



# Neonatal incubator or artificial womb? Distinguishing ectogestation and ectogenesis using the metaphysics of pregnancy

Elselijn Kingma | Suki Finn

Faculty of Humanities, University of Southampton, Southampton, United Kingdom of Great Britain and Northern Ireland

## Correspondence

Elselijn Kingma, Faculty of Humanities, University of Southampton, Highfield, Southampton SO17 1BJ, UK.  
Email: e.m.kingma@soton.ac.uk

## Funding information

H2020 European Research Council, Grant/Award Number: 679586

## Abstract

A 2017 *Nature* report was widely touted as hailing the arrival of the artificial womb. But the scientists involved claim their technology is merely an improvement in neonatal care. This raises an under-considered question: what differentiates neonatal incubation from artificial womb technology? Considering the nature of gestation—or metaphysics of pregnancy—(a) identifies more profound differences between fetuses and neonates/babies than their location (in or outside the maternal body) alone: fetuses and neonates have different physiological and physical characteristics; (b) characterizes birth as a physiological, mereological and topological transformation as well as a (morally relevant) change of location; and (c) delivers a clear distinction between neonatal incubation and ectogestation: the former supports neonatal physiology; the latter preserves fetal physiology. This allows a detailed conceptual classification of ectogenetic and ectogestative technologies according to which the 2017 system is not just improved neonatal incubation, but genuine ectogestation. But it is not an artificial womb, which is a term that is better put to rest. The analysis reveals that any ethical discussion involving ectogestation must always involve considerations of possible risks to the mother as well as her autonomy and rights. It also adds a third and potentially important dimension to debates in reproductive ethics: the physiological transition from fetus/gestating to baby/neonate.

## KEYWORDS

artificial womb, ectogenesis, ectogestation, ethics, fetus, gestating, metaphysics, pregnancy

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## 1 | INTRODUCTION

In 2017 *Nature* reported a successful extra-uterine support system for extremely premature lambs.<sup>1</sup> This was variously reported as “a uterus-like plastic sack,”<sup>2</sup> a “unique womb-like device”<sup>3</sup> and, more often, an “artificial womb.”<sup>4</sup> It sparked widespread media speculation about the imminent arrival of human ectogenesis,<sup>5</sup> to the express frustration of the authors of the study who are notably careful to avoid any such terminology in their article.<sup>6</sup> They state their “goal is not to extend the current limits of viability”<sup>7</sup> but strictly to improve “the outcomes for those infants who are already [...] cared for in neonatal intensive care units.”<sup>8</sup>

Yet the media reaction is hardly surprising. The idea of artificial gestation—of growing “babies in bottles”—has a proud and prominent place in our cultural history.<sup>9</sup> And although the promise of a genuine artificial womb remains sci-fi, its lure is understandable; what pregnant person has not wished—albeit only briefly—that they could leave their “body in its bulk and weight”<sup>10</sup>; or that she

could “park her fetus on a shelf”<sup>11</sup>—and run, drink, smoke, jump, dance, work or make love ad libitum, free from the risks, burdens and moral and physical constraints that actual gestation entails?

Bioethical speculation about the risks and benefits of ectogenesis tends to focus on two strands. One concerns its effects on women: optimistically, the liberation of women from natural inequalities due to differential reproductive physiology<sup>12</sup> and the social inequalities built on the back of that.<sup>13</sup> More pessimistic visions concern further and new forms of pressure, oppression and devaluation of women that may be enabled by these technologies.<sup>14</sup> The second strand considers what the possibility of ectogenesis could tell us about, and how it might affect, abortion rights and debates about moral status and fetal personhood.<sup>15</sup>

This paper highlights an important metaphysical dimension that is non-linear and may add to the latter debate: birth marks a substantive physiological transition that makes fetuses and neonates different from each other, regardless either of their development or gestational age, or of their location inside or outside the pregnant organism. This allows us to give precise accounts of the difference between fetuses, gestatelings (Romanis’ 2018 term for the subjects of artificial gestation)<sup>16</sup> and neonates; between artificial gestation and neonatal incubation; and between different kinds of extra-corporeal fetal and neonatal support systems: artificial wombs, artificial amnion and placenta technology, and neonatal incubators.

Section 2 introduces ectogenesis, ectogestation and the central question about their difference. Section 3 considers an earlier attempt to analyze this difference and finds it to be insufficient. Section 4 introduces investigations into the metaphysics of pregnancy, and explains how such a reflection invites us to differentiate fetuses from neonates, regardless of gestational age or viability.

<sup>1</sup>Partridge, E., Davey, M., Hornick, M., McGovern, P., Mejaddam, A., Vrecenak, J., ... Flake, A. W. (2017). An extra-uterine system to physiologically support the extreme premature lamb. *Nature Communications*, 8, 15112.

<sup>2</sup>Mullin, E. (2017, April 25). Animals set survival record inside artificial womb. *MIT Technology Review*. Retrieved from: <https://www.technologyreview.com/s/604261/animals-set-survival-record-inside-artificial-womb/>

<sup>3</sup>Moore, A. (2017, April 25). A unique womb-like device could reduce mortality and disability for extremely premature babies. *CHOP News*. Retrieved from: <https://www.chop.edu/news/unique-womb-device-could-reduce-mortality-and-disability-extremely-premature-babies>

<sup>4</sup>See e.g. Mullin, op. cit. note 2; Talpos, S. (2017, September 29). Nurturing controversy: the real science behind the artificial womb. *Undark*. Retrieved from: <https://undark.org/article/artificial-womb-ectogenesis/>; Yuko, E. (2017, May 9). Weighing the ethics of artificial wombs. *New York Times*. Retrieved from: <https://www.nytimes.com/2017/05/08/health/artificial-wombs-ethics.html>; Engelhaupt, E. (2017, April 25). Artificial womb could offer new hope for premature babies. *National Geographic*. Retrieved from: <https://news.nationalgeographic.com/2017/04/artificial-womb-lambs-premature-babies-health-science/>; Avril, T. (2017, April 25). Children’s Hospital ‘Artificial Womb’ raises hope for extreme preemies. *The Inquirer*. Retrieved from: <https://www.philly.com/philly/health/CHOP-artificial-womb-preemies-placenta-premature-baby.html>.

<sup>5</sup>See e.g. Talpos, op. cit. note 4; Yuko, op. cit. note 4; Glosswitch (2017, May 5). Artificial wombs are only three years away – how scared should women be? *New Statesman*. Retrieved from: <https://www.newstatesman.com/politics/feminism/2017/05/artificial-wombs-are-only-three-years-away-how-scared-should-women-be>; Sedgwick, H. (2017, September 4). Artificial wombs could soon be a reality. What will this mean for women? *The Guardian*. Retrieved from: <https://www.theguardian.com/lifeandstyle/2017/sep/04/artificial-womb-women-ectogenesis-baby-fertility>; Prasad, A. (2017, May 1). How artificial wombs will change our ideas of gender, family and equality, *The Guardian*. Retrieved from: <https://www.theguardian.com/commentisfree/2017/may/01/artificial-womb-gender-family-equality-lamb>

<sup>6</sup>Talpos, op. cit. note 4; Partridge et al., op. cit. note 1. The authors use the terminology “fetal lambs.”

<sup>7</sup>Partridge et al., op. cit. note 1.

<sup>8</sup>Partridge et al., op. cit. note 1, p. 11. See also Moore, A., op. cit. note 3; Yuko, op. cit. note 4; Engelhaupt, op. cit. note 4.

<sup>9</sup>Huxley, A. (1932). *Brave new world*. Chatto & Windus, London, UK; Firestone, S. (1974). *The dialectic of sex*, London, UK: Verso; Sedgwick, H. (2017). *The growing season*. Vintage Digital.

<sup>10</sup>Young, I. M. (1984). Pregnant embodiment: Subjectivity and alienation. *Journal of Medicine and Philosophy*, 9, 45–62 (Reprinted in her (2005) *On female body experience: ‘Throwing Like a Girl’ and other essays*. Oxford, UK: Oxford University Press). Page references are to the book. p. 51.

<sup>11</sup>Kingma, E., & Woollard, F. (under review). Can you do harm to your fetus? Pregnancy, physical indistinctness, and difficult deontological distinctions.

<sup>12</sup>See e.g. Smajdor, A. (2007). The moral imperative for ectogenesis. *Cambridge Quarterly of Healthcare Ethics*, 16(3), 336–345; Kendal, E. (2015). Providing equal opportunity to ectogenesis. In their *Equal opportunity and the case for state sponsored ectogenesis* (pp. 93–111). London, UK: Palgrave Pivot.

<sup>13</sup>See e.g. Firestone, op. cit. note 9; Singer, P., & Wells, D. (1984). *The reproductive revolution: New ways of making babies*. Oxford, UK: Oxford University Press.

<sup>14</sup>See e.g. Coren, G. (1985). How the new reproductive technologies could be used to apply the brothel model of social control over women. *Women’s Studies International Forum*, 8(4), 299–305; Donchin, A. (1986). The future of mothering: Reproductive technology and feminist theory. *Hypatia*, 1(2), 121–138; Overall, C. (2015). Rethinking abortion, ectogenesis, and fetal death. *Journal of Social Philosophy*, 46, 126–140, p. 131; Murphy, J. S. (1989). Is pregnancy necessary? Feminist concerns about ectogenesis. *Hypatia*, 4, 66–84; Finn, S., & Isaac, S. (in press). Evaluating ectogenesis via the metaphysics of pregnancy. In R. Davis-Floyd (Ed.), *Social science perspectives on birth and reproduction*. London, UK: Routledge.

<sup>15</sup>e.g. Cohen, I. G. (2017). Artificial wombs and abortion rights. *Hastings Center Report*, 47(4), inside back cover; Overall, op. cit. note 14, p. 131; Räsänen, J. (2017). Ectogenesis, abortion and a right to the death of the fetus. *Bioethics*, 31(9), 697–702; Mathison, E., & Davis, J. (2017). Is there a right to the death of the fetus? *Bioethics*, 31, 313–320; Greasley, K. (2017). *Arguments about abortion: Personhood, morality, and law*. Oxford, UK: Oxford University Press, p. 59; Kaczor, T. C. (2014). *The ethics of abortion*. Oxon, UK: Routledge.

<sup>16</sup>Romanis, E. C. (2018). Artificial womb technology and the frontiers of human reproduction: Conceptual differences and potential implications. *Journal of Medical Ethics*, 44, 751–755, p. 753 notes a “... paucity of academic commentary on this matter,” before attempting to tackle the question herself.

Section 5 delivers a precise classification of ectogenetic technologies and their subjects. Section 6 considers consequences and ethical implications.

## 2 | ECTOGENESIS: INCUBATION OR ECTOGESTATION?

What is ectogenesis? Strictly speaking, the roots of the words “ecto” (outside) and “genesis” (development), suggests that this literally means “development outside”—i.e. outside the body. But since that is the norm in most of the biological world, the focus in practice is on the development of placental mammals<sup>17</sup>—specifically humans—outside the maternal body, where this development would normally happen inside.

A distinction is usually made between full and partial ectogenesis.<sup>18</sup> Full ectogenesis is the “babies in bottles” vision often espoused in science-fiction<sup>19</sup>: the complete development of a new human (or other mammalian) being outside the maternal body, from conception to babyhood. Partial ectogenesis is the partial development of new mammals outside the maternal body, where normally this development happens inside. In contrast to full ectogenesis, partial ectogenesis is both real and prevalent. IVF involves partial ectogenesis; the embryo initially develops in a petri-dish rather than a mammalian body. At the opposite end of the process, the neonatal incubation of preterm infants also involves partial ectogenesis: the 28-week-old, 1 kg preemie undergoes development for many weeks to come that normally happens inside the womb.

But if partial ectogenesis is already a reality, then why did the *Nature* report spark such controversy and feverish speculation? Why should an improvement in neonatal care call for special issues such as the present one? Indeed, why should we think that partial ectogenesis raises any special or new ethical questions at all, as opposed to just revisiting the questions that have become familiar in the wake of ongoing improvements in neonatal care over the past half century<sup>20</sup>—developments that have transformed the survival of extremely premature infants from sci-fi territory/curiosity<sup>21</sup> to routine medical reality?<sup>22</sup>

What all of this suggests is that in the popular imagination, as well as much of the bioethical literature, there exists a difference between neonatal incubation and artificial gestation. But if we take that seriously, then what people mean by “ectogenesis” cannot merely be the development outside the body that normally happens within, as we defined it earlier. It must (also) be a *kind of development* outside the body that is in some way relevantly different from neonatal incubation. What, then, is this? Perhaps it is development inside an artificial womb, as opposed to in an incubator. But that just leads us to the following question—what makes something an artificial womb as opposed to a neonatal incubator?

There is a mix here of genuine question and mere linguistic confusion. The latter is easily dealt with: let *ectogenesis* be a general term for mammalian development outside the maternal body, where this normally happens within. Thus both IVF and the neonatal incubation of premature infants<sup>23</sup> genuinely involve (partial) ectogenesis. Let *ectogestation* be the term for whatever it is that people want to pick out when they *differentiate* between neonatal incubation and what they think of as “genuine” artificial gestation (be it full or partial).<sup>24</sup>

The genuine, and under-considered,<sup>25</sup> question before us, then, is to spell out what makes something *ectogestation* rather than just ectogenesis. Setting other important social and ethical questions aside—which no doubt will be discussed elsewhere in this volume—this will be the focus of the current paper. And our contention is that spelling out this difference requires that we consider the nature—or metaphysics—of pregnancy.

## 3 | ROMANIS ON DISTINGUISHING ARTIFICIAL WOMB TECHNOLOGY VS. INCUBATION

But first we shall consider a proposal by Romanis<sup>26</sup> that distinguishes between what she calls “artificial womb technology” (AWT) and neonatal intensive care (NIC). Her analysis is a step in the right direction, but as we shall see is insufficient to grasp fully the difference between ectogenesis and ectogestation.

First Romanis states that the “purpose of AWT is to treat a gestating [her term for the subject of AWT] *as if it had never been born.*”<sup>27</sup> This makes the gestating “more ontologically similar to the pre-viability fetus in utero, than to what is thought of as a ‘newborn baby.’”<sup>28</sup> But what does this mean? For surely birth, if anything, is the leaving of the maternal body—whether

<sup>17</sup>Placental mammals are the subset of mammals that have placental pregnancies. This excludes marsupials (e.g. kangaroos) and monotremes (e.g. platypus).

<sup>18</sup>e.g. Cannold, L. (1995). Women, ectogenesis and ethical theory. *Journal of Applied Philosophy*, 12, 55–64, p. 56; Kaczor, op. cit. note 15, pp. 219–220.

<sup>19</sup>Huxley, op. cit. note 9.

<sup>20</sup>See e.g. Rieder, T. N. (2017). Saving or creating: Which are we doing when we resuscitate extremely preterm infants? *The American Journal of Bioethics*, 17, 4–12; Wilkinson, D. J. (2011). A life worth giving? The threshold for permissible withdrawal of life support from disabled newborn infants. *The American Journal of Bioethics*, 11, 20–32; Hayden, D., & Wilkinson, D. (2017). Asymmetrical reasons, newborn infants, and resource allocation. *The American Journal of Bioethics*, 17, 13–15; Nuffield Council on Bioethics. (2006). *Critical care decisions in fetal and neonatal medicine: ethical issues*. London, UK: Latimer Trend & Company; Lantos, J. D., & Meadow, W. L. (2006). *Neonatal bioethics*. Baltimore, MD: Johns Hopkins Press.

<sup>21</sup>Barry, R. R. (2018, August 15). Coney Island’s incubator babies. *JSTOR Daily*. Retrieved in May 2019 from: <https://daily.jstor.org/coney-islands-incubator-babies/>

<sup>22</sup>It is presumably the idea expressed in this paragraph that the *Nature* (2017) authors wish to invoke when emphasising the only aim to improve “the outcomes for those infants who are already [...] cared for in neonatal intensive care units.” Partridge et al., op. cit. note 1, p. 11.

<sup>23</sup>But not of term infants—who can also reside in a NICU.

<sup>24</sup>Murphy op. cit. note 14 also explicitly notes a difference between “extracorporeal gestation” and “mere ectogenesis” (i.e. in IVF). But she fails to tell us what the difference is. Note, though, that on her view ectogestation need not be artificial; we might achieve it by implanting human fetuses in pigs. We would be inclined to call this *xenogestation* rather than ectogestation.

<sup>25</sup>Romanis, op. cit. note 16.

<sup>26</sup>Ibid. 753.

<sup>27</sup>Ibid: 753 *emphasis original*.

<sup>28</sup>Ibid: 753.

vaginally or abdominally. A gestateling *has* left the maternal body, so in what way can it be treated as if it had never been born? And, indeed, in *what way* is the gestateling “ontologically similar to the pre-viability fetus in utero”<sup>29</sup>? Romanis does not answer these questions.

Second, Romanis claims that the “AWT requires of its subject *no exercise of any independent capacity for life*.”<sup>30</sup> But that is false. Embryos/fetuses have many capacities for life that on several reasonable understandings can be characterized as “independent.” Most obviously they sustain their own independent circulation/heartbeat, which the recent technological developments directly exploit.<sup>31</sup> Perhaps all Romanis meant to indicate here was that AWT requires *less* independence than NIC. But that is hardly helpful. Neonatal care of a 24-, compared to a 30- or 36-week old preemie also requires comparatively less independence—as does the care of a newborn compared to that of a pre-schooler. Which of the many possible transitions along this continuum matters for distinguishing AWT and NIC? Romanis does not tell us.<sup>32</sup>

Third, Romanis claims that “Gestation, whether in or ex utero, is distinct from ‘continuing to develop after being born’ [...] Gestation [...] is a process of formation [...]. Conventional NIC is not a ‘creative process’, AWT, however, is.”<sup>33</sup> But in what way is gestating a 40-week fetus for another week creative, in a way that incubating a 25-week-old neonate is not? On the face of it, a 25-week-old neonate undergoes much more substantive and rapid development (especially cognitively) than the 39-week-old fetus (which is mostly just packing on fat). Romanis’ characterization of gestation is, as such, unhelpful here.

Fourth—and finally—Romanis remarks on the different options for environmental engagement that AWT facilitates, as compared to NIC:

*The premature neonate is available for social interaction, can experience the benefits of connection with other human beings and become embedded in social networks. [...] The gestateling is shut off from the outside world and does not touch, smell or interact with anything other than its artificial gestator.*<sup>34</sup>

<sup>29</sup>Ibid: 753.

<sup>30</sup>Ibid: 753 *emphasis original*.

<sup>31</sup>Partridge et al., op. cit. note 1: p. 11. Healthy fetuses can even continue their development in an almost completely incapacitated, but appropriately supported, brain-dead maternal body. See BBC News (2019, March 29). Portugal baby born to woman brain dead for three months. Retrieved from: <https://www.bbc.co.uk/news/world-europe-47741343>

<sup>32</sup>Romanis, op. cit. note 16, p. 754 states: “AWT is closer to technologies sustaining individuals with brain stem death, than to forms of artificial support provided to comatose patients with working nervous systems still coordinating some important bodily functions. The latter is more comparable to NIC.” This only serves to illustrate that we have a continuum of progressive (in)dependence here—it does not helpfully define an actual contrast between AWT and NIC.

<sup>33</sup>Ibid: 754.

<sup>34</sup>Ibid: 754.

But surely, the effects on human interaction are much more complicated than Romanis lets on here. The fetus in utero may not be able to see or touch others, nor be seen or heard. But it is constantly touching the maternal body from the inside, and is hearing and experiencing, through her, some of her social network. The neonate, by contrast, may be seen as well as heard, but it is residing in hospital and therefore is mostly isolated from the maternal body (which it can now only touch from the outside)—and almost completely isolated from its (future) social environment. Things are different again for the gestateling, which in the current set-up does not feel or taste the maternal body at all, nor has any access to her wider social world.<sup>35</sup>

Romanis deserves credit for identifying the right questions, but falls short of providing answers. This is not surprising. To actually understand these issues (or so we submit), we need to understand the under-considered nature of gestation and birth.

#### 4 | THE METAPHYSICS OF PREGNANCY: DISTINGUISHING FETUSES AND NEONATES

What is the metaphysics of pregnancy, or the nature of gestation? What are the entities involved in this process? How do they relate to each other? And how do these questions differ for similar entities that have a different reproductive biology, such as a bird sitting on, or an embryo developing in, an egg? Given both the common and mundane nature of pregnancy as an essential part of the mammalian life cycle, and its highly unique aspects—the physical intertwinement of what might be considered two separate individuals—it is truly astonishing that no more attention in philosophy or bioethics has been paid to these questions.

In recent work Kingma has begun to address them, focusing on the metaphysical relationship between the fetus and the pregnant organism.<sup>36</sup> Kingma tentatively argues in favor of what she calls the *parthood view*: the view that embryos/fetuses are a proper part of the pregnant organism, like organs, tissue, blood or any other body part.<sup>37</sup> But we don’t need to accept this claim to treat Kingma’s research as a source of inspiration for considering the

<sup>35</sup>Sedgwick (op. cit. note 9) imagines a “wearable” artificial womb which allows a gestateling—unlike a neonate in a NICU—to be taken home and “worn.” In this vision the gestateling experiences much of the social embedding of a fetus in utero—although not its direct physiological interaction with the maternal body. Developments are underway to make the *Nature* technology “parent friendly” and will allow the gestateling e.g. to hear the parent’s heartbeat (Partridge et al., op. cit. note 1). A Dutch team developing similar technology, by contrast, envisages an opaque sack—so the gestateling is not on display (Schalij, N. (2019, April 1). *Kustmatige Baarmoeder: droom of nachtmerrie*. [Artificial womb: Dream or nightmare?]. *Cursor*. Retrieved from: <https://www.cursor.tue.nl/nieuws/2019/april/week-1/kustmatige-baarmoeder-droom-of-nachtmerrie/>).

<sup>36</sup>Kingma, E. (2019). Were you a part of your mother?: The metaphysics of pregnancy. *Mind*, 128(511), 609–646.

<sup>37</sup>Kingma, op. cit. note 36; Kingma contrasts the parthood view with its negation: the *containment view*: the embryo/fetus is *not* part of the pregnant organism, which means it merely resides inside them “the way the metaphorical bun is in the oven” (Kingma, op. cit. note 36, p. 613.) See also Kingma, E. (2018). Lady parts: The metaphysics of pregnancy. *Royal Institute of Philosophy Supplement*, 82, 165–187; Kingma, E. (in press). Nine months. *The Journal of Medicine and Philosophy*, (in press).

more general question about the nature of pregnancy in the context of distinguishing ectogestation from neonatal incubation—as we shall do in this paper. Our claims and arguments are therefore compatible with, but not reliant on, the truth of Kingma's parthood view.

What we do directly take from Kingma is the more general idea that contemporary Western culture fosters an understanding of pregnancy Kingma labels the *fetal container model*: a tendency to depict, speak of and imagine fetuses as already separate, individuated "babies" that are incubated in pregnant women.<sup>38</sup> Kingma writes:

*[the fetal container model] emphasises the physical resemblance and continuity between human [fetuses] and babies, presenting them as already-separate individuals, while at the same time de-emphasising the [fetus's] location within, and connection to, the [gestator]. Images of human pregnancy, for example, [...] de-emphasise, fade out, or omit altogether the [gestator], placenta and umbilical cord. Our language similarly reinforces this idea: it is common to refer to human fosters as 'babies' almost regardless of their developmental stage.*<sup>39</sup>

The existence of this cultural understanding of the fetal container model is not Kingma's invention, and is well supported: Kingma cites "a rich tradition in history and sociology [that] documents its cultural dominance."<sup>40</sup>

If this claim is correct, then it suggests an explanation for why so little progress can be made on differentiating ectogenesis from ectogestation. For according to the fetal container model there is nothing more to pregnancy than the incubation of an already separate individual—a baby—inside the womb.<sup>41</sup> If gestation is nothing more than incubation, then neonatal incubation already is ectogestation; there is no room for a gap here. And birth, on this view, is a mere change of environment;<sup>42</sup> the only difference between neonates and fetuses is their

location. This leaves no room for treating an extra-corporeal gestating "as if it had never been born,"<sup>43</sup> nor for saying how such a gestating, ontologically, is more like a pre-viable fetus rather than a neonate.

But the fetal container model is highly misleading; our instinctive judgment that there is a difference between neonatal incubation and ectogestation indicates correctly that there is more to gestation than incubation. So what can a more nuanced consideration of the nature of pregnancy—and the entities involved in it—tell us about the nature of ectogestation?

Let's start with what Romanis called the "ontological" difference between fetuses/embryos and neonates. It is difficult to see how such a difference can be delivered by location alone. For why should location affect what things are? Nor can the difference be one of developmental stage alone. For although the fetus-stage normally precedes the baby-stage—both temporally and developmentally—premature birth complicates this. A 39-week-old fetus, about to emerge into healthy, screaming babyhood, is much more developed—physically, physiologically and cognitively—than a 24-week, 600 gram preemie, barely clinging on to life in a top-level NICU. Yet the latter is classed as a neonate—albeit a very immature one—whereas the former is undeniably a fetus (even though it will become a baby very soon). There appears to be a difference between neonates and fetuses that cuts across linear progressive development which is not captured by viability alone; and—if there is a difference between incubation and ectogestation—is not just a matter of location either.

Kingma's parthood view gives us one way of understanding this difference: fetuses are body parts; neonates are not body parts.<sup>44</sup> But we need not accept that claim to appreciate that fetuses and babies have a very different physiology. Most obviously, fetuses do not breathe but oxygenate their blood via the placenta. This results in different normal arterial and venous oxygen tensions compared to neonates; requires a different kind of hemoglobin; and so on. It also necessitates a completely different cardiovascular set-up: the fetal heart functions as a single (rather than, in neonates, a double) pump; and the cardiovascular system in fetuses compared to neonates has multiple shunts, different flow rates and blood pressures in different parts of the system, and so on.<sup>45</sup>

We tend to overlook these physiological differences, because the cultural fetal container model conditions us to forget about them, teaching us to view the fetus *merely* as a baby-within. But these differences are well known in medicine and are of profound relevance to fetal-maternal and neonatal specialists. They explain why, sometimes—for example in placental malfunction—fetuses are in great peril inside, but absolutely fine as soon as they are delivered. This is because they have difficulty performing certain physiological requirements of gestation, but no difficulty performing the physiological requirements of babies. The opposite also happens; some

<sup>38</sup>Kingma, op. cit. note 36; Kingma argues that this cultural understanding drives the metaphysical "containment view" (see previous footnote). But the cultural understandings and metaphysical claims should be kept distinct. Our general cultural conviction that tables exist and persist—for example—may drive a metaphysical commitment to their existence, but is still compatible with a wide range of precise metaphysical views on the existence and persistence of tables.

<sup>39</sup>Ibid: 614.

<sup>40</sup>Ibid: 614.

<sup>41</sup>The cultural incarnation of this view has perhaps reached its most evident extreme in how our practices construe surrogate pregnancy: an embryo or "baby" is created by two gametes—and then implanted (for incubation) in a surrogate mother: "Here, we find descriptions of pregnant women as [...] 'containers', 'incubators', 'hatcheries' [...], or 'alternative reproductive vehicles'." (Baron, T. (2019). Nobody puts baby in the container. *Journal of Applied Philosophy*, 36(3), 491–505. <https://doi.org/10.1111/japp.12336>). Which surrogate mother it is appears to be rather irrelevant; this womb or that—or even an artificial incubator—any womb will do as long as the baby is seen to be safely "housed." See also: Finn, S. (2018). The metaphysics of surrogacy. In D. Boonin (Ed.), *The Palgrave handbook of philosophy and public policy* (pp. 649–659). Basingstoke, UK: Palgrave Macmillan; Katz Rothman, B. (2014). The legacy of patriarchy as context for surrogacy. *The American Journal of Bioethics*, 14(5), 36–37.

<sup>42</sup>See e.g. Smith, B., & Brogaard, B. (2003). Sixteen days. *Journal of Medicine and Philosophy*, 28, 45–78, p. 65: "birth is the mere passage of an entity from one environment to another (it is analogous to an astronaut leaving her spaceship)."

<sup>43</sup>Romanis, op. cit. note 16, p. 753 *emphasis original*.

<sup>44</sup>Kingma, op. cit. note 36. Note that Kingma's parthood view on its own does not commit to a view on whether fetuses are organisms; it is possible that fetuses are body parts *and* organisms. See also Kingma (2018), op. cit. note 37.

<sup>45</sup>Preserving this fetal hemodynamic system was one of the three key challenges in the *Nature* study, only achieved by moving from a carotid artery/jugular vein set up to umbilical cannulation, and by the development of a near-resistance free, pump-less oxygenator (Partridge et al., op. cit. note 1).

pregnancies can be wholly uncomplicated, only for birth to reveal that this baby cannot, or struggles to, perform certain physiological requirements of babies that weren't required for fetal physiology. Think of lung-problems, heart defects, etc.

There is thus a difference in normal physiological set-up between fetuses and neonates that is much more profound than location alone. We can quibble over the precise ontological weight we should assign to this difference.<sup>46</sup> But we can all agree that it is a much more substantial difference than either location or gestational age alone. Thus, very roughly, to be a fetus is to have a physiology characteristic of a fetus; and to be a neonate is to have a physiology characteristic of a neonate. To be a gestating, then, is to have a physiology characteristic of a fetus, but to exist *outside* of a gestating mammal.

Once we appreciate that, it is immediately obvious that fetuses and neonates also have different *physical* characteristics. The fetus, to be precise, has an entire organ that the neonate lacks: a placenta. It also has an umbilical cord, an amnion and chorion, and—so we argue—an additional body-cavity, filled with amniotic fluid. The neonate has none of these, for these parts were shed at or around birth.

This may initially seem a surprising claim because the amniotic cavity is usually presented as a cavity in the gestator—or at least the cavity in which the fetus resides. So let us offer three brief points of defense. First, all of the amnion, chorion and amniotic fluid, as well as most of the placenta (which also incorporates some maternal tissue) is made and produced by organic material clonally derived from the zygote. This ought to make the view that this is all part of the fetus the default. An alternative—the view that only the future body or “future baby” is the fetus—leaves all this extra stuff unaccounted for.<sup>47</sup> What is it and to what organism does it belong?<sup>48</sup> Such an alternative view requires defense. Second, there is nothing

intrinsically surprising about the shedding of substantial body parts at transitional developmental stages; this is an entirely common occurrence in the natural world. Tadpoles lose their tail as they become frogs; honey-ant-queens lose their wings after they have been fertilized and settle underground; stags lose their antlers every season; and so on. Third, remember that the “baby inside a cavity” picture is precisely what the culturally dominant fetal container model conditions us to believe; that the fetus looks like a baby—without funny extra parts—that *merely* resides inside a cavity in the pregnant organism.<sup>49</sup> No wonder that the claim that the amniotic cavity is in fact part of the fetus would initially seem surprising.

If our claim about the physical characteristics of fetuses is correct, then this marks a second, yet related, important difference between neonates and fetuses that is irrespective of their gestational age or linear development: fetuses and neonates do not just have different *physiological* but different *physical* characteristics.

Finally our analysis so far illuminates in what way birth is more than just a morally relevant<sup>50</sup> change of location from within the gestator's physical body, to outside it. According to the parthood view, birth also marks the transition from being part of another organism, to no longer being such a part. But even without accepting the parthood view, our analysis shows that birth is not just a change of location, but involves topological, physical and physiological changes: the loss (and, possibly, gain<sup>51</sup>) of body parts; the loss of topological, physical and physiological connections to the gestator; and an internal physiological transformation that includes changes to vasculature, heart, lungs, hemoglobin, etc. Some of these (e.g. cardiovascular changes) happen near-instantly at or around birth; others (e.g. moving to mature hemoglobin) take longer.

## 5 | DISTINGUISHING ECTOGENESIS AND ECTOGESTATION—AND FURTHER CONCEPTUAL CLARIFICATIONS

How can all of this deliver a distinction between ectogenesis and ectogestation? Remember that Romanis<sup>52</sup> attempted to provide such a distinction but did not succeed because she did not tell us (a) what it meant to treat a gestating “as if it had never been born”; (b) in what way a gestating was ontologically more similar to a pre-viable fetus than to a neonate; (c) in what (relevant) way a neonate behaves more independently than a fetus/gestating; or (d) in what way gestation differed from development-after-being-born. Our

<sup>46</sup>In Wiggins' ((2012). *Sameness and substance renewed*. Cambridge, UK: Cambridge University Press) terms, should we consider “fetus/gestating” and “neonate” to be distinct substance sortals, picking out distinct entities? If so, there is no numerical identity between fetuses and neonates; newborn mammals were never fetuses but begin at birth. Or should we consider them phase sortals, picking out the same entity at different phases of life, comparable to “adolescent” and “adult,” or “caterpillar” and “butterfly”? Note that on either view using one sortal rather than another conveys useful information: a fetus/gestating has a placenta—whether real or artificial—whereas a neonate does not. Equally only butterflies—not caterpillars—have wings. The present discussion is compatible with either a phase or substance understanding of these terms, and Romanis does not specify what sort of “ontological similarity” she has in mind. We leave a proper discussion of such matters for a different time (see also Kingma (2018), op. cit. note 37).

<sup>47</sup>See also Kingma (in press), op. cit. note 37 for this terminology and a discussion of different views on the fetus and its boundaries.

<sup>48</sup>This “extra-embryonic material” motivates some to consider the “division” of the early embryo into “embryo proper” and “extraembryonic material” as a further logical division puzzle, alongside (the possibility of) twinning (e.g. Burgess, J. (2010). Could a zygote be a human being? *Bioethics*, 34, 61–70). No such puzzle arises if the placenta is part of the fetus, as we argue. (After all, no one considers such a problem to arise because the embryo forms—say—a kidney.) One might then wonder what the relation is between the placenta and the gestator? Well, if, following Kingma, op. cit. note 35, the fetus is part of the gestator, then all of the fetus' parts, including the placenta, will also be part of the gestator. This is due to the transitivity of parthood—if *a* is part of *b*, and *b* is part of *c*, then *a* is part of *c*. If the fetus is not part of the gestator, then the placenta, which is built from mostly fetal tissue but incorporates some maternal tissue too, may, for example, be considered a site of overlap, with either all or part of the placenta being part of both gestator and fetus. Or it could be argued that, upon incorporation into the placenta, the maternal-origin tissue ceases to be part of the mother. Any such claims would require further defense.

<sup>49</sup>Kingma, op. cit. note 35.

<sup>50</sup>Morally relevant because it means that the neonate—regardless of its moral status—can now be accessed, interacted with, treated and kept alive without having to consider the mother's rights to bodily integrity/physical autonomy. See e.g. Warren, M. A. (1989). The moral significance of birth. *Hypatia*, 4, 46–65.

<sup>51</sup>At birth a neonate is colonized by symbiotic bacteria. If this “microbiome” is part of the human organism, as some argue (see e.g. Hutter, T., Gimbert, C., Bouchard, F., & Lapointe, F. (2015). Being human is a gut feeling. *Microbiome*, 3(9). <https://doi.org/10.1186/s40168-015-0076-7>) then the neonate also gains parts at birth (Kingma, op. cit. note 35, fn 45).

<sup>52</sup>Romanis, op. cit. note 16.

analysis of the nature of pregnancy in the previous section allows us to answer all of these questions in detail.

First, gestatelings are treated as if they had never been born, not in the sense that they haven't left the maternal body—for they have—but in the sense that they haven't undergone the transition from a fetal physiology to a neonatal physiology. Thus they are only “born” in the sense that they have changed location from inside to outside the maternal body, i.e. “born-by-location-change”. But they are not “born” in the sense that they have changed their physiology from fetus to neonate, i.e. “born-by-physiology-change.”<sup>53</sup> Second, this specifies the way in which gestatelings are “more ontologically similar”<sup>54</sup> to fetuses than neonates: they retain fetal physiology (as they have not undergone the “born-by-physiology-change” from fetus to neonate). Third, the relevant way in which neonates behave more independently than gestatelings is that, however much supported, they operate on the physiological blue-print of a neonate, which is almost entirely independent from maternal physiology, as opposed to a fetal physiological blue-print, which is (normally) entirely dependent on and integrated in maternal physiology.<sup>55</sup> Finally, and this is the fourth point, our analysis elucidates how development during gestation “is distinct from ‘continuing to develop after being born.’”<sup>56</sup> Not in the sense that one is creative where the other is not—which is vague—but in the sense that one involves developing on a fetal physiological blue-print—or, we might say *as a fetus/gestatel-ing*—whereas the other involves developing on a neonatal physiological blue-print—or, we might say, *as a neonate/baby*.

In combination this delivers the contrast we seek: between ectogenesis and ectogestation. Incubators, as a non-ectogestative version of ectogenetic technology, support neonates, taking over, or assisting with, functions they cannot yet perform. They do so on the physiological blue-print of a “born-by-physiology-change” (as well as “born-by-location-change”) neonate. Ectogestative technologies, by contrast, support gestatelings; they take over, or assist with, functions that cannot be performed on the physiological blue-print of a fetus. Ectogestation—and here is our rough definition—is thus development after being “born-by-location-change” but before being “born-by-physiology-change”: i.e. development outside the maternal body that prevents the physiological transformation from fetus to neonate.

<sup>53</sup>In ordinary birth, of course, both of these happen pretty much simultaneously. Which one of these truly defines “birth” when they come apart is not a question we settle here. Note that this question does seem to arise; in a Dutch public panel on ectogestation a member of the public asked: “would these babies have two birthdays?” (Schaliq, op. cit. note 34).

<sup>54</sup>Romanis, op. cit. note 16. Note that Romanis, in this quote, spoke of similarity between the gestateling and the *pre-viable* fetus (our emphasis). But we think the emphasis of this claim must be about similarity to fetuses, not about *pre-viability*. For it is difficult to see why, say, a 39-week-old gestateling (if we were to create one) would be more similar to a *pre-viable* fetus than to a viable fetus. We consider “*pre-viable*” to be a slip caused by the focus on very premature lambs, as well as Romanis’ focus on the as-yet unrealized possibility of keeping alive fetuses/gestatelings before what is now considered the “viability threshold.”

<sup>55</sup>Kingma (in press), op. cit. note 37.

<sup>56</sup>Romanis, op. cit. note 16.

With this clearer understanding of the difference between ectogenesis and ectogestation—and between fetuses, gestatelings and neonates, regardless of gestational age—we are in a position to make further conceptual distinctions that may help to clarify future discussion on these topics.

First, using Romanis’<sup>57</sup> helpful terminology, we should distinguish fetuses, gestatelings and neonates. Fetuses and gestatelings (however much supported) are not yet “born-by-physiology-change,” and have fetal physiology and characteristics; neonates, by contrast, are “born-by-physiology-change,” and have neonatal physiology and characteristics—again, however much supported. Gestatelings share with neonates, in contrast to fetuses, that they are “born-by-location-change”—and hence reside outside rather than inside the maternal body. We agree with Romanis that it is helpful to clearly distinguish these categories because the terms “neonate” and “fetus” each carry connotations that are not, or are only sometimes, applicable to gestatelings. Keeping these distinctions in mind does not in itself settle ethical questions, but does help to separate relevant moral concerns that are otherwise too easily run together.

For example, it is widely, and reasonably, supposed that those who are pregnant have *some* special say over their fetus (even if it is deemed a person or possessor of moral status), because it resides in/is part of/uses their body.<sup>58</sup> In normal pregnancy these three characterizations (“resides in,” “is part of” and “uses”) run together, and there is no obvious need to distinguish them for moral purposes; any one of them means that the pregnant person’s autonomy over their body ought to be included as a main (though not the only) relevant consideration in virtually any ethical discussion involving pregnancy/fetuses. After birth, by contrast, although the (formerly) pregnant person usually still has some say over the neonate, they no longer have a say on grounds of their bodily autonomy.

Ectogestation may mean some of these three characterizations could come apart. The gestateling is neither inside, nor uses, the gestator’s body. But it might be possible to argue that it is still a body part—albeit a detached one.<sup>59</sup> Such a claim needs defense, of course, as do its supposed implications, which are far from clear. Even if the gestateling were such a body part, it is a further question whether and how the ethics of detached body parts (consider sperm or blood)—let alone the ethics of detached body parts over which there are competing claims (consider donated blood or an a kidney promised and ready for transplantation)—compare to the ethics of attached body parts.

Conversely, if the gestateling is not a body part (or if it is not relevant that it is a body part), then the ethics of gestatelings and fetuses, whatever their cognitive, physiological and developmental similarities, will always be different because one—but not the

<sup>57</sup>Romanis, op. cit. note 16.

<sup>58</sup>See e.g. Thomson, J. J. (1971). A defense of abortion. *Philosophy and Public Affairs*, 1(1), 47–66.

<sup>59</sup>We are grateful to an anonymous reviewer, whose suggestion we are developing in this paragraph.

other—must involve consideration of the gestator's autonomy. Either way, carefully bearing in mind the relevant differences between gestatelings, fetuses and neonates is essential for the quality of these and other ethical debates.

Second, we can distinguish between different extracorporeal support systems. We already distinguished the more general category of ectogenesis, including neonatal incubation and IVF, from its more specific subset: ectogestation. But we can make further distinctions amongst ectogestative technologies. For consider again the *Nature* report.<sup>60</sup> Its system is extracorporeal and maintains fetal physiology: it runs blood out of the umbilical cord through a pump-free oxygenator, and suspends the gestateling's body in amniotic-like fluid. Cardiovascular set-up and oxygenation happens on the blue-print of a fetal physiological system. We therefore concur with Romanis<sup>61</sup>—and contrary to what the scientists themselves implied in various press statements—that this is definitely an *ectogestative* technology; not mere incubation. But—and here we separate from Romanis—this does not mean it is the provision of an artificial womb. Instead it is the provision of engineered replacements for parts of the fetus/gestateling's body. Just as a kidney dialysis machine replaces, or takes over, the function of kidneys; and just as a bionic leg replaces the leg; the reported technology replaces the placenta and amniotic sac. The womb itself is not replaced; the “lamb-in-a-sack” is most like a free-floating fetus in its artificial amnion. Hence a more apt label would be: artificial amnion and placenta technology (AAPT).

Setting physical and technological possibility aside, we can conceive of different kinds of ectogestative technologies that replace fewer of the fetus/gestateling's body parts. We could conceive of a technology that, instead of using a biobag, leaves the actual amnion/chorion intact. All that would be replaced is the placenta. Or we could imagine leaving the placenta intact (which probably means removing the gestator's womb, or part of the womb, as well as the fetus); what then could be replaced would be the maternal circulation, perhaps via a combination of heart-lung and kidney-dialysis machine that feeds the major arteries and veins serving the placenta/womb on the maternal side. Perhaps such technologies would more appropriately be called artificial wombs—though *really* they would not be artificial wombs either, but something more like partial artificial gestational bodies.

We should pause here to ask why the artificial womb is such an alluring concept when of all the things that can be replaced—amniotic sac, placenta, maternal circulation and/or vascular interface—the womb itself is actually of least interest.<sup>62</sup> Why then do we find it so tempting to think of, and present, these technologies as artificial

wombs as opposed to artificial fetal organs? Again this is neatly explained by the cultural dominance of the fetal container model. This conditions us to think of pregnancy as incubation; as providing a house—a womb—a container!—in which resides a free-floating baby (a pink one, without funny parts). This gives us only one way in which to frame, report and understand ectogenetic scientific developments: as the beginning of the “artificial womb.” This, in turn, results in an understanding and reporting that reinforces that fetal container model. Given how much the fetal container model leads our thinking astray, we would do well to break the cycle. It would be both helpful, as well as scientifically and metaphysically more accurate, to put the term “artificial womb” to rest and to speak of ectogestation (as opposed to ectogenesis) in its place, and of the more specific technology at stake: artificial placenta; artificial decidua; artificial amnion; etc.

## 6 | CONCLUDING REMARKS

Considering the metaphysics of pregnancy, or the nature of gestation, can spell out clear conceptual distinctions where previously there lay confusion. It identifies clear physical and conceptual differences between fetuses, gestatelings and neonates, which cut across developmental stage or length of gestation, and which are about more than location alone. It also delivers a distinction between neonatal incubation and ectogestation: the former supports the physiological blue-print of a neonate; the latter a fetal physiological system. That does not mean there could not be gray areas. For example, we could imagine technologies that mix some elements of both blue-prints; e.g. maintenance of fetal physiological cardio-vasculature and oxygenation, but without a biobag so that the skin functions in the way it would do after birth.<sup>63</sup> That is not a problem for our claims. Such a technology would result in a genuine intermediary case and we could then quibble about which aspect of physiology ought to be dominant for adequate classification into gestateling or neonate. Technology often allows us to blur or suspend transitions that in nature are relatively clear-cut, involving a cascade of related changes. We can similarly suspend people on the cusp of death, for example, resulting in a lively literature on which of many transitions that occur in nature together *really* spell death. That does not undermine that there is a firm and meaningful difference between alive and dead organisms—and neither would an intermediate technology undermine the difference between fetuses and neonates.

Let us finish, then, with some remarks on what the conceptual work here does—and does not—suggest, as well as noting any issues that remain.

First—what are the ethical implications? These rarely follow directly from any metaphysical analysis.<sup>64</sup> On the one hand, many conceptual and ethical questions that supposedly derive from *ectogestation* may actually just be generic to all ectogenetic

<sup>60</sup>Partridge et al., op. cit. note 1.

<sup>61</sup>Romanis, op. cit. note 16.

<sup>62</sup>Permit us a speculation: even attempts to develop ectogestation at the beginning of pregnancy are more likely to focus on the development of an appropriately vasculated interface, than on making a “womb.” Embryo/fetuses do not need wombs to develop; they already—in nature—occasionally develop successfully by implanting on the liver. See e.g. Tshivhula, F. & Hall, D. R. (2005). Expectant management of an advanced abdominal pregnancy. *Journal of Obstetrics and Gynaecology*, 25(3), 298.

<sup>63</sup>Such a description may describe earlier versions of the technology; Partridge et al., op. cit. note 1.

<sup>64</sup>Here, again, we depart from Romanis (op. cit. note 16) who seems to expect more direct and substantial ethical results.



technologies. If, for example, ectogestation pushes forwards the limits of viability or significantly improves survival and lowers the risks of premature birth, then that is relevant for ethical decision-making. But the relevant questions would be affected just as much if other forms of ectogenesis—such as neonatal incubation—had these effects. And, indeed, our recent history shows that improvements in neonatal incubation *do* have such effects.<sup>65</sup>

Second, we also submit that the details of ethical questions are likely to depend much more on the actual technological abilities afforded by any particular system, rather than on the type of technology that it is. As we argued, the *Nature* system is genuinely ectogestative. That remains true even if for technological reasons, the technology could only ever be used on—say—26-week-old preemies. That would leave the seemingly paradoxical situation that 23–26-week-old preemies need to be—and remain—incubated as neonates (assuming, plausibly, that having transitioned physiologically to a neonate, there is as yet no way back), whereas 26+ week-old preemies can be ectogestated as fetus/gestatelings. But this only seems paradoxical if one expects too much from one distinction; it emphasizes once again that progressive linear human development is cross-cut by the distinction between neonates, fetuses and gestatelings. Equally the relative actual safety profiles of different systems will have much more significant ethical consequences—for example affecting maternal decision-making in premature onset of labor—than the type of system it is.

Third, we want to revisit an observation by Romanis that AWT, unlike neonatal incubation, is “almost entirely non-invasive. Support mechanisms surround rather than aggressively invade the gestateling.”<sup>66</sup> According to our analysis, this is incorrect—or at least misleading. The recent technological developments *are* invasive ones: they remove and replace entire fetal organs (the placenta, amnion, etc.) and invade main (umbilical) veins and arteries. Now this invasion may well be “less stressful and painful for the developing human,”<sup>67</sup> and less disturbing to its physiology, than neonatal incubation. It may also be the case that—where artificial oxygenation is only done in cases of impending miscarriage—the placenta and amnion were about to be lost anyway. Invasiveness alone does not have direct ethical consequences. Even so it is important to be precise, particularly if we were to consider ectogestation for reasons other than impending miscarriage/premature birth. It may then matter ethically that such a technology does invade the fetus/gestateling.

Fourth, our analysis foregrounds another aspect of invasiveness that is morally relevant but tends to be underappreciated: on the gestator’s body. In the view outlined, ectogestation (as opposed to incubation) involves the preservation of fetal physiology. But since birth is not (just) a change of location, but also a physiological transition, successful ectogestation requires that this physiological transition from fetus to neonate is prevented from

happening. Almost certainly this requires a caesarean section,<sup>68</sup> to prevent a physiological transition from being triggered by the actual birthing process: the expulsion via the vagina. Put more vividly: successful ectogestation almost certainly requires what is, effectively, a fetal transplant rather than a birth. And this requires invasive medical action on the maternal body.<sup>69</sup> This is the one aspect of ectogestation that clearly does raise ethical issues that do not apply to neonatal incubation: any ethical discussion involving ectogestation must therefore always involve considerations both of the woman’s bodily autonomy/rights and of possible risks to her health and wellbeing.<sup>70</sup> This is relevant to moral analysis tout court, but especially—again—if use of ectogenesis is suggested for reasons other than impending premature birth.

Fifth, the fuller and more nuanced understanding of gestation, ectogestation, fetuses and birth offered in this paper could improve speculation—as that is all it can currently be—about possible trajectories towards full ectogenesis. Partial ectogenesis presently exists at both ends of the gestational period: (early) embryos can spend time in a petri-dish in the first few days of development; neonates can spend months in an incubator at the other. It may, and frequently is, glibly assumed that it is only a matter of time before improvements at both ends “meet in the middle”—so to speak.<sup>71</sup> But considering the difference between incubation and ectogestation suggests things are rather more complicated. First, until 2017, none of the existing developments were actually *ectogestation*. Whilst ectogestation now seems feasible in the latter half of pregnancy, it is worth noting that IVF still does not involve ectogestation. For, plausibly, IVF precedes pregnancy; Kingma<sup>72</sup> intimates that implantation—at least in the case of IVF—is when a blastula becomes a physiological part of the pregnant organism. If that indeed defines the start of a pregnancy, then the challenge of *ectogestation* as opposed to ectogenesis, still has to be met, at the beginning part of pregnancy.

And even if it can be met, it is still not clear that the two technologies could meet in the middle quite so easily. For ectogestative efforts at the beginning of pregnancy do (or would) focus on an interface—most likely: vasculated tissue—in which the blastula can develop and implant. After this it must then develop its own chorion, placenta, etc. as well as a fetal body. But—as we saw—at the other end of pregnancy,

<sup>65</sup>See e.g. Royal College Of Obstetricians and Gynaecologists (2019). Q&A: The abortion time limit. <https://www.rcog.org.uk/en/news/campaigns-and-opinions/human-fertilisation-and-embryology-bill/qa-the-abortion-time-limit/>

<sup>66</sup>Romanis, op. cit. note 16, p. 754.

<sup>67</sup>Ibid.

<sup>68</sup>The *Nature* report used a modified caesarean section: an EXIT procedure. Partridge et al., op. cit. note 1; Hirose, S., & Harrison, M. R. (2003). The ex utero intrapartum treatment (EXIT) procedure. *Seminars in Neonatology*, 8, 207–214; Bouchard, S., Johnson, M. P., Flake, A. W., Howell, L. J., Myers, L. B., Adzick, N. S., & Crombleholme, T. M. (2002). The Exit Procedure: Experience and outcomes in 31 cases. *Journal of Pediatric Surgery*, 37, 418–426.

<sup>69</sup>See also Romanis, op. cit. note 16; Overall, op. cit. note 14.

<sup>70</sup>Caesarean sections—like any abdominal surgery—carry risks. Not just for the pregnant woman, but also for both mother and baby in future pregnancies. (Royal College of Obstetricians and Gynaecologists. (2015). Choosing to have a caesarean section. *Information for You*. <https://www.rcog.org.uk/globalassets/documents/patients/patient-information-leaflets/pregnancy/pi-choosing-to-have-a-c-section.pdf>). Some of these risks are likely to be more pronounced after ectogenesis; because the caesarean section is likely to be done at considerable prematurity, the womb is less stretched than in a term pregnancy. As a result the scar will be comparatively bigger, increasing future risks of e.g. uterine rupture, placenta accreta, etc.

<sup>71</sup>See e.g. Cannold, op. cit. note 17.

<sup>72</sup>Kingma, op. cit. note 35.

ectogestational efforts do not focus on an interface in which the placenta may form, but on replacing fetal parts. The two developments may well meet in the middle, but such a meeting would not be seamless; the meeting may still require a transfer of the fetal body from its previous womb-like artificial environment or vascular interface, onto ectogestative support technology that invasively removes and replaces its placenta and amnion.<sup>73</sup>

We want to conclude with the following remark. In bioethics and philosophy there is a considerable metaphysical and ethical body of literature on fetuses. Mostly this focuses on the ethical implication of progressive fetal development—for example its implications for moral status and/or the permissibility of abortion. A second focus—though more often forgotten—is the moral relevance of the physical location inside the maternal body; this brings the fetus within the purview of her bodily autonomy, and means it is directly affected by her self-regarding actions.<sup>74</sup> This paper highlights a third important metaphysical issue that is non-linear, and which may have moral implications: birth marks a substantive physiological transition beyond change of location alone, which makes fetuses and neonates very different from each other, regardless of gestational age or level of linear development. It is not clear what, if any, the ethical implications of that is—and we leave that work for others. But it is sometimes claimed that physiological transformations may not just happen to heart and lungs, but also cognitively.<sup>75</sup> If that is true, then that would add what seems, on the face of it, an important moral dimension separate from linear development alone.

#### ACKNOWLEDGMENTS

Special thanks go to Sasha Isaac, Joonas Räsänen, Barbara Katz-Rothman, and members of the 'BetterUnderstanding the Metaphysics of Pregnancy' (BUMP) research group – Alexander Geddes, Jonathan Grose, Anne Sophie Meincke, Teresa Baron & Ziggy Schilpzand at the University of Southampton, for their ideas and very helpful comments on earlier drafts of this paper. This paper was written both within the research project: Philosophy of Birth: Rethinking the Origin from Medical Humanities (PHILBIRTH), University of Alcalá, Program for Research, Development and Innovation Oriented to Societal Challenges, Ministry of Economy in Spain, AEI/FEDER/UE, 2016-19 (FFI2016-77755-R), and as part of Better Understanding the Metaphysics of Pregnancy (BUMP),

which is funded by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 679586).

#### CONFLICT OF INTEREST

The authors declare no conflict of interest.

#### ORCID

Elselijn Kingma  <https://orcid.org/0000-0001-9787-3198>

Suki Finn  <https://orcid.org/0000-0001-7319-9848>

#### AUTHOR BIOGRAPHIES

**Elselijn Kingma** is Associate Professor in Philosophy at the University of Southampton, and Socrates Professor in Philosophy & Technology at the Technical University of Eindhoven, the Netherlands. Kingma has research interests in philosophy of science, applied ethics and metaphysics, with a special focus on medicine, pregnancy and birth. She is lead-investigator on a 5-year, 1.2 million Euro ERC Research Grant investigating the Metaphysics of Pregnancy.

**Suki Finn** is a Postdoctoral Research Fellow on the ERC funded project 'Better Understanding the Metaphysics of Pregnancy' at the University of Southampton, and soon will join Royal Holloway University of London as a Lecturer in Philosophy. Her research on the project investigates the mereotopological relationship between the gestator and fetus, and the methodological constraints and bioethical applications of such an investigation. Outside of the project, her research interests include metametaphysics and the epistemology of logic.

**How to cite this article:** Kingma E, Finn S. Neonatal incubator or artificial womb? Distinguishing ectogestation and ectogenesis using the metaphysics of pregnancy. *Bioethics*. 2020;00:1–10. <https://doi.org/10.1111/bioe.12717>

<sup>73</sup>This is all speculation; perhaps the gestating could stay where it is. But quite possibly it could not; technologies are rarely perfect. Perhaps the placenta built in the artificial interface would be more limited in capacity than a normal placenta, thus necessitating the ectogestative transfer after 20 weeks or so when metabolic demands are on the increase.

<sup>74</sup>e.g. Warren, op. cit. 49; Kingma & Woollard, op. cit. 11.

<sup>75</sup>See e.g. pp. 10–11 and references therein from the report by the Royal College of Obstetricians and Gynaecologists. (2010). Fetal awareness: Review of research and recommendations for practice. Retrieved from: <https://www.rcog.org.uk/en/guidelines-research-services/guidelines/fetal-awareness---review-of-research-and-recommendations-for-practice/>; and Koch, C. (2009, September 1). When does consciousness arise in human babies? *Scientific American*. Retrieved from: <https://www.scientificamerican.com/article/when-does-consciousness-arise/>