Dissecting the **Maternal Mind**

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With a row of highly inspirational people shaping her early thinking, Professor Alison Fleming started studying maternal behaviour as an undergraduate student. She has now spent her entire research career trying to understand how 'nature and nurture' interact to enhance mothering.

Describe the early influences inspiring you to pursue a lifelong career investigating the biological basis of mothering.

I believe the first influence was my mother, in part because she was a professional economist at the United Nations at a time that women didn't hold professional jobs like that. She also travelled a great deal, working in New York and only coming home to us in Washington DC for weekends. I knew she had an important job and greatly admired that. But I also resented the fact that she was not around very much. I suspect my interest in the study of mothering derived in part from not understanding why she was absent. However, my desire to go my own way was likely derived from the fact that she pursued her goals the way she did.

I became interested in psychology as an undergraduate at Columbia. I particularly admired two Professors in psychology; Ted Schaeffer who studied the effects of early 'handling' of rat pups on development of brain and behaviour, and Burt Slotnick, who studied the role of the brain's septal region for maternal behaviour in mice. Once in graduate school at Rutgers University, I came to work with Dr. Jay S. Rosenblatt, who has been the biggest influence on my research career directed at the study of mothering. He studied maternal behaviour and development in the rat, just as I did. I consider Jay the Father of Mothering.

You have been involved in studies showing strong intergenerational effects of adverse early life experiences on mothering. Is your research being used to design interventions for mothers with a known history of adverse early life events?

While we don't do intervention studies ourselves, we are of course interested in interventions to enhance mothering, in particular in studies building on our knowledge that many behavioural systems become activated when women give birth and become maternal. Hence, factors that we know can affect mothering can be brought into the development of parenting interventions to help mothers (and fathers) respond more appropriately to their infants.

For instance, we know that mothers with post-partum depression are less responsive and display problems with attention and ability to shift attention. Interventions that ameliorate depression or anxiety in depressed mothers would also enhance maternal behaviour. Mothers can also be trained to focus attention on salient cues and to be more attentive to cues emanating from their babies. Focusing attention allows them be more sensitive, and respond more contingently to their babies. This process also often enhances the reward value of the infants. Another approach is to film mothers with their infants. By watching the videos, mothers receive feedback on aspects of their behaviour that are maladaptive or not sufficiently attuned.

Your data supports the notion that brain changes also occur in non-biological mothers. Is there any research on potential fathering brain changes?

From animal studies we know that the same brain systems are involved in regulation of parental behaviour in females who care for babies but who are not mothers, as well as in fathers. In fathers, we also know hormones can play a role. In humans, a decrease in testosterone levels along with increased prolactin levels, are associated with more nurturance among fathers. Experience interacting with young and being parented well are however the largest predictors of quality of parenting, whether we are talking about mothers, fathers, or 'alloparents' (relatives, other children, community members, SH). Fathering research and research on 'alloparents' exist and we have done some, but there is a lot more that can and should be done.

Your neuroimaging data shows that many brain regions, connected through complex pathways, are involved in mothering – how can this knowledge impact the science of social and psychological aspects of mothering?

Knowledge of brain function and pathways is not a goal in itself. However, pathways related to perception, memory, reward, executive function, cognition, attention and affect reflect behavioural functions important for appropriate mothering, and understanding how these functions and their pathways intersect with a maternal circuit helps us understand how mothering is regulated and why it is sometimes dysregulated.

Speaking of pathways, it is also crucial to include knowledge of neurochemistry. There are now a number of ways in which our knowledge of neurochemistry can be used to impact behaviour. Examples involve the use of selective serotonin reuptake inhibitors (SSRI's) for depression, the effects of oxytocin on memory, the importance of dopamine for reward and the regulation of stress by cortisol. These neurotransmitters and hormones are important for brain function and are involved in the regulation of behaviour.

In general however I believe interventions should be based primarily on psychological phenomena, based on knowledge of how they are regulated by the brain, and not based on physiology and neuroscience alone.

Defining Psychobiological Correlates of Maternal Behaviour

Optimal maternal behaviour is a cornerstone of the survival of the human race. But what is characterizing the transition into motherhood on a psychological and physiological level, and what can cause the process to go awry?

AN INTEGRATED VIEW

Human babies are born into a helpless state, entirely depending on others for survival and optimal development, and for this to take place, it takes more than just providing food and shelter. Being a highly sociable species, human infants also require intimate social bonds to thrive and usually, but not always, the mother is the first affectional bond. The strength of the attachment between an infant and its mother is, in fact a solid predictor of further cognitive and psychosocial development of the child. In some cultures the infant is cared for by multiple affectionate caregivers (fathers, grandparents, aunts) and these relationships can serve the same function.

For such a connection to develop, an infant needs to make the mother aware of its needs, and the mother, in turn, must find it rewarding to act upon these demands. Consequently, optimal mothering behaviour depends on a number of highly integrated psychological processes.

One fundamental aspect of mothering behaviour is sensitivity in picking up, interpreting and acting upon cues related to the infant needs. Such cues need to be salient and able to activate the intrinsic reward system in the mother's brain. Additionally, mothering is often taking place against a backdrop of multiple, rapidly changing and competing stimuli. Therefore, the ability to both focus and to briskly change the focus of attention when necessary is also essential for successful maternal behaviour. Finally, it is fundamental to harness impulsivity to maintain a consistent and restrained behaviour.

These features are all built up by well known cognitive building blocks; executive function, cognitive flexibility, working memory and attentional control – processes that are effectively studied in experimental animals. Studying maternal behaviour in rats was therefore where Professor Fleming started out, only later transitioning into the field of human mothering studies. Presenting with the advantage of allowing experimental manipulation, rat studies can, however, not mirror the complexity of human mothering behaviour. "In humans, we are left to correlational studies, for example measuring the hormones in blood or saliva as a mother engages with her offspring", says Professor Fleming, adding that although the study techniques are different, the questions they ask of animal and human mothers are similar.

It is obvious that the process of mothering may depend on brain circuitry in animals and humans alike – but what constitutes the changes in the body and brain when a woman transitions into motherhood?

HORMONAL SHAPING

The cascade of hormones a woman is subjected to during pregnancy and birth is a well studied phenomenon, likely to increase the mother's attraction to infant cues and impact her affective state. A typical pregnancy presents with high and shifting levels of progeserone, estrogens and lactogens/prolactin, and a parturitonal rise in oxytocin.

In nursing mothers, the postpartum period, in turn, is characterized by elevations in levels of prolactin and oxytocin and a reduction in the stress response (see work by Barbara Woodside and Dominique Walker). Both prolactin and oxytocin are strongly linked to formation of attachment in a mother infant pair, and a mother typically displays high levels of oxytocin both during affectionate interactions and while engaging in attachment related thoughts. These effects of prolactin and oxytocin are believed to be a result of earlier priming of the brain by oestrogen.

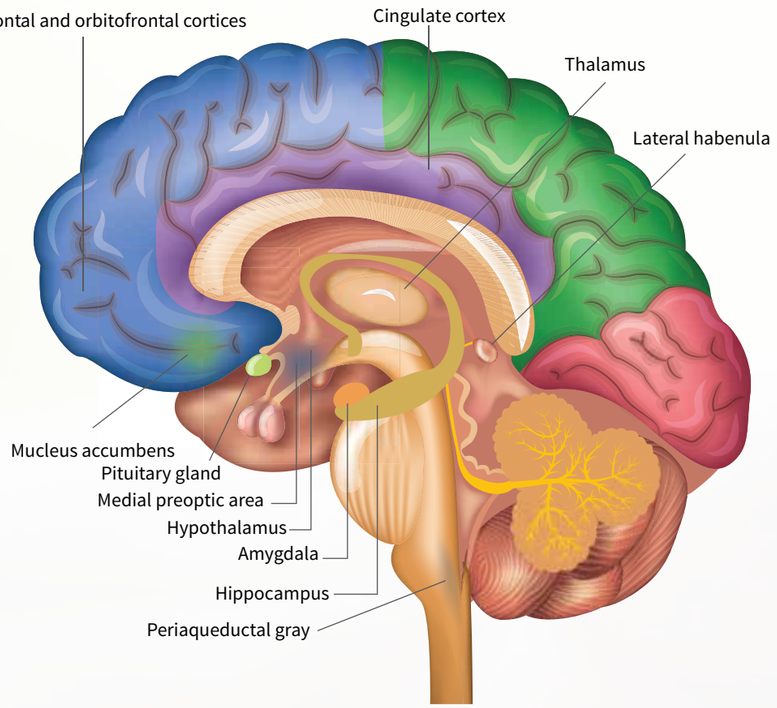
Consistent with rat studies by Bob Bridges, Harold Siegel, and Cort Pedersen, research by Professor Fleming also shows that in human mothers a robust increase in the ratio between estradiol and progesterone, during the period from early to late pregnancy, is associated with strong attachment, thus displaying the profound effects of hormones on the maternal brain. Mothers, in which this shift in ratio during pregnancy was larger, also experienced higher levels of feelings of nurturance and well-being post partum – another predictor of stronger attachment.

Yet another hormone – cortisol – which we usually associate with a negative stress reaction, are also associated with maternal feelings and behaviour. Cortisol levels at day 3-4 post partum are strongly associated with approach behaviour, positive maternal attitude and more vocally active infants. They are also associated with more positive reactions to infant odors and an enhanced ability to recognize own baby 's odors in a choice test. Later in the post partum period, nevertheless, cortisol might have the opposite effect, contributing to a negative mothering development. The relation of these cortisol effects with effects of oxytocin is now being explored in new mothers.

NEUROANATOMICAL KEYSTONES

But how is it then possible that shifting levels of hormones affect the way we behave? Professor Fleming has a specific interest in investigating the neuroanatomy of mothering with the help of functional neuroimaging. "To understand which brain areas are involved in mothering behaviour, it is necessary to look for the neuroanatomical correlates of the behavioural constituents", says Professor Fleming. Prior research, employing neuroimaging techniques, has provided insight into the anatomical counterparts of the reward system, regions handling emotion and affect, as well as the parts of the brain handling executive function.

Animal studies have identified a number of brain regions that are involved in maternal behaviour. Human behaviour is naturally far more complex, and a human mother taking care



THE MATERNAL BRAIN

The medial preoptic area (MPOA) of the hypothalamus is the brain's mothering centre – shaped by maternal hormones. The hypothalamus and pituitary produces oxytocin and prolactin. Oestrogen and progesterone also promote neuronal branching in hippocampus – an area crucial for memory and learning. The cingulate-, prefrontal-, and orbitofrontal cortices are regulating features such as empathy, impulse control and attention. Neural projections from cortical regions enter MPOA, along with input from sensory neurons and from amygdala – a region mediating affective states. From the MPOA neural projections run to the ventral tegmental area and to the periaqueductal grey, which are, along with the nucleus accumbens, lateral habenula and thalamus, also involved in mothering behaviour.

of her infant likely employs the greater part of her brain in the process. "A way to reduce this complexity while studying human mothering, is to focus on neural systems associated with social behaviour, emotion perception or regulation, action initiation and stimulus salience," says Professor Fleming.

In this way, Professor Fleming has built on discoveries made by colleagues (especially Michael Numan) who have identified a mothering pathway, involving a specific area of the hypothalamus, with neural projections going into the midbrain and hindbrain. Professor Fleming and her students have focussed primarily on Information from sensory, limbic, and cortical systems which project back onto the mothering pathway. They have explored in both animal models and humans the effect on the maternal system of limbic pathways that mediate affect, stimulus salience, and reward (especially amygdala and nucleus accumbens); as well as the prefrontal and cingulated cortical systems that mediate executive function, impulsivity, and attention. They have also explored, along with many other scientists (including Craig Kinsley, Liisa Galea, Frederic Levy, Joe Lonstein and their colleagues) how these structures in the maternal brain also show plasticity and can be changed by experience. While these neuropsychologic systems may be viewed as secondary in affecting the quality and intensity of mothering, the hypothalamus is viewed as imperative for mothering (in animal models), not least because it contains receptors for all the hormones involved in the activation of maternal behaviour.

HINDRANCES IN MOTHERING'S WAY

While the assumption that mothering comes 'naturally' when a baby is born is strongly believed, under certain circumstances there is a risk of mothering becoming compromised. The emotional ups and downs of the early post partum period (the so-called 'blues') is a well-known phenomenon, with up to 85% of women experiencing mild to moderate lability with depressive symptoms post partum. It has been hypothesized that the rapidly changing affect might serve as a way to heighten the early impressions and experiences of the baby, hence promoting attachment. When the depression is more serious and more long-lasting (in up to 18% of North American mothers), however, a less than optimal situation arises.

Depression in the post partum period can have deleterious effects on cognitive, emotional, motor and neural development of the infant. These effects can be observed already after a few months post partum, with noticeably less mutual attentiveness, vocal and visual communications, touching interactions and smiles in depressed mother infant pairs. More importantly, it is also associated with the development of psychopathology in the child later in life. There are many theories as to the hormonal and situational factors that increase risk of postpartum depression, however the causes are still little understood. Fortunately, in most mothers postpartum depression remits by 6 to 8 months after the birth and is amenable to supportive interventions and/or antidepressants.

Also, among the most influential factors for how a woman behaves when she becomes a mother, is how she herself has been shaped by early experiences. The qualitative aspects of mothering, such as warmth, vocal and visual exchanges, physical interaction and contingent responding, are extremely important for the healthy development of a child. Likewise, parental neglect, as well as physical, sexual or emotional abuse, has a strong negative impact on the attachment between a mother and her child, hence shaping the entire development.

Data from animal studies show a strong intergenerational effect of these qualitative aspects of mothering, and there is evidence for intergenerational transmission of parenting style and degree of bonding and attachment also in humans. In fact, the biggest risk factor for child abuse is a history of abuse of the mother.

Connecting these phenomena is evidence that both depression and early adverse experiences are tightly linked to a hyperactive stress response. This abnormal stress response in turn seems to contribute to the negative effects on maternal sensitivity and executive function. Early adverse experiences are also potentially interfering with mothering behaviour through psychopathology, since adverse experiences in childhood are strongly associated with the development of depression and anxiety later in life. Protective factors such as social support in the environment in the form of other relatives, community members, friends, or professional interventions can, however, break this potentially vicious circle.

Professor Fleming likes to think of mother infant interactions as a dance, and with this tender notion in mind, she enthusiastically continues investigating the steps and missteps characterizing mothering.

Researcher Profile

Professor Alison Fleming
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As an undergraduate student, Professor Alison Fleming got hooked on psychology, choosing the subject over her English and history majors. This interest led to a lifelong research career trying to understand the biological basis of mothering behaviour. She is now the principal investigator of the Psychobiology of Maternal Behaviour Lab at the University of Toronto. Starting out by studying maternal behaviour in rats, she now focuses on animals and humans alike in her attempts to gain more knowledge about how physiology and the environment act and interact to enhance women's motivation to mother.Professor Fleming has received several prestigeous awards; the University of Toronto Excellence in Research Award in 2003, the UTM excellence in teaching award in 2005, a Canada Research Chair in Neurobiology in 2006 and in 2013 she received the Daniel S Lehrman Lifetime Achievement award from the Society for Behavioral Neuroendocrinology. She was also inducted into the Royal Society of Canada in 2004. Her passion for mothering goes beyond the professional, and her four daughters, two in-laws, and two glorious grand daughters are the recipients of that passion. In her spare time, she engages in her new avocation, perfect for retirement, as can be seen above.

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