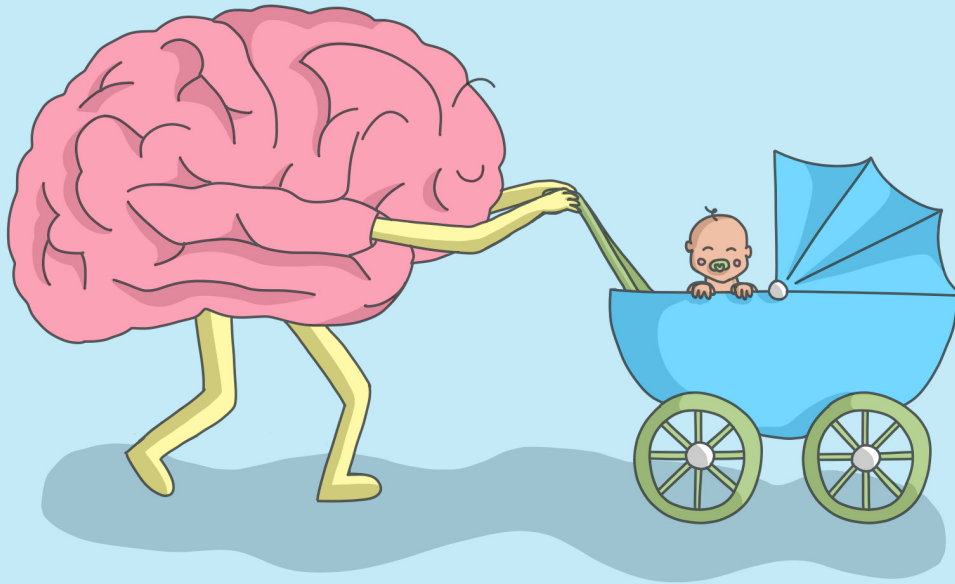


WHEN THE



BRAIN HAS A BABY

BY MATTHEW MCCORMICK
ART BY RIDWANA RAHMAN



Motherhood is the journey a woman embarks on that drives a multitude of changes that reshape the lives around her and the billions of neurons that form her brain. A mother typically entails a female who has given birth or raised a child; however, the concept expands beyond biological definitions, encompassing all those who take on the role of motherhood. This includes, but is not limited to, those who adopt or are surrogates. However, this article will focus on the neurological changes that occur in those who have given birth. These neurological modifications, as research indicates, prepare the brain for motherhood [1]. The mother-infant dynamic significantly alters a mother's brain through neuroplasticity as well as oxytocinergic and dopaminergic activity shifts. These shifts can have profound effects on their parenting behaviors and, in turn, child development. A child's early development directly correlates to their mother's mental health, as maternal figures who have poor mental health are more likely to raise children with poor overall general health [2]. Despite its valuable applications to women's mental health, our understanding of maternity neuroscience remains at a relatively fundamental level. However, promising research elucidates the possibility of new cell growth in the human maternal brain, which could have extensive applications on maternal health. Through research, understanding, and application of the neurological underpinnings of how motherhood changes the brain, a stride toward understanding and effectively treating maternal mental health issues can be initiated.

SHAPING MOTHERHOOD

Motherhood, a life-altering physiological and psychological event, affects a woman's physiology and neurology in remarkable ways. Evidence suggests that these changes are accompanied by the reshaping of structures in the brain, known as neuroplasticity. Neuroplasticity is the process by which the brain reorganizes its structure whilst adapting to experiential changes by forming new neural connections or weakening existing ones [3]. The phenomenon improves and strengthens brain systems in the mother's mind through critical processes such as learning and formulating memories to enhance adaptation to new

experiences throughout our lives [3]. In motherhood, neuroplasticity specifically influences a tissue in the brain and spinal cord, referred to as grey matter, to potentially enhance or diminish its function. Grey matter consists of neuron endings and cell bodies that specifically support information processing in the nervous system [4].

An increase in grey matter results in enhanced cognitive processing, better memory, and greater emotional regulation; conversely, a decrease often sequels poor memory and/or an increased risk of developing a mood disorder [4]. Moreover, in a mother's brain, grey matter plasticity activity contributes to the motherhood circuit, which is the strengthened class of brain structures that cooperate to prime vital, emotional, and social cognitive brain systems for motherhood. Central brain structures encompassed in this circuit are various subcortical regions, including the prefrontal cortex and orbitofrontal cortex, which are necessary for cognitive processing and decision-making. Occupying approximately one-fifth of human brain volume, the subcortical area consists of extensive connections with brain structures that are necessary for emotional and memory processes [5]. In addition, the orbitofrontal cortex processes and integrates sensory information, decides whether a stimulus is good or bad, and makes decisions accordingly. Through neuroplasticity, connections among these essential maternal brain systems can be strengthened or weakened, ultimately presenting adaptability to the brain [6].

An increase or reduction in the grey matter of interconnected structures, including those in the maternal caregiver circuit, not only results in a modified attention span and altered emotional sensitivity, but a shifted navigation through the difficult process of motherhood [4, 3]. Specifically in the motherhood circuit, mothers experience a decrease in grey matter in major subcortical structures such as the hypothalamus, hippocampus, and amygdala, as well as the prefrontal cortex [1]. The decreased grey matter volume in these areas further facilitates and reinforces a mother's ability to recognize and respond appropriately to their infants' needs, while also inducing what is commonly referred



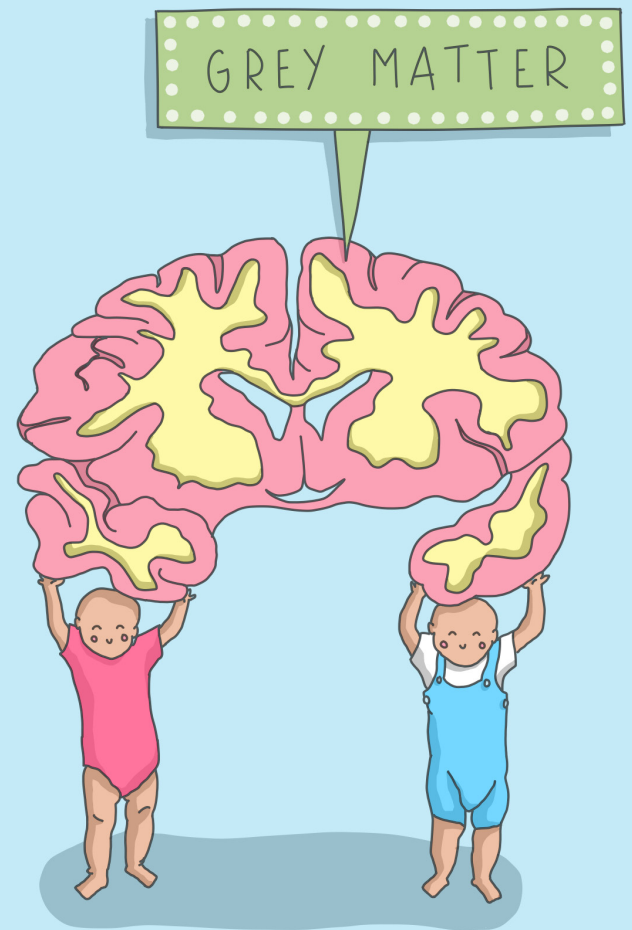
General Editor: Rudra Dave | Graduate Scientific Reviewer: Nikkita Salla
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to as “Pregnancy Brain” [5]. This phenomenon refers to the mental state resulting from these changes, typically characterized by poor memory and trouble concentrating. These reductions are quite significant, as one study found that, up to six years postpartum, researchers were able to differentiate between which brain had gone through pregnancy versus not [1]. The cause and effect of loss in brain mass during parenthood is unknown: however, it is not necessarily a negative thing, as this could simply be the brain’s way of depleting the neural networks it does not need [7]. Although neuroplasticity largely governs the transformations that the human mind makes during parenthood, it is important to understand these changes are further underpinned by pivotal neuroendocrine modulations, or variances in how nerves release hormones into the bloodstream [8].

THE CHEMICAL BEHIND CONNECTIONS AND CHILDBIRTH

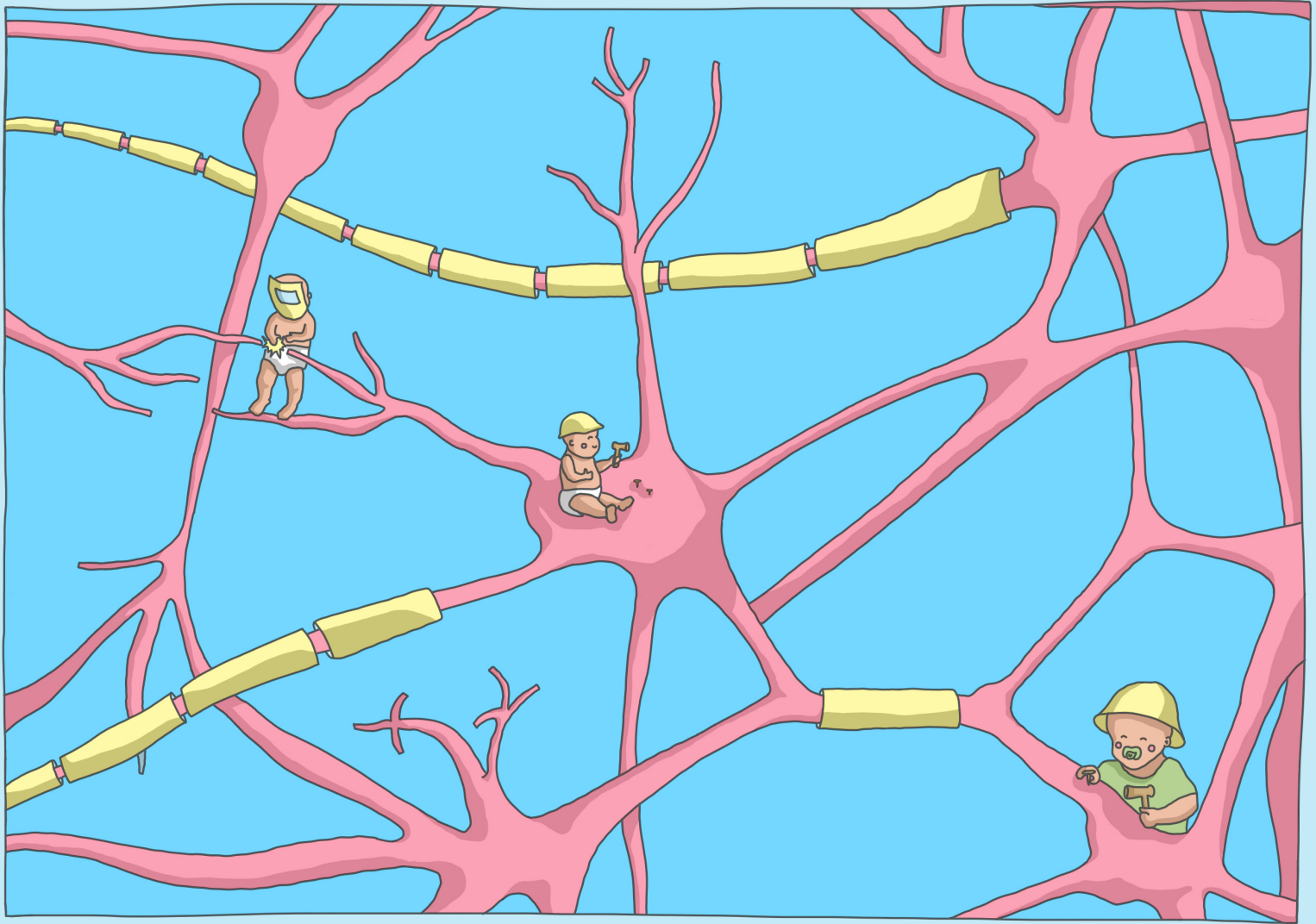
One neuroendocrine force behind a mother’s biological condition of being drawn to their child is largely due to the neuromodulatory hormone known as oxytocin. Oxytocin is produced in the hypothalamus which is a brain structure associated with regulating mood, hunger, and sex drive. Linked to the feelings of love, trust, arousal, and sexual activity, oxytocin plays a vital role in supporting the facilitation of emotions produced by the mother-infant dynamic. Moreover, it is central in maternal behaviors such as uterine contractions, milk nourishment through lactation, and bonding with the child [8]. Oxytocin levels tend to increase in mothers through more affectionate parenting behaviors, such as gazing and touching. In addition, research suggests a positive correlation between oxytocin levels and mother-infant contact in the infancy period [8].

Understanding the function of oxytocin and its role in motherhood becomes particularly significant when talking about postpartum blues (PPB). Postpartum blues are attributed to the onset of a low, mellow mood with mild depression within ten days postpartum [9]. Oxytocin levels, along with that of other maternal hormones, pose a noticeable correlation to PPB. Additionally, there is an interesting correlation between cesarean sections and increased risk to the PPB [10]. In a comprehensive study lasting 36 weeks, researchers collected salivatory samples from mothers four different times over the allotted period. Researchers found a substantial decrease in oxytocin levels in postpartum mothers who had gone through a cesarean section versus delivery type [11]. Noting the link between



PPB and reduced oxytocin, women who received an emergency cesarean section rather than a vaginal delivery reported higher rates of PPB symptoms in just two days postpartum [10]. This suggests women may be exposed to an increased physiologically disturbed state postpartum after receiving an emergency C-section [10, 12]. The reductions in oxytocin levels and consequently low mood could be attributed to the rush of oxytocin a mother receives during childbirth to relieve pain and stress, and further promote the social bond between her and her child [13]. Exploring the connection between important hormones like oxytocin and postpartum blues can further present more defined emotional and physiological factors of maternal well-being, and refine the postpartum experience for women. Although crucial neuroendocrine changes prove to be sufficient in influencing adult brain structures, research links other neurobiological changes that contribute to the remarkable transformation.

The field of maternal neurological research is continually evolving. Amid the evolution, researchers are finding different neurological



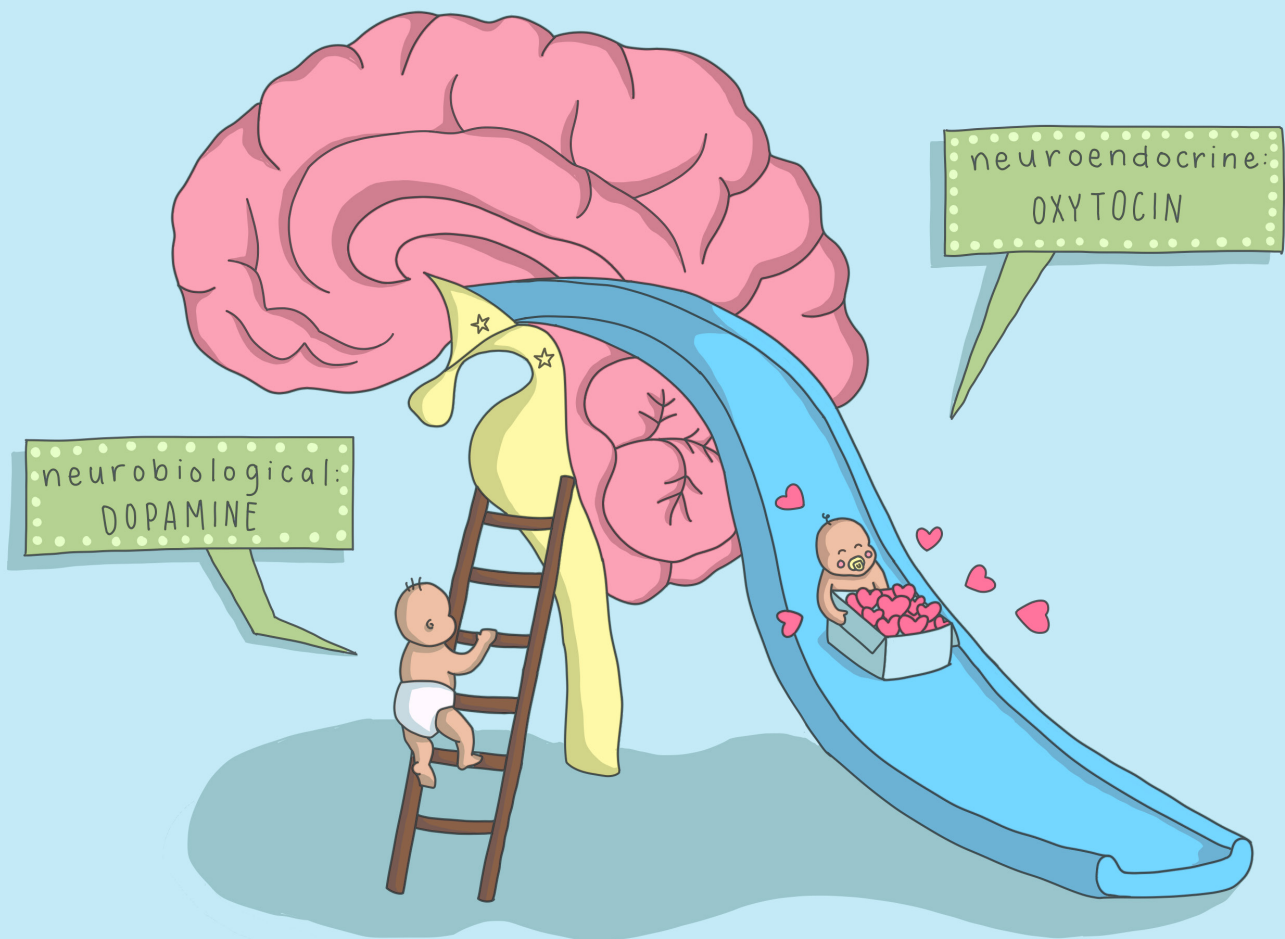
shifts to be present and responsible in a mother's brain for playing a significant role in initiating and maintaining a relationship with her child. One of which is through bonding. Bonding is the individualized first experience shared between a parent and their child. Bonding experiences between a parent and their child, including skin-on-skin contact, embracing, holding, kissing, and even eye contact, are subtle but significant interactions that lead to an emotional bond that further serves as the infant's first close relationship [14]. Maternal bonding research finds that mothers are able to identify and prefer their child's natural body odor to other children. This bonding phenomenon can only be found in mothers due to the neuroplasticity and neurochemical signaling present in the brain [10, 15]. Through these initial bonding interactions, different brain structures in the motherhood circuit experience neuroplasticity and 'rewire' themselves, one being the reward system [1].

MATERNAL DOPAMINE AND DYSFUNCTIONS

Dopamine is a neurotransmitter associated with many brain

processes that primarily manage motivation, incentivized behavior, purposeful movement, and addiction. The mesolimbic dopamine system pathway, or the neural circuit that receives dopamine inputs, starts in the midbrain, hence the Greek prefix 'meso-' meaning 'middle'. Particularly in the midbrain, the ventral tegmental area (VTA) projects dopamine onto the ventral striatum (VS). Within the VS, dopamine synapses and activates the brain area heavily associated with reward and motivation, known as the nucleus accumbens (NAcc). When projected and activated onto the NAcc, the mind psychologically feels the effects of dopamine, which now becomes sufficient enough to cue a rewarding behavior [16].

Studying dopaminergic activity, or activity involving dopamine, in maternal neuroscience research is essential to elucidate how dopamine and motherhood relate to each other. Consistent studies reveal an increased activation of dopamine pathways in mothers when spending time with their infants [14]. One study recruited mothers and showed them a picture of their infant



compared to a child that was not theirs. Researchers concluded that greater activation in the reward parts of the brain, specifically the VTA and orbitofrontal cortex, was generated when shown a picture of their child versus an infant that was not theirs [1]. Inversely, the dysfunction in the mesolimbic dopamine system, or the neural circuit that receives dopamine inputs, during pregnancy and postpartum implicates symptoms of postpartum depression, a condition experienced by almost fourteen percent of mothers [17]. If left untreated, it can persist for years.

Postpartum depression (PPD) is characterized by disruption in sleep, impaired mood, social isolation, and sometimes suicidal ideation. Regarded as the most common complication of childbirth, PPD is also the largest cause of death for postpartum women [18]. PPD is different from PPB in that the symptoms are more intense and persist longer. The risk factors of PPD are still being studied today; however, environmental stressors like poor peer support, genetic factors, or an overall stressful personal life may predispose mothers to PPD [19]. The onset of symptoms appears approximately six weeks before childbirth, coinciding with arguably the most demanding stage for a mother and the most vulnerable for an infant. Symptoms include reduced vocal

communication, less smiling, decreased visual cues, and overall less affection towards an infant, creating emotional distance between a mother and her child [18]. This disrupts bonding and can create future mother-child relationship issues, as research shows poor mother-child relationships retrospectively cause higher levels of daily physiological anxiety and distress for both the mother and child [20]. Despite PPD's prevalence, existing studies remain rather ambiguous on etiology and risk factors, similar to postpartum blues. Understanding and continuing to study the neurological influences of hormonal fluctuations and genetic factors allows us to target the needs of individual mothers and their struggles, while also allowing us to explore other neurological influences.

GIVING BIRTH TO NEW CELLS

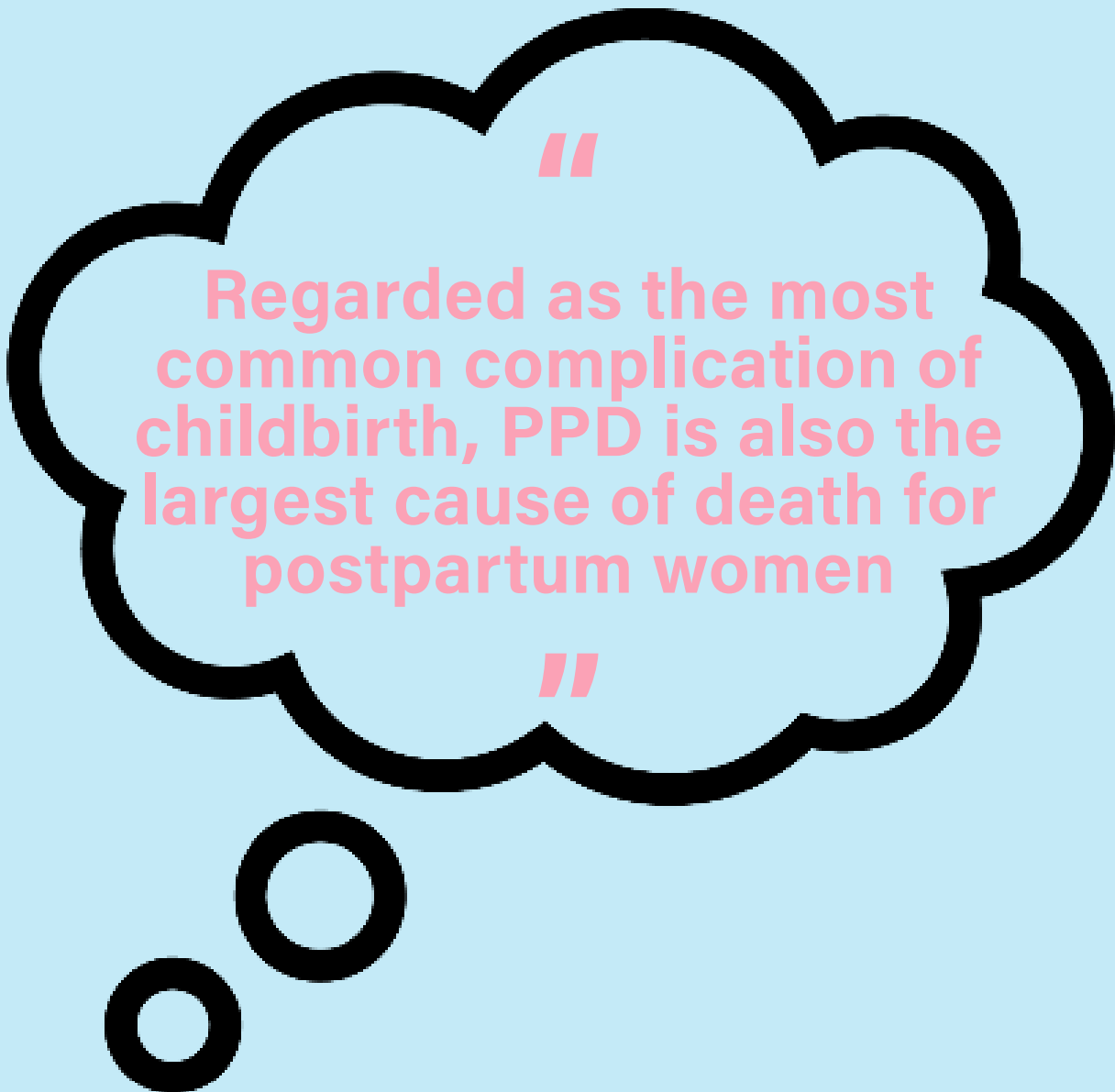
Although the discussed role of neuroplasticity, neuroendocrine, and neurobiological processes are imperative for priming motherly instincts, another phenomenon has been found to possibly play a role in motherhood: neurogenesis. Unlike neuroplasticity - the formation of new connections within the brain - neurogenesis is the growth of new neurons from stem cells and has recently surfaced as a fascinating field of study, specifically in

maternal research. First established in humans during the 1990s, neurogenesis is a relatively new research subject that has been scarcely studied in humans; however, animal research ignites curiosity about potential translations to humans [21]. Research shows in adult postpartum mice, profound hormone fluctuations during pregnancy and postpartum prompt neurogenesis, specifically in the subventricular zone (SVZ) and olfactory bulb. The creation of neurons is targeted in areas associated with cell renewal and olfactory processing. In humans, neurogenesis can be seen at a low level in the maternal olfactory bulb [21, 22]. Despite the lack of studies, human maternal research suspects neurogenesis occurs in the SVZ and olfactory bulb to prepare a mother for bonding [21]. While numerous mothers claim their smell changes during pregnancy, research can not confidently pinpoint an association between neurogenesis and maternal brain processes involving olfactory processes. Although it is highly probable that neurogenesis influences the maternal brain in some way, researchers acknowledge the complexities that

surround the topic and continue to work on constructing innovative studies [22]. Working toward finding potential influences of neurogenesis on the maternal brain advances awareness of maternal brain health and the overall neurological changes experienced in motherhood.

CONCLUSION

Interpreting the neurological changes and their underpinnings of how motherhood unfolds in the brain can further help us conclude how the maternal brain reacts to childbirth, which can shed light on proper treatments for mental health issues such as postpartum blues or postpartum depression. Throughout motherhood, a woman's mind experiences a substantial array of neurological changes, from structural shifts to hormone abundance & depletion. Although studies regarding the neuroendocrine and neurobiological impact on motherhood are limited, future studies relating to neurogenesis work towards disclosing effective maternal mental health treatments. 🧠



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