layer of biological processes underlying the psychological concepts of attachment theory. Some of the unanswered questions left open by attachment theory are posed in the sections that follow. The answers that came from our laboratory research, although they tended to support clinical observations, also extended them in unexpected ways. The most exciting results, to me, have been the new ideas and new ways of thinking about early human attachment that have emerged from this animal model research. We cannot settle questions of human nature by studying other animals, but we can generate new hypotheses, concepts and ways of thinking that ultimately we may be able to apply to our clinical work with patients.

2. Methods and results

2.1. Attachment revealed

“Our own feelings revolt against the idea of infants living under the condition of air raid danger and underground sleeping … A child of 1 [to] 4 years of age will shake and tremble with the anxiety of its mother … The primitive animal tie between mother and baby … [making] one being out of the two, is the basis for the development of this type of air raid anxiety in children … [But] London children were on the whole much less upset by the bombing than by the evacuation to the countryside, as a protection against it”

A. Freud and D. Burlingham, 1943 [4]

From our present perspective, it is hard for us to understand the surprise people expressed during the bombing of London in 1941–1942, in finding that children were much more distressed by evacuation and separation from their families in the city to safe homes in the countryside, than by the collapse of buildings around them
when they were with their mothers in London. The quotation also shows the authors’ intuitive understanding that a ‘primitive animal tie’ exists between mother and baby. But it was not until 25 years later that John Bowlby’s evolutionary synthesis [2] and Harry Harlow’s early deprivation studies in monkeys [3] made the possibility of studying the biology of attachment become a reality. In Bowlby and Harlow’s work, as well as in the clinical observations of Freud and Burlingham [4] a generation before, it was maternal separation that revealed the existence of a deeper layer of processes beneath the apparently simple interactions of mother and infant. Bowlby and Harlow viewed these processes as primarily psychological. The behavioral and physiological responses of the infant to separation, in their conception, were a consequence of ‘rupture’ of a psychological ‘bond’ that was formed as part of an integrated psychophysiological organization that Bowlby called ‘the attachment system’. More recent research, however, has revealed a network of simple behavioral and biological processes that underlie this and other psychological constructs used to define and understand early human social relationships.

2.2. Searching for what was lost

Experiments in our laboratory have shown that infant rats have complex and lasting responses to maternal separation similar to primates in a number of different physiological and behavioral systems. A number of years ago we found that the slower developing components (Bowlby’s ‘despair’ phase) was not an integrated psychophysiological response, as had been supposed, but the result of a novel mechanism. As separation continued, each of the individual systems of the infant rat responded to the loss of one or another of the components of the infants’ previous interaction with its mother. Providing one of these components to a separated pup, for example maternal warmth, maintained the level of brain biogenic amine function underlying the pups’ general activity level [5,6] but had no effect on other systems, for example, the pups’ cardiac rate continued to fall regardless of whether supplemental heat was provided [7]. The heart rate, normally maintained by sympathetic autonomic tone, we found was regulated by provision of milk to neural receptors in the lining of the pup’s stomach [8]. With loss of the maternal milk supply, sympathetic tone fell and cardiac rate was reduced by 40% in 12–18 h.

By studying a number of additional systems, such as those controlling sleep–wake states [9], activity level [10], sucking pattern [11] and blood pressure [12], Harry Shair, Herbert Weiner and I found different components of the mother–infant interaction, such as olfaction, taste, touch, warmth and texture, that either up-regulated or down-regulated each of these functions. Thus we concluded that in maternal separation, all these regulatory components of the mother–infant interaction are withdrawn at once. This widespread loss creates a pattern of increases or decreases in level of function of the infant’s systems, depending upon whether the particular system had been up- or down-regulated previously by specific components of the previous mother–infant interaction. We called these components ‘hidden regulators’ because they were not evident when simply observing the ongoing mother–infant relationship.

2.2.1. The protest response to separation, affect regulation and communication

One of the best known responses to maternal separation is the infant’s separation cry, a behavior that occurs in a wide variety of species [13,14]. In the rat, this call is in the ultrasonic range (40 kHz) and appears in the first or second postnatal day. Pharmacological studies by Susan Carden in our lab and by a number of others showed that the ultrasonic vocalization (USV) response to isolation is attenuated or blocked in a dose-dependent manner by clinically effective anxiolytics that act at benzodiazepine and serotonin receptors. Conversely, USV rates are increased by compounds known to be anxiogenic in humans, such as benzodiazepine receptor inverse agonists (beta-carboline, FG 1742) and GABAa receptor ligands such as pentylene-tetrazol [15,16]. Within serotonin and opioid systems, receptor subtypes known to have opposing effects on experimental anxiety in adult rats and humans also have opposing effects on infant USV calling rates. Neuroanatomical studies in infant rats show that stimulation of the periaqueductal grey area produces USV calls, and chemical lesions of this area prevent calling [17]. The more distal motor pathway is through nucleus ambiguus and both laryngeal branches of the vagus nerve. Higher centers known to be involved in cats and primates suggest a neural substrate for isolation calls involving primarily the hypothalamus, amygdala, thalamus, and hippocampus and cingulate cortex, brain areas known to be involved in adult human and animal anxiety responses [13].

This evidence strongly suggests that separation produces an early affective state in rat pups that is expressed by the rate of infant calling. This calling behavior, and its inferred underlying affective state, develop as a communication system between mother and pup. Infant rat USVs are a powerful stimulus for the lactating rat, capable of causing her to interrupt an ongoing nursing bout, initiate searching outside the nest and direct her search towards the source of the calls [18]. The mother’s retrieval response to the pup’s vocal signals then results in renewed contact between pup and mother. This contact in turn quiets or comforts the pup.

The separation and comfort responses in attachment theory are described as expressions of interruption and re-establishment of a social bond. Such a formulation would predict that since the pup recognizes its own mother by her scent (as described below), pups made acutely anosmic would fail to show a comfort response. But anosmic pups show comfort responses that are virtually unaffected by loss of their capacity to recognize their mother in this way [19].
Instead Harry Shair, Susan Brunelli and I have found multiple regulators of infant USV within the contact between mother and pup: warmth, tactile stimuli, and milk as well as her scent [20]. Provision of stimulation in these modalities separately (e.g. artificial fur lacking warmth or scent) and then progressively combining modalities, elicited graded responses. The full ‘comfort’ quieting response was only elicited when all modalities were presented together, and maximum calling rates occurred when all were withdrawn at once. In essence, we found parallel regulatory systems involving different sensory modalities. These functioned in a cumulative or additive way, the rate of infant calling reflecting the sum total of effective regulatory stimuli present at any given point of time.

2.2.1.1. To summarize. In the development of interactions between the infant rat and its mother, a vocal communication system becomes established. The infant separation call rate appears to be mediated by the same neural systems that mediate anxiety in adult animals and humans, apparently a strongly conserved neural response. This system is regulated by multiple modalities of the infants’ sensory contact with its mother or by their withdrawal in separation.

2.3. Hidden regulators of early development

Other investigators, using our approach, have since discovered other maternal regulatory systems of the same sort. For example, Saul Schanberg, Cynthia Kuhn and colleagues found that removal of the dam from rat pups produced a rapid (30 min) fall in the pup’s growth hormone (GH) levels, and vigorous tactile stroking of maternally separated pups (mimicking maternal licking) prevented the fall in GH [21]. Brain substrates for this effect were then investigated and it now appears that GH levels are normally maintained by maternal licking, acting through serotonin 2A and 2C receptor modulation of the balance between growth hormone releasing factor (GRH) and somatostatin (SS), that together act on the anterior pituitary release of GH [22]. The withdrawal of maternal licking by separation allows GRH to fall and SS to rise, resulting in a precipitous fall in GH.

There are several biological similarities between this maternal deprivation effect in rats and the growth retardation that occurs in some variants of human reactive attachment disorders of infancy. Applying this new knowledge about the regulation of GH to low birth weight prematurely born babies, Tiffany Field and co-workers joined the Schanberg group [23]. They used a combination of stroking and limb movement, administered 3 times a day for 15 min each time and continued throughout their 2 weeks of hospitalization. This intervention increased weight gain, head circumference and behavior development test scores in relation to a randomly chosen control group, with enhanced maturational effects discernible many months later. Clearly early regulators are effective in humans, and over time periods as long as several weeks.

As we began to understand the infants’ separation response as one of loss, loss of a number of individual regulatory processes that were hidden within the interactions of the previous relationship, an important implication of this finding emerged: these ongoing regulatory interactions could act to shape the development of the infants’ brain and behavior throughout the preweaning period when mother and infant remained in close proximity. We could now think of the mother–infant interaction as a regulator of normal infant development, variations in the intensity and patterning of the mother–infant interactions gradually shaping infant behavior and physiology. These processes go beyond the adaptive evolutionary role of attachment as a protection against predators, as proposed by Bowlby [2]. Regulatory effects of early interactions are likely to have evolved because of their capacity to shape the adaptive capabilities of the infant in accordance with the prior experience of the mother, as reflected in her maternal behavior towards her infant. Such a mechanism for intergenerational transmission of traits would provide a preadaptation for the next generation in the rapidly changing ecological conditions as mammals evolved (see below). But such long-term regulatory processes in mammalian development require a means of ensuring a prolonged close association between parents and offspring, the formation of an attachment bond.

2.4. Deconstructing the attachment bond

Infants of mammalian species that are born in an immature state, such as the human and the laboratory rat, face a daunting task. They must find a way to identify, remember and prefer their own mother, and they must use these capacities to reorganize their simple motor repertoires, long-adapted to the uterine environment, so as to be able to approach, remain close and orient themselves to their mothers. It has been assumed until recently that these ‘bonding’ processes were well beyond the capacities of newborn mammals (except in precocial species such as the sheep) and that the relationship initially depended almost entirely upon maternal behavior until well into the nursing period [24,25]. An attachment bond has thus been supposed to be built-up slowly in the weeks or days after birth through repeated mother–infant interactions, starting with stereotyped reflexes in the newborn. But the last decade has produced a number of studies revealing earlier and earlier evidence of learning, even extending into the prenatal period, as will be described below. In addition, coordinated motor acts have been demonstrated experimentally in fetuses in response to specific stimuli that will not be encountered until after birth. Thus, the solutions for the infant’s tasks appear to be found much earlier than previously thought and to take place through novel developmental processes that had not been imagined until recently.
2.4.1. Prenatal origins

The first strong evidence for fetal learning came from studies on early voice recognition in humans, in which it was found that babies recognize and prefer their own mother’s voice, even when tested within hours after birth [26]. Bill Fifer [27] continued these studies in our department using an ingenious device through which newborns can choose between two taped recorded voices by sucking at different rates on a pacifier rigged to control an audio tape player. He has found that newborn infants, in the first hours after birth, prefer human voices to silence, female voices to males, their native language to another language and their own mother to another mother reading the same Dr Seuss story. In order to obtain more direct evidence for the prenatal origins of these preferences (rather than very rapid postnatal learning), Fifer filtered the high frequency components from the tapes to make the mother’s voice resemble recordings of maternal voice by hydrophone placed within the amniotic space of pregnant women. This altered recording, in which the words were virtually unrecognizable to adults, was preferred to the standard mothers’ voice by newborns in the first hours after birth, a preference that tended to wane in the second and third postnatal days. Furthermore, there is now evidence that newborns prefer familiar rhythmic phrase sequences to which they have been repeatedly exposed prenatally when pregnant mothers read out loud a specific text in a quiet place [28].

In a striking inter-species similarity, rat pups were subsequently shown to discriminate and prefer their own dams’ amniotic fluid in preference to that of another dam when offered a choice in a head turning task [29]. Newborn pups were also shown to require amniotic fluid on a teat in order to find and attach to it for their first nursing attempt [30]. Robinson and Smothersman [31] have directly tested the hypothesis that pups begin to learn about their mothers’ scent in utero. They have been able to demonstrate one trial taste aversion learning and classical conditioning in late term rat fetuses, using intraoral cannula infusions and perioral stimulation. Taste aversions learned in utero were expressed in the free feeding responses of weanling rats nearly 3 weeks later. They went on to determine that aversive responses to vibrisa stimulation were attenuated or blocked by intraoral milk infusion, a prenatal ‘comfort’ effect they found to be mediated by a central kappa-opioid receptor system.

These forms of fetal learning involving maternal voice in humans and amniotic fluid in rodents, appear to play an adaptive role in preparing the infant for its first extrauterine encounter with its mother. They are thus the earliest origins we have as yet found for attachment to the mother. The spontaneous motor acts needed for an attachment system also appear to be developing prior to birth. Rat fetuses engage in a number of spontaneous behaviors in utero, including curls, stretches, trunk and limb movements. These acts were observed to increase markedly in frequency with progressive removal of intrauterine space constraints, as pups were observed first through the uterine wall, then through the thin amniotic sac and finally unrestrained in a warm saline bath [32]. When newborn pups are observed prior to their first nursing bout, they resemble exteriorized fetuses, until the mother lowers her ventrum over them. Their behavior then changes rapidly over the first few nursing bouts, into the complex repertoire described below.

2.4.2. How newborns approach and orient to their mothers

Jon Polan and I showed that, when pups less than a day old are stimulated gently by soft surfaces from above, as when the mother hovers over them, they show a surprisingly vigorous repertoire of behaviors [33]. These include the curling and stretching seen prenatally, but now also include locomotor movement toward the suspended surface, directed wiggling, audible vocalizations and, most strikingly, turning upside down toward the surface above them. Evidently these behaviors propel the pup into close contact with the ventrum, maintain the pup in proximity and keep it oriented towards the surface. These appear to be very early attachment behaviors. In a series of experiments, we found that these are not stereotyped reflex acts, but organized responses that are graded according to the number of maternal-like stimulus modalities present on the surface presented experimentally (e.g. texture, warmth, odor). Furthermore, they were enhanced by periods of prior maternal deprivation, suggesting the rapid development of a motivational component. By 2 days of age, we found that pups discriminate their own mother’s odor in preference to equally familiar nest odors [34] and by the first postnatal week, Hepper [29] has shown that older pups discriminate and prefer their own mother, father and siblings to other lactating females, males or agamates.

Recent work in humans, inspired by these findings in lower animals, have shown that human newborns too are capable of slowly locomoting across the bare surface of the mother’s abdomen and locating the breast scented with amniotic fluid in preference to the untreated breast [35]. Although newborns are attracted to natural breast odors even before the first nursing bout [36], amniotic fluid can override this effect. Apparently, human newborns are not as helpless as previously thought, and possess approach and orienting behaviors that anticipate the recognized onset of specific maternal comfort responses at 6–8 months.

2.4.3. A novel postnatal learning system

Bowlby was uncertain about exactly how a behavioral attachment system or bond developed in mammals and hypothesized that some learning mechanism must exist that is similar to the phenomenon of ‘imprinting’ in birds, made famous by Lorenz [37]. We are now beginning to gain an understanding of how such a specific proximity-maintenance system develops in animals and humans at the level of basic learning mechanisms and the brain systems mediating them.
Regina Sullivan and Steven Brake in our lab discovered that within 2–3 days after birth, neonate rat pups were capable of learning to discriminate, prefer, approach and maintain proximity to an odor that had been associated with forms of stimulation that naturally occurred within the early mother–infant interaction (e.g. milk or stroking) [38]. Random presentations of the two stimuli had no such effect, a control procedure that identified the change in behavior as due to associative conditioning and not some non-specific effect of repeated stimulation. Since the learning required only 2 or 3 paired presentations and since the preference was retained for many days, it seemed to qualify as the long sought ‘imprinting-like process’ that is likely to be central to attachment in slow-developing mammals. Indeed, a human analogue of this process has been found by Sullivan [39] who showed that when human newborns were presented with a novel odor and then rubbed repeatedly along their torsos to simulate maternal care, the next day they became activated and turned their head preferentially towards that odor. This suggests that rapid learning of orientation to olfactory cues is an evolutionarily conserved process in mammalian newborns.

Early attachment-related odors appear to retain value into adulthood, although the role of the odor in modifying behavior appears to change with development. Work done independently in the labs of Elliot Blass [41] and Celia Moore [40], demonstrated that adult male rats exhibited enhanced sexual performance when exposed to females scented with the artificial odors they had learned in infancy.

2.4.4. Aversive learning in attachment

Clinical observations have taught us that attachment occurs not only to supportive caretakers, but that children can endure considerable pain and even injury while remaining strongly attached to an abusive caretaker. Although it may initially appear to be counterproductive from an evolutionary perspective to form and maintain an attachment to an abusive caretaker, it may have been better for a slow developing mammalian infant to have a bad caretaker than none at all.

This aspect of human attachment is also represented in the infant rat. During the first postnatal week we found that a surprisingly broad spectrum of stimuli can function as reinforcers to produce an odor preference in rat pups [38,42]. These stimuli ranged from apparently rewarding ones such as milk and access to the mother [11,43–45] to apparently aversive stimuli such as moderate shock and tailpinch [38,46], stimuli that elicit escape responses from the pups. It should be noted that threshold to shock [47] and behavioral response [48] to shock does not change between the ages of 9 and 11. As pups mature, and reach an age when leaving the nest becomes more likely, olfactory learning comes to resemble learning in adults more closely. Specifically, odor aversions are easily learned by 2-week olds and acquisition of odor preferences are limited to odors paired with stimuli of positive value [49]. Thus, the odor learning which underlies early attachment appears to take place in response to a very broad range of contingent events while pups are confined to the nest, but becomes more selective at a time in development when pups begin leaving the nest and encountering novel odors not associated with the mother.

2.4.5. Brain substrates for early attachment learning

This rapid learning has been traced to focal odor-specific areas in the olfactory bulb by Sullivan and Donald Wilson [45,50], specific cell types alter their firing rates in response to the specific odor as a result of the learning experience. This altered firing rate is the result of activation of norepinephrine (NE) pathways leading from the locus coeruleus. Indeed the behavioral learning can be driven by stimulation of the locus or NE injection in the olfactory bulb in association with the novel odor, without the association of any maternal stimuli with the novel odor.

Recent evidence from Sullivan’s group has shown that associations that are based on traumatic levels of stimulation in the first week are dependent on endogenous opioid receptor pathways whereas positive associations are not [51]. When aversion develops to intense stimulation after the first 10 days, the amygdala becomes involved in mediation of the response, which had not been the case before. This maturation of amygdala functioning appears to be the neural mechanism primarily responsible for bringing the sensitive period for aversive learning of attachment behaviors to an end. Importantly, the period for this form of learning can be extended by beginning the associative training within the period and then repeating the training daily. The neural mechanism for the prolongation of this early sensitive period is under investigation.

2.4.6. Parallel processes in maternal attachment to infants

Successful mother–infant interactions require the reciprocal responding of both individuals in the mother–infant dyad. Human mothers rapidly learn about their baby’s characteristics and can identify their baby’s cry, odor and facial features within hours of birth [52–54]. An animal model for this rapid learning has received considerable attention [55,56]. Indeed, there are interesting parallels between the early attachment behavior of infants and the attachment behavior of the newly parturient mother. In rats and sheep, a temporally restricted period of postpartum olfactory learning in the mother, involving NE, facilitates the mother’s learning about her young [57,58]. It is possible that mammalian mothers and their young use similar neural circuitry to form their reciprocal attachments, both abusive and normal.

2.5. From biology to psychology

In humans, the early learning processes and the wide-spread regulatory interactions described above are also the first experiences out of which mental representations
and their associated emotions arise. So far as we understand the process for the human, experiences made up of the infant’s individual acts, parental responses, sensory impressions and associated affects are laid down in memory during and after early parent–infant interactions [59,60]. These individual units of experience are integrated into something like a network of attributes in memory, invested with associated affect, and result in the formation of what Bowlby referred to as an ‘internal working model’ of the relationship.

It seems likely that these mental structures combine the infant’s newly developing capacities to anticipate events and to respond to symbolic cues, with the earlier biological functions of the ‘hidden’ regulatory interactions, through processes similar to the functional links involved in the classical conditioning of physiologic responses. In this way our concept of the ‘mental representation’ can be thought to link together into a functional network within the child’s brain, the learned patterns of behavior and the physiological response systems previously regulated by the mother–infant interaction. In this way we can envisage the development of self-regulation of the behavioral and physiological systems underlying motivation and affect, gradually supplanting the sensorimotor, thermal and nutrient regulatory systems found in the interactions of younger infants with their mothers. This would link biological systems with internal object representation and would account for the remarkable upheavals of biological as well as psychological systems that take place in adult humans in response to cues signaling impending separation, or in response to losses established simply upon hearing of a death, for example, by telephone [61].

Mother–infant relationships which differ in quality and which necessarily involve different levels and patterns of behavioral and physiological regulation in a variety of systems, will be reflected in the nature of the mental representations present in different children as they grow up. The emotions aroused during early crying responses to separation, during the profound state changes associated with the prolonged loss of all maternal regulators, and during the reunion of a separated infant with its mother, are apparently intense. These emotional states have commanded our attention, they are what everyone intuitively recognizes about attachment and separation, and what we feel about the people we are close to. As inner experiences, these occur at a different level of psychobiological organization than the changes in autonomic, endocrine and neurophysiological systems we have been able to study in rats and monkeys, as well as in younger human infants. Hidden regulators thus form a developmental as well as a conceptual bridge between the tangible and the intangible in our understanding of attachment.

2.6. Lasting effects of early relationships

In clinical work and in attachment theory we use the concept of an enduring mental representation that is formed early in the infants life, through its particular interaction with each of its parents and consistent caretakers. This conceptual model helps us to organize and understand what our patients tell us about their lives: for example how a person’s later relationships and responses to stress tend to be shaped by their experiences as children. In research with a simple mammalian working model system, we and others have found evidence of similar lasting effects that can be attributed to the processes of maternal regulatory interactions described early in the chapter. First, Sigurd Ackerman, Herbert Weiner and I [62] found that permanent maternal separation early in the weaning period produced a greatly increased vulnerability to stress-produced gastric ulcer in adolescent and young adult rats. To our surprise, this effect persisted in the next generation in the normally rearred offspring of mothers that had been early separated as infants. A cross fostering study revealed that the transmission took place during the fetal rather than the postnatal period. In a different study, Michael Myers, Susan Brunelli and I [63] found evidence of a lasting effect of a particular pattern of naturally occurring early maternal behavior that systematically modified the expression of hypertension in the genetically identical offspring of a hypertensive strain of rat. These surprising findings led us to realize that the hidden maternal regulators that we had discovered in our separation studies were not only regulating development during the preweaning period, but could have long-term regulatory effects on subsequent development, even into the next generation. Could these represent a level of biological processes underlying some of the lasting effects associated with different early object relations and their mental representations in patients?

The work of Michael Meaney and his colleagues [64] over the past decade has greatly enlarged our understanding of the biological processes at work in these lasting effects of early relationships. They discovered that normal variation in one of the same maternal behaviors implicated in our studies on the transmission of hypertension, the level of maternal licking and grooming of pups, systematically modifies (regulates) the development of the adrenocortical stress response and the behavioral fear behavioral response to open spaces in her adult offspring: low levels of this maternal behavior leading to greater adrenocortical and fear responses in adult offspring. In a remarkable series of cell biological studies, Meaney and his colleagues have been able, first, to trace the effects of maternal behaviors to the hippocampal cell membrane receptors that sense the level of adrenocortical hormone and inhibit the hormonal response to stress in the adult. Next they found that the genes responsible for the synthesis of these receptors in the infant offspring of the high or low licking/grooming mothers were differently regulated by their specific transcription factors and that release of these transcription molecules was dependent on a process of methylation within the chromatin layer that surrounds the DNA within the genome [65]. These findings link normally occurring levels of certain maternal
behaviors to molecular processes regulating gene expression in the developing young.

Meaney’s group has gone on to find that high and low licking mothers pass these maternal behavior patterns on to their daughters, along with the different levels of adult stress and fear responses. This trans-generational effect on maternal behavior is beginning to be linked to the effects of those maternal behaviors on estrogen-induced oxytocin receptor modification in the preoptic area of the developing infant brain, the area most central to maternal behavior in the adult [64]. This remarkable research is revealing a network of biological processes, extending down to the regulatory mechanisms within the genome, that appear to be developmental and evolutionary precursors of psychological processes, such as the enduring mental representations, that are fundamental to the attachment and object relations theories of psychoanalysts and psychotherapists.

3. Discussion

The research I have described, using an animal model system, has revealed new features of early attachment that appear to generalize to important aspects of human attachment. The results suggest a new view of early attachment that begins much earlier than previously supposed, even before birth. Fetal and newborn behaviors are not simple reflexes, as previously thought, but sensory-guided and modifiable by experience from their earliest beginnings. Learning, previously thought to be a developmentally advanced capability, appears to occur very early in development, perhaps as soon as movement itself. Thus, the specific attachment behaviors that have been thought to be relatively mature expressions of early bonding can be carried out in newborns through a novel rapid learning process. Furthermore, a critical period was discovered during which attachment can be learned even as a consequence of association with aversive interactions. Functional brain systems mediating the closing of this critical period have been identified.

Early separation, we found, elicits its widespread behavioral and biological responses through a novel mechanism not dependent on an attachment bond, but instead being a consequence of the simultaneous loss of multiple regulators hidden within the preceding mother–infant interaction such as touch, warmth or milk letdown, for example. These operate together, forming a maternally based homeostatic regulatory system maintaining age-specific levels of function prior to separation and creating an assemblage of withdrawal effects following maternal loss.

Over time, these maternal regulators can shape development through their capacity to increase or decrease the level of function of the infant’s behavioral, neuroendocrine and autonomic systems on an ongoing basis throughout infancy. Different overall patterns or qualities of mother–infant interaction are composed of different relative intensities, rhythms or timing of these regulatory interactions. Different variations in these patterns can exert long-term shaping effects on biological responses of the infant, such as corticosterone stress responses and behavioral fear reactions in adulthood. Finally these mother–infant regulatory processes also act on the early precursors of the neural circuitry for maternal behavior, present in daughters as infants, shaping the later development of this circuitry. The adult maternal behaviors of the daughter in the next generation can be shaped by these early experience effects, resulting in a biological parallel to cultural transmission.

In applying these results to early human development, we can begin to see how psychological constructs such as a ‘bond’ and a ‘mental representation’ have their beginning in the changed neural circuitry for these early learned behaviors and regulatory functions being laid down in highly individual forms by the particular patterns or qualities of the individual mother–infant interactions that characterize individual dyads. The early developmental processes found in our studies thus can be thought of as ‘underlying’ the psychological concepts that we have invented to help us think about complex behaviors and mental experiences. Learning about them has enlarged and clarified our understanding of attachment. We now have a richer understanding of an early bond and how it can be formed and of why early separation is so traumatic. We can even begin to see how trans-generational effects of early trauma may be mediated biologically, through maternal regulation of development, as well as through the expression of altered mental representations and through the culture of poverty.

The discovery of regulatory interactions and the effects of their withdrawal allow us to understand not only the responses to separation in young organisms of limited cognitive-emotional capacity, but also the familiar experienced emotions and memories that can be verbally described to us by older children and adults. It is not that rat pups respond to loss of regulatory processes, while human infants respond to emotions of love, sadness, anger and grief. Human infants, as they mature, can respond at the symbolic level as well as at the level of the behavioral and physiological processes of the regulatory interactions. The two levels appear to be organized as parallel and complementary response systems. Even adult humans continue to respond in important ways at the sensorimotor-physiologic level in their social interactions, separations and losses, continuing a process begun in infancy. A good example of this is the mutual regulation of menstrual synchrony among close female friends, an effect that takes place out of conscious awareness and has recently been found to be mediated at least in part by a pheromonal cue [66]. Other examples may well include the role of social interactions in entraining circadian physiological rhythms, the disorganizing effects of sensory deprivation and the remarkable therapeutic effects of social support on
the course of medical illness [61]. In this way, adult love, grief and bereavement may well contain elements of the simpler regulatory processes that we can clearly see in the attachment responses of infant animals to separation from their social companions.

A role for non-verbal features of the early mother–infant interaction in the specification of lasting mental representations of maternal behavior in the adult is a central hypothesis of clinical attachment theory. It would be difficult to confirm scientifically this useful idea. But the trans-generational effects of early experience on maternal behavior, vulnerability to stress, fear responses and their underlying gene expression patterns described in this chapter can serve as a research model for understanding the psychobiological mechanisms underlying the early formation of mental representations. Prospective clinical studies from infancy to childhood would be most interesting and could reveal which residues of particular early interactions can be related to which later characteristics of the stories, play or social relationships of older children, and eventually the parental behavior of adults.

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