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Intergenerational Transmission of Depression: Clinical Observations and Molecular Mechanisms

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Abstract

Maternal mental illness can have a devastating effect during the perinatal period, and has a profound impact on the care that the baby receives and on the relationships that the baby forms. This review summarises clinical evidence showing the effects of perinatal depression on offspring physical and behavioural development, and on the transmission of psychopathology between generations. We then evaluate a number of factors which influence this relationship, such as genetic factors, the use of psychotropic medications during pregnancy, the timing within the perinatal period, the sex of the fetus, and exposure to maltreatment in childhood. Finally, we examine recent findings regarding the molecular mechanisms underpinning these clinical observations, and identify relevant epigenetic and biomarker changes in the glucocorticoid, oxytocin, estrogen and immune systems, as key biological mediators of these clinical findings. By understanding these molecular mechanisms in more detail, we will be able to improve outcomes for both mothers and their offspring for generations.

Introduction

The perinatal period represents a time in which substantial brain development of the offspring occurs: during pregnancy, where the fetal genetic makeup interacts with maternal biology, and postnatally, influenced by the primary caregiver for nourishment, security and emotional regulation[1,2]. It is perhaps then no surprise that maternal mental disorders during this period, such as depression and postpartum psychosis, may have profound effects on the child's social, emotional, behavioural and cognitive development.

Maternal depression affects 10-15% of new mothers in both pregnancy and the postpartum period. It is associated with symptoms such as pervasive sadness, fatigue and rumination, which could impact mothers' ability to bond with the baby *in utero* or postnatally, which may lead to a lack of mothers' responsiveness to infant cues and to a disruption in the mother-child relationship.[3,4] Postpartum psychosis is far less common than postpartum depression, occurring in 1-2 of 1000 childbearing women within the first 2-4 weeks after delivery[5]. It presents as early as 2-3 days after childbirth, with symptoms such as mood swings, confused thinking, grossly disorganised behaviour and paranoid, grandiose or bizarre delusions, and can severely impair the mother's ability to look after her child, often resulting in temporary separation.

There are consistent findings showing that the offspring of mothers suffering with perinatal mental health problems are more likely to have a psychopathology diagnosis in later life. This is likely to be influenced by the interplay of inherited genetic and epigenetic profiles, 'fetal programming', changes in neuroendocrine systems, and the experience of maternal care. This review starts by discussing clinical evidence of the effects of perinatal mental disorders on offspring outcomes, including the factors moderating this relationship, then explains some proposed biological mechanisms for this intergenerational transmission of psychopathology. Most of the evidence comes from studies on perinatal depression, although it is important to note that, in a majority of cases, perinatal depression is experienced together with clinically-significant anxiety[3]. It is therefore likely that the high arousal levels due to anxiety have a large contributory effect on parenting ability and perhaps on the biological mechanisms explained here, so this research has been included where appropriate. Much less research has been conducted on the consequences of postpartum psychosis on the offspring, and this evidence will be briefly considered in terms of the neuroendocrine and genetic alterations that accompany this disorder.

Clinical Evidence

Developmental Outcomes in Childhood

A mother's attachment to her baby can be strongly influenced by her experience of depressive symptoms, resulting in difficulty bonding and non-optimal maternal behaviours. In turn, a baby's early attachment relationship with the primary caregiver has a strong impact on its emotional regulation throughout development into adulthood[6]. Indeed, research suggests that offspring of depressed mothers typically show more behavioural difficulties[7]. The resulting attachment relationship can therefore be strained and affect multiple areas of the offspring's emotional, behavioural, cognitive and social development.

The main offspring abnormalities associated with perinatal psychopathology have been extensively reviewed before, for example recently by Stein and colleagues[3]. Hence, we concentrate here on reporting the most robust findings obtained in the largest available cohorts, which have usually investigated perinatal depression. These cohorts include: in the UK, the Avon Longitudinal Study of Parents and Children (ALSPAC)[8–12], a birth cohort study with 14,000 women recruited in pregnancy; in Canada, the National Longitudinal Survey of Children and Youth (NLSCY)[13,14], with over 35,000 children and their mothers, and the Quebec Longitudinal Study of Child Development (QLSCD)[15], with over 2000 children; and, in the Netherlands, the Generation-R cohort[16–18], with nearly 10,000 mothers recruited in Rotterdam, and the Tracking Adolescent's Individual Lives Survey (TRAILS)[19] with a population of 2230.

The most robust findings from these large cohorts are summarised in Table 1: they demonstrate an overall increased risk of internalising and externalising difficulties, as well as of low IQ, in the children of mothers suffering from perinatal depression. Antenatal depression, but not postnatal, is also associated with increased risk of depression in the offspring that manifests in adolescence and young adulthood, as further discussed below. However, it must also be noted that many other studies, although often with smaller sample sizes, do not find any such significant associations[20,21], or even present contradictory findings[20]. Some of these other studies, for example, have found that perinatal depression alone has no significant impact, but, when comorbid with perinatal anxiety, it impairs development of the offspring.

There are far fewer and smaller studies investigating the developmental impact on offspring of mothers experiencing psychotic symptoms. Interestingly, compared to women with depression, women with postpartum psychosis have no impairment in bonding, possibly because they do not share the same negative cognitions, and feelings of inadequacy and self-doubt, that influence the bonding experience of depressed mothers[22]. Still, mothers with psychosis appear similar to depressed mothers in interactive behaviour, with impaired responsiveness and less patience than mothers with no mental health problems, and one study found disturbances in both the bond to the infant and the interaction between mother and infant in this type of patient[23]. Interestingly, when mothers have delusions that the baby might be in danger, they are more likely to show affectionate behaviour and normal competence and care for baby's basic needs; in contrast, when mothers have delusions that the baby is a devil or ill-fated, or is someone else's baby, they are more likely to have significant abusive incidents towards the baby[24]. This points to an important role not just for the

diagnosis or the presence of symptoms, but also for the content of the symptoms that characterise the presentation.

[TABLE 1 AROUND HERE]

Psychopathology in Later Life

Research has recently focused on 'intergenerational transmission' of maternal psychopathology to offspring, resulting in psychopathology later in life. Various studies have found that maternal antenatal depression is linked with offspring depression in adolescence and young adulthood[10,25]. The first study to describe this finding was the South London Child Development Study (SLCD), which includes 151 mother-child dyads and has found that adolescents exposed to antenatal depression have approximately 5-fold greater risk of depressive symptoms at age 16 than those not exposed[25]. The subsequent, much larger ALSPAC cohort has reported the increased risk of adolescent offspring mental disorder at 2-fold, compared with controls[26], probably because it examines depressive symptoms in the community, as opposed to clinically-diagnosed depression in the SLCD study. A subsequent SLCD study paper has confirmed these findings when the offspring are young adults, at age 25[27]. Antenatal depression also increases the risk of offspring being diagnosed with emotional disorders by age 16[28], and anxiety disorders by age 18[29]. Finally, a recent study has shown that maternal mood symptoms during and after pregnancy are risk factors for the development of disruptive mood dysregulation disorder by 11 years[30].

These effects of antenatal depression are likely to be mediated, at least in part, by biological changes in the *in utero* environment, as we extensively discuss below. However, postnatal factors are also very important: one proposed mechanism for this 'transmission' of depression from parent to offspring is via impaired parenting[31], as shown by behaviours such as parental withdrawal and parental intrusion[32], which are more common in mothers suffering with mental health problems. In contrast, a good parental environment, showing low levels of maternal over-involvement and high maternal warmth, produces higher resilience in offspring[33].

Interestingly, children born before 32 weeks' gestation are 3-fold more likely to have depressive disorder than those who grow to term[34], perhaps suggesting a further role for incomplete fetal development in the risk for psychopathology. As pre-term birth is associated with perinatal depression[35,36], this could be another mechanism by which depression is 'transmitted' from mother to offspring.

Potential Confounding Factors

Despite the evidence suggesting a link between perinatal depression and an increase in developmental impairment and psychopathology in offspring, this should not be interpreted as indicating a deterministic relationship, as there are several factors which may confound or moderate this association. These factors operate from pregnancy through to the early life of the offspring, with a broad range of consequences, from buffering against the negative impact of perinatal psychopathology, to exacerbating its effects. Some of the best-studied of these include the role of

genetics, maternal childhood maltreatment and use of antidepressants during pregnancy. These factors will be discussed below. Other less studied factors, including the role of the father, feeding habits and the timing of mental health problems, are reviewed in Stein's paper[3].

Genetics

We cannot ignore the role of genetic inheritance in the intergenerational transmission of psychopathology, as a recent review on this topic clearly states[37]. The genetic heritability of major depressive disorder is well-established, with particularly robust evidence coming from twin studies, reporting around 40% heritability in women and 30% in men[38]. In addition to this, a major risk factor for adolescent psychopathology is family history, particularly parental depression[39]. More recently, the genetic influences on postpartum depression have been established, with the most common genes relating to major depressive disorder, such as those involved in the metabolism of key neurotransmitters, also showing an association with postpartum depression[40] (some of the most robust findings are also discussed below, with reference to the relevant biological mechanisms). In addition, a genome-wide linkage study has identified the hemicentin 1 gene locus, to be associated with postpartum depressive symptoms[41]. Overall, one study recently reported that the heritability of perinatal depression as shown by a twin study design was 54%, whereas when using a sibling design, heritability was estimated at 44%. Interestingly, further analysis reported that 14% of the total variance in perinatal depression was unique for perinatal depression[42].

It is likely that the genetic predispositions for major depressive disorder and perinatal depression overlap substantially, and thus it is difficult to disentangle this genetic inheritance effect from the impact of environmental factors, either because of transmission of heritable genetic variants, or because of the role of genetic variants as moderators of the effects of the prenatal environment, through gene x environment interactions.

In terms of transmission of heritable genetic risk from mothers to offspring, one approach that has attempted to disentangle this has been the use of a prenatal cross-fostering design including mothers either related or unrelated to their child as a result of *in vitro* fertilisation. In one such study, the reported association between prenatal stress and offspring outcomes show different genetic effects, i.e., prenatal maternal anxiety and depression predict offspring anxiety or antisocial behaviour in both related and unrelated mothers, while the link between prenatal stress and attention deficit hyperactivity disorder (ADHD) is explained solely by the genetic contribution[43].

A number of other study designs have confirmed that the intergenerational transmission of psychopathology is influenced, or moderated, by a genetic component. For example, the effects of low birth weight in increasing the risk of depression are stronger in children of depressed parents than in children with no such family history, indicating a genetic influence[44]. Indeed, several genetic variants have been found to moderate the relationship between birth weight and children's social and emotional development, including classical 'psychiatric genes' such as the serotonin transporter[45] and the dopaminergic receptor D4[46]. As depression in pregnancy is associated with low birth weight[35], it is likely that genetic variants also moderate the association between psychopathology in pregnancy and psychopathology in offspring. Indeed, recent reports found that a polygenic risk score for depression moderates the effects of antenatal depression on babies' brain

development in the first days of life[47], and a polygenic score based on genes coexpressed with the serotonin transporter predicts the effects of prenatal adversities on children's behavioural problems at 4-5 years[48]. Interestingly, this latter polygenic score seems to identify children that are not only more susceptible to prenatal 'adverse' environment, but also more likely to benefit from a 'supportive' prenatal environment[49].

While GWAS-driven or biologically-informed polygenic scores have been used most frequently so far, it is also of note that we have recently published a cross-species approach, integrating data from a rat model of prenatal stress and human exposure to childhood maltreatment, which also identifies SNPs which show significant gene x environment interactions between exposure to stress and depressive symptoms[50].

Childhood Maltreatment

There is a growing body of evidence suggesting that childhood maltreatment is a key moderating factor in the development of adolescent psychopathology in the offspring of depressed mothers[27,51,52]. A study conducted by our group[51] has shown that children exposed to antenatal maternal depression are twice as likely to report having experienced childhood sexual or physical abuse or harsh parenting by the age of 11 years, while such link is not present in the case of postnatal depression. Furthermore, offspring who have been exposed to both antenatal depression and childhood maltreatment are almost 12-fold more likely to have a diagnosis of depressive disorder or conduct disorder in adolescence, but exposure to one or other of these factors in isolation does not lead to an increased risk. We have recently replicated these findings in a subsequent follow-up of the offspring at age 25[27]. Interestingly, these studies also show that mothers suffering from antenatal depression are not more likely to be the sole perpetrators of maltreatment than healthy mothers; instead, the main perpetrators tend to be other close adults or even peers. Of note, a subsequent study conducted in the ALSPAC cohort has replicated the association between maternal antenatal depression and offspring exposure to childhood adversity[53].

Use of Antidepressants

Studying the risks and benefits of antidepressant use in pregnancy is very important, as this time represents a key point at which clinicians could intervene to optimise outcomes for unwell mothers and their babies. However, the issue is highly complex, due to the difficulties in disentangling the potentially toxic effects of any antidepressants that reach the fetus via the amniotic fluid[54], from the negative effects of untreated depression itself[55]. Then, after birth, the picture becomes more complex still, as the effect of any antidepressants (or metabolites) transmitted to the baby through lactation must be weighed against the impact on the parenting behaviours of the mother due to her depressive symptoms.

The amount of research addressing the impact of antidepressants on a developing fetus or infant is substantial, especially for selective serotonin reuptake inhibitors (SSRIs), often the first-line treatment. SSRI use has increased during pregnancy in recent years, with up to 13% of pregnancies in both Europe and the US now involving exposure at some point[56,57]. The potential adverse effects

of antidepressants on the risk of congenital malformations have been extensively reviewed before[58,59], and therefore will not be discussed here. In general, studies report that increased duration of antidepressant exposure is significantly associated with non-optimal obstetric outcomes, such as reduced gestational age, decreased birth weight, and increased risk of respiratory distress in the neonate[60]. However, untreated depression also reduces gestational age and birth weight[35]. The risk of reporting bias must also be considered, namely that a higher frequency of negative outcomes is reported by those taking antidepressants, as they are likely to be more vigilant.

In terms of behaviour, neonates that have been exposed to SSRIs during late gestation show symptoms affecting the central nervous system as well as the motor, respiratory and gastrointestinal systems[61]. This neonatal 'abstinence syndrome' is present in up to 30% of exposed babies[62], and manifests as crying, tremor, reflux, jitteriness and sneezing, as well as sleep disturbances[63].

There is also some suggestion that drugs used to treat maternal depression may affect the neurobehavioural development[64,65] and psychomotor development[66] of offspring, as well as slowing their reaching of major developmental milestones, such as sitting and walking unaided[67]. However, other studies show these effects to be transient[68], and others do not find any association at all[69]. One study found that antidepressant dose and duration does not predict cognitive or behavioural outcomes, and that the IQs of offspring exposed to depression with or without antidepressant treatment *in utero* are similar, although lower than those of the offspring of nondepressed mothers[70].

While attention often focuses on the potentially toxic effects of psychotropic medications on a developing fetus, it is also important to consider the negative impact of depression in women not taking their medication. A study by Cohen *et al.*[71] has shown that 70% of depressed women who discontinue medication relapse during pregnancy, mostly in the first and second trimesters. It is also more likely that those who suffer from depression during pregnancy will continue to suffer from depression after birth[72], which may affect the care quality that the infant receives, further impairing development. There is also a significantly higher risk of self-medication in depressed pregnant women[28], such as smoking or consuming alcohol and other legal and illegal drugs, and this also affects birth weight and other outcomes. Furthermore, despite concerns that psychotropic medications may be transmitted to the infant during breastfeeding, current evidence suggests that most medications show little or no risk to the infant[73].

Although this is a very difficult decision for every woman, on balance current evidence suggests that the consequences of untreated depression, especially for clinically-significant cases of depression, are more severe than those of antidepressants[68,74–76], especially considering all the evidence reviewed in this paper that testifies to the profound and enduring negative consequences of antenatal depression on the offspring[74]. It is therefore vital that this risk of unmedicated depression is adequately evaluated before considering any detrimental effects of taking antidepressants.

Biological Mechanisms

There are many potential mechanisms which explain how an adverse intra-uterine environment can predispose to disorders later in life, including inflammation, epigenetic regulation, the development of brain structures, and placental mechanisms regulating the passage of stress hormones, such as cortisol[77], to the fetus. For postpartum psychosis, only few, very recent studies have started to evaluate the biological alterations in hormonal- and immune-mediated mechanisms, with biological samples usually acquired in the postpartum period. We will now review individual biological pathways, including specific genetic and epigenetic findings. For each pathway, we will first describe the available clinical evidence, and then we will present key preclinical evidence, where it adds further mechanistic insight.

Before we start this section, however, it is important to highlight the complexity involved in the interpretation of epigenetic findings. Indeed, recent research focusing on the intergenerational transmission of psychopathology, and on the associated maternal parenting styles, has proposed epigenetics as a key mechanism[78,79], with epigenetic changes occurring in the offspring in response to early life adversity[80] and abnormal parenting behaviours[81,82], and suggestions that these changes can be maintained over several generations by DNA methylation in the germline, although so far, pre-clinical evidence only supports this mechanism in the paternal germline[83]. As Szyf and Bick[84] suggest, DNA methylation is capable of "embedding early life experiences in the genome". However, it must be noted that epigenetic transmission does not need to occur only via the classical inheritance mechanisms. For example, if mother and offspring are exposed to similar environmental circumstances, they may develop similar epigenetic signatures independently of inheritance. Epigenetics may also be influenced by the effects of health-related circumstances on the growing fetus and developing child. For example, recent research shows that maternal obesity[85] can alter the methylation status of the infant, and maternal smoking can alter the methylation signature on the fetal side of the placenta[86]. Indeed, even the mode of delivery can alter the infant's methylation status, as measured in leucocytes[87]. MicroRNAs are also considered a possible mediator of intergenerational effects on child outcomes, and indeed in the aforementioned paper from our group[50] we have identified 68 miRNAs (out of a total of 1218 miRNAs) that are significantly modulated by prenatal stress in the offspring rat hippocampus. Contributing to this complexity is also the notion that non-genetic inheritance can occur in relation to psychiatric conditions, where traits or characteristics are transmitted via molecular substrates, such as hormones and cytokines, travelling from mother to fetus through cord blood[88] . Taken together, these lines of evidence demonstrate a need for caution when drawing 'deterministic' conclusions in the relationship between maternal behaviour and epigenetic changes in the offspring.

Hypothalamic-Pituitary-Adrenal Axis

The strongest body of evidence relating to perinatal psychiatry is that regarding the hypothalamic-pituitary-adrenal (HPA) axis, which not only has its own effects via different regulation of the glucocorticoid receptor or circulating cortisol levels, but also interacts with other major biological systems. For example, the interaction of estrogen and progesterone with the HPA axis is thought to

be crucial in the pathogenesis of perinatal depression, and has also been proposed as one of the pathophysiological mechanisms underlying the rapid onset of postpartum psychosis[89].

The Maternal HPA axis and its Effects on the Fetus

The accepted model postulates that exposure of the fetus to high levels of cortisol may result in subsequent effects on HPA axis, behaviour, and cognitive function of the offspring[90–97]. For example, elevated levels of corticotrophin releasing hormone (CRH) and cortisol[98–100] have been described in association with antenatal symptoms of depression. Moreover, studies have found associations between antenatal HPA axis and offspring HPA axis[101–103], or between antenatal HPA axis and infant behaviors or cognitive and motor development[104–107]. Interestingly, by adolescence, data shows that exposure to maternal anxiety during pregnancy may reduce the cortisol awakening response in offspring[108], thus showing a complex and dynamic relationship between depression/anxiety-related HPA axis hyperactivity in pregnancy and changes in offspring HPA axis. The exact molecular mechanisms underlying these associations are however still unclear[109]. Here we present some of these mechanisms.

Glucocorticoid Receptor and related genes

Glucocorticoid hormones, the final product of the HPA axis, play a crucial role during fetal development, in processes such as tissue maturation and cellular differentiation[110]. The glucocorticoid receptor (GR) is a central mediator in fetal programming and in the development and regulation of the HPA axis, and has thus been the focus of much research in recent years[111]. There are many factors which affect the function and expression of the GR in the placenta, with one study showing that up to twelve different isoforms are present, whose expression can be dictated partly by fetal sex, as well as fetal size[112]. Recently, attention has turned to the effects of stress on the epigenetic profile of the GR.

In humans, methylation of the GR gene in offspring is increased by parental psychopathology[113] and early-life trauma[114]. However, it must be noted that, aside from a handful of studies looking at post-mortem brains[115–117], human studies usually analyse the epigenome of peripheral tissues (most often, blood), which may not represent tissue-specific epigenetic changes occurring in the brain. Indeed, there is some debate about how reliable peripheral measurements are when compared to methylation changes in the brain. For example, one study in mice shows similar methylation changes of the GR-related gene, the FK506 binding protein 5 (FKBP5), in the blood and hippocampus following treatment with high dose of corticosterone[118]. Another paper demonstrates that a functional polymorphism in the FKBP5 gene increases the risk of developing stress-related psychiatric disorders by allele-specific, childhood trauma-dependent DNA demethylation, leading to a global effect on the function of immune cells and brain areas associated with stress regulation[119]. However, the blood-brain correlations may be smaller when using genome-wide analyses rather than individual, hypothesis-driven genes, or in other brain areas. For example, one study correlating epigenetic signatures in the blood and temporal lobe biopsy tissues shows that only 8% of

methylation markers are consistent in the blood and brain, although this is still more than expected by chance[120].

Antenatal stress also affects the epigenetic profiles of GR (and GR-related genes), but the effects in mother and infant are distinct. For example, maternal antenatal experience of war[121] or of intimate partner violence[122] increase the GR methylation status analysed in blood samples from the newborn, even into adolescence[122], while mother's epigenetic profile is unaffected. Moreover, pregnancy increases mRNA expression of the genes regulating the GR complex, FKPB5, BAG1, NCOA1 and PPID; however this increase is attenuated in women experiencing depression in pregnancy, indicating abnormal GR sensitivity[123]. While there are no data in pregnancy from women who later develop postpartum psychosis, samples collected in the postpartum period from women with current symptoms of psychosis show that a dysregulation of the GR is also present in these women[89].

In addition to this clinical evidence, rodent models have shown that expression of the GR can be affected by the level of postpartum care, with the offspring of high licking-and-grooming mothers (a model of good maternal care) showing increased GR mRNA in the hippocampus and reduced HPA axis sensitivity to stress in adulthood[124]. Evidence *in vitro* points to serotonin, and in particular to the 5-HT_7 receptor, as playing a role in increasing GR expression in this experimental condition[125], with enhanced serotonergic signalling increasing the expression of the transcription factor, nerve growth factors inducible protein A (NGFI-A), which then interacts directly with the GR promoter to increase its expression[126].

Interestingly, a study by Weaver *et al.*[81] in rats has shown that licking and grooming not only alters GR expression in the offspring, but also changes the epigenome at the GR gene promoter. Neonates of mothers that are 'low licking-and-grooming' (i.e., showing low maternal care) have differences in hippocampal GR methylation which persist into adulthood and are associated with hypermethylation of the exon 1_7, hypoacetylation of histone H3 and reduced NGFI-A binding. This is thought to increase the stress response, by decreasing the GR-mediated negative feedback on the HPA axis.

Finally, our own *in vitro* work has shown that stress and glucocorticoids regulate neurogenesis in a human *in vitro* model using fetal hippocampal cells, as well as an animal model of prenatal stress[127], via stimulation of the GR. SGK1, a Serine/Threonine kinase which is implicated in neuronal function and cellular stress responses, mediates this cortisol-induced reduction in neurogenesis by phosphorylation of the GR. Expression of mRNA encoding SGK1 has also been shown to be elevated in the peripheral blood of depressed patients[128], suggesting that this molecular mechanism is relevant to the maintenance of psychopathology in adulthood.

Cortisol and 11-Beta-Hydroxysteroid Dehydrogenase Type 2

Epigenetic regulation of GR expression is not the only mechanism by which perinatal mental health can affect HPA axis function and regulation. As mentioned above, antenatal depression in humans is associated with high cortisol levels, a proportion of which is likely to be transported via the placenta to the fetus. To protect the fetus against some of these effects, the placenta forms a partial barrier which controls the proportion of maternal cortisol that reaches the fetus. Cortisol is converted by

the enzyme 11-beta-hydroxysteroid dehydrogenase type 2 (11β-HSD-2) into the less active, cortisone; however antenatal stress, depression, and exposure to antidepressants, reduce the expression of this enzyme[129,130], potentially allowing the fetus to be exposed to the high cortisol levels in maternal circulation. In fact, it has been shown that low activity of placental 11β-HSD2 correlates with lower fetal weight[131] and with higher stress reactivity in the offspring[129]. Consistent with this, in rodents, the offspring of 11β-HSD2 knockout females are more prone to anxiety-related behaviours in later life[132].

On a molecular level, inhibition of this enzyme in the placenta has been shown to affect GR expression in varying ways across the brain, with mRNA levels increased in the amygdala, but reduced in the hypothalamic paraventricular nucleus[133]. Moreover, although the mechanism is unclear, sex differences are apparent in this protective mechanism, with male mouse fetuses showing superior protection to high levels of cortisol than females[134]. It is possible that this is caused by functional and expression changes in 11β-HSD2 due to differing methylation states of this enzyme, which are maintained in the offspring. In human preterm babies, lower levels of methylation of this enzyme are associated with a worse neurologic integrity and behavioural functioning[135].

Corticotrophin Releasing Hormone

In the first few weeks after childbirth, it is characteristic for women to show hyporeactivity of the HPA axis[136], as shown by blunting of the stress-related secretion of adrenocorticotrophic hormone (ACTH), a polypeptide tropic hormone. This hyporeactivity may be involved in explaining the sensitivity to mental health problems in the immediate weeks postpartum. In illustration of this, depressed mothers show more severe and long-lasting blunting of ACTH in response to corticotrophin releasing hormone (CRH) challenge at up to 12 weeks postpartum, in contrast to healthy women, for whom this blunting is less severe and has resolved by 12 weeks postpartum[136]. A blunted ACTH response to CRH is considered a hallmark of major depression, and it is interpreted as a consequence of the increased production of hypothalamic CRH in these patients[137]; therefore this evidence points toward an increased CRH drive also in perinatal depression (as mentioned above). In fact, one genetic association study found that a polymorphism in the CRH receptor 1 is associated with both pre- and post-natal depressive symptoms[138], although another group was subsequently unable to replicate these findings in the ALSPAC cohort[139].

Indeed, CRH has been considered as a potential pregnancy biomarker, predicting the development of depression later in pregnancy or postnatally. One particular focus has been the elevated CRH levels produced by the placenta, particularly when stimulated by glucocorticoids[140]. CRH levels increase throughout pregnancy, via a positive feedback loop originating in the placenta[64], with levels in the plasma peaking during the third trimester[141], before rapidly dropping after childbirth[142]. A relatively small study of antenatally depressed and non-depressed women has shown that elevated maternal blood CRH levels in the blood from weeks 24 to 37 predict a higher likelihood of depressive symptoms in the antenatal period[100]; however this is conflicted by more recent research suggesting no such association[142], and this association is also not found in the postpartum[98]. In our recent paper, women with clinically-significant depression in pregnancy show raised diurnal cortisol secretion, raised evening cortisol and blunted cortisol awakening response together with an 8-day

shorter length of gestation; most relevant to this review, these women also have neonates with suboptimal neurobehavioral function and increased cortisol response to stress at one year of age, and maternal cortisol correlates with infant stress response, suggesting a mechanistic link[143]. High levels of maternal CRH can also influence the neonatal behaviour of the offspring, such as impaired responses to novelty and heightened arousal[144].

Oxytocin

Oxytocin, the hormone commonly associated with childbirth, maternal attachment and lactation[145], is directly stimulated in offspring and mothers during attentive maternal behaviour. Indeed, mothers showing low maternal oxytocin levels during pregnancy are likely to show a lower frequency of positive bonding behaviour with their infants[146]. This may be due to the apparent reciprocal link between oxytocin levels and mood in the perinatal period: antenatal depression is associated with low levels of oxytocin after birth[147], and low maternal oxytocin levels during pregnancy are significantly associated with increased risk of developing postnatal depression[148]. Furthermore, there is some evidence to suggest that the genotype a woman carries at two loci for the oxytocin peptide, and one specific locus in the oxytocin receptor gene, can affect maternal interaction with her infant, and her experience of antenatal depression, respectively[149].

Administration of Intranasal Oxytocin

Given this link, studies have attempted to use oxytocin therapeutically, by administering a dose intranasally and measuring its effects on maternal bonding behaviours, but results have not been conclusive. Some of these studies have shown that a dose of intranasal oxytocin induces more protective behaviour in postnatally depressed mothers, who usually have a higher risk of less attentive behaviour toward their baby[150]. Indeed, giving depressed mothers oxytocin increases their likelihood of rating the lowest pitch infant cries as urgent, when usually this type of cry is perceived as not urgent in healthy mothers; however, these oxytocin-treated mothers are also more likely to choose a harsh caregiving strategy[151]. It is therefore possible that (intranasal) oxytocin exacerbates a depressed mother's sensitivity to stress and the negative cognitive processes associated with the interpretation of infant cues. In addition, there is some evidence to suggest that intranasal oxytocin may negatively impact maternal mood[152], perhaps unexpectedly, given the negative correlations between oxytocin levels in the perinatal period and mood disorders discussed above. Indeed, a recent study has shown that women exposed to synthetic oxytocin in the peripartum period have over 30% increased risk of developing postpartum depression or anxiety[153].

The interpretation of these studies must be cautious, however, as recent evidence indicates that the majority of the intranasal dose of oxytocin does not reach the cerebrospinal fluid, but instead remains in the periphery, thus acting on other organs such as the gastrointestinal, cardiovascular and reproductive systems[154]. Recently it has been argued[154] that many earlier trials reporting positive effects on maternal behaviour were conducted using inaccurate methods to process blood

samples prior to oxytocin analysis, and recommend that plasma samples should be extracted to avoid matrix interference, prior to oxytocin measurement.

Regulation of Endogenous Oxytocin

Clinical studies have shown a robust association between mother and offspring levels of oxytocin, in sample types such as plasma, saliva and urine[155,156]. One such study suggests that, mediated by level of maternal care experienced, both maternal and offspring levels of oxytocin predict children's social development and interaction with peers[157]. Indeed, it is thought that well-adapted parenting is underpinned by oxytocin and the activation of reward-related brain mechanisms, while anxious parenting is associated with activation of stress-related regions of the brain[158]. This is further demonstrated by studies showing that securely attached mothers show more activation of oxytocin-related regions of the brain, such as the hypothalamus and pituitary regions, on viewing their baby smiling or crying[159]. In addition to this, women with a history of childhood abuse have decreased oxytocin concentrations in the cerebrospinal fluid[160].

Recent clinical research also suggests that oxytocin and its response is regulated by epigenetic modifications of the oxytocin receptor gene (*OXTR*). There is suggestive evidence of a correlation between childhood neglect or abuse and higher methylation of two sites of *OXTR*, in exon 3[161]. Another study[162] also showed a significant association between postpartum depression and methylation at cg12695586 on *OXTR*. Furthermore, a higher number of stressful life events experienced by the mother during pregnancy, and elevated maternal cortisol levels, both reduce *OXTR* methylation in the cord blood[163], but increase *OXTR* methylation in offspring at birth[164]. Finally, research in older people also indicates that methylation of the oxytocin receptor gene is dynamically regulated and influenced by environmental factors such as psychosocial stress[165]. Taken together, this evidence suggests that the epigenetic profile of the infant can be programmed in utero by stressful maternal experience. Nevertheless, this evidence is not unequivocal. The pathway leading from prenatal adverse environment to altered OXTR methylation in humans is complicated, based on the definition of prenatal adverse environment. For example, two studies, both assessing cord blood, use different dimensions of psychopathology and psychosocial environment, and find different associations: one study found that increased number of life events in the two years up to middle gestation correlates with lower methylation (and hence, theoretically, higher expression)[163], while another study (in children with severe conduct disorder) shows that prenatal maternal psychopathology, criminal involvement and substance use are associated with higher OXTR methylation, but only in children who have conduct disorder and lower internalizing problems, perhaps reflecting genetic confounding rather than a causal relationship between in utero environment and cord blood methylation[164].

Animal models have been used to study the effects of oxytocin in the brain in more detail. Oxytocin release, similarly to in humans, can be stimulated by attentive maternal behaviour, such as licking and grooming in rats[166]. Champagne and Meaney[167] have shown that 'high licking and grooming' lactating female rats have higher expression of oxytocin receptor in multiple brain areas, including the hypothalamus (medial preoptic area, MPOA) and the central nucleus of the amygdala; moreover, maternal stress reduces oxytocin receptor expression in these brain areas, which in turn is associated with reduced maternal care and is transmitted to offspring who, in adulthood, also show

low oxytocin receptor levels and poor maternal care quality. However, other brain areas are also involved in the effects of oxytocin on maternal behaviour. For example blockade of the oxytocin receptor in the medial pre-frontal cortex of postpartum female rats impairs maternal care behaviours and enhanced maternal aggression[168]. In contrast, induction of the oxytocin receptor by estrogen in the ventromedial nucleus of the hypothalamus promotes female sexual behaviour, while induction in the central nucleus of the amygdala by dopamine gives rise to anxiolytic effects[169].

Taken together, this evidence points to multiple and complex effects of oxytocin beyond the simple regulation of maternal behaviour, depending on distinct signal transduction pathways and different regions of the brain, and tapping into a broad range of behavioural effects relevant to psychopathology.

Estrogen

Estrogen, a female sex hormone, is a potent regulator of a range of neural aspects such as mood and cognition[142]. Interestingly, a study in women with a history of postpartum depression reports that they show normal levels of circulating estrogen when euthymic, but abnormal sensitivity to childbirth-like estrogen withdrawal. Specifically, if these women are administered levels of estradiol and progesterone similar to those present during pregnancy, and then these hormones are withdrawn, mimicking the fall after childbirth, around 60% will develop mood symptoms, an effect which is absent in women with no history of postpartum depression[170]. This notion further supported by data showing that women with postpartum depression have increased sensitivity to estrogen signalling in the third trimester of pregnancy, as shown by enrichment of estrogen-responsive mRNA transcripts' expression in the blood[171]. Women at risk of postpartum depression are also more sensitive to reprogramming of estrogen-based DNA methylation of genes associated with synaptic plasticity in the hippocampus[172]. Finally, a genome-wide linkage study has identified the hemicentin 1 gene locus, which contains multiple estrogen binding sites, to be associated with postpartum depressive symptoms[41], although this finding was no longer significant after adjusting for multiple comparisons.

In addition to its independent actions, evidence emerging from preclinical models points to a pathway whereby the association between oxytocin, mood and maternal care behaviour discussed previously is also regulated by the presence of circulating estrogen and by epigenetic changes to the hypothalamic estrogen receptors[78]. This could contribute to this lifelong pattern of abnormal response of the oxytocin system to changes in circulating levels of estrogen, and thus to abnormal maternal care behaviour. Interestingly, however, reduced maternal care seems to be associated with decreased sensitivity to estrogen signalling, due to increased methylation and thus reduced expression of the ERα in the hypothalamus. This contrasts with the aforementioned evidence of an increased estrogen sensitivity in the blood of women at risk of post-partum depression. This inconsistency may be underpinned by different epigenetic and functional regulation in the blood and in the brain.

A number of preclinical studies have confirmed the role of estrogen signalling in oxytocin regulation, including outcomes such as levels of maternal care. For example, in mouse models of anxiety-like behaviour, treatment with oxytocin has anxiolytic effects that are absent in ovariectomised animals,

unless they receive estradiol supplementation, possibly because estrogen may act by increasing oxytocin binding density in the lateral septum of the brain[173]. Interestingly, these effects of estrogen on oxytocin regulation and activity seem to be specific for ERα, as this is essential for estrogen's induction of oxytocin receptor binding in the brain[174]. Indeed, studies conducted in the 'licking and grooming' model shows that the aforementioned differences in oxytocin receptor expression in the MPOA between high and low LG females are estrogen dependent[175]. A subsequent cross-fostering study confirmed an association between lower maternal care and decreased ERα expression in the MPOA, which is associated with higher levels of cytosine methylation across the ERα1b promoter[82], eventually leading to the aforementioned decreased estrogen sensitivity.

Neuroplasticity and Neurodevelopment

The significance of early neurodevelopment as a risk factor for mental health disorders is becoming increasingly apparent[77]. Given that maternal mental illness during pregnancy has been shown to affect fetal neurodevelopment, it appears an important avenue of research when considering 'intergenerational transmission' of psychiatric disorders.

In the GUSTO (Growing up Towards Healthy Outcomes) study, a large and comprehensive birth cohort study in Singapore, prenatal maternal depression is associated with increased functional connectivity of the amygdala with the left temporal cortex and insula, as well as the medial orbitofrontal, bilateral anterior cingulate and ventromedial prefrontal cortices in the infant at 6 months[176]; this is a pattern similar to that which is observed in adolescents and adults with major depressive disorder. However, a study from the same GUSTO cohort, but with a larger sample size, found that at age 4, prenatal maternal depressive symptoms were correlated with lower functional connectivity of the amygdala with other brain regions, although this was only observed in girls[177].

In another cohort, high levels of anxiety during pregnancy (particularly around week 19) is associated with a reduction in the density of grey matter in multiple regions of the brain of offspring aged 6-9, including the prefrontal cortex, premotor cortex, medial temporal lobe, postcentral gyrus and the cerebellum[178]. This altered grey matter could explain the increased risk of psychopathology in the offspring. Reduced hippocampal volume has been observed also in children who have experienced trauma in childhood, and has been reported in patients remitted with major depression[179], so it likely contributes to resultant psychopathology in adulthood. Further, significant cortical thinning in the right frontal lobes has been shown in children exposed to maternal depression *in utero*[180].

As well as anatomical changes, there also appears to be parallel changes in maternal and infant neurotransmitter regulation, with lower levels of dopamine and serotonin reported in depressed mothers during pregnancy being mirrored in offspring urine samples taken within 24h of birth[181]. Interestingly, recent preclinical evidence also suggests that the reduction in maternal hippocampal neurogenesis caused by prenatal stress can be reversed using SSRI treatment[182].

Of note, low levels of brain-derived neurotrophic factor (BDNF), which plays an important role in the development and maintenance of neural circuits, has been associated with vulnerability to the

development of various mental disorders in humans[183], and we have shown a concomitant reduction in GR and BDNF mRNA levels in the same adult depressed patients[184] . While direct clinical evidence in the perinatal period is lacking, rodent models show that BDNF expression in the offspring can be affected by both maternal antenatal stress and early life stress. Specifically, neonates of a prenatally stressed rat show a reduction in BDNF in both the olfactory bulbs and in the hippocampus[185], while early maternal separation causes reduced levels of BDNF mRNA in the hippocampus of the offspring 9 days post-birth[186], and of BDNF protein in the medial prefrontal cortex (mPFC) in adulthood[187]. This potential long-lasting effect of antenatal stress on BDNF expression found in preclinical models supports a role for BDNF, and its subsequent effect on synaptic plasticity, as a risk factor for intergenerational transmission of psychopathology.

Immune System

Recently, it has become apparent that the process of biological embedding of perinatal or childhood stress into adult psychopathology is also underpinned by changes in inflammatory pathways[188,189], as shown by studies in women suffering with postpartum depression[190] as well as children exposed to maltreatment[191]. In addition, recent data from our group in the aforementioned paper[143] have shown that women with antenatal depression have elevated levels of interleukin-6 (IL-6), tumour necrosis factor alpha (TNFα) , IL-10 and vascular endothelial growth factor during pregnancy; moreover, as for cortisol, maternal inflammatory biomarkers correlate with infant stress response, suggesting a mechanistic link.

Depression is often manifested in conjunction with high levels of inflammatory biomarkers, especially in patients that are resistant to classic antidepressants[192,193] and are exposed to maltreatment during childhood[194]. Indeed, many studies now show that the inhibition of pro-inflammatory cytokines may improve low mood and, conversely, stimulation of the immune system may lower mood[193,195,196]. Furthermore, a number of studies have shown that adults who experienced childhood trauma show elevated levels of many immune biomarkers, such as c-reactive-protein (CRP), TNFα and interleukins[188,197–199], an effect which can be seen in children as young as 12 years old[191]. There is also evidence that childhood exposure to medically-related inflammation, because of infections or medical disorders, is associated with a significantly increased risk of depression in adulthood[200].

There is some evidence that altered immune activation is present in pregnancy and in the postpartum period in association with depressive symptoms[201,202]. Indeed, one study has shown that regulatory T-cells are significantly increased in both the prenatal and postnatal period in mothers suffering depression[190]. Another study has shown that experience of abuse may be the key moderator of this relationship, as experience of abuse and depression in pregnant adolescents predicts higher IL-6 concentration during pregnancy, but none such association in absence of exposure to abuse[203]. However, other studies investigating cytokine levels have shown that depressive symptoms during pregnancy are negatively correlated with cytokines such as IL-1β, Il-7

and TNFa[204,205]. The results of these studies are partially confounded by the fact that, in general, they study variation of (self-related) depressive symptoms in large samples of pregnant women, rather than clinically-significant cases of antenatal depression. There is also evidence of an association between antenatal inflammation and behavioural outcomes in offspring[206], suggesting that maternal inflammation may be relevant to some of the transgenerational outcomes observed in offspring. There is also evidence of an association between antenatal inflammation and behavioral outcomes in offspring[206], suggesting that maternal inflammation may be relevant to some of the transgenerational outcomes observed in offspring.

Higher levels of pro-inflammatory cytokines have also been reported in individuals with psychoses suggesting that inflammatory pathways may also underpin psychotic symptoms[207,208], and in fact, a dysregulation of the immune system and glucocorticoid response has also been reported in postpartum psychosis[89]. Specifically, compared to postpartum women with no psychosis, those who develop postpartum psychosis have been found to have higher serum IL-1β levels and T-cell numbers, together with an upregulation of genes involved in the immune system[89]. In addition, women with postpartum psychosis show a decreased glucocorticoid receptor α/β gene expression in monocytes, which strongly correlates with the immune activation[209]. This points to the presence of alterations in both immune and neuroendocrine systems in postpartum psychosis that are similar to that observed in mood disorders and other psychoses.

One possible molecular mechanism by which immune dysregulation is associated with psychopathology is through abnormal serotonin metabolism[210]. Indoleamine 2,3-dioxygenase (IDO) and tryptophan 2,3-dioxygenase (TDO) are the two major enzymes involved in the metabolism of tryptophan, the serotonin precursor. IDO is directly activated by pro-inflammatory signals, such as TNFα and IFNγ, while TDO is activated by cortisol[211,212]. Of particular interest in pregnancy, TDO is also inhibited by estrogens and progesterone, a potential mechanism for the putative antidepressant effects of these hormones during pregnancy[213].

There is evidence that differences in the accumulation of neurotoxic kynurenine metabolites may precipitate the psychiatric symptoms in the perinatal period[210,214]. Indeed, a recent study[202] has shown that both cortisol and the ratio between pro- and anti-inflammatory cytokines are elevated postpartum in mothers with depression (although TNFα levels are significantly lower in depressed mothers), confirming the hypothesis that a combined increase in activators of both IDO and TDO could play an important role in serotonin availability. This mechanism may also participate to the association between antenatal depression and low fetal birth weight[213], since tryptophan availability is vital for protein synthesis in fetal development.

It is possible to speculate that epigenetic changes to the genes encoding immune molecules, as a result of perinatal or childhood adversity[215], provokes long-term immune dysregulation, which then, in addition to the high cortisol levels associated with perinatal depression, may deplete serotonin availability in the offspring, thus maintaining the risk for depression in adulthood[213]. Indeed, we have recently shown that adult offspring of mothers who were depressed in pregnancy show, at age 25, increased inflammatory levels, as measured by blood CRP, even in the absence of depression; this confirms the notion that perinatal events, and antenatal depression in particular, induce long-term activation of the immune system in the offspring[216].

Of note in this context is also the possibility of using omega-3 fatty acids, a potentially anti-inflammatory treatment, as a safe antidepressant during pregnancy. In our trial using this approach in women with a diagnosis of major depressive disorder in pregnancy, we found that omega-3 supplementation reduces depressive symptoms[217]. Subsequent studies that have investigated the prophylactic effects of omega-3 in women 'at risk' of depression in pregnancy or postpartum, however, have not found beneficial effects[218,219], suggesting that the effects are most evident in more severe forms of antenatal depression. Our in vitro work has also recently shown that omega-3 fatty acids, like some antidepressants, reduce activation of the IDO pathways[220].

A lot of research in animal models has used biological immune challenges, such as lipopolysaccharide, during pregnancy, to investigate the effects of a hyperactive maternal immune system on the developing fetus[221–223]. However, for this review we focus on psychological or stress challenges, as they are more relevant to prenatal psychopathology. Recent work[224] has studied the effects of psychological stress in late gestation on postpartum neuroimmune function. After exposure to a forced swim test in late gestation, region-specific neuroimmune changes were observed in the mother's brain postpartum, such as a reduction of IL-1β in the mPFC and an increased microglia density in the hippocampus. Increased expression of genes associated with the immune system can also be seen in the placenta following prenatal stress, particularly where the fetus is male, as shown by higher mRNA levels of IL-1β[225].

Interestingly, changes in the expression of immune biomarkers can be seen also in the offspring following prenatal stress. For example, studies have reported increased levels of IL-1β mRNA in the hippocampus of both male[226] and female[227] offspring in adulthood (4 months). Interestingly, another study has shown increased inflammation in adult rats aged 6 months, with higher mRNA expression of interferon gamma (IFNγ) as a result of prenatal stress; however these alterations were undetectable in the rats when they were just 7 weeks old[228]. Recent evidence both *in vitro*[229] and *in vivo*[230] suggests that these long-lasting inflammatory alterations in adult rodents exposed to prenatal stress may be associated with malfunctions in fractalkine signalling, a chemokine important for the migration, differentiation and proliferation of neuronal and glial cells.

Concluding Remarks

There is a wealth of research studying the effects of perinatal psychiatry on offspring outcomes, with at least three, parallel molecular pathways operating across the two generations: oxytocin, glucocorticoids, and inflammation (see figure 1). However, the methods of research are challenging, as experimental studies cannot capture the heterogeneity and complexity of the clinical conditions, and the clinical samples often present many contributing factors and outcomes that occur in parallel. For example, perinatal depression is often suffered in conjunction with perinatal anxiety or high current stress levels, and often in women with a previous history of mental illness and exposure to life adversity in childhood. In terms of outcome, and especially the increased risk of psychopathology in the offspring, it is important to note that the offspring of mothers suffering with depression are not only exposed to 'the environment' (for example, abnormal HPA axis function *in utero* or poor attachment and parenting behaviours postpartum), but are also likely to have a genetic predisposition to psychopathology, which may partly be related to the same molecular mechanisms[231].

Future research should investigate fetal programming in humans by combining in-depth clinical assessments with sophisticated molecular investigations, in cohorts of mothers and babies assessed prospectively. Ultimately, the ambition is that of elucidating the mechanisms by which the regulation of the maternal molecular systems discussed above can be 'transmitted' to the fetus and eventually culminate in psychopathology in the offspring during later life, and of using this understanding to predict, prevent or treat perinatal psychopathology, thus breaking the vicious intergenerational cycle.

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Table 1: Summary of research findings from large cohorts relating to offspring outcome as a result of depression in the perinatal period.

Offspring Outcome Factor	Antenatal Depression		Postnatal Depression	
	Study Details	**Findings**	**Study Details**	**Findings**
Internalising Behaviour	Generation-R, n=2698	Associated with internalising behaviour at 3 years, as shown by emotional reactivity, anxiety/depression, somatic complaints and withdrawal[16]. [OR 1.18 per 1 SD increase (95% CI 1.08;1.29), p<0.001]	TRAILS, n=2729	Significantly associated with internalising difficulties in early adolescence[19]. [β=0.28 (95%CI 0.14;0.41), p<0.001]
Externalising Behaviour	Generation-R, n=2698	Associated with child externalising difficulties, such as attention problems and aggressive behaviour[16]. [OR 1.19 (95% CI 1.09;1.30), p<0.001]	ALSPAC, n=3298	Associated with offspring externalising behaviour such as inattention and hyperactivity[11]. [R^2=0.09, p<0.05]
	Generation-R, n=2280; ALSPAC, n=3442	Higher risk of child attention problems[17]. [OR 1.23, (95% CI 1.05;1.43); OR 1.33 (95% CI 1.19;1.48)]	QLSCD, n=2057	Associated with high trajectories of inattention and hyperactivity-impulsivity[15]. [OR 1.35 (95% CI 1.18;1.54)]
			ALSPAC, n=8598	Increased risk of conduct problems[12]. [OR 1.74 (95% CI 1.33;2.52)]
			NLSCY, n=10033	Association with physical aggression[13]. [OR 2.94, P<0.05]
Emotional Development	ALSPAC, n=2891	Total emotional problems score negatively associated with exposure to antenatal depression, when controlling for psychological and maternal lifestyle variables[8]. [β=0.22 (SE 0.07), p<0.01]		

Cognitive Development	ALSPAC, n=5059	Low full-scale IQ scores[9]. [SE=0.78, (95% CI 101.57;104.64)]	ALSPAC, n=5059	Low full-scale IQ scores[9]. [SE=1.17 (95% CI 104.26;108.84)]
Attachment	Generation-R, n=627	Not associated with attachment insecurity[18]. [OR 0.96 (95% CI 0.81;1.14)]	Generation-R, n=627	Not associated with infant attachment insecurity[18]. [OR 0.91 (95% CI 0.75;1.10)]
Adolescent Psychopathology	ALSPAC, n=8937	1 SD increase in maternal EPDS score positively associated with offspring depression aged 18 years, when controlling for maternal lifestyle and depression history[10]. [OR 1.23 (95% CI 1.03;1.44), p=0.025]	NLSCY, n=937	Infants exposed to depression at 2-3 years and 4-5 years postpartum had a 2-fold increased risk of emotional disorder at 12-13 years[14].