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How Many Organisms During a Pregnancy?

Abstract.

Mammalian placental pregnancy is a neglected problem case for theories of organismality. This example is "closer to home" than those typically discussed within philosophy of biology. I apply evolutionary and immunological accounts of organismality to the "counting question": how many organisms are present during a placental pregnancy? I conclude that an evolutionary approach yields the answer "two", due to bottlenecking, germ-soma sequestration and sexual recombination. By contrast, an immunological approach answers "one", due to pervasive interactions across the placenta. This analysis expands and refines recent work on a biologically informed metaphysics of pregnancy, an under-theorised area of philosophy of science.

Dr Jonathan Grose
Department of Philosophy,
Faculty of Arts and Humanities,
University of Southampton,
Avenue Campus,
Southampton,
SO17 1BF
United Kingdom
Email: j.n.grose@soton.ac.uk

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1. Introduction.

The issue of the correct way to conceptualise organismality is typically investigated via examination of problematic cases. Such cases are usually plants, microbes or other organisms, such as Portuguese man-of-war, only distantly related to homo sapiens. By contrast, mammals, or even all higher metazoans, have been viewed as relatively unproblematic regarding the question of counting organisms. For instance, Peter Godfrey-Smith uses homo sapiens as his illustrative example of a "paradigmatic" individual organism (2009, 95). More recently, this position is challenged by literature on symbiotic gut flora in mammals and the so-called "holobiont" theory, according to which the genuine organism is what is usually taken to be the whole organism *plus* its symbiotic microbial communities (Dupre and O'Malley 2009; Gilbert, Sapp and Tauber 2012).

In what follows, I demonstrate that the case of placental pregnancy diversifies examples of "problems of individuality"[1] in mammals and expands them beyond the micro scale. In addition to highlighting this novel, "close to home" case in which counting organisms is not straightforward, I contribute to a biologically informed philosophy of pregnancy.[2]

[1] To use Clarke's (2010) phrase.

[2] Kingma (2019) convincingly argues that pregnancy has been severely neglected by the philosophy of science. This paper extends her recent work addressing that lack of attention.

Section two briefly introduces the general problem of counting organisms and examines its relation to Elselijn Kingma's "metaphysics of pregnancy" project. Section three presents and applies Ellen Clarke's (2013) evolutionary account of the organism to pregnancy. I demonstrate that this approach yields the clear verdict that there are two organisms, on the grounds that both the gestator and foetus, but not the gestator_foetus can be targets of a natural selection process in a "Darwinian population" (Godfrey-Smith 2009).[3] They are distinct targets due, principally, to processes of bottlenecking, germ-soma sequestration and sexual recombination. Section four provides a contrasting assessment by applying to pregnancy Thomas Pradeu's immunological theory (2012). I show that the immunological approach yields the answer that there is one organism, due to pervasive interactions across the placenta.[4]

Section five concludes that the different perspectives offer different answers to the question, "how many organisms are present during a placental pregnancy?" Hence pregnancy is a novel example of the problem of counting organisms; novel because it is mammalian but, unlike the holobiont, is at the scale of "macrobes" (Dupre and O'Malley

[3] The term gestator emphasises that my interest is only in placental mammalian organismality, rather than more human concerns such as personhood. The term foetus is used, somewhat improperly, in an inclusive sense. I take it to include all pre-birth stages after fertilization. Kingma (2019) uses "gravida" and "foster" to refer to gestator and foetus respectively.

[4] I assume throughout that the pregnancy is not one with twins etc.

2009, 3) of the same species. Additionally, the question of whether holobionts are genuine organisms remains contested (Bourrat and Griffiths 2018; Skillings 2016). Section five also briefly examines which account of the organism is most relevant to a philosophy of pregnancy.

2. Theories of the Organism and Metaphysics of Pregnancy.

The issue of how to individuate organisms is central and fundamental to the philosophy of biology. Clarke (2010) presents only a subset of many proposed criteria for counting organisms, demonstrating that they draw different conclusions about various problematic cases such as Portuguese man-of-war colonial "individuals", aspen, aphids with mutualistic bacteria and eusocial insect colonies. This is a problem because in various biological disciplines, from evolutionary to ecological theory, it is crucial to be able to count organisms. Discussion of this subject typically proceeds via examination of the biology of one or other problematic species. One of this paper's aims is to show that mammalian placental pregnancy is an under-considered example of a problematic case when it comes to counting organisms. As evidence of this lack of consideration of pregnancy in the philosophy of biology literature on individuating organisms, take Clarke's introduction of her "unproblematic" puppy. "They share with humans all the features that have been historically taken to be reliable hallmarks of individuality. Any definition that excludes this example will be strongly counterintuitive. We'll assume it's a "normal" healthy puppy — it doesn't have any twins, transplanted organs, or tumors, although each of these

suppositions would be interesting in their own right".[5] (2010, 321) Regardless of whether or not pregnancy counts as abnormal, a pregnant dog would, I contend, be an equally interesting supposition. Take too Godfrey-Smith's comment on "dramatic case(s)" (2009, 78) with complex life histories. "Protists, primitive plants, fungi, and invertebrate organisms often go through elaborate sequences of states, increasing or decreasing their number of chromosomes, fusing or fragmenting, occupying very different environments" (ibid). Again, I contend, whilst perhaps not being quite as awkward to tackle as some of the above phenomena, placental pregnancy is a similarly dramatic but common phenomenon, with which many of us have first-hand experience.

In addition to a novel application of theories of organismality, my other aim is to strengthen the foundation of a biologically informed metaphysics of pregnancy. Kingma (2018, 2019) argues against a mere "container" model of mammalian pregnancy which, she claims, has floated free from consideration of the actual biology of pregnancy. Instead, she argues for a part_whole relation between gestator and foetus. Relevant to this paper, her argument is based heavily on the claim that both gestator and foetus fail to meet various criteria of organismality proposed in the literature, but that the gestator_foetus whole does satisfy some of these criteria.

[5] I take "have any twins" to mean the puppy is not one of identical twins rather than it is not pregnant with twins. I also assume, on the basis that it isn't mentioned, that the choice of a puppy is not made specifically with the issue of pregnancy in mind.

This paper contributes to the metaphysics of pregnancy in two ways. Firstly, it engages more fully with the literature on organisms than Kingma's initial exploration. When it comes to section three's evolutionary approach, Kingma's analysis (2019) does not focus on the mechanisms that are most important for individuating organisms. She neglects "bottlenecking", germ-soma differentiation and sexual recombination, which form the core of my analysis.

My other contribution to the metaphysics of pregnancy is to separate Kingma's mereological thesis from what I take to be the related but distinct "counting question": how many organisms are present during placental pregnancy? It might appear that the two issues are inextricably tied together, in that an answer "one" implies that the part_whole thesis is correct and an answer "two" implies that the part_whole thesis is false. In fact, matters are not so straightforward. To claim that a two-organism result implies the falsify of the part_whole claim is to prematurely assume that one organism cannot be part of another organism. The one-organism answer does not immediately vindicate the part_whole claim because we cannot rule out a priori that the foetus is not part of the gestator but does not yet constitute an organism. This is not to say that the counting question is irrelevant to the mereological question, only that the relationship between them is complex and beyond the scope of this paper. However, I lay the groundwork here for that more detailed examination by clearly separating out and answering here the counting question.

Before moving to evolutionary organismality, a note on terminology. Much of the literature labels the concept I refer to as organismality as "biological individuality".

Indeed, Clarke's papers use "biological individual" in their titles, while Pradeu predominantly uses "organism". That said, Clarke explicitly "use(s) the terms … interchangeably" (2013, fn.1) and switches between them in her papers, while Pradeu often uses the term "individual" when picking out a single organism (2012, 227). Yet such switching is somewhat problematic because various authors argue that the two terms are not coextensive (Pradeu 2016a; Wilson and Barker 2018). One reason for this is that Hull's (1978) influential "species as individuals" position does not claim that species are organisms, making "biological individual" a more inclusive term than "organism". It is beyond the scope of this paper to adjudicate on the relation between the two terms, but I use "organism" throughout for consistency.

3. Pregnancy and an Evolutionary Approach to Organismality.

Recently, Clarke (2013), among others, develops an evolutionary approach to the question, what is an organism? I think that other evolutionary accounts, such as Godfrey-Smith's (2009), yield the same judgement regarding pregnancy, but I focus on Clarke in this paper. This is because she explicitly claims that her approach unifies various other ones and because it is unambiguously evolutionary in its perspective.

Clark's central claim is that an entity is an organism if and only if it can be the target of a process of natural selection. She reaches this definition via rejecting the necessity or sufficiency of various conditions, proposed in the literature, for the existence of an organism. These include genetic homogeneity, sexual reproduction, bottlenecks, germ-

soma separation, policing mechanisms, spatial boundaries and immune response (2013). Her position is that "the actual properties picked out by the classical views are red herrings, insofar as we are interested in finding general criteria for counting organisms" (2012, 342).

Of course, Clarke does not deny that the proposed criteria are relevant to the issue of organismality. For her though, each is one of a plurality of mechanisms that act, in various but not all circumstances, as realisers of one of two functional roles. It is these roles which, in conjunction, allow natural selection to act on the organism. The two functions are suppression of intra-organism selection via fitness-aligning policing mechanisms and "demarcation" mechanisms that promote inter-organism selection via fitness variation. Taken together, instantiation of both functional roles is necessary and jointly sufficient for something to be a potential target of evolution by natural selection. I will now examine the two functions in relation to pregnancy.

3.1. Policing

During pregnancy, two paradigmatic policing mechanisms are present with respect to both gestator and foetus and hence one of Clarke's requirements is met. Gestator and foetus are on opposite sides of a single-cell reproductive "bottleneck" and both exhibit germ-soma division of reproductive labour. Taking these briefly in turn, mammalian reproduction proceeds via fusing of gametes to produce a single cell with a full complement of chromosomes and all subsequent foetal cells are derived from repeated mitotic or meiotic divisions tracing back to that first "bottleneck" cell. Germ-soma sequestration in mammals

(and many other organisms) refers to the existence of specialist germ cells which are the only cells capable of passing their genetic material to the next generation. Other cells, reproducing only via mitosis, are somatic cells, often referred to as evolutionary dead-ends.[6]

Clarke and others (Godfrey-Smith 2009) demonstrate that single-celled bottlenecks are not necessary for organismality,[7] but Clarke's account requires only that a sufficient combination of realisers be present. Bottlenecks can be single or multicellular and the wider the bottleneck the less it acts as a policing mechanism. In contrast, the single-cell bottleneck that begins a mammalian pregnancy is a highly, though not fully, effective mechanism for aligning fitnesses. In the absence of other effects, the bottleneck guarantees genetic homogeneity of cells, which eliminates fitness variation. Nevertheless, genetic mutations in somatic cells cause heterogeneity within mammals and this is where germ-soma differentiation plays a role. The mechanism of germ-soma sequestration acts to damp down the potential for competition between genetically heterogenous cells. The

[6] During pregnancy, we can identify four kinds of cell: the gestator's germ cells and somatic cells and also foetal somatic cells and germ cells. This is not to say that all these types are present at all times during pregnancy. Oocytes and spermatogenic cells develop with foetal reproductive system development. As early as the stage of gastrulation, in the third week of human pregnancy, cell differentiation occurs that rules out a large proportion of foetal cells from becoming germ cells (Moore et al 2016). The theory that all oocytes are formed before birth is suspect, (Bukovsky et al 2005) but that all germ cells be present at birth is not required for us to be able to distinguish the cell types when they do exist.

[7] Various plants reproduce via multi-cell bottlenecks.

fact that somatic cells have zero fitness prevents them from participating as individuals in a process of natural selection.[8]

I conclude that the combination of a single-cell bottleneck and germ-soma sequestration jointly act as powerful realisers of the policing function that aligns fitnesses of cells both within the gestator and within the foetus. These realisers are not ones Kingma (2019) considers when she draws on theories of organismality to examine pregnancy.

3.2. Demarcation

I now move to Clarke's "demarcation" mechanisms. These promote intra-organism fitness differences within a population; variation which leads, where there is heritability of fitness, to evolution by natural selection. If mammals reproduced asexually, it could be questionable whether a demarcation mechanism exists. Taking Janzen's (1977) classic example; for dandelions and other asexual plants, what might be viewed as reproduction can be interpreted as growth due to the lack of genetic variation. This, in Clarke's terms, prevents "demarcating" fitness differences. The same can be said for aphids undergoing reproduction by parthenogenesis, although Clarke argues that in this case other mechanisms are present that produce inter-organism fitness variation (2013, 428). The

[8] The case of the Tasmanian Devil's lethal and virulent facial tumours is a very rare example in mammals of the catastrophic consequences of a breakdown of the germ-soma distinction (Pearse and Swift 2006).

importance of sexual reproduction, and the recombination that goes with it, is decisively illustrated by the fact that its evolution is postulated to have occurred for precisely that reason. The evolution of sex is not easily explained, and a prevalent solution is that it promotes inter-organism variation (Otto 2008).

As with bottlenecking and germ-soma sequestration, Kingma's examination of theories of organismality during pregnancy does not focus on sexual recombination as an individuating mechanism. The gestator and foetus are on either side of a variation-producing recombination event; hence the second of Clarke's two jointly sufficient roles is fulfilled.

That there are distinct fitness values for gestator and foetus is, of course, complicated by the fact that the expected foetal fitness appears as an element of the gestator's fitness.[9] Nevertheless, gestator fitness is not identical to foetal fitness. For instance, the gestator could have large expected lifetime fitness (if she is highly fertile, for instance) but the foetus a small lifetime expected fitness (if it possesses a trait that makes it unlikely to be carried for a full-term of pregnancy). Similarly, the gestator could have low expected fitness (if she has a low probability of conceiving), while the foetus has a high expected fitness (where it does not inherit the low fertility trait).

With both policing and demarcation mechanisms present, I conclude that, according to Clarke's evolutionary view, the gestator and foetus constitute two organisms. Note that Clarke is willing to allow that organismality can be a matter of degree, rather than an all or

[9] As part of the direct fitness component of the gestator's inclusive fitness.

nothing matter. This allowance is made to allow an account of the evolution of novel levels of individuation (Clarke 2013. 432). For instance, bottlenecks come in degree, but in mammals the policing and demarcation mechanisms are not the marginal ones found in problem cases such as acacia groves and other plants made up of clonal ramets produced by vegetative growth via "runners" (Godfrey-Smith 2009, 71); they are paradigmatic examples of the instantiation of Clarke's two functional roles. If (evolutionary) organismality is a matter of degree, both gestator and foetus possess it to a high degree, possibly the highest degree. Having established that an evolutionary account of organismality yields the verdict that there are two during pregnancy I move on to why a physiological account gives the verdict one.

4. Pregnancy and Immunological Organisms.

Thomas Pradeu develops a detailed account of organismality based on physiology (2012). Some of the criteria Clarke attacks for failing to be necessary or sufficient for organismality fall under the umbrella of physiology, but Pradeu's account is one that cites immunological tolerance as the single defining physiological feature of organisms.[10] In fact, his account can be seen as challenging Clarke's, on the grounds that it sees no need to

[10] Histocompatibility is one of the criteria Clarke discusses (2010, 318). It is also raised by Kingma (2019).

move to a functional definition of organismality because there is, contrary to Clarke, a single mechanism underpinning individuation of all organisms.[11]

Pradeu's characterisation is that organisms are the discrete, cohesive physiological biological entities, whose boundaries and cohesiveness are marked out by what is immunologically tolerated. As he recently summarises, "*any entity which interacts regularly with the immune system and is not eliminated by it is part of the physiological individual*". (2016b, 805. Italics in the original)

These entities are very heterogenous and include, for instance, tolerated microbial flora. Such heterogeneity is a central part of Pradeu's theory and his rejection of the self, non-self theory of immunology. That theory has been very influential and interprets immune responses as differentiating between the organism's own cells and foreign invaders (Pradeu 2012, ch.2). Pradeu supports his claim that this is a mischaracterisation with the case of gut flora, along with the fact that some "self" cells such as cancerous ones can be rejected.

[11] Clarke might not view this as a challenge if Pradeu is right that it is only recent evidence prompting his claim that an immune system is found in all organisms. She can claim that immune systems turn out to be a crucial mechanism for policing and/or demarcation, which has evolved in all lineages. (And in different forms because Pradeu's definition allows for a plurality of mechanisms to constitute an immune response.) Clarke can still claim that what fundamentally matters is the functional role played by immune systems.

Having established his view, I can now consider how it can be used to count organisms during pregnancy.[12]

It is well established that the gestator displays a high degree of immunotolerance of the foetus and vice versa.[13] Mechanisms of tolerance begin within a few days of fertilization, within 24-48 hours of the beginning of implantation of the foetus[14] (when it is a blastocyst) (Moore et al 2016, 23).[15] Tolerance is required because the foetus carries, for instance, paternal major histocompatibility antigens (Murphy 2012, 62). Murphy characterises the foetus's status thus: "The foetus is thus tolerated for two main reasons: it occupies a site protected by a nonimmunogenic tissue barrier, and it promotes a local immuno-suppressive

[12] Pradeu discusses maternal-foetal toleration in some detail (2012, 111), but does not go so far as to explicitly apply his account to pregnancy.

[13] The immunological detail in this section focuses on placental pregnancy in homo sapiens. There is considerable variation in placentation across mammals; human placentas are of the most invasive, haemochorial type (Wooding and Burton 2008). In principle, this leaves open the possibility that, in some mammalian species, the immunological account gives different results.

[14] In humans.

[15] Lack of immune system pre-implantation suggests that perhaps, on this account, during the period between fertilization and implantation there are two organisms, or that the pre-implantation morula stage (Moore et al 2016) is not an organism.

response in the gestator. Several sites in the body, such as the eye, have these characteristics … They are usually called immunologically privileged sites". (2012, 663)

Note the way in which the foetus is categorised with other parts of the gestator. Also, that tolerance of the foetus is not merely down to a barrier (as was theorised in the past), but is an active, bidirectional process of the action of immunological factors. These include HLA-G antigens, regulatory T cells and TGF-β and IL-10 cytokines (Murphy 2012, 662; Pradeu 2012, 112; Wegmann et al. 1993). Furthermore, foetal cells, can persist and are tolerated by the gestator's system, even many years after birth and vice versa, phenomena known respectively as foetal and maternal microchimerism (Boddy et al 2015; Jeanty et al 2014; Williams et al 2009).[16] Hence, under Pradeu's approach, the gestator_foetus appears to be one immunological organism. I say "appears" because I now want to consider two potential objections to my conclusion that the immunological approach gives a one-organism answer. I examine these only with regard to whether Pradeu's theory does in fact give that answer during pregnancy. Potentially, these objections could be developed to argue that there is something wrong with Pradeu's account if it yields this verdict, but, some brief comments aside, that is an issue for future work and I focus here on confirming the verdict itself.

One might object that the foetus is not part of the gestator organism because it does not obviously play a functioning role in gestator physiology. In response, Pradeu is very clear

[16] It is unclear to what extent microchimerism is adaptive, in which cases maladaptive and in which cases neutral. (Boddy et al 2015; Williams et al 2009)

that under his immunological approach, contribution to the whole is not relevant. "If one adopts my immunological perspective on physiological individuality, then the physiological individual admits among its constituents the resident microbes with which its immune system interacts and that it tolerates—regardless of their functional contribution to the whole". (2016b, 810)

A second potential objection refers to maternal-foetal evolutionary conflict theory. Gestator "tolerance" of the foetus might be interpreted, at least partly, as manipulation of the immune system by the foetus (Haig 1993; McGovern et al 2017). The thought here is that if entity X is manipulating organism Y into accepting it then that undermines the case for X being a genuine part of Y. However, Pradeu is explicit that analogous immunological manipulation by parasites does not disallow them from being part of the "host's" immunological organism: "Counterintuitively, it tells us that entities such as gut bacteria, skin bacteria or long-term tolerated parasites are *parts* of the mouse". [17] (2012, 254. Italics in the original)

As he suggests, such a position appears to flout folk-biological ideas about organisms and is also a point of disagreement with evolutionary approaches to organismality. If one is unsympathetic to Pradeu's account, due to its judgement on parasites, then pregnancy may be another reason to be suspicious of the immunological approach. On the other hand, the case of pregnancy might be taken to be less unintuitive than that of parasite tolerance and

[17] Here we see that the immunological approach also speaks to the mereological question from section two.

provide some support for this more radical feature of the approach. As mentioned above, I leave examination of such arguments for future work.

5. Conclusion.

My answer to the organism counting question during placental pregnancy is that an evolutionary approach yields the answer two, but an immunological approach yields the answer one. When it comes to evolution by natural selection, a single-cell bottleneck and germ-soma specialization align fitness both within gestator and within foetus, and sexual recombination acts as a demarcation mechanism yielding variation in fitness between the two. Hence both can be targets of a process of natural selection. By contrast, application of Pradeu's immunophysiological theory leads to an equally firm but different conclusion regarding pregnancy. The extensive systems of immunotolerance acting across the placenta from the beginning of pregnancy until birth mark out one immunological organism.

Thus, placental pregnancy is an up-to-now unexplored example of a problem of counting organisms. This result is important because it diversifies discussion of organismality in mammals from gut flora and contested holobionts. Unlike gut flora, pregnancy is at the macro scale and involves only one species (Bourrat and Griffiths 2018). It is also important because it applies to homo sapiens, making its absence from previous examinations striking given that noticing the exotic phenomenon of pregnant mammals did not even require the invention of the microscope.

In addition to reinforcing the fact that counting mammals is not as straightforward as has often been thought, I have offered a fuller examination of pregnancy and organismality than previous work on the metaphysics of pregnancy. As explained in section two, Kingma (2019) uses literature on organisms and individuality to argue for her part_whole mereological thesis. In doing so, she neglects to discuss the mechanisms that are most important in individuating evolutionary organisms. She does not consider bottlenecking, germ-soma differentiation or sexual recombination. She does briefly consider immunology and my detailed application of Pradeu's theory, couched as it is in terms of parts of immune systems, does appears to support Kingma's part_whole claim.[18]

On might ask, finally, which approach to organismality is most relevant to the metaphysics of pregnancy? The evolutionary, two-organism answer to the counting question may be unsurprising. Given that natural selection theory deals with lifetime expected fitness, it is, in a sense, an atemporal analysis. It is not that development within a lifetime is ignored by the theory but, where organisms change over time (including being pregnant or a foetus), fitness values are amalgamated according to life-history theory (Charlesworth 1994). Hence the gory details of developmental or physiological matters are, in a sense, invisible to the evolutionary calculus. By contrast, application of Pradeu's concern with immunophysiology is, unsurprisingly, focused on the specific biology of placental pregnancy. One might well take from this that the evolutionary approach is wholly

[18] As noted in section two, full exploration of the connection between the counting organisms and mereological issues is beyond this paper's scope.

unsuited to the fields of obstetrics, midwifery and veterinary medicine, though the theory of maternal-foetal conflict speaks against such a hasty, strong conclusion (Haig 1993, 2010). Nevertheless, there is a stark contrast between obstetric concerns and, for instance, theoretical biological work on evolutionary transitions of individuality, which seem wholly suited to Clarke's approach. There, physiological change is to be explained via evolutionary theory, whereas the most pressing concern for vets, doctors and midwives with pregnant patients is the physiological entwinedness in front of them.

References.

Boddy, Amy M., Angelo Fortunato, Melissa Wilson Sayres, and Athena Aktipis. 2015. "Fetal Microchimerism and Maternal Health: A Review and Evolutionary Analysis of Cooperation and Conflict Beyond the Womb." *BioEssays* 37 (10): 1106-18.

Bourrat, Pierrick, and Paul E. Griffiths. 2018. "Multispecies Individuals." *History and Philosophy of the Life Sciences* 40 (2): 33. https://doi.org/10.1007/s40656-018-0194-1

Bukovsky, Antonin, Michael R. Caudle, Marta Svetlikova, Jay Wimalasena, Maria E. Ayala, and Roberto Dominguez. 2005. "Oogenesis in Adult Mammals, Including Humans." *Endocrine* 26 (3): 301-16.

Charlesworth, Brian. 1994. *Evolution in Age-Structured Populations*. Cambridge: Cambridge University Press.

Clarke, Ellen. 2010. "The Problem of Biological Individuality." *Biological Theory* 5 (4): 312-25.

--------. 2012 "Plant Individuality: A Solution to the Demographer's Dilemma." *Biology and Philosophy* 27 (3): 321-61.

--------. 2013. "The multiple realizability of biological individuals." *The Journal of Philosophy* 110 (8): 413-35.

Dupré, John. and Maureen A. O'Malley. 2009. "Varieties of Living Things: Life at the Intersection of Lineage and Metabolism." *Philosophy and Theory in Biology* 1: 1-25.

Gilbert, Scott F., Jan Sapp and Alfred I. Tauber. 2012. "A Symbiotic View of Life: We Have Never Been Individuals." *The Quarterly Review of Biology* 87 (4): 325-41.

Godfrey-Smith, Peter. 2009. *Darwinian Populations and Natural Selection*. Oxford: Oxford University Press.

Haig, David. 1993. "Genetic Conflicts in Human Pregnancy." *Quarterly Review of Biology* 68 (4): 495-532.

--------. 2010. "Transfers and Transitions: Parent–offspring Conflict, Genomic Imprinting, and the Evolution of Human Life History." *Proceedings of the National Academy of Sciences* 107 (suppl 1): 1731-35.

Hull, David L. 1978. "A Matter of Individuality." *Philosophy of Science* 45 (3): 335-60.

Janzen, Daniel H. 1977. "What Are Dandelions and Aphids?" *The American Naturalist* 111 (979): 586-89.

Jeanty, Cerine, S. Christopher Derderian, and Tippi C. MacKenzie. 2014. "Maternal-fetal Cellular Trafficking: Clinical Implications and Consequences." *Current Opinion in Pediatrics* 26 (3): 377-82.

Kingma, Elselijn. 2018. "Lady Parts: The Metaphysics of Pregnancy." *Royal Institute of Philosophy Supplements* 82: 165-87.

--------. 2019. "Were you a part of your mother? The Metaphysics of Pregnancy." *Mind* 128 (511): 609-46.

McGovern, Naomi, Amanda Shin, Gillian Low, Donovan Low, Kaibo Duan, Leong Jing Yao, Rasha Msallam et al. 2017. "Human Fetal Dendritic Cells Promote Prenatal T-cell Immune Suppression Through Arginase-2." *Nature* 546 (7660): 662-66.

Moore, Keith L., Trivedi Vidhya Nandan Persaud, and Mark G. Torchia. 2016. *Before We Are Born*. 9th Edition. Philadelphia: Elsevier.

Murphy, Kenneth M. 2012. *Janeway's Immunobiology*. 8th Edition. Abingdon: Garland Science.

Otto, Sarah P. 2008. "Sexual Reproduction and the Evolution of Sex." *Nature Education* 1 (1): 182.

Pearse, A-M. and K. Swift. 2006. "Allograft Theory: Transmission of Devil Facial-tumour Disease." *Nature* 439 (7076): 549.

Pradeu, Thomas. 2012. *The Limits of the Self: Immunology and Biological Identity*. Oxford: Oxford University Press.

--------. 2016a. "The Many Faces of Biological Individuality." *Biology and Philosophy* 31 (6): 761-73.

--------. 2016b. "Organisms or Biological Individuals? Combining Physiological and Evolutionary Individuality." *Biology and Philosophy.* 31 (6): 797-817.

Skillings, Derek. 2016. "Holobionts and the Ecology of Organisms – Multi-Species Communities or Integrated Individuals?" *Biology and Philosophy* 31 (6): 875-92.

Wegmann, Thomas G., Hui Lin, Larry Guilbert, and Tim R. Mosmann. 1993. "Bidirectional Cytokine Interactions in the Maternal-fetal Relationship: Is Successful Pregnancy a T_H2 phenomenon?" *Immunology Today* 14 (7): 353-56.

Williams, Zev, Dimity Zepf, Janina Longtine, Raymond Anchan, Betsy Broadman, Stacey A. Missmer, and Mark D. Hornstein. 2009. "Foreign Fetal Cells Persist in the Maternal Circulation." *Fertility and sterility* 91 (6): 2593-95.

Wilson, Robert A. and Matthew Barker. 2018. "The Biological Notion of Individual." *The Stanford Encyclopedia of Philosophy*. (Summer 2018 Edition). Edward N. Zalta (ed.), https://plato.stanford.edu/archives/sum2018/entries/biology-individual/

Wooding, Peter and Graham Burton. 2008. *Comparative Placentation: Structures, Functions and Evolution.* Berlin: Springer.