Science Fiction and the Futures of Artificial Womb Technology: Towards a Carrier Bag Theory of Design Fiction

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Abstract

This article brings together science fiction literary theory and Design research to examine how the narrative modes used to frame novel technologies shape biomedical futures. Focussing on current research into Artificial Womb Technologies (AWTs) we show how scientific innovation in this area is currently framed using the archetypal "hero narrative," defined by Joseph as the story of the struggle and triumph of the individual. Such a framing, we argue, restricts understanding of this technology's transformative potential while also occluding the intersubjective nature of reproduction as well as the labour of gestation. Drawing on Ursula K. Le Guin's 1986 articulation of a feminist mode of science fiction in *The Carrier Bag Theory of Fiction* (2019), we argue that a narrative frame rooted instead in multiplicity, resourcefulness, and collectivity is necessary for approaching speculation about AWTs.

To show how Le Guin's theory might reshape futures debates, we propose a theoretical framing of a design method: a carrier bag theory of design fiction. Reflecting upon a design fiction exercise developed through engagement with Le Guin's essay, we show how taking account of a diverse range of perspectives as well as a broad spectrum of possible futures fosters discussion of a technology that is not restricted to individual benefit and desirability. Rather, such an approach decentres existing narratives juxtaposing them with alternative fictions that educe the wider impacts of novel technologies. By reflecting on this process, the essay considers the affordances of the carrier bag as a form, showing how narrative structure shapes the types of futures that can be imagined.

Keywords

Ectogenesis; Artificial Womb Technology; Biomedical innovation; Narrative; Speculative Design; Bioethical Speculation; Ursula K. Le Guin; Science Fiction; Design Fiction

Introduction

In 2023, *Nature* reported that the Children's Hospital of Philadelphia (CHOP) were seeking approval for human trials of their Extra-uterine Environment for Newborn Development (EXTEND) (Kozlov 2023). This device, also known as the 'Biobag', provides artificial womb-like conditions for extremely premature infants, aiming to improve upon the neonatal incubators that have been used, with minor developments, since the nineteenth century. The CHOP team have successfully gestated lamb fetuses for four weeks (Partridge et al. 2017) and now hope to move to human testing. The US Food and Drug Administration (FDA) met to discuss such a development in 2023, though permission has not yet been granted (Christensen 2023). Despite this regulatory hurdle, progress in this area continues.

Sharing details of their experiment in academic publications and through public-facing media, the team emphasise the Biobag's benefits for human health outcomes. In a short documentary about the experiment released on CHOP's YouTube channel, Kevin Dysart, a neonatologist on the team, explains that the challenges faced by extremely premature infants are firstly "surviving," and then "walking, talking, seeing, hearing, and developing along the normal path" (The Children's Hospital of Philadelphia 2017, 0:36). This is shortly followed by a shot of a physiologically fragile and underdeveloped newborn in an incubator with the words "New Hope for Premature Infants" stretching out above it, before the documentary moves into a description and discussion of the Biobag (1:20). The film introduces the experiment within a story in which infants battle to survive prematurity, and scientists valiantly attempt to save them. Thus, in public messaging, the CHOP team frame their artificial womb technology (AWT) using the archetypal mode of struggle and triumph, defined in 1949 by Joseph Campbell as the "hero narrative" (2004). In this, a protagonist undertakes a journey, encounters a decisive crisis and returns home triumphant, bringing positive benefit to wider society.

The hero narrative offers a story of individuation that is structured around personal resilience and ingenuity. In employing this mode, CHOP's researchers rely on and further a narrow, individualistic perspective, positioning the neonate both as the rationale for the technology's intervention and as its desired outcome. However, as we explore here, the creation of AWTs and their usage has implications beyond those for these individual infants. Indeed, the successful development of AWTs and their introduction into society has the potential to radically alter the ways we understand gestation, birth and parenthood (Takala 2009; Firestone 2015; Segers 2021).

To understand the breadth and complexity of this transformative potential, we argue that an alternative narrative mode is necessary. More specifically, we contend that the implications of AWTs can only be understood using a framework that is not predicated upon individual struggle and triumph, but rather on multiplicity and collectivity. By this we mean a framework that takes account of a diverse range of perspectives and experiences to explore impact rather than benefit. We contend that CHOP frame public messaging about the potential of their research using the hero narrative. While such a framing has value for shaping a direct and compelling value proposition that helps to drive technological innovation, we find that the hero narrative's reliance on individual triumph obscures the broader contexts into which AWTs emerge. Furthermore, limiting the narrative perspective on AWTs in this way prevents analysis of the interests or agendas that they may further. We argue that framing AWTs through the structure of the hero narrative curbs exploration and understanding of their broader implications.

In this article we have two main aims. The first is to explore alternative forms of narrative framing with the aim of fostering and collecting wide-reaching and multifaceted perspectives on artificial wombs as a class of technology. To do so, we turn to Ursula K. Le Guin's 1986 essay *The Carrier Bag Theory of Fiction* (2019). This explores alternatives to the hero narrative as a structuring device for science fiction (sf), a genre it characterises as the "mythology of modern technology" (36). Le Guin finds an alternative to the hero narrative in the form of the carrier bag, a device she sees as the earliest human technology. Her essay is centrally concerned with the intertwined relationships between culture, technology and reproduction and, in it, the carrier bag is associated with childrearing, food gathering, and home making. Through this metaphor,

Le Guin offers a feminist mode of sf based on multiplicity, resourcefulness, and collectivity as opposed to the linearity, personal resilience and individualism of the hero narrative.

To explore ways in which Le Guin's theory might be put into practice, we describe and reflect upon a design fiction exercise undertaken by academics and staff on the Future of Human Reproduction project. Design fiction is a design method used to explore and critique possible futures. Taking Le Guin's central metaphors of gathering and carriage as its starting point, this exercise in design fiction involved a design researcher — the corresponding author — working with academics from a variety of disciplines to speculate on the possible futures of complete ectogenesis, the gestation of a fetus outside the body for the full term of maturation. We chose to focus on complete ectogenesis because it offers an exaggerated version of current envisionments in AWT research. Thus, it usefully amplifies the issues such technologies raise, offering opportunity for discussion and analysis. In reflecting on the design fictions that this exercise produced, we show here how alternative forms of narrative framing engender different futures. This is important because the parameters of speculation ultimately dictate how, for whom, and under what circumstance the benefits of technology accrue.

Our second aim is to provide an example of interdisciplinary approach to methods in Medical Humanities research. By showing how literary theory's analysis of genre and mythology can be brought to bear on biomedical innovation and design fiction practices, we build on Raymond Holt and Stuart Murray's "network[ing]" of metaphorical, imaginative understandings and material design or technological practices within Medical Humanities research (2020, 59). As a design researcher and a literary critic, we bring together our individual disciplinary concerns to demonstrate the impact of narrative modes for design practice. Drawing on Caroline Levine's use of a design concept to understand the possibilities and potentialities of literary forms, we explore the "affordances" of the carrier bag as a formal structure (2015, 6). We demonstrate how, when used to inform the design fiction method, it fosters interdisciplinary communication through an emphasis on gathering, carrying, and combining multiple approaches and perspectives.

In what follows we first provide a brief overview of ectogenesis and its relationship to sf, science fact and the development of AWT. In doing so we set out a rationale for our own focus on this concept as a method for exploring the implications of AWT. Turning to *The Carrier Bag Theory of Fiction*, we draw on Le Guin's analysis of the intertwined relationships between cultural form, technology, and reproduction to show how narrative structure determines the types of futures that can be imagined. Acknowledging a conceptual elision between AWT and ectogenesis, we explore the carrier bag as a metaphor for an alternative narrative formation and then discuss how we used this metaphor to shape use of the design fiction method within an interdisciplinary study of complete ectogenesis. Finally, we reflect on the narrative frames employed by several works of design fiction and propose a carrier bag theory of Design Fiction.

Ectogenesis: Science Fiction and Science Fact

The term ectogenesis was first used to describe the concept of an artificial womb by the biologist JBS Haldane. In a 1923 lecture to the Cambridge Heretics Society, Haldane speculated about the complete gestation of prenates outside the uterus in artificially constructed environments at an industrial scale. To arrive at these speculations, he extrapolated from Walter Heape's embryo transfer experiments, conducted between 1890 and 1897, and Albert Brachet's study of the development of entire rabbit blastocysts in 1912 and 1913. In these experiments, Haldane saw the potential for the biological sciences to shape the future of human reproduction. After Haldane's use of the term, ectogenesis became more widely known when it was depicted in Aldous Huxley's dystopian novel *Brave New World* (1932). Since then, it has become a recognisable trope in works of sf where it has been invoked to explore a variety of future scenarios. For example it has been used: to imagine how technological change might impact women's rights in Marge Piercy's *Woman on the Edge of Time* (1976); to symbolise the drudgery of existence under capitalism in *The Matrix* (1999); and, more recently, to explore the intersections of capital and medicine in Helen Sedgwick's *The Growing Season* (2017) and Lavanya Lakshminarayan's *The Ten Percent Thief* (2023).

There has been scientific progress in cognate technologies throughout the twentieth century (Schoberer et al. 2012). Most notably, an early patent for an artificial womb (Greenberg 1954), initial developments in artificial placenta (Callaghan et al. 1963; Zapol et al.1969) and the subsequent development of pumpless oxygenators (Awad et al. 1995). Despite these advancements, ectogenesis remains speculative. However, several pre-clinical research projects are currently investigating AWT including: Ex Vivo Uterine Environment Therapy (EVE) (e.g. Usuda et al. 2017; Miura et al. 2016; Usuda et al. 2019); EXTra-uterine Environment for Neonatal Development (EXTEND) (e.g. Hornick et al. 2019, 2018; Partridge et al. 2017; Partridge, Davey, and Flake 2018); Extracorporeal Life Support system (ECLS) (e.g. Reoma et al. 2009; Gray et al. 2013; Kading et al. 2020); and Extracorporeal Membrane Oxygenation (ECMO) system (e.g. Darby et al. 2021; Charest-Pekeski et al. 2022). Additionally, Eixarch et al. have addressed issues of methodological reproducibility in pre-clinical AWT research (2023), and the Placental Life Support system (PLS) has been developed with a participatory values-led approach using models and manikins rather than adopting animal testing methods (e.g. van der Hout-van der Jagt et al. 2022; van Haren et al. 2024).

Each of these programmes of research is predicated on the idea that physiologically immature fetuses require a radically new intervention at the point that in utero gestation becomes non-viable. They focus on creating a suite of technologies and techniques to support the continued development of extremely preterm infants ex utero in a womb-like environment. When discussing these technologies, academics and commentators frequently invoke well-known sf representations of ectogenesis, most commonly *Brave New World* (Klass 1996; Mitchell 2017; Romanis 2020). However, whether the fantastic narratives of complete ectogenesis presented in sf are related to these more mundane, yet still radical, narratives of partial ectogenesis is contested.

Notably, and perhaps because of the dystopian representation both in Huxley's novel and elsewhere, the CHOP research team, who are in the process of bringing their EXTEND platform to market, have distanced their intervention from discussions regarding complete ectogenesis. They call the concept "nothing more than a technically and developmentally naive, yet sensationally speculative, pipedream" and argue against the relevance of discussing "unlikely" future scenarios in relation to their work

(De Bie et al. 2023). At the same time, commentators have described being shut out from conversations with the researchers after revealing an interest in "the history of ectogenesis" (Lewis 2019). Therefore, we can see a concerted effort from some researchers developing AWTs to steer the narrative used in communication and discussion of their interventions in neonatal care. One of the reasons for this, as we explore below, is that in preparation for the commercial application of the intervention researchers want to curtail association with dystopian imaginaries that radically disrupt our conceptions of the human. These scientists resist relating their work either to the history of ectogenesis or to its future, refusing any fantastic speculation around its transformative potentialities. Instead, they favour a tightly controlled, hermetic story that focusses exclusively on the technological breakthrough and the prenates whose lives their intervention seeks to save.

Unlike the CHOP team, the Dutch consortia developing PLS have engaged with the concept of ectogenesis. They position their work as part of the history of ectogenesis, placing it in relation to both literary depictions and historical medical experimentation (van der Hout-van der Jagt et al. 2022). At the same time, they have been careful to avoid conflation between the speculative (that which exists only in imagination), the prospective (that which is informed by what is imminently scientifically feasible and commercially viable), and the actual (that which is grounded by current practice). For example, van der Hout-van der Jagt et al. coined a neologism, "perinate," as an alternative to another recently coined term, "gestateling" (Romanis 2018). Their aim was to avoid association with the hypotheticals both of complete ectogenesis and ectogenesis prior to the current threshold of fetal viability to which Romanis' term alludes. In using "perinate" as a sub-category of "gestateling," they more specifically describe a fetus ex-utero at the perinatal stage to "mark the temporary and specific purpose of perinatal incubation after (extreme) preterm birth" (van der Hout-van der Jagt et al. 2022). Thus, some researchers acknowledge that their work relates both to the history and potential futures of ectogenesis. They remain attentive to, yet cautious of, speculative narratives in relation to their prospective interventions into neonatal care. In their academic writings, the PLS team adroitly position their work as part of the wider

story of ectogenesis, while maintaining clear boundaries between that which is currently feasible and actively being pursued, and that which is speculative.

While different groups of AWT researchers have opposing attitudes towards ectogenesis as a concept, the reality is, that though they may not be pursuant of ectogenesis practically, their experiments remain associated with it theoretically. This association is compounded by claims that the gap between existing interventions such as in vitro fertilisation (IVF) and neonatal intensive care will continue to diminish until it is possible to undertake the full term of gestation outside the body. As Peter Singer and Deane Wells argue, the technical ability to support complete ectogenesis "will occur almost by accident because the ability to keep the immature fetus alive outside the womb will not be developed by researchers deliberately seeking to make ectogenesis possible but rather by doctors attempting to save the lives of premature babies" at earlier and earlier stages of gestation (2006,10). Thus, the intentions of research teams developing AWTs is unimportant as the law of unintended consequences — the idea that people's actions always have unintended or unanticipated outcomes — comes into play (Norton n.d.). No matter the motivations of scientists, research into AWT opens a multitude of possible futures that reasonably includes complete ectogenesis.

Furthermore, technological development and scientific research do not exist in a vacuum and remain inextricably tied to sf narratives and the wider cultural imaginary. Indeed, Caroline Bassett, Ed Steinmueller and Georgina Voss describe a complex network of "mutual influence" between sf and science fact, noting the "multi-directional and on-going pathways connecting SF and science" (2013, 0). In their development of AWT, researchers have had to navigate the complexities created by the legacy of sf narratives as they develop and define their narratives of science fact. However, the contestation between different AWT researchers' positions suggest that it may prove useful to look more closely at the narratives and language choices that shape AWT alongside the potential futures of ectogenesis. To do so, we turn to Le Guin's essay *The Carrier Bag Theory of Fiction*, which discusses the narrative modes of sf, a genre fundamentally concerned with understanding and mythologising the role of technology in modernity.

The Carrier Bag Theory of Fiction

The Carrier Bag Theory of Fiction outlines a feminist framework for the writing of sf. At its close, Le Guin concludes that "[i]f science fiction is the mythology of modern technology, then its myth is tragic" (2019, 36). The reason for this tragedy, she explains, is that technology and modern science are framed as "heroic undertaking[s]" that, in being "conceived as triumph," are ultimately tragic. For Le Guin, the heroic victories over "earth, space, aliens, death, [and] the future" (2019, 36) that preoccupy much sf are inextricable from the apocalyptic devastations and holocausts that are also archetypal features of the genre. She suggests that the story of an individual's triumph is narratively possible only alongside the widespread suffering of others. *The Carrier Bag Theory of Fiction* contends that the heroic stories of conquest and mastery endemic to the mythology of technology cannot exist independently from the tragic.

These twinned modes of triumph and tragedy are at play in the narratives that structure both the rationale for, and the communication of, developments in AWTs. As we described in our introduction, the CHOP research group frame their AWT experiment in a way that conforms to the standard model of technological mythologisation that Le Guin identifies in mid-century sf; they position the hero's triumph (neonatal survival and health) over an obstacle (pulmonary underdevelopment) of circumstance (extremely premature birth). The CHOP team narrate their experiment as a heroic victory over the tragedies of loss and disability associated with preterm birth. Yet, childbearing and rearing have rarely been depicted as heroic. Indeed, in traditional narrative formulations such gendered, domestic activities usually operate as the antithesis of the heroic journey, consigned, instead, to the home that is left at the start of the narrative and returned to at its end. Furthermore, gestation and parenting are inherently intersubjective. Because of this, we suggest that the archetypal hero narrative is an insufficient mode through which to conceive of AWTs. In Le Guin's carrier bag, we find a form that accommodates the multiple perspectives which inhere in the ordinary and fundamentally interrelated work of reproduction.

To arrive at her carrier bag theory, Le Guin draws on a glossary of alternative meanings for words written by Virginia Woolf in the notes for her feminist essay, "Three Guineas."

In Woolf's glossary heroism is defined irreverently as "botulism," then redefined through wordplay as "bottle" (Le Guin 2019, 28). Inspired by this, Le Guin proposes a playful, yet compelling, idea, the "bottle as hero" (Le Guin 2019, 28). By this she means a bottle as a container used to gather, hold and transport, a "recipient" (2019, 29). Such an object, Le Guin argues, was "probably" the "first cultural device," an argument she adopts from anthropologist Elizabeth Fisher's "Carrier Bag Theory of Evolution." This proposes that the origins of human culture and technology, which are here almost synonymous, lie in the use of containers. Fisher writes that "the earliest cultural inventions must have been a container to hold gathered products and some kind of sling or carrier bag" (Le Guin 2019, 29). Le Guin applies this idea to narrative form, positioning the carrier bag as an alternative to the "hero narrative'' that, she argues, dominated contemporaneous sf. Instead of narrating individual stories of conquest and personal transformation, Le Guin values the actions of gathering and holding as modes for writing novels. Indeed, this is a method evident in the construction of the essay itself; Le Guin arrives at her theory by borrowing from Woolf and Fisher, gathering together different strands of feminist thought in her own carrier bag.

Le Guin's theory has been taken up by various writers, thinkers and practitioners as a method for fostering and gathering multiple perspectives. For example, it has been used to consider the intertextual networks of fanfiction (Jensen et al. 2023) and the artistic and environmental ecologies of plastic (Lee 2021). Most notably though, Donna Haraway cites it as an alternative method of "worlding," a form of imaginative and political worldbuilding (2016, 118). Key for Haraway are the ways in which Le Guin's discussion of the co-evolution of narrative form and technology is inextricably bound up with cultural mythologies of human reproduction. Le Guin's essay represents reproduction as having (almost) always been technologically mediated, and technology as fundamentally reproductive. At the same time, Le Guin also posits narrative form as fundamentally imbricated with both the development of technology and human reproduction.

The relationship between technology, culture and reproduction is inherent to Le Guin's definition of the hero narrative. She evidences this through allusion to Stanley Kubrick's

2001: A Space Odyssey (1968). While she does not explicitly name the film, its opening scene is immediately recognisable in her description:

> But no, this cannot be. Where is that wonderful big, long, hard thing, a bone, I believe, that the Ape Man first bashed someone with in a movie and then, grunting with ecstasy at having achieved the first proper murder, flung up in the sky, and whirling there it became a space ship thrusting its way into the cosmos to fertilise it and produce at the end of the movie a lovely fetus, a boy of course, drifting around the Milky Way without (oddly enough) any womb, any matrix at all? (29)

Le Guin explains how, in the film, the origins of human technology are explicitly located in the murderous, phallic bone, which is tossed into the air and, with a scene transition that indicates millennia of progress, becomes a spaceship. With its bulbous tip and long tail following behind, this spaceship resembles a sperm "thrusting its way through the cosmos" to reach Earth, which appears as a gigantic floating ovum. In the film, the drama of human conception is writ large on a cosmic scale and, at the end, results in what Le Guin calls a "lovely fetus." This, as she says, floats unmoored from a gestating body, perhaps signalling a new phase of human evolution.

Kubrick's floating fetus appears at a cultural moment in which embryos began to be represented in a way that abstracted or absented the gestating body. The film was released shortly after the publication of Lennart Nillson's 1965 photo essay "Drama of Life Before Birth." Nilson's groundbreaking images in *Life* magazine show embryos and fetuses at different stages of gestation, with all but one of his images using miscarried or aborted fetuses. As numerous commentators have observed, the proliferation of such images in pregnancy manuals, scientific texts and coffee-table books has increased attention to the fetus at the cost of the gestating person (Petchesky 1987; Franklin 1991; Duden 1993). Nillson's move to visualise the fetus, is crystallised in and through the widespread adoption of ultrasonography and the subsequent ubiquity of the ultrasound photo. An effect visible in the relish with which anti-abortion propagandists have taken up such images with the aim of proving the personhood of the fetus. Images of the prenatal subject unmoored from a gestating body form part of an aesthetic regime that conjures a fantasy of individuation and individuality. As well as

enshrining the personhood of the fetus, such images are also used to disavow the labour and risks of the gestating person. Instead of being seen as a process of development that requires labour and care, images of the fetus seemingly unattached to the maternal body erase the gestational work of reproduction. With no other visible support, the moment of conception and this free-floating fetus collapse in time to become everything necessary to the origin of life.

This is a moment frequently figured using the heroic mode. For example, Judith Roof has pointed out that conception is often presented as an "allegorical epic or romance" in which the sperm as "heroic mite" battles through the dangers of the womb's environment to claim the passive egg as his prize (1996, 4, 3). The moment of fertilisation then becomes the heroic transformation, the all-or-nothing instant in the abyss that Campbell sees as the defining point on the hero's "journey" (2004, 35). Indeed, Arthur C. Clarke who wrote the stories that *2001: A Space Odyssey* is based on and co-wrote its screenplay, says that Kubrick gifted him a copy of Campbell's book *The Hero with a Thousand Faces* during the film's production (1972, 34). This anecdote shows how the authors of the film consciously replicated the hero mythology that Campbell identifies as recurring throughout human history. Thus, we can see that the modes through which we typically dramatised prenatal life in the twentieth century rest on fantasies of heroic individuation which occlude its profoundly intersubjective reality. The way in which AWTs are currently being framed furthers such an aesthetic regime and its concomitant fantasy of individuation.

Through the carrier bag, Le Guin offers instead a view of life as fundamentally interrelated. Unlike the heroic journey of the sperm and the firework moment of conception in *2001*, carrier bag narratives emphasise mundane daily activities, first of gestation and then of care that support human life beyond these moments. Le Guin claims primacy for the carrier bag as the root of human technology. For her, this technology is one that is imbricated with modes of collectivity. At the same time, this somewhat unprepossessing device is fundamentally associated with the act of childrearing:

> If you haven't got something to put it in, food will escape you—even something as uncombative and unresourceful as an oat. You put as many as

> you can into your stomach while they are handy, that being the primary container; but what about tomorrow morning when you wake up and it's cold and raining and wouldn't it be good to have just a few handfuls of oats to chew on and give little Oom to make her shut up, but how do you get more than one stomachful and one handful home? So you get up and go to the damned soggy oat patch in the rain, and wouldn't it be a good thing if you had something to put Baby Oo Oo in so that you could pick the oats with both hands? A leaf a gourd a shell a net a bag a sling a sack a bottle a pot a box a container. A holder. A recipient (2019, 28).

Le Guin identifies the carrier bag with the everyday actions and requirements of survival and reproduction. She focusses on the labour of childcare, highlighting the processes that are required in keeping the next generation alive in a way that contrasts with the singular moment of conception represented in *2001*. Where Kubrick's thrusting phallus of a spaceship visually depicts "the Story of the Ascent of Man the Hero" (32), Le Guin's carrier bag is a "vast sack", denoting an encompassing worldview that takes account of the quotidian (37). Yet the carrier bag also presents a promise of fecundity, it is described as "this belly of the universe, this womb of things to be" (Le Guin, 37) and as Haraway notes "[p]lanting seeds requires medium, soil, matter, mutter, mother" (2016, 120). While mid-twentieth-century technological advancement allowed us to imagine conception without a gestating body, paving the way for AWT, nothing grows without the environment that nurtures it. This idea is figured in the carrier bag's defining quality: the ability to hold things. Le Guin makes the act of holding the primary locus of activity.

Some may argue that the metaphor of carriage is insufficient to describe the labour of gestation, that it does not adequately convey the nourishing and nurturing undertaken by the pregnant body. However, as Claire Horn points out "[t]o 'carry' is a verb" denoting an action that you are "continuously engaged in [...] throughout your pregnancy" (2023, 192). Le Guin too sees carriage as an active element of (pro)creation, writing that "[a] book holds words. Words hold things. They bear meanings" (2019, 34) With the use of "bear," Le Guin invokes the language of pregnancy and birth. In doing so, she associates authorial creativity and technological innovation with female anatomy. Like Horn she sees carriage as an active process, stating that "[a] novel is a medicine bundle, holding

things in a particular, powerful relation to one another and to us" (2019, 34). The acts of gathering, holding and juxtaposing are not the passive activities they seem next to action-packed tales of hunting and fighting associated with the hero narrative. Le Guin finds meaning in these more commonplace pursuits so that sf viewed through the lens of the carrier bag becomes "a far less rigid, narrow field, not necessarily Promethean or apocalyptic at all, and in fact less a mythological genre than a realistic one" (2019, 36). Because of this, we argue, it is a fitting form through which to frame speculation about the futures of AWTs and their potential to transform reproduction.

The Futures of Artificial Womb Technologies

Stories shape the world and influence what is acceptable and imaginable. As Haraway writes, "[i]t matters what stories we tell to tell other stories with; it matters what concepts we think to think other concepts with" (2016, 118). The stories we use to narrate new technologies determine for whom benefit accrues and for whom it does not. Working from this premise, we argue that the mode through which AWTs are envisioned and made tangible shapes not just individual concrete instances of AWT, but also the potential emergent futures of ectogenesis. Scientific research into AWTs underpins their feasibility while commercialisation strategies shape their viability. At the same time, explorations of probable and plausible applications test their desirability. Societal expectations of a particular innovation are influenced by its potential to transform lives. On the one hand, radical innovations' promise of paradigmatic technological shifts affect their commercial reception, as well as the direction of, and enthusiasm for, scientific exploration in the longer-term. On the other hand, the stories we tell about an innovation's feasibility, viability and desirability focus attention on the direct consequences of design action, on near-term change.

As key members of the CHOP team have moved beyond the patent stage (Flake and Davey 2020; 2022) in an effort to commercialise their platform, we begin to see one future of AWT that appears both probable and near. While the technology is not yet confirmed as feasible, the EXTEND team's spin-off company, Vitara Biomedical, has secured $50 million in series B venture capital to prepare for first-in-human clinical trials (Femtech Insider 2024), and so is evidently viewed by the market as potentially

viable. The company has published a website to showcase EXTEND's potential, telling a story about its desirability (Vitara Biomedical 2024). In this engagement with various publics EXTEND relies on the hero narrative. This is unsurprising when we consider Le Guin's understanding of the mode as inherently capitalistic (2019, 36). The hero narrative's focus on personal success furthers capitalist agendas which are commonly understood to promote individualism (Benke 2022). The development of individualised narratives of value was evident on an earlier iteration of the Vitara Biomedical website's contact page which highlighted key audiences necessary to help make the company vision a reality: a section of the website solicited enquiries related to media interest, staff recruitment, and capital investment (Vitara Biomedical 2024). The website addressed these audiences with the aim of channelling the necessary elements of a capitalist enterprise. The company's rhetorically powerful claims, such as that "[t]he impact of this technology will be life changing" and that it represents "a new paradigm in pediatrics" (Vitara Biomedical 2024) appeared to be directed to these audiences. However, since then, the site has changed to manage customer expectation, cautioning that the technology is an investigational device without regulatory approvals (Vitara Biomedical 2025). Vitara Biomedical must balance how it promotes its technology's potential among key audiences ahead of the EXTEND platform becoming a scientifically feasible option to ensure that it might become a commercially viable one.

The narratives at play in the media and among potential financiers and AWT research scientists, as well as those received by potential users are all critically important for the spin-off company. A key element of business success is telling both the potential investor and prospective customer base compelling and relevant stories about a product (or service). These narratives, known in marketing as "value propositions," are an essential part of the organisation's wider business strategy and a central strategy of most marketing messaging (Anderson et al. 2006). The customer value proposition clearly identifies and communicates the benefits that future customers will receive from a product. Entrepreneur and educator Steve Blank distilled the customer value proposition construction to the phrase, "We help X do Y by doing Z" (2011). In this format, a basic narrative is presented where X is the potential customer, Y is their goal and Z is the solution to an obstacle that the business's product overcomes. While this

could be understood simply as an act of assistance, where a product helps to solve a user problem, advertising frequently promotes an exaggerated reading for rhetorical advantage (Adi et al. 2015; Cooke 2019). In this reading, one commonly taken to establish a customer value proposition, the product aids in the completion of the heroic journey and the company is positioned as what Campbell calls a "helper," mentor possessing knowledge that can assist the hero in overcoming their difficulties (2004, 89). In their public-facing messaging, businesses centre the user as the protagonist of the story.

The user becomes a hero who is aided by the company's product, enabling them to overcome obstacles and fulfil their goals. This strategy is evidently at play in the way the "The Vitara Solution" is presented:

> When a premature baby is born into the world, they're faced with severe physiological challenges. With the help of Vitara's technology, we hope to provide a comfortable and stable environment for the baby to acclimate outside of the womb while continuing to develop (Vitara Biomedical 2024).

"The Vitara Solution" persuasively articulates a hero's journey, with the narrative frame simplified to its most basic form: we help the hero (neonate) reach their goal (survival and health) by helping them to overcome an obstacle (physiological challenges associated with prematurity). While AWTs do not disavow the role of the womb in gestation, its technological sublime rests on the effacement of the maternal body. The Biobag reductively casts the gestating body as a container, erasing the "chemical, biological, emotional and spiritual" symbiosis between the gestator and the fetus (Aliaga-Lavrijsen 2021, 66). This, in turn, produces and promotes the individuation of the fetus held within. It is useful, at this stage, to briefly introduce two competing models that are often at work, either implicitly or explicitly, in narratives of gestation. The parthood model views the fetus "as a part of the gestating organism" (Kingma 2019) treating it as a temporary part of the gestating body–physiologically continuous, metabolically entangled, and not straightforwardly separable without transformation. While in the containment model, "the fetus is not a part of, but merely contained within or surrounded by, the gestating organism" (Kingma 2019). It understands the gestating person as a vessel for an already individuated fetus; it frames the fetus as a discrete

patient and renders the gestator's role as primarily spatial or custodial. Returning to our point, with the heroic neonate and their predicament centred, the interrelationship of the fetus and gestator, outlined in the parthood model of gestation is ignored. Furthermore, the gestator as a mere "container" for the fetus, is unaccounted for. The fetal neonate becomes individuated as a patient allowing, in turn, for them to be characterised as a heroic subject. The hero's predicament becomes an urgent and important problem used to demonstrate the value of medical intervention and secure further research funding. Emily Partridge, a member of the CHOP team, describes the premature neonate as "fascinatingly resilient" but also presenting "a real clinical conundrum" (The Children's Hospital of Philadelphia 2017, 0:15). Such infants thus offer the ideal heroic subject. They are characterised as plucky and adaptable in the face of seemingly insurmountable difficulty and danger, but they also present a problem to be solved, one that requires the ingenuity and innovation of modern science.

Furthermore, while Vitara frame the fetus as a hero, they also present the researchers themselves as heroic. This is a familiar story; doctors are frequently represented as heroes selflessly battling to save lives and end suffering by waging war on illness (Khan et al. 2021). In this way, Le Guin's analysis of the mutually reinforcing modes of triumph and tragedy within the hero narrative is apparent. The Vitara Biomedical website presents a shorthand version of this narrative with images of traditionally incubated neonates alongside those of inventors hard at work. Here, an image of the researcher-as-hero merges with that of researcher-as-mentor figure presented in the fetus-as-hero narrative of the value proposition. The two hero narratives combine so that a successful outcome is doubly asserted.

As we have seen, the CHOP team argue that discussion of the speculative futures of ectogenesis obstructs focussed analysis of the specific issues raised by their platform. However, we suggest here that being solely responsive to a medical development and focussing only on the near-term futures it suggests, limits understanding of the possible futures that may arise from the technology. Indeed, such attempts to delimit discussion of AWT by avoiding associations and conflations with speculative futures of ectogenesis could be seen as a form of what Ruth Levitas calls "anti-utopianism," whereby alternative futures are shut down (2013, 123). By hoping to dispel discussion of

ectogenesis from critical appraisal of the EXTEND platform, the CHOP team "actively [oppose] the imagination and pursuit of alternatives" (Levitas 2013, 123). Adoption of such an approach could place bioethical speculation inadvertently in service to innovation and its myopic interests. Conversely, being prefigurative and proactive while imagining a range of latent futures enables a greater breadth of possibilities to be considered. Thus, we argue that there is a strong case for pursuing the practical application of novel technologies through scientific innovation alongside a theoretical exploration of their potential impacts. We join Leah Lomotey-Nakon and Elizabeth Lanphier in finding in speculative fictions a "method of discovering new moral landscapes and encouraging critical ethical reflection to reimagine the social worlds of medicine" (2023, 101). We do so via a carrier bag theory of design fiction which enables exploration of a spectrum of possible futures related to complete ectogenesis yet grounded in the current development of AWTs.

A Carrier Bag Theory of Design Fiction?

Design fiction was initially conceived of by the author Bruce Sterling as an approach to sf that resisted the genre's fantastic tropes and instead foregrounded the mundane (2005). Sterling specifically used it to engage with the quotidian aspects of sf stories that take place within the physical parameters of our own world. Thus, the research method shares with Le Guin's carrier bag an interest in telling the everyday stories of sf. Furthermore, fiction is fundamental both to design and to the practice of futures. Designers trade in narratives about the world, showing how it might be transformed by new products. By 2009, design fiction had transmuted into a transdisciplinary design method that imbricated science fiction with science fact to create insights into plausible technological futures (Bleecker). The method has developed as a way for researchers to explore the near-future potential of innovations and to critically engage with nascent classes of technology before they are introduced into society. The design fiction method explores and examines the potential changes arising from technological innovation by generating speculative artefacts using two interwoven strategies: worldbuilding and narrative creation (Darby 2023, 31–34). It is used to consider and critique nascent technologies on the cusp of becoming "buildable, profitable and

desirable" (Sterling 2013), engaging fiction and near-futures to explore potential value. While diegetic prototypes are shaped for, and by the parameters of, a fictive universe, design fictions explore technological possibility and are thus grounded in scientific fact. At the same time, they should be independently coherent so that they can be engaged with and interpreted by others (Dunne and Raby 2013). The design fiction method is well positioned, therefore, to support the development of insights into AWT through an exploration of complete ectogenesis. Furthermore, this method has the added benefit of allowing a retrospective consideration of Le Guin's insights into narrative form and framing, showing how these might extend beyond the literary text, into another kind of fiction.

The exercise that was undertaken by the project team acted as an introduction to the design fiction method. The team is multidisciplinary and includes academics from Design, English Literature, Law, Linguistics, Philosophy, and Psychology (n=10), as well as project staff (n=2). The methodological approach was informed by a Research through Design methodology (Gaver 2012) and the guidance that it is "not [as] a formal methodological approach with a particular epistemological basis," but rather "a foundational concept for approaching inquiry through the practice of design" (Durrant et al. 2017). The corresponding author used *The Carrier Bag Theory of Fiction* to shape the research design of a preliminary study into complete ectogenesis. In the planning of the activity, the "carrier bag" acted as a metaphor which enabled creating and collecting without hierarchy. It suggested multiplicity as a strategy and allowed for the gathering of different fictional futures, developed in collaboration yet underpinned by the resourcefulness of individual team members. It made a figurative "home," by promising a time and a place for team members to meet and take different design fictions out of "the carrier bag," reflecting and discussing them. This facilitated collectivity among the research group through the development of a shared set of references. Furthermore, the "carrier bag" facilitated the exploration of a wider range of potentiality than the commercial narratives of AWT. At the same time, this formal structure resists the tacit dominance implied by the narratives of probability and desirability used by AWT researchers. The planning was undertaken with the expectation that speculating on these potentialities would provide perspectives and insights relevant to the nature of

complete ectogenesis and, by extension, the development of partial ectogenesis/AWT in neonatal care settings.

Though it informed the planning stage, *The Carrier Bag Theory of Fiction* was not explicitly referenced by the corresponding author during the study in work with participating team members. Instead, they were given an open brief to respond speculatively to complete ectogenesis and engaged in one-to-one sessions with the corresponding author to cocreate their design fictions. No specific kind of narrative framing was encouraged among team members, though a focus on speculation related to products was maintained. Through this process twelve design fictions were made and figuratively put into "the carrier bag." Once completed, we held a day-long workshop in which we shared these speculative artefacts. These discussions generated insight through reflection on the making and sharing process. The exercise operated as a way for members of a research group to explore futures informed, to varying degrees, by their own research interests while also encouraging discussion and knowledge exchange between the whole group.

Patient and public involvement

No patients or members of the public were involved in the design, conduct, analysis, or reporting of this study.

Some Exercises in Design Fiction

As exploratory speculative artefacts, each of the design fictions discussed here move away from CHOP's delimitation of the narrative around AWTs to examine other possible futures by shaping unique fictional worlds around different products and services. Below, we describe the twelve design fictions that were generated through this process, detailing the speculative artefact (in italics) that exists in the diegesis as well as the value proposition it articulates:

1. *A museum exhibit* offers an historical overview of the developments in materials that offered wearable AWTs users the option to make the fetus visible or invisible at will using thermochromic coverings and flexible electrochromic films for both medical and social purposes.

2. *An NHS web page* offers prospective parents considering AWT an overview of the medical assistance available to them, including the routes to parenthood for cisgendered women under 40 and the additional hurdles set for older women and trans-people. It highlights the policy obstacles people face when attempting to access NHS treatment and costly private treatment alternatives.
3. *An executive summary of a policy review* details a UK government initiative which aimed to increase the "skilled" workforce by leveraging AWTs potential to bypass gestational labour and extend the window of maternal fertility to counter a shortage of skilled workers in the UK labour market created by low birth rates among professionals and limited immigration quotas.
4. *A not-for-profit website* run by a US Christian ministry offers believers the opportunity to glorify their God by financially supporting the use of AWT to bring to birth and adopt the "spare" and unused embryos created by the widespread increase in the use of fertility treatments.
5. *A commercial advertisement* offers prospective parents using transparent home-based artificial wombs custom-made colourful amniotic fluids as a solution to the problem of visible fetal excreta.
6. *An NHS web tool* offers prospective parents using an AWT facility the opportunity to determine their fetus' auditory experiences to improve its psychological development.
7. *A priority seating poster* offers pregnant women and wearable AWT users the same access to priority seating on Korean public transport with the aim of lessening the physical burden of carrying a fetus.
8. *An NHS health campaign* targeting Black women exclusively offers them AWT in response to the high mortality rates during childbirth experienced by that demographic within NHS care.
9. *A promotional leaflet* for a retirement community in which early retirees starting a family using AWTs can live supported by a wide range of health and community programmes to help them cope with childcare.
10. *A corporate blog post,* by a guest blogger with personal experience of birthing rituals, helps prospective parents planning an AWT birth navigate the available options.

11. *A company web page* offers potential users of their artificial womb facility a range of services to help improve and assure successful maternal-fetal bonding during ex-utero gestation.
12. *A newspaper spread* reporting a case of ex-utero gestation fraud describes how a male couple's luxury reproductive tourism vacation was in fact a scam that played on their desire for a child and cost them financially and emotionally. In these design fictions a value proposition identifies a hero, the user-customer-client-commissioner, overcoming an obstacle with the support of a product to reach their goal.

In these artefacts the beneficiaries of complete ectogenesis are most often assumed to be the prospective parents. This can be seen in items 1, 2, 5-11 & 12, all of which target this market. The products described in 3, 4 & 8 have additional aims. For example, item 3 leverages complete ectogenesis to support economic benefit, while item 4 demonstrates a religiously motivated desire to preserve life. In Item 8 the intervention is used to mitigate harm within the present-day healthcare system. However, all these design fictions also show benefits for the prospective parents.

Items 2, 4, 6, 10, 11 & 12 state that complete ectogenesis is provided in AWT facilities, and it can be inferred that this is also the case in items 3, 8 & 9. Item 5 sees complete ectogenesis provided at home and items 1 & 7 imagine a wearable technology. Each of these imagined biomedical developments articulate potential futures that generate different concerns. Inspired by the sight of the lamb fetus in CHOP's AWT, two design fictions explore fetal visibility. In item 1, a museum exhibit tracks the development of materials supporting fetal visibility in wearable AWTs, with transparent or opaque acrylic casings giving way to thermochromic coverings and flexible electrochromic films. The need for fetal visibility for medical oversight opens new possibilities for sight-based social interaction throughout its gestation. In item 5, society is so well-used to seeing fetuses in ectogenic pods that another problem presents itself. The visibility of fetal excreta in transparent home-based ectogenic pods reflects poorly on the prospective parents, the problem is minimized with a choice of colourful artificial amniotic fluids providing aesthetically driven bespoke solutions for image conscious users. While futures beget futures, creating a multiplicity of viewpoints, they are also

underpinned by a concern for sensemaking. Setting the reality of the Biobag's translucence against transparent ectogenic pods and electrochromic films covering wearable wombs allows us to explore potential relationships with fetal visibility and the disquiet it may elicit.

Two items, 6 & 11, focus on issues relating to fetal development in AWT facilities, they imagine obstacles for the fetus that result directly from its relocation into an artificial womb. The former explores concerns about the psychological maturation of the fetus without auditory stimulus from the gestating body while the latter addresses the quality of maternal-fetal bonding resulting from the technology's use. As with CHOP's work, the fetus is centred as a heroic figure requiring technological assistance.

Figure 1, item 7 sets up two kinds of heroes, pregnant women and wearable AWT users, who are each deserving of consideration. However, with limited priority seating, disagreement seems inevitable. When two heroes contest one priority seat, one will triumph while one must suffer their burden. Managing access to limited resources exacerbates inequitable consequences. The correlation between triumph and suffering is further explored in Figure 2, item 12. This newspaper spread presents a story about a fraudulent service which sets up then undercuts the expected relationship between the heroes, here prospective parents, and the service. This item extends and then removes the possibility of returning from a vacation with one's new artificially gestated baby, generating pathos which results in a narrative of heroic suffering. Items 7 & 12 suggest we might usefully give more attention to the suffering that Le Guin identifies as necessarily attendant to triumph in the hero narrative, in particular, the suffering created by the very existence of a product. We now continue to explore how suffering figures in AWT futures by explaining how Le Guin's theory directly informed the creation of a speculative artefact.

A Carrier Bag Design Fiction

The mis-carrier bag, Figure 3, is a speculative artefact which aims to show one possible reaction to the emergence and assumed widespread adoption of AWT. It was made during the writing of this article by the corresponding author and is theoretically and conceptually informed by Le Guin's reflections on tragedy in *The Carrier Bag Theory of*

Fiction. Unlike in the creation of the design fictions above where it served as a metaphorical touchpoint informing the methodological approach, Le Guin's writing directly informed the creation of this artefact. *The mis-carrier bag is* an empty, blood-stained and screwed-up carrier bag, inside a ziplocked bag labelled with a description of its contents: "A carrier bag used to recreate a Biobag during a miscarriage (20 wks.)."

In AWT narratives, the artificial womb is a product integrated into neonatal care services to assist the fetus, the hero. In such speculations, the role of the hospital goes unmentioned and the role of client and that of user, of parent and fetus, are decoupled from one another as the container model supplants the parthood model. While the user-hero's survival become a common goal, the client, or rather the gestating body, is sidelined. Unlike the design fictions described above, *The mis-carrier bag,* is not itself a product, but rather an artefact resulting from the simultaneous existence and lack of an AWT product within a diegesis. It evokes the actions of an anonymous pregnant individual who experiences a miscarriage. As they face personal tragedy with the loss of their pregnancy, the knowledge of the hero-product relationship – the availability of AWTs -, shapes their reaction, leading them to attempt to create their own makeshift device from a household plastic bag. *The mis-carrier bag* presents only the aftermath of this attempt while also alluding to a tragic outcome: the loss of the fetus. By speculating about possible actions taken in a world in which AWTs are widespread but also exclusive, this design fiction points to unintended consequences of a technology's ubiquity. In *The mis-carrier bag* speculation, heroic escape of circumstance appears remote and triumph over tragedy is far from assured. It highlights the inequity of exclusionary access arrangements while demonstrating the collateral damage and emotional cost for those without access to AWT.

We have been arguing here that the narrative framing of emergent technology is central to how it is developed and understood. Taking a carrier bag approach means first recognizing the role of the hero narrative in technological rhetoric and then decentring the hero as well as, to varying degrees, the product that is placed in service to the hero's goals. So, the focus is shifted to consider how the hero-product relationship impacts those not considered as heroes and to understand how the world reshapes itself around a technology's existence. Because heroic triumph requires tragedy as its counterpoint,

its benefits will never be accessible to everyone. Carrier bag design fictions present a fragment of a life story. They focus on the non-heroes suffering in the light of the heroic victories made possible for the hero by the existence of, and access to, a product. They are held in close relationship with the hero narratives of a technology. They make sense only because they are tied to other speculations, their number and variety create a richer description of a potential future.

Towards a Carrier Bag Theory of Design Fiction

We have here provided an alternative to the hero narrative as a framework for speculating about possible futures that might arise from the development of AWTs. However, we do not wish to discard the stories of struggle, confrontation and triumph that the hero narrative entails. Rather we seek to reframe these, allowing other stories to also enter the frame. Indeed, Le Guin herself does not reject such narrative elements, describing herself as not “an unaggressive or uncombative human being” but “an aging, angry woman laying mightily about me with a handbag, fighting hoodlums off” (2019, 33). The difference, she suggests, is that she doesn’t “consider [herself] heroic for doing so" (ibid). Le Guin does not wish to jettison either personal resilience or conflict from her narrative, rather she hopes to reframe traditional modes of mythologisation and storytelling to attend to a wider variety of experience, recasting the hero’s story so that instead of being the singular and dominant mythology, it becomes one story among many.

In proposing a carrier bag theory of design fiction we aim to provide researchers with the theoretical underpinning to undertake a more holistic consideration of biomedical futures and to resist a purposefully myopic focus on the heroic user and product relation. We chose the carrier bag, because, as a form, it affords the development of non-hierarchical structures; as Le Guin writes, “the Hero does not look well in this bag. He needs a stage or a pedestal or a pinnacle. You put him in a bag and he looks like a rabbit, like a potato” (35). Such an act of decentring is depicted in the below diagram, which illustrates how we conceive of the carrier bag theory of design fiction. As can be seen, the hero narrative is placed in the carrier bag alongside additional and alternative product relations.

Through this research, we have tentatively begun to explore how a literary theory applied to a design method might produce useful and wide-ranging perspectives relevant to the futures of biomedical technologies. To develop and consolidate the carrier bag theory of design fiction proposed here further practical exploration is needed by design researchers engaged in biomedical speculation. However, in employing a narrative frame which captures triumph and suffering, or benefits and consequence, the carrier bag theory of design fiction also has utility for medical humanities scholars responding to technological innovation in reproductive medicine. This research provides a theoretical underpinning that accommodates anticipatory consideration of a range of experience that includes both prospective users and non-users who would be impacted by the introduction of a novel class of technology into the world.

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Figure Legends

Figure 1: Priority Seating poster for the Seoul underground in South Korea, Item 7 (Image © Darby, 2025).

Figure 2: A newspaper spread, Item 12 (Image © Darby, 2025).

Figure 3: The mis-carrier bag (Image © Darby, 2025).

Figure 4: A Carrier Bag Theory of Design Fiction (Image © Darby, 2025).

Competing Interests

None declared.

Funding

This work was undertaken as part of the Future of Human Reproduction project and funded by the Wellcome Trust under Grant [222858/Z/21/Z].

Ethics Approval

Not required.