HORMONES AND CLOSE RELATIONSHIP PROCESSES

Neuroendocrine bases of partnering and parenting

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Introduction

In this chapter, we review research on the social neuroendocrinology of close relationship processes, with special attention to human romantic relationships and the context of parenthood. We focus primarily on steroid hormones— including testosterone, cortisol, estradiol, and progesterone— that have important implications for the development and maintenance of pair- and parent-child bonds (see Feldman, 2012; Johnson & Young, 2015, for recent reviews on peptide hormones such as oxytocin and vasopressin). Although these hormones have been studied fairly extensively in humans and other animals, relatively less is known about their role in romantic relationships. Further, most hormones tend to be studied and conceptualized in isolation from one another (but see Schneiderman, Kanat-Maymon, Zagoory-Sharon, & Feldman, 2014; van Anders, Goldey, & Kuo, 2011; Wardecker, Smith, Edelstein, & Loving, 2015, for some notable exceptions). Thus, we aim to synthesize current knowledge about the implications of these different hormones, with the goal of better understanding their unique and shared contributions to human romantic relationships.

Further, and perhaps surprisingly, although both partnering and parenting are inherently dyadic processes that unfold over time, the vast majority of research on neuroendocrine processes in close relationships has been conducted with individuals (as opposed to couples or parent-child dyads) and at one point in time (rather than longitudinally). This work also tends to be somewhat sex-stereotyped, in that (for instance) stereotypically “male” hormones such as testosterone are much more likely to be assessed in research on men versus women, whereas stereotypically “female” hormones such as estradiol are much more likely to be assessed in research on women versus men. Additionally, relatively few studies assess individual differences in associations between hormones and relationship processes or outcomes. Thus, in this review, we highlight understudied topics such as (a) how hormone levels may change over time as a function of relationship experiences such as parenting, (b) how one individual’s hormones may be associated with his or her partner’s relationship functioning, and (c) how these processes may differ across people, including the extent to which hormone-relationship links may differ by sex or gender.

We also acknowledge that psychologists and neuroscientists alike have become increasingly concerned with issues of replicability and reproducibility, particularly in the last 5–10 years.
(e.g., Barch & Yarkoni, 2013; Simmons, Nelson, & Simonsohn, 2011), and that “best practices” for data collection and reporting have changed fairly significantly as a result (Shrout & Rodgers, 2018). Thus, particularly in retrospect, at least some of the studies we discuss may have been limited in statistical power due to relatively small sample sizes and/or limited in generalizability due to flexibility in data-analytic decisions. We therefore report sample sizes and effect sizes for key studies when relevant (and when they could be estimated) and consider statistical power and data-analytic flexibility as possible explanations for seemingly inconsistent patterns of findings.

Overview of steroid hormones

Testosterone, cortisol, estradiol, and progesterone have been studied fairly extensively in humans and other animals; they fluctuate in response to relationship experiences and have important downstream implications for close relationship processes (e.g., Loving & Slatcher, 2013; Wardecker et al., 2015; Wynne-Edwards & Reburn, 2000). As described in more detail in the following sections, these hormones have been linked with interpersonal processes across the lifespan in both humans and other animals, including changes that may occur as a function of partnering and parenting and individual differences in orientations toward close relationships. In most cases, we review studies in which hormone data were obtained from salivary measures and note exceptions as relevant. Salivary hormone measures have been widely used in research with humans, in part because they are generally less intrusive and less expensive to collect compared to other bodily substances, such as blood (Schultheiss & Stanton, 2009). However, as noted elsewhere in this handbook, immunoassays of salivary hormones may be more prone to measurement error than other techniques, particularly at lower concentrations, as is often the case for women’s testosterone (Miller, Plessow, Rauh, Gröschl, & Kirschbaum, 2013; Welker et al., 2016). Thus there are reasons to expect that other techniques, such as mass spectrometry, may ultimately become a preferred assessment tool over immunoassays.

Briefly, testosterone has been associated with both dominance and parental care (Mazur & Michalek, 1998; van Anders et al., 2011; Wingfield, Hegner, Dufty, & Ball, 1990). In both men and women, higher levels of testosterone appear to support the initiation and establishment of sexual relationships (e.g., Edelstein, Chopik, & Kean, 2011; McIntyre et al., 2006); lower levels of testosterone appear to support more nurturant behaviors such as caregiving and the longer-term maintenance of close relationships (e.g., Edelstein et al., 2017; Gettler, McDade, Feranil et al., 2011). Cortisol is a stress hormone that is particularly responsive to social stressors and challenges (Dickerson & Kemeny, 2004). Although short-term increases in cortisol are thought to be adaptive for coping with acute stressors, long-term or chronic cortisol reactivity can be problematic for health and relationship functioning (e.g., Adam et al., 2017; Loving & Slatcher, 2013). Estradiol is generally thought to support caregiving and bonding in humans and other mammals (Mileva-Seitz & Fleming, 2011), and has been associated with individual differences in desire for and responses to emotional closeness (e.g., Edelstein et al., 2010). However, there is some evidence that parental behavior might benefit from declines and/or lower levels of estradiol that occur during the transition to parenthood (e.g., Edelstein et al., 2017; Glynn et al., 2016). Finally, progesterone has been associated with social closeness, maternal behavior, and affiliation in humans and other mammals (e.g., Brown et al., 2009). However, like cortisol, progesterone also increases in response to stress, and is thought to down-regulate physiological stress responses (Wirth, 2011).

Although all four hormones have clear implications for close relationship processes, research in this area has focused most extensively on testosterone (more so in men than women) and
cortisol; thus, our review is necessarily weighted more heavily toward these hormones. However, we argue that a more complete understanding of the social neuroendocrinology of close relationship processes necessitates understanding the contributions of multiple hormones, and that future research should more fully explicate the roles of estradiol and progesterone in both men and women.

**Hormones in the context of partnering**

**Differences in hormones as function of relationship status**

At perhaps the most basic level of analysis, hormones appear to vary systematically as a function of people’s partnered status: People in committed romantic relationships tend to have lower baseline levels of testosterone compared to single people, a difference that is thought to reflect a focus on relationship maintenance versus initiation (see Roney & Gettler, 2015; Wardecker et al., 2015, for review). For instance, in a study of 4,462 United States Army veterans, men who were married had significantly lower serum testosterone levels than those who were divorced, $d = -0.45$, and those who had never been married, $d = -0.26$ (Mazur, 2014). Fewer studies include women, but those that do generally find similar patterns (e.g., Edelstein et al., 2011; van Anders & Goldey, 2010; van Anders & Watson, 2006), with effect sizes ranging from $d = -0.09$ (Edelstein et al., 2011, in a sample of 134 undergraduate students) to $d = -0.22$ (van Anders & Watson, 2006, in a sample of 72 heterosexual women). Although these findings allude to smaller effect sizes for women compared to men, in most studies, data are typically presented only for men or for women, or are analyzed separately if both men and women are included. Thus, there are relatively few formal statistical tests of gender differences (e.g., interactions between gender and the construct of interest), making it difficult to draw firm conclusions about such differences (Nieuwenhuis et al., 2011). Additionally, measurement error tends to be higher for assays of women’s versus men’s salivary testosterone (e.g., Welker et al., 2016), which could contribute to differences in effect sizes across studies.

Although most research has focused on North American (male) participants, differences in testosterone as a function of relationship status have also been observed cross-culturally, including among men in Senegal, Japan, and China, and women in Norway and the Philippines (e.g., Alvergne et al., 2009; Barrett et al., 2013; Gray et al., 2006; Kuzawa et al., 2010; Sakaguchi et al., 2006). Sample sizes tend to be somewhat smaller in cross-cultural studies (e.g., 67 Pilipino women in Kuzawa et al., 2010, $d = -0.68$; 81 Senegalese men in Alvergne et al., 2009, $d = -1.84$), but these findings suggest that the mechanisms that drive differences or changes in testosterone as a function of relationship status may be somewhat universal. However, as we describe later, these mechanisms have been understudied, leaving major gaps in our understanding of the processes that might support relationship-status differences or changes in testosterone, let along with other hormones.

Individual differences research points to a similar conclusion: Partnered men who are less invested in or committed to their relationships tend to have testosterone levels that are more similar to single men (e.g., Edelstein et al., 2011; McIntyre et al., 2006). Men and women who engage in simultaneous emotional and/or sexual relationships with multiple partners also typically have higher levels of testosterone than those who are involved with only one partner (e.g., Alvergne et al., 2009; van Anders et al., 2007), again suggesting that commitment to a single partner may be a key determinant of differences in testosterone levels. Further, partnered women appear to have testosterone levels more similar to single women to the extent that they report higher levels of uncommitted sexual activity, extraversion, and sensation-seeking (Costa...
et al., 2015; Edelstein et al., 2011), traits that could promote interest in alternative romantic or sexual partners (Penke & Asendorpf, 2008).

Much less is known about how other hormones might differ according to partnered status. However, like testosterone, cortisol appears to be lower among people who are partnered compared to those who are single (e.g., $d = -.38$ in a sample of 152 adults, Maestripieri et al., 2013; $d = -.16$ in a comparison between 484 single men and 146 men who were married and/or fathers, Gettel, McAdoo, & Kuzawa, 2011). These differences may even be apparent in the early stages of romantic relationships: In one study, 79 people who had become partnered in the last 3 months were compared to 34 demographically matched single people (Weisman et al., 2015). Those who had recently become partnered showed lower overall cortisol production, $d = -.44$, and smaller cortisol awakening responses, $d = -.53$ (suggesting potentially attenuated stress responses; Fries et al., 2009). Moreover, in sample of 572 adults, people who were married showed lower overall cortisol output compared to never- or previously married individuals, $d = -.25$ and $-.28$, respectively, and a more rapid decline of cortisol levels throughout the day (Chin et al., 2017), again suggesting better health outcomes (Adam et al., 2017). Together, these findings suggest that changes in cortisol might be one pathway through which close social bonds can have positive effects on health (e.g., Slatcher & Selcuk, 2017).

Very few studies explicitly examine or report differences in estradiol or progesterone as a function of partnered status; however, in a study of 185 normally cycling Norwegian women, Barrett et al. (2015) found that women (ages 25–35) who were married or living as married had higher average estradiol and progesterone (both $d = .40$) levels averaged over a 1-month period compared to unmarried women. Their analyses adjusted for women’s age, body mass index (BMI), history of contraceptive use, and several other demographic variables known to influence hormone levels. In our own study of 212 undergraduate students, including 108 women, we did not find evidence for differences in estradiol between single and partnered people, $d = .08$, including when analyses were conducted separately by gender (Edelstein et al., 2012). However, single men and women (65% of the sample) showed larger estradiol responses after watching a video clip that depicted an emotionally intimate father-daughter exchange, $d = .52$, compared to an equally positive but less emotionally intimate social interaction, $d = .12$ (Edelstein et al., 2012). These differences might reflect a stronger drive for emotional connection among single versus partnered individuals, or perhaps single participants’ greater ability to identify with the protagonists in the video.

Differences across studies with respect to relationship status–hormone associations could also reflect differences between the samples in terms of age (adult women versus undergraduate students) or simply greater statistical power in the Barrett et al. (2015) study. It is also worth noting that Barrett et al. restricted their sample to normally cycling women, due to the effects of hormonal contraceptives on neuroendocrine levels, whereas the sample in Edelstein et al. (2012) included 18 women taking hormonal contraceptives. (Excluding women taking hormonal contraceptives did not change any of the reported findings.) More generally, such differences across studies could obscure findings when comparing hormone levels for single versus partnered women, and there is fairly little consistency across studies with respect to this important inclusion criterion. Issues surrounding contraception also raise an important question about sample generalizability: National surveys suggest that approximately 20%–30% of sexually active women ages 15 to 44 are using some form of hormonal contraceptive at any given time, and nearly 80% have done so at some point in their lives (Jones et al., 2012). Thus, excluding women taking hormonal contraceptives necessarily limits the extent to which conclusions can be drawn about the larger population.
Changes in hormones as a function of relationship status

Relationship status effects are generally assumed to be causal, in that experiences related to partnering are thought to lead to changes in hormones over time, most notably to declines in testosterone and cortisol. Although the mechanisms that might support such changes have not yet been well articulated, nurturant experiences that occur in the context of close relationships (e.g., close physical contact, emotional support) can have short-term effects on hormones that are consistent with the presumably long-term changes described earlier. For instance, nurturant or affectionate interactions can lead to short-term declines in testosterone (e.g., Kuo et al., 2016; see Zilioli & Bird, 2017). Physical touch and intimacy have also been associated with lower daily cortisol output and attenuated cortisol reactivity to laboratory stressors (Ditzen et al., 2008; Ditzen et al., 2007).

Most research on relationship status “effects” has thus far been cross-sectional, making it difficult to determine whether changes in partnered status in fact lead to changes in hormones. However, the few longitudinal studies of testosterone-partnering links provide fairly convincing support that changes in partnering generally precede changes in hormones (Das & Sawin, 2016; e.g., Gettler, McDade, Feranil et al., 2011; but see Goldey et al., in press; van Anders & Watson, 2006). For instance, in a 10-year longitudinal study of 2,100 male air force veterans (mean age of 43 at the first assessment), men’s serum testosterone levels showed a pattern of increase prior to divorce and decrease following remarriage (Mazur & Michalek, 1998). Another 10-year longitudinal study of 1,113 Danish men (ages 30–60 at the initial assessment) provides further support for the idea that changes in relationship status lead to changes in testosterone (Holmboe et al., 2017): Men’s serum testosterone levels declined with age, overall, but men who went from unmarried to married over the course of the study showed an accelerated decline, \( d = -0.55 \), whereas those who went from married to unmarried showed an attenuated decline, \( d = 0.26 \). These findings held even when controlling for BMI, smoking, and physical activity, suggesting that changes in marital status may moderate normative age-related declines in testosterone over and above other lifestyle variables. Moreover, there was relatively little evidence that baseline levels of testosterone predicted changes in marital status in this sample; that is, findings were more consistent with the idea that changes in relationship status precede changes in testosterone, at least for men.

In a similar vein, in a 1-year longitudinal study of 78 first-year male college students, men who were single had higher testosterone compared to men in committed relationships (Dibble et al., 2017). Relationship dissolution was also associated with increases in men’s testosterone; however, men who became partnered additionally showed pre-emptive testosterone declines, providing some reason to believe that causality may ultimately be bidirectional. It is worth noting, however, that the vast majority of participants in this study (more than 95% of cases across repeated measurements) did not experience changes in relationship status during the study period, so findings regarding testosterone changes as a function of relationship status in this study should be treated cautiously. Dibble et al. (2017) also examined several potential mediators of the testosterone-relationship status link – partnered sexual activity, masturbation, and relationship desires – but did not find that any of these variables could help to explain why partnered men tended to have lower testosterone overall compared to their single counterparts. These findings beg the question of potential mechanisms; future research might explore whether other kinds of relationship experiences, such as physical contact and emotional intimacy, might contribute to long-term changes in testosterone as a function of partnering. More generally, to our knowledge, all published longitudinal research on hormone changes as a function of partnering
has focused on testosterone in virtually all male samples (see Goldey et al., in press; van Anders & Watson, 2006, for exceptions that include women). Of course, insofar as null findings have historically been more difficult to publish than significant effects, it is possible that at least some of the underrepresentation of women in testosterone research, or the lack of published research on other hormones, could be due to file drawer effects resulting from null effects for women and/or other hormones. Future research should examine whether and how other hormones fluctuate as a function of changes in relationship status and how these fluctuations might differ by sex or gender.

**Hormones and romantic relationship outcomes: individual and dyadic associations**

Regardless of their source, changes in hormones related to partnering are generally thought to be functional, in that they support the establishment and maintenance of romantic relationships (Roney & Gettler, 2015; Wardecker et al., 2015). Evidence consistent with this idea indicates that, among people involved in committed romantic relationships, lower levels of testosterone and/or cortisol are associated with indicators of better relationship functioning, such as greater relationship, commitment, satisfaction, and investment; less interest in alternative relationship partners; greater empathy; more self-disclosure and intimacy; and lower levels of partner-directed verbal and physical aggression and hostility (Denes et al., 2017; Ditzen et al., 2008; Edelstein et al., 2014; Gray et al., 2017; McIntyre et al., 2006; Soler et al., 2000). For instance, in a sample of 54 men in committed relationships, those with higher baseline testosterone levels reported higher levels of both verbal and physical partner-direction aggression, \( r = .37 \) and \( .24 \), respectively. Schneiderman et al. (2014) similarly reported positive associations between cortisol and hostility in both men and women in a sample of 60 couples. Taken together, these findings suggest that the changes that occur once people enter into relationships may well promote better relationship functioning in the long-term.

Much less is known about the implications of estradiol and progesterone for romantic relationship functioning; however, both hormones appear to be positively related to physical intimacy and/or feelings of closeness, especially among women (e.g., Schultheiss et al., 2003; Wardecker et al., 2015). For example, in a sample of 100 undergraduate students, endogenous estradiol levels were positively associated with individual differences in implicit (i.e., nonconscious) intimacy motivation among men and women who were more comfortable with closeness, \( \beta = .39 \) (Edelstein et al., 2010). As described earlier, emotionally intimate experiences may also lead to short-term increases in estradiol (Edelstein et al., 2012). Among women, estradiol and progesterone levels have additionally been associated with higher levels of sexual motivation and desire (Grammer et al., 2004; van Anders & Dunn, 2009). For instance, sexually explicit stimuli (i.e., videos depicting heterosexual encounters) may temporarily increase women’s estradiol levels (van Anders et al., 2009, \( d = .38 \) in a sample of 31 naturally cycling women).

Further, in a study of 33 naturally cycling partnered women, women’s endogenous progesterone levels were positively linked with greater partner-directed sexual desire, \( \beta = .38 \) (Grebe et al., 2016), whereas estradiol levels were positively associated with greater sexual attraction toward other men as opposed to partners, \( \beta = .39 \). Roney and Simmons (2013), however, found that within-cycle changes in progesterone were negatively associated with day-to-day changes in sexual desire in a sample of 43 normally cycling women (approximately one-third of whom were partnered); within-cycle changes in estradiol were largely unrelated to changes in sexual desire. As noted earlier, inconsistent findings across studies could simply reflect low statistical power; it is also possible that unique characteristics of these samples and/or differences in
data-analytic approaches contributed to these differences. Future research would benefit from higher-powered replication efforts to more fully assess links between estradiol, progesterone, and sexual desire.

Further, as with research on effects of partnering per se, most studies of hormone–relationship quality links are cross-sectional; thus it is difficult to determine whether differences in hormones lead to changes in relationship quality, whether differences in relationship quality lead to changes in hormones, or (perhaps most likely) whether these changes might be bidirectional. In one notable exception, Das and Sawin (2016) examined relationship quality and endogenous testosterone in a representative sample of 1,270 older Americans (average age of 67 at the first assessment). For men, higher testosterone at the first assessment was predictive of lower relationship quality at the second assessment 5 years later, but the reverse causal pathway was not significant, suggesting that changes in testosterone may have led to differences in men’s relationship quality. For women, testosterone at the first assessment was not significantly associated with relationship quality at the second assessment; however, there was a trend in support of the reverse causal pathway. These findings provide some evidence for the primacy of testosterone in predicting relationship outcomes, at least in men, and for potentially different causal pathways for men versus women. This study is notable in terms of its sample size and composition, as well as its longitudinal design; however, because data from men and women were analyzed separately, it would be premature to conclude that the pattern of findings in fact differs significantly by gender. Moreover, it is unclear whether these results might generalize to younger populations, particularly given that testosterone levels generally decline with age (e.g., Leifke et al., 2000).

Even less is known about longitudinal changes in other hormones with respect to relationship quality. Although some work has investigated changes in women’s estradiol and progesterone as a function of the menstrual cycle (e.g., Grebe et al., 2016; Roney & Simmons, 2013), these studies have generally focused on women’s sexual desire as opposed to relationship quality and have not explicitly addressed issues of causality between hormones and relationship outcomes. Future research should examine such links in both men and women, ideally including more than two time points to more fully document patterns of change.

We also currently know very little about dyadic links between hormones and relationship outcomes because the vast majority of relevant studies focus on individuals rather than couples (e.g., men and women in the Das & Sawin, 2016, study were in romantic relationships but not with other study participants). Yet extant data provide growing evidence that individual differences in hormones have implications not only for individuals, but also for their partners (Schneiderman et al., 2014). For example, men and women report higher relationship satisfaction and commitment when their partners have lower testosterone levels (r ranging from $-0.37$ to $-0.51$ in a sample of 39 couples, Edelstein et al., 2014). Couples in which both partners have relatively high levels of testosterone also tend to show higher levels of partner-directed hostility and aggression (Kaiser & Powers, 2006; Schneiderman et al., 2014).

Although not focused on romantic relationships per se, one recent study investigated changes in testosterone and cortisol as a function of an experimental manipulation designed to increase intimacy among previously unacquainted individuals (Ketay et al., 2017). In a sample of 58 undergraduate students, participants with lower baseline testosterone levels, and those who showed larger pre- to post-task declines in testosterone, reported greater desired and actual closeness toward their partner following the manipulation (a self-disclosure task) compared to a less intimate task. Participants with lower baseline cortisol, and those who showed larger pre- to post-task declines in cortisol, similarly reported greater desired and actual closeness to their partner following the intimate task, suggesting that cortisol and related stress-linked changes might impair relationship processes (friendship formation in this case). Moreover, people whose
interaction partners had lower baseline cortisol, or showed larger cortisol declines, reported
greater desires for closeness toward those individuals following the intimate task, providing
some evidence for dyadic associations between cortisol and interpersonal outcomes. Taken
together, these findings are consistent with the idea that lower levels of testosterone and cortisol
may support or promote relationship functioning, and that positive intimate interactions may be
a particularly fruitful context in which to investigate dyadic associations between hormones and
interpersonal outcomes (Loving & Slatcher, 2013). The extent to which these findings might
generalize to romantic relationships, and particularly whether such intimacy “interventions”
might lead to changes in hormones among those in long-term relationships, is a promising
direction for future research.

In addition to illuminating within-dyad associations, studies that include both partners also
provide intriguing evidence that hormonal coordination or synchrony between partners may be
important for romantic relationship functioning. For instance, couples often show between-
partner correlations in cortisol, and those with stronger correlations tend to report poorer
relationship quality and show evidence of less optimal relationship functioning (e.g., Saxbe &
Repetti, 2010; Schneiderman et al., 2014; see Timmons et al., 2015, for a review). Insofar as
cortisol production is a marker of stress, these finding suggest that couples who are “in sync” in
cortisol might experience more relationship stress, be more impacted by their partner’s experi-
ences of stress, and/or have more difficulty coping with stressful experiences.

Cortisol has been most often investigated compared to other hormones in studies of coor-
dination or synchrony (Timmons et al., 2015); however, there is limited evidence for within-
couple correlations in testosterone and progesterone (Booth et al., 2005; Edelstein et al., 2014;
Edelstein et al., 2015; Saxbe et al., 2017). Moreover, as we describe in the section on parenting,
within-couple correlations in testosterone may predict positive relationship outcomes during
the transition to parenthood (Saxbe et al., 2017).

**Summary and implications**

In sum, partnering appears to have important implications for baseline levels of steroid hor-
mones, particularly testosterone and cortisol. Both men and women in committed relationships
tend to have lower levels of testosterone and cortisol compared to single people, yet there may
be differences depending on the specific type of partnering and gender. Lower levels of testos-
sterone and cortisol have also been linked with more positive relationship outcomes, suggesting
that changes that occur when people become partnered may be adaptive or beneficial in main-
taining that relationship. Most work remains somewhat gendered, however, in that differences
in testosterone have been more fully explored among men versus women. Moreover, very few
studies include both men and women, and those that do typically analyze data separately by
gender, making it difficult to formally assess gender differences. More work is also needed to
tease apart issues of causality, and to better understand the mechanisms that might contribute
to changes in hormones over time. Moreover, relatively little is known about how estradiol and
progesterone may differ according to partnered status, how these hormones might change over
time as a function of changes in partnering, and whether they are associated with relationship
outcomes. Finally, there is emerging evidence to suggest that an individual’s hormone levels
have implications for his or her partner’s relationship well-being as well as their own, and that
coordination or synchrony in hormones between couples may be an important indicator of
relationship functioning. The vast majority of studies on hormone-partnering links do not
include both couple members, however, and further research is needed to more fully understand
how hormones influence and are influenced by dyadic processes.
Hormones in the context of parenting

**Differences in hormones as a function of parental status**

Hormones appear to vary systematically as a function of parental status, in that men and women with children typically have lower testosterone compared to those without, even when controlling for potentially important covariates such as age and BMI (e.g., Barrett et al., 2013; Gettler & Oka, 2016; Gray et al., 2006). For instance, in a sample of 75 Swiss men, fathers had lower testosterone than men without children, \( d = -0.59 \) (Perini et al., 2012). Kuzawa et al. (2010) similarly found, in a sample of 67 Pilipino women, that mothers had higher levels of waking testosterone compared to women without children, \( d = -1.02 \); mothers and non-mothers did not significantly differ in their levels of evening testosterone, \( d = -0.38 \), but this difference was significant when only mothers with children younger than 2 years of age were included in analyses, \( d = -0.81 \). Further evidence that children's age may be an important consideration comes from a study of 195 Norwegian women: Women with children ages three and under had lower testosterone levels compared to women without children and those with children older than 3 years, both \( d = -1.58 \) (Barrett et al., 2013). Studies on parenting are more likely to include women compared to those focused on partnered status exclusively, but again it is very rare for both men and women to be included in the same study. Further, the consistency of findings across cultures suggests that there could be some universal mechanisms underlying changes in hormones associated with parenthood, such as physical contact with infants, changes in the parental relationship, or changes in identity as one becomes a parent; yet as with research on partnering, there are relatively few direct investigations of such mechanisms.

It is also worth noting a recent exception to this pattern of findings: In the large sample of military veterans described earlier, married men with children living in the home had higher serum testosterone than married men who did not, \( d = .28 \) (Mazur, 2014). A similar, albeit somewhat weaker, pattern emerged when number of children rather than presence or absence of children was considered. The reasons for the discrepancy between these results and those of previous research are not entirely clear, but Mazur’s findings are particularly notable given the statistical power of this compared to most samples. However, the ages of the children in this sample were unknown and thus not accounted for. As described above, there is some evidence that women with younger children have lower testosterone than women with older children, and most studies of fatherhood focus on those with infants or relatively young children (e.g., Gettler, McDade, Feranil et al., 2011; Perini et al., 2012). It is also possible that men involved in the military, such as those in this sample, are particularly competitive and/or dominant; perhaps in this context fathers may feel more competitive or protective of their children, in some cases leading to increases in testosterone when children are present. Of course, these possibilities remain to be tested and would present interesting avenues for future research. Moreover, as described in the following section, cross-sectional data, even in such a highly powered sample, cannot speak to changes in testosterone over time, as opposed to pre-existing differences between men who do and do not become fathers; it is certainly possible that men in this sample experienced declines in testosterone when they initially became fathers.

There are very few systematic assessments of cross-sectional differences in hormones other than testosterone as a function of parenthood; however, there is some evidence, from a sample of 346 naturally cycling women, that women without children may have higher baseline urinary estradiol levels than women who had given birth in the last 3 years, \( d = -0.53 \), and those who had given birth more than 3 years earlier, \( d = -0.28 \) (Barrett et al., 2014). Gettler, McDade, and Kuzawa (2011) also found that men who were neither married nor fathers had higher morning
and evening cortisol levels compared to men who were married and/or fathers, $d = .16$ and .20, respectively (in a sample of 630 Pilipino men that was not stratified by fatherhood status per se).

**Changes in hormones as a function of parental status**

As with research on partnering, the vast majority of work on hormone-parenting links has thus far been cross-sectional. Based on these data alone, it is difficult to assess whether it is parenthood per se, rather than other changes or demographic factors associated with parenthood, that lead to between-person differences in hormones. However, several longitudinal studies have recently begun to address this gap by investigating changes in women's (and in some cases men's) hormones throughout the transition to parenthood. Findings from these studies indicate that expectant mothers show large prenatal increases in testosterone, cortisol, estradiol, and progesterone (Edelstein et al., 2015; Fleming et al., 1997; Glynn et al., 2016); these changes are thought to support fetal development, maintain the pregnancy, initiate parturition, and generally prepare women to become mothers (Makieva et al., 2014). After delivery, new mothers' hormone levels gradually decline closer to pre-pregnancy levels, with estradiol and progesterone dropping most rapidly (Fleming et al., 1997). Given that cross-sectional comparisons indicate lower baseline levels of testosterone and estradiol among mothers compared to women without children, these findings suggest that the short-term hormone changes observed during pregnancy may not extend into the postpartum, and may in fact reverse when women become mothers. Yet longitudinal data assessing women's hormones from the prenatal to the postpartum period are rare, so it remains somewhat unclear whether and how mothers' hormones may change long term as a function of parenting experiences.

Less is known about hormone changes among expectant fathers compared to mothers, but there is some evidence that men show declines in testosterone and estradiol and increases in cortisol during the transition to parenthood, and that these changes may begin even during the prenatal period (Berg & Wynne-Edwards, 2001; Storey et al., 2000). For instance, in our longitudinal study of 29 first-time couples, expectant fathers showed declines in testosterone and estradiol from the beginning through the end of the prenatal period, $d = −.58$ and $−.63$, respectively (versus increases among expectant mothers, with $d$ ranging from 1.09 for cortisol to 3.05 for progesterone; Edelstein et al., 2015). Given cross-sectional findings that fathers typically have lower testosterone compared to men without children, these data suggest that the changes that begin during the prenatal period, perhaps as men prepare to become fathers, likely continue or are maintained once babies are born. As with mothers, there are relatively few longitudinal studies of changes in men's hormones that span the prenatal to postpartum period. However, in one notable exception, Gettler, McDade, Feranil et al. (2011) followed a representative sample of 624 men in the Philippines over a 4-year period as they experienced transitions in partnering and parenthood. Men who became partnered fathers during this time showed larger declines in testosterone than single men who did not have children; those who became partnered but did not have children had testosterone levels that were not significantly different from men who remained unpartnered at the follow-up assessment. These findings suggest that fatherhood specifically, rather than partnering more generally and/or the passage of time, may be an important contributor to longitudinal changes in testosterone. Moreover, testosterone declines were most pronounced among fathers who were more directly involved in infant care. This study is notable in that it is among the few to follow participants over time, thus more directly addressing issues of causality, and because the data can speak to potential mechanisms (e.g., preparing for and/or interacting with children) that might drive changes in hormones as a function of parenthood.
Hormones and close relationship processes

Hormones and parenting outcomes: individual and dyadic associations

Like hormone changes associated with partnering, those associated with parenting are thought to be functional in that they may support care of offspring and the relationship between parents (Wynne-Edwards & Rebur, 2000). For example, long-term declines in testosterone are thought to reduce aggression toward infants, focus attention away from mating effort and toward the pair-bond relationship, and/or facilitate infant-parent attachment (Zilioli & Bird, 2017).

Indeed, in a sample of 149 couples, lower paternal testosterone (assessed at 6–9 months postpartum) was associated with lower mother-reported rates of intimate aggression, $\beta = .18$, and lower maternal depressive symptoms, $\beta = -.21$ (Saxbe et al., in press). Moreover, the association between paternal testosterone and maternal depressive symptoms was mediated by maternal relationship satisfaction, such that mothers were more satisfied when their partners had lower testosterone. These findings are consistent with those indicating that people may experience better relationship quality when their partners have lower levels of testosterone (Edelstein et al., 2014); they also extend that work into the realm of intrapersonal adjustment, suggesting that one’s well-being may influence or be influenced by his or her partner’s hormones. Interestingly, however, in this study, fathers with lower testosterone reported more depressive symptoms, $\beta = -.17$, suggesting that what might be advantageous with respect to the parental relationship might confer risk for fathers themselves. Further research is needed to better understand how these processes might play out over time and the extent to which similar associations would be observed for mother’s testosterone (which was not collected in this study) or for other hormones.

Lower levels of estradiol have been similarly linked with more adaptive postpartum outcomes in other longitudinal studies. For instance, Fleming et al. (1997) found that expectant mothers with lower levels of serum estradiol, and lower estradiol-to-progesterone ratios (thought to be related to the onset of maternal behavior; Mileva-Seitz & Fleming, 2011), reported stronger postpartum feelings of attachment toward their infant, $r$ ranging from $-.34$ to $-.60$ ($n = 16–20$) depending on the timing and measure. In another study, women’s ($n = 177$) hormones were assessed from blood samples at multiple time points throughout the prenatal period, and their behavior was observed during a free play interaction with their infants at 12 months (Glynn et al., 2016). Again, mothers with lower levels of estradiol, lower estradiol-to-progesterone ratios, and smaller increases in estradiol over time, were rated as being more sensitive during the play session.

Our longitudinal study of expectant couples provides additional evidence for links between prenatal hormones and postpartum outcomes, as well as for the dyadic implications of these links. At 3 months postpartum, fathers who had larger prenatal declines in testosterone and estradiol reported that they provided more infant care and that they were more satisfied with, committed to, and invested in their romantic relationships (Edelstein et al., 2017; Saxbe et al., 2017). Their female partners corroborated these reports, indicating that they received more postpartum support and assistance with household tasks from fathers who showed larger prenatal declines in testosterone. Similarly, despite normative prenatal increases in testosterone and estradiol, expectant mothers who showed smaller increases in these hormones were rated by their male partners as providing more postpartum parenting support.

These data are consistent with the idea that hormone changes associated with parenthood may help people become more effective caregivers and more responsive relationship partners. However, it is worth noting the different patterns of findings for estradiol in the context of parenthood versus those in the context of romantic relationships: Estradiol has generally
been positively associated with romantic partnering and romantic relationship outcomes (e.g., Edelstein et al., 2010), but as just described, is often negatively associated with parenting-related outcomes (e.g., Glynn et al., 2016). There is currently relatively little human research on this topic, but animal research also provides evidence for both facilitative and inhibitory effects of estradiol on parental behavior (see Wardecker et al., 2015). Thus, it is possible that estradiol plays a different role in the context of romantic versus parent-child relationships. It is also possible that demographic differences across studies (e.g., in age or relationship status) or small sample sizes contribute to different patterns of findings. Given that there is relatively little human research to date, particularly high-powered studies of individuals or couples over time, more research is clearly needed to better understand the role of estradiol in human interpersonal relationships.

Additionally, as described earlier, in our longitudinal sample, we found that average levels of testosterone, progesterone, and cortisol were correlated within couples throughout the prenatal period, ranging from .32 to .62 (Edelstein et al., 2015). Moreover, the magnitude of within-couple correlations in testosterone increased over time, and fathers who showed stronger correlations in testosterone with their female partners reported greater relationship satisfaction, commitment, and investment at 3 months postpartum (Saxbe et al., 2017). These findings were specific to testosterone, in that within-couple synchrony in other hormones did not predict fathers’ postpartum outcomes in our sample. We also found some evidence in support of causality from hormone synchrony to relationship outcomes, in that prenatal relationship quality was not associated with subsequent within-couple correlations in testosterone (although any null effects should be interpreted cautiously given the relatively small size of our sample). Thus, within-dyad covariation in testosterone (unlike cortisol) may reflect or predict positive relationship processes, perhaps due to links between testosterone and nurturance or caregiving (van Anders et al., 2011). Nevertheless, given the dearth of work on this topic, further research is warranted to better understand the extent of within-dyad covariation of hormones, including hormones other than testosterone and cortisol, and the implications of such covariation for parenting and romantic relationship processes.

**Summary and implications**

In sum, parenthood appears to have important implications for hormones, and changes in hormones appear to have downstream consequences for parenting and relationship outcomes. Most research has focused on testosterone; this work indicates that parents generally have lower levels of testosterone than people without children, and that declines in testosterone may facilitate parental care. As is the case for partnering, research on hormone-parenting links tends to be somewhat gendered, in that we know much more about testosterone among fathers than mothers, and (relatively) more about estradiol and progesterone among mothers versus fathers. However, recent findings point to the importance of estradiol for both mothers and fathers, and suggest that estradiol may have different associations with behavior in the context of parent-child versus romantic relationships. Further, limited longitudinal data (mostly conducted with men) suggests that hormone changes associated with parenthood may occur over and above those attributed to partnering, and that these changes may be most evident among those who are most invested in the parental role. There is also emerging evidence that hormone changes associated with parenthood may have consequences for both the individual and his or her partner. Further research is needed to better understand these associations and, more broadly, to understand the implications of multiple hormones for parenthood and vice versa.
Conclusions and future directions

Taken together, the findings reviewed here suggest that relationship transitions are closely tied to baseline hormone levels and changes in hormones over time. Most work in this area has thus far been cross-sectional, however, which makes it difficult to tease apart the causal nature of any links between hormones and relationship processes or outcomes. The few notable exceptions provide evidence that changes in relationship status are more likely to precede changes in hormones than vice versa, and that differences in hormones may then lead to differences in relationship quality or outcomes; yet there is also some evidence for bidirectional associations between hormones and relationship processes. Future research would benefit from more comprehensive assessments of changes in hormones and relationship processes over time, in both men and women, ideally including repeated assessments of multiple hormones so that changes can be documented more precisely.

Most neuroendocrine research on partnering and parenting also tends to focus on individuals as opposed to couples, which has critically limited our understanding of dyadic effects. The few notable exceptions suggest that hormones may have implications not only for one’s own adjustment and interpersonal outcomes, but also for his or her partner’s. Moreover, the extent to which couples’ hormones are coordinated or synchronized may be an important predictor of relationship outcomes; coordination of cortisol appears to reflect more negative relationship outcomes, whereas coordination of testosterone appears to reflect more positive outcomes. As with other areas of research, however, much less is known about dyadic effects of estradiol and progesterone, and we believe that this would be a fruitful area of research.

Future research might also focus on moderators or correlates of hormone changes and dyadic effects; for instance, who might be most likely to show hormone changes associated with partnering or parenting? Do partner effects become more or less influential over time as relationships develop? What are the predictors and long-term consequences of hormonal synchrony? Further, to our knowledge, the vast majority of research in these areas has been conducted with heterosexual couples and in two-parent households. What might such associations look like in same-sex couples or people engaged in consensually non-monogamous relationships? Expanding the scope of this work to include same-sex couples and more diverse family configurations would not only increase generalizability and inclusivity but could help to shed light on potential boundary conditions and moderators of hormone-relationship links.

Additionally, although many studies of basic partnering and parenting effects are fairly high-powered, sample sizes in many longitudinal and/or dyadic studies tend to be relatively small. There are certainly practical and financial reasons for such choices, but future research would benefit from higher-powered investigations to assess more nuanced questions about hormone changes over time and dyadic interdependence between couple members. Meta-analytic work could also be helpful in reconciling inconsistent findings across studies, particularly those that tend to be less highly powered, and to provide more precise estimates of basic effect sizes and the robustness of these effects. Such efforts have been useful for understanding links between testosterone and aggression (Book et al., 2001) and cortisol and health outcomes (Adam et al., 2017), for instance; to our knowledge, however, such efforts have not yet focused on the social neuroendocrinology of close relationship processes.

Finally, although the resources required to collect hormone data from both couple members can be fairly prohibitive, especially longitudinally and in samples large or diverse enough to make strong causal inferences, future research would benefit from study designs that assess multiple hormones as people become partnered, prepare for parenthood, and ultimately become parents. Such data could provide important new information about a wider variety of hormones,
individual and gender differences in hormone-relationship links, and the implications of hormone changes for parenting and interpersonal outcomes. Longitudinal study designs could also contribute much needed data on the mechanisms that may contribute to long-term changes in hormones and links between hormones and relationship outcomes. We hope that research will continue to move in these exciting directions to advance knowledge about the social neuroendocrine bases of partnering and parenting.

References


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