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The evolutionary biology of cryptic pregnancy: A re-appraisal of the ‘‘denied pregnancy’’ phenomenon

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Summary Previous research on ‘denied pregnancy’, i.e. lack of subjective awareness of pregnancy until the end of gestation in pregnant women, is reviewed and reinterpreted in an evolutionary biological framework. Recent epidemiological studies show that this condition has a much higher incidence than previously thought (about 1:475). Very often, bodily symptoms of pregnancy (nausea, amenorrhea and abdomen swelling) are absent or greatly reduced, and neonates tend to be underweight; in many cases, pregnancy goes undetected also by relatives and physicians. Current explanations in the clinical literature are based on psychodynamic hypotheses about pregnancy-related unconscious conflicts; the lack of symptoms is accounted for by ‘somatic denial’. I argue that such psychodynamic accounts are misguided for two reasons: (1) they rest on a failure to recognize the active biological role of the fetus in determining the course of pregnancy, and (2) they ignore the many levels of mother-fetus conflict over resource allocation described by biological theories of parent-offspring conflict.

Here I propose to redefine this condition as ‘cryptic pregnancy’, and begin to explore its possible physiological correlates and evolutionary significance. In the light of parent-offspring conflict theory, cryptic pregnancy appears to reduce the costs of pregnancy, both energetic and ecological (mobility, dependence on kin/mate, etc.), thus favoring the mother at the expense of the fetus. Reduced hCG production and/or effectiveness is likely to be involved in the process. I propose and discuss three nonexclusive evolutionary hypotheses to account for this phenomenon: (1) cryptic pregnancy could be a nonadaptive outcome of conflict resolution processes over resource allocation in pregnancy, possibly related to minor disruptions of genomic imprinting mechanisms. (2) Cryptic pregnancy could result from missed spontaneous abortions of low-quality fetuses. (3) Finally, cryptic pregnancy could be an adaptive pattern of ‘forced cooperation’ between mother and fetus in stressful or threatening ecological circumstances, as suggested by the reported association with elevated psychosocial stress. In case of reduced survival probability, both mother and fetus would benefit if the mother reduced investment in pregnancy in order to maximize her chances of surviving and reaching delivery.

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Introduction

'Denied pregnancy': an enduring mystery

'There are few conditions more difficult to comprehend, than the denial of pregnancy by an otherwise healthy and "normal" woman' [1]. These words of puzzlement, written by an influential researcher in the field, refer to the odd phenomenon of women who show no awareness of their pregnancy until the last weeks of gestation, and in some cases until delivery. Adding to the mystery, case studies often report that neither relatives nor family doctors had realized the woman's condition. In many cases, women present pseudo-menstrual bleedings and suffer from few (or none) of the typical pregnancy-related symptoms like nausea [1,2]. So-called 'denied pregnancies' have long been regarded as rare events, mostly associated with psychopathological conditions in the mother [3]. However, a few epidemiological studies in the last decade have dramatically changed the picture: current estimates, based on a large prospective study in Germany, range from 1:475 for the ratio of pregnancies discovered after the 20th week to about 1:2500 for the ratio of totally unexpected deliveries [4,5]. These figures are hardly consistent with a rare, unimportant psychiatric condition, and suggest that this phenomenon is far more common than is usually realized.

Searching the literature for explanatory hypotheses, one will find that the only attempts to shed light on the matter are based on psychoanalytic concepts like 'primitive defense mechanisms' and 'unconscious conflict about pregnancy'. Indeed, the current label for the syndrome itself is highly indicative: mothers are thought to 'deny' their pregnancy (and related somatic symptoms) for unconscious reasons. The fact that relatives and practitioners also fail to recognize pregnancy is accommodated, somewhat uncomfortably, by referring to interpersonal defense mechanisms such as 'projective identification' [3,6]. Despite common reliance on psychopathological concepts, however, there is increasing awareness that psychotic states (although present in a minority of cases) are by no means a necessary feature of this syndrome [7–9]. The term 'nonpsychotic denial of pregnancy' has been proposed [8] to describe those cases in which the mother has no diagnosis of psychiatric illness, and is usually able to adjust to the new condition and to function well with her child after birth [10].

In this paper, I will argue that most cases of 'denied pregnancy' are best understood within an

evolutionary biology framework, with little need to resort to psychoanalytic concepts. I also propose *cryptic pregnancy* (which I will use from now on) as a more general and appropriate label, devoid of unwanted interpretational biases.

Two illusions: passivity of the fetus and perfect cooperation

Why do we feel compelled to attribute 'denial' to a woman who fails to recognize her pregnancy? I suspect that one reason lies in the naïve conception of pregnancy as something happening to the mother alone, with the developing fetus seen as a passive entity unable to influence the course and outcome of gestation. An even more pervasive misconception is that of pregnancy as a perfectly cooperative enterprise between mother and fetus. As I will briefly review in the next section, this view has been successfully challenged by evolutionary biology, leading to models of pregnancy which involve conflict at many levels. The failure to recognize conflict at the biological level, together with persistent neglect of the active role of the fetus during all stages of gestation, leads to ad-hoc explanations which inevitably place conflict in the intrapsychic domain of the mother.

As I will show in this paper, biological analysis of cryptic pregnancy brings about a much more complex and intriguing picture. In the following sections, I will review the existing literature on cryptic pregnancy to attempt a systematic description of the phenomenon and to point out its likely physiological correlates. I will then present three alternative hypotheses on the functional explanation of cryptic pregnancy, review the supporting evidence, and propose some directions for future research to further clarify the issue.

Conflicts in pregnancy

Parent-offspring conflict

Although the metaphor of pregnancy as a battle between mother and fetus is not new (see [32] for a historical review), we owe to Trivers [11] the first formal treatment of parent-offspring conflict (see [12] for an updated synthesis). The theory predicts that when parental investment in current offspring comes to a cost in terms of parent's future reproductive success, the optimal investment level will be different if calculated from the parent's or from the offspring's point of view. Offspring will be selected to request a higher amount of parental

investment (energy, time, etc.) than is optimal for the parent to provide: thus, conflicts of interest will arise about the amount of investment provided, possibly involving 'arm races' of reciprocal manipulation. Parent-offspring conflict is expected at different life stages, starting before conception and potentially extending to offspring's adult life. Conflict is expected to be even more intense when confidence of paternity is low and/or there is no perfect monogamy, so that the probability that future offspring will not have the same father is higher [13–15].

Costs and conflicts in pregnancy

Haig [16–18] was the first to provide a thorough analysis of the many mother-fetus conflicts that take place during pregnancy. Drawing from his work, we can identify three main points of conflict to be expected in pregnancy:

1. *Conflicts about abortion.* Mother will gain by spontaneously aborting nonviable or low-quality offspring. The 'decision threshold' about whether to carry or abort is, however, susceptible to differ between mother and fetus, with fetus favoring a higher rejection threshold [19,20].
2. *Conflicts about fetal growth.* Nutrient supply to the fetus is metabolically costly to the mother; again, there will be conflicts about mother's allocation of resources between the developing fetus, its already born siblings, and herself.
3. *Conflicts about timing.* We can expect that mother and fetus will disagree about timing of delivery, with the fetus favoring longer gestation (implying higher investment) than mother.

Of course, these three kinds of conflict are expected to reach their peak of intensity in different phases of pregnancy. In order to gain a clearer understanding of what is actually included under the label of 'parental investment', we now need to summarize the different costs that mothers suffer during pregnancy, ranging from the physiological to the ecological level. Costs to mother, which more or less directly translate into benefits to the fetus, can be roughly categorized as follows:

1. *Pregnancy-related health risks.*
2. *Metabolic/energetic expenditures.*
3. *Nausea.* It has been proposed that the evolved function of pregnancy-related nausea is to protect the developing fetus against potentially teratogenic foods [21]. Excessive nausea, however, can have detrimental effects on infant birth-

weight [22]. For a different interpretation of nausea as a side effect of conflict in offspring selection, see [20].

4. *Reduced mobility.* It is reasonable to suggest that reduced mobility during pregnancy also has the effect to protect the fetus. Costs to mother (in an ancestral environment) include lower foraging ability, increased dependency on kin and/or mates and higher predation risk.
5. *Social costs.* A visibly pregnant woman which, for example, is deserted by her mate, will have fewer opportunities to find a new partner. Thus, pregnancy per se represents a potential social cost if there are reliable external signs (such as abdominal swelling or amenorrhea).
6. *Future costs.* In our species, a woman investing in a child must consider a long period in which dependent offspring will need to be nourished, protected, and so on. Postpartum depression has been analyzed as a possible adaptation of mothers, who must decide whether they can afford to keep the newborn after delivery [23,24]. For a comprehensive treatment of human infanticide from a behavioral ecology perspective, see [25].

As we have seen, a pregnant woman has many potential costs to weight against the benefit of a new offspring. We can expect women to be adapted to make several 'decisions', both physiologically and psychologically, about the course of gestation. Of course, the embryo/fetus is also adapted to exert some influence on the same process, mainly by means of physiological regulation.

Genomic imprinting: widening the conflict

Parent-offspring conflict in pregnancy is rendered more complex by the existence of imprinted genes, which are *conditionally* expressed in the fetus (including the placenta) depending on the allele's parent of origin [26]. Some of these genes are expressed solely (or predominantly) when the allele is maternally derived, while others are expressed when paternally derived; conditional expression can also depend on the specific tissue. There is no room here for a detailed treatment of the issue; however, one of the recurrent findings in mammals is that many imprinted genes are involved in the regulation of fetal growth [27]. The most influential theory on the evolution and function of imprinted genes is the 'kinship theory' of genomic imprinting [16,28]. Kinship theory extends classical parent-offspring conflict to conflict between maternally derived and paternally derived genes expressed in the offspring. The main prediction is

that, especially when confidence of paternity is low and/or there is no strict monogamy, paternally expressed genes will tend to favor the fetus at the expense of the mother, while the opposite is expected from maternally expressed genes. Pregnancy will then involve a 'tug-of-war' between different sections of the genome, which is expected to reach some kind of equilibrium since interests of mother and fetus diverge only in part. Evidence of a conflictual equilibrium (opposed to a purely cooperative one) can be found when regulatory mechanisms involve high and seemingly useless costs, or show cues of escalated feedback between mother and fetus.

hCG and the physiology of conflict

Human chorionic gonadotropin (hCG) is a placental hormone which is produced at high levels during pregnancy, with a peak between the 8th and 12th week. This hormone is of particular interest for our analysis, since it is involved in many symptomatic aspects of pregnancy. Indeed, hCG stimulates the release of maternal progesterone and thus inhibits menstruation; moreover, a role for hCG has been repeatedly proposed in the etiology of pregnancy-related nausea, with higher hCG levels generally related to more severe symptoms [17,20,29,30]. There is also a strong possibility that the β -subunit of hCG is imprinted, and expressed predominantly from the paternally derived allele [31,32].

Haig [17] proposed that placental hormones may play a crucial role in conflict resolution during pregnancy. Placental hormones can be seen as fetal attempts to manipulate mother's metabolism for fetal benefit; the mother is expected to develop appropriate defenses to counter and limit fetal influences. The extremely high level of hCG production in the placenta could be the result of such an escalated evolutionary process. However, another interpretation has been put forward by the same author. Theoretical work on parent-offspring signaling predicts that, in situations of conflict, selection will favor the evolution of costly, honest signals [33,34]. Haig proposed that elevated hCG levels in the first trimester could serve as a honest signal of 'vigor' or viability by the fetus, precisely at the time when the mother is 'deciding' whether to spontaneously abort the fetus or not. Sufficient hCG levels would then serve as a 'screening device' for the mother [18]. Low hCG levels are indeed associated with high spontaneous abortion rates [19]. Some genes coding for the hCG β -subunit (CGB1 and CGB2) may have specific roles in the implantation phase; their expression levels differ

substantially in failed pregnancies compared with normal pregnancies [35].

Cryptic pregnancy: putting the evidence together

What do we know about human cryptic pregnancy? Unfortunately, to date there has been almost no attempt to understand the phenomenon from a biological point of view, so the available evidence is much less complete than one could wish for. Recent epidemiological studies are more informative, although there is still need to rely on indirect evidence to evaluate explanatory hypotheses. In this section I will attempt a first systematic description of cryptic pregnancy, together with a discussion of its possible etiological factors.

Absence of subjective awareness

The absence of subjective awareness of pregnancy, distinguished from intentional concealment, is actually the *only* criterion clinicians use to formulate a diagnosis of 'denied pregnancy'. But how does a mother realize she is pregnant? It seems quite obvious, yet apparently underappreciated, that women use bodily cues to make a self-diagnosis of being pregnant. In most cultures, nausea and amenorrhea are considered the primary cues to pregnancy [21]. Another cue is provided by abdominal swelling, which however is highly variable and can go unnoticed in the first weeks.

I propose to restrict the definition of cryptic pregnancy to those pregnancies in which all or most of these cues are absent or highly reduced, as is often the case (see below). When a woman has insufficient cues to realize she is pregnant, she will probably not. The underlying biological reason is that pregnancy is not initiated by the woman alone, but is the effect of a joint 'decision' by two (partially) autonomous actors; ectopic pregnancies provide a striking illustration of how fetal autonomy can sometimes override the mother's decisional mechanisms. Failure to recognize the active role of the fetus has caused much puzzlement, but, I suggest, little understanding of the phenomenon.

Psychiatric disorders

Association of cryptic pregnancy with psychiatric conditions shows substantial variation between studies. In an Austrian sample of 27 cases [1], 48% of the woman met the criteria for a psychiatric diagnosis after a structured interview. Diagnoses were however highly variable: schizophrenia (7%),

depression (15%), personality disorders (15%) and mild mental retardation (11%).

A quite different picture emerges from the German prospective study [4], who identified 62 cases; 5% of the women were given a diagnosis of schizophrenia, and only a minor proportion of the sample (8%) showed signs of personality disturbances or mental retardation in an unstructured clinical interview. What is recognized by all authors is that psychiatric symptoms are not an essential feature of the syndrome, and they could be associated only to a minority of cases. Even more importantly, there seems to be no *specific* psychiatric correlate of cryptic pregnancy.

Pseudo-menstrual bleedings and absence of nausea

Although 'somatic denial' in the form of pseudo-menstrual bleedings and absence of nausea has been often reported [10], the only systematic investigation of the phenomenon can be found in the study by Brezinka and colleagues [1]. In this sample, only 26% of women reported amenorrhea, and some of them (who were in their 40s) had mistaken it for the onset of menopause. The great majority of women reported bleedings, from irregular spottings to regular 'menses'. At the same time, only 26% of women had nausea in early pregnancy (correlation between nausea and amenorrhea was not reported); interestingly, *none* of the women who were unaware of pregnancy until delivery had suffered from nausea. This suggests an association between absence of nausea and other variables, like low birthweight and reduced abdominal swelling, which may contribute to conceal the state of pregnancy.

Reduced abdominal swelling

This is a likely feature of cryptic pregnancy, although the evidence is only indirect. In the study by Brezinka and colleagues [1], 56% of women, interviewed after delivery, reported 'none or very little' weight gain during gestation. This data are consistent with the observation that relatives and physicians often fail to recognize pregnancy as well [6]. Other indirect evidence comes from the high proportion of underweight neonates found in all studies (see below).

Low birthweight and prematurity

Low birthweight is definitely a major feature of cryptic pregnancy. The proportion of viable

neonates weighing <2500 g is very high, 26% in the Austrian sample [1] and 22% in the German sample [4], compared with about 7% in the general population. There is also an increase in prematurity, with 13% pre-term births in the Austrian sample and 18.5% in the German sample.

Fetal and neonatal risk

Surprisingly, there is no clear indication of elevated fetal or neonatal risk in cryptic pregnancy. In the Austrian sample, there was a higher than usual rate of intrauterine fetal death (15%, only before the 26th week), not replicated in the larger German sample. Although there have been claims of elevated risk in cryptic pregnancy [36], such claims are based mainly on low birthweight and high incidence of surgical delivery rather than on actual medical outcomes in neonates. Of course, good fetal outcomes could be strongly due to present-day obstetrical care; in ancestral environments, risk factors could have been multiplied by the absence of medical support. Investigators agree that the major risk factor is probably the absence of proper antenatal care: mothers who are unaware of their pregnancy may adopt risky behaviors like engaging in vigorous physical activity, taking drugs, smoking, and eating inappropriate foods (absence of nausea clearly enhances this risk).

Risk of neonaticide, neglect and abuse

In the two largest studies, there were no occurrences of neonaticide and only two cases of late abortion. Moreover, in the Austrian sample a 2-years follow-up was conducted, which found no evidence of emotional neglect, physical abuse or malnutrition. There is the possibility, however, that most cases of cryptic pregnancy followed by neonaticide escape hospital-based sampling. There have been some previous reports of high incidence of 'denial' in women who commit neonaticide [37,38], so the association cannot be entirely ruled out. In the general population, though, women seem capable of accepting and taking care of the newborn after a cryptic pregnancy, and many feel intensely guilty for putting their babies at risk before diagnosis [2,36].

Etiological factors

Little is known about the etiology of cryptic pregnancy. Psychosis can be excluded, since it only accounts for a small minority of cases. Epidemiological studies so far seem to rule out factors like

age of the mother, parity and other demographic variables. In the Austrian sample, investigators found a high incidence of psychosocial stressors, which led them to describe nonpsychotic cryptic pregnancy as an 'adjustment disorder'. Notably, 44% of the mothers experienced separation from partner at the beginning of pregnancy, and 56% were judged to suffer from familial conflicts, social isolation and/or lack of social support (note that the two categories are partially overlapping). Remember that in this sample there was also a high incidence of psychiatric diagnoses, so the two factors may be correlated. In the German sample, again, investigators report a different picture: 83% of the mothers stated they had a close partner, and 65% lived with him at the moment of diagnosis. It should be noted, however, that there was no probing for specific psychosocial risk factors; this could have led to underestimate the true incidence of conflicts and separations in this sample.

Finally, one should consider the possible influence of heritable traits. Both birthweight [39–41] and severity of pregnancy-related nausea [42,43] show heritable patterns, so there might be genetic (or epigenetic [44]) transmission of some predisposing factors.

Explanatory hypotheses

Who is winning the conflict?

In this section, I will use parent-offspring conflict theory as a framework to understand the biological basis of cryptic pregnancy. The first step is to evaluate the above profile in the light of the costs and conflicts involved in pregnancy. The question is: who (if anyone) is going to benefit from cryptic pregnancy?

The answer seems straightforward: low birthweight, prematurity, absence of nausea and reduced abdominal swelling are all factors that benefit the mother at the expense of the fetus. The latter suffers from reduced energetic intake and greatly decreased antenatal protection (from injuries, food teratogens, etc.), while the mother pays only a small fraction of the costs typically associated with pregnancy. In addition to reduced metabolic costs, there are other likely advantages for the mother: increased mobility and concealment of pregnancy to potential partners. Does this mean that the mother is simply 'having the edge' in parent-offspring conflict? The answer is no. In fact, at least three hypotheses can be formulated to explain the phenomenon of cryptic pregnancy in

evolutionary terms. Given the current state of knowledge, the three hypotheses are not mutually exclusive, and could well account for different pathways to phenotypically similar outcomes.

Hypothesis 1: nonadaptive byproduct of conflict resolution

If mothers and fetuses are involved in conflicts about parental investment, and if conflicts are resolved in a dynamic equilibrium of reciprocal influences, the outcome will not be fixed but will rather show variation around the population mean. Different selective forces act on mothers and fetuses, and we can expect the tug-of-war of pregnancy to sometimes favor one side over the other just by chance. Cryptic pregnancies may represent one extreme of the range, where pregnancy is characterized by unusually low parental investment. Disruption of genomic imprinting mechanisms could be involved, since both loss of imprinting in maternally derived genes and deletion/inactivation of paternally derived genes are likely to result in reduced maternal investment. This hypothesis is strengthened by the evidence of parent-specific effects on hCG synthesis; also note that instead of low hCG production by the fetus, lowered sensitivity to hCG by the mother could be involved in some instances.

Hypothesis 1 is parsimonious and is consistent with a picture of increased fetal risk, since the phenomenon is thought to be basically nonadaptive. However, the fact that neonates are in the low birthweight range, but show no other obvious problem and seem able to function normally after birth (see above), is not entirely supportive of this hypothesis. Moreover, although low birthweight is often taken as synonymous to 'neonatal risk', this association may actually not be entirely warranted. It has been recently proposed [45] that variation in fetal growth could be influenced by adaptive developmental plasticity, with resulting 'low-weight' and 'high-weight' phenotypes predisposed to different ecological situations. Increased postnatal risk could be due not to weight *per se*, but rather to mismatches between the 'expected' and the actual nutritional environment. Regulation of fetal weight is likely to be very complex, involving various adaptive mechanisms and a host of genetic and epigenetic effects. For example, it has been shown that infant mortality is high when the newborn is small *compared with mother's own birthweight*; underweight babies of mothers who have been underweight themselves show no increase of neonatal death risk [46].

Hypothesis 1 would be supported by two kinds of results. First, if evidence was found of minor disruptions of imprinting, this would suggest a quasi-pathological condition with no specific adaptive significance. Second, if the occurrence of cryptic pregnancies was proven to be essentially random and unrelated to ecological variables or fetal quality (contrary to hypotheses 2 and 3), this would be consistent with the idea of a statistically infrequent 'tail' in the distribution of parental investment in the population.

Hypothesis 2: missed abortions

In a previous section, spontaneous abortion was described as a potential source of early conflict in pregnancy. Mother and fetus are expected to disagree over decision thresholds, whether the reason for aborting is low fetal quality, reduced ability to sustain pregnancy or difficult ecological conditions. Cryptic pregnancy might then be explained, in a more counterintuitive way, as the result of low-quality fetuses 'escaping abortion'. Consider a fetus whose hCG production is just near the mother's rejection threshold: if it is lucky enough to get through the first weeks of gestation without being aborted, it could then be able to survive until delivery, despite greatly reduced parental investment from the mother due to low hCG levels.

Two interesting possibilities arise from hypothesis 2. First, epidemiological data on the age of mothers should be analyzed in greater detail, since we can expect lower abortion thresholds in older women [19]; under closer scrutiny, cryptic pregnancy could reveal such age-related incidence patterns. Second, this hypothesis leaves room for the existence of *paternally* biased genetic effects in the determination of cryptic pregnancy, which would appear paradoxical under other hypotheses. In fact, when one compares cryptic pregnancy with the normal course of gestation the balance appears to be shifted towards the mother, suggesting a maternally biased effect. However, the picture changes if one compares cryptic pregnancy with *no pregnancy at all*; indeed, paternally derived genes would benefit if they could prevent rejection of a low-quality fetus at the expense of the mother.

Hypothesis 3: forced cooperation in a threatening environment

While it is the mother who, in cryptic pregnancies, gains some advantages at the expense of the fetus, there are ecological conditions in which such a

tradeoff would come to benefit both. A mother facing a difficult environment, where her survival is threatened and/or she lacks protection, social support and food provisioning, might not be able to carry viable offspring and could suffer serious damage herself. It would then be in the interest of the fetus if the mother invested less, both in terms of energy and protection, while retaining high mobility and the ability to take care of herself (by foraging, escaping predators, etc.). A mother who does not suffer from nausea and gains very little weight is able to move freely and to get energy from food of any kind, thus being in the best conditions to survive in the face of transient difficulties.

This hypothesis suggests that cryptic pregnancy may be an adaptive 'emergency' mechanism, to be toggled in stressful life conditions. Data from the Austrian sample seem to support this hypothesis, showing a high incidence of psychosocial stress in the mothers, notably represented by situations of mate desertion, social isolation and the like. However, data from the German sample are not so readily interpreted in this light, although there was no specific probing of psychosocial stressors.

Three conditions are needed to support hypothesis 3. First, there has to be some physiological translation of psychosocial stress into factors capable to affect pregnancy regulation. Second, if forced cooperation between mother and fetus is to hold, these factors should affect not only the mother's physiology, but should transmit some message to the fetus as well. In this way, the fetus would be able to regulate its own 'behavior' (for example, by limiting the production of placental hormones) in order to reduce the costs imposed on the mother. Finally, the statistical relationship between ecological factors and the occurrence of cryptic pregnancy should of course be confirmed by new studies.

Hypothesis 3 is especially intriguing because psychosocial stress has been shown to be abortogenic, with the possible mediation of heightened immune reactions by the mother [47]. Increased environmental stress could influence abortion thresholds, thus linking hypotheses 2 and 3. However, the hypothesis of forced cooperation between mother and fetus is consistent with the fact that newborns from cryptic pregnancies do not seem to show increased rates of malformations or developmental problems, an observation which is problematic for both hypotheses 1 and 2. The insight is that low fetal quality is not necessarily implied by low hCG production, since the latter could result from a fetal 'decision' to lower parental investment, maybe at the additional cost of increased abortion risk. The optimal fetal strategy would seem to be low,

but not too low, hCG production (just above the mother's rejection threshold). A complementary strategy by the mother could be to lower her sensitivity to the effects of hCG; this would result in a reduction of pregnancy-related symptoms, without the risk of lowering the rejection threshold too much and accepting low-quality fetuses. Formal game-theoretic modeling will be needed to find the optimal strategy for both actors; here I want to stress that, in order to understand the mechanism of cryptic pregnancy, the costs and benefits to both mother and fetus must be taken into account.

Conclusion

Cryptic pregnancy in humans is a fascinating phenomenon, which to date has only been interpreted as a pathological manifestation of unconscious conflict. I showed that cryptic pregnancy can be explained as the outcome (or byproduct) of adaptive processes, where the conflict is about parental investment and its consequences on fitness. Parent-offspring conflict theory offers the general explanatory framework, although the present state of knowledge leaves room for several specific hypotheses about the functional significance of cryptic pregnancy and the physiological mechanisms involved.

To gain a deeper understanding of this phenomenon, further research is needed at many different levels: from the genetics (and epigenetics) of regulatory processes in pregnancy to the interplay between those processes and social/environmental cues. Investigation of 'extreme' situations like cryptic pregnancy, where the balance between mother and fetus appears to be dramatically shifted to one side, has the potential to illuminate some otherwise hidden aspects of this interaction. In particular, the mechanisms involved in the initial phases of pregnancy, including spontaneous abortion, are not well known and are likely to reveal an intricate web of adaptations. Consideration of the costs and conflicts involved in the conception of a new life will greatly improve our ability to see through the complexity, and even to make sense of apparent paradoxes.

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