Special Focus

Artificial Wombs and the Posthuman World

A few years ago, Marvel Comics began making a series of bold moves with its most important characters. In an effort to attract new readers, the publisher began shaking up its cast of superheroes to make their universe more diverse. Steve Rogers was replaced as Captain America by his longtime friend Sam Wilson (aka Falcon), an African American. Jane Foster assumed the mantle of Thor. With the deaths of Bruce Banner and Logan, Amadeus Cho (a Korean American) became the Hulk and Laura Kinney (a teenage girl) became the Wolverine, respectively. Miles Morales (an Afro-Latino) is now the Ultimate Spider-Man. And Kamala Khan, a Pakistani teenager, is now Ms. Marvel. In short, Marvel Comics has replaced many of its heterosexual, white, male superheroes with a diverse ensemble of heroes and heroines.[1]

For Marvel Comics, diversity has become a marketing strategy. According to Alex Alonso, editor in chief at Marvel:

> You know, in 2015, Peter Parker can look like Kamala Khan, and really that's what we're trying to do here—take stock of the world around us, the issues of the day, and the vast variety of our population, and tell stories through them and for them. . . . Marvel Comics' driving philosophy dating back to Stan Lee is to reflect the world outside your window, and the world outside your window has changed since the early '60s. We're following that mantra. Our new stories reflect the world outside your window in all its diversity.[2]

In the July 2016 issue of *The Invincible Iron Man* (written by Brian Michael Bendis) Riri Williams—a 15-year-old African American girl—made her full debut as the "new" Iron Man amid both fanfare and controversy.[3]

Created by Brian Michael Bendis, Riri is a student prodigy at MIT. She uses materials from university labs to design a suit of armor modeled after Iron Man. Then she uses the armor to capture two inmates escaping from the New Mexico State Penitentiary and attracts Tony Stark's attention. After visiting Riri at her home, Stark supports her decision to become a superhero. Williams (now Iron Heart) assumes Iron Man's place when Stark becomes incapacitated while fighting Captain Marvel during Civil War II.

With her introduction, Riri Williams becomes one of the few African American superheroes, and she belongs to an even more elite group: African American *female* heroes. As Marvel Comics moves toward greater diversity in its superhero lineup, it is also ushering in a new generation of superheroes who embody the feminist ideal.[4] No longer do female comic book heroes stand in the shadows of their male counterparts. As Williams exemplifies, they are complex, intelligent characters who are competent and in control.

To the delight of many of its readers, Marvel Comics has made significant strides toward accomplishing gender equality in its publications—a wise move considering nearly 50 percent of comic book readers are women.[5] In the Marvel universe, female superheroes not only use their superpowers to transcend the limitations of human biology, but they also use their superhuman abilities to transcend the limitations society often imposes on their gender.

Transhumanism and a Postgender Future

The desire to transcend the limitations of gender is not just a feminist ideal that plays out in comic books. It is integral to the transhumanist movement. For many transhumanists, using technology to transcend biological limitations includes the constraints imposed by gender. Transhumanists regard the human body as limited—even flawed—and in need of improvement. One flaw is gender—our sexual dimorphism, to use technical language. Some transhumanist thought leaders see gender as a source of antipathy, not as something to be celebrated. Gender limits human potential. Accordingly, the injustices experienced by women are not fundamentally rooted in *sociology*, but in human *biology*. Transhumanists want to use technology to create a separation between the posthuman person and gender.

Scholar J. Jeanine Thweatt-Bates assesses the intersection of transhumanism and feminism this way:

> The problems of gender inequality and heterosexism reside not primarily in the social but in the biological realm—not

> in human relationships but in the human body. The solution must therefore be not simply social but also biological.[6]

That is, some feminists think it is primarily through reengineering gender that we can succeed in eliminating patriarchy and heterosexism from society.

For those transhumanists seeking to transcend gender, the greatest hindrance of all is that imposed by pregnancy and childbirth. In 1970, radical feminist Shulamith Firestone advocated for the development of artificial womb technology to free women from (what she perceived as) the oppression caused by their reproductive system.[7] Following in Firestone's footsteps, transhumanists see artificial womb technology as necessary to free women from the unfair constraints imposed by pregnancy and childbirth. Philosopher Anna Smajdor, who argues that pregnancy and childbirth are barbaric, placing unfair burden and risks on women, puts it this way:

Transhumanists see artificial womb technology as necessary to free women from the unfair constraints imposed by pregnancy and childbirth.

> When a man wishes to have offspring, he is able to do so without risking his bodily integrity, his health, or his privacy. Thus, in terms of personal resource holdings, women are systematically at a disadvantage.[8]

Transhumanists also see other benefits to artificial womb technology. Artificial wombs could potentially eliminate many of the physical risks associated with pregnancy and delivery. The technology would also provide greater control over the processes of fetal growth and development. This step will hopefully improve the outcome of the birthing process and even facilitate the reengineering of humans before birth. However, instead of dealing with these perceived and real inequalities through social changes, the proposed solution is more radical, involving reengineering women's bodies. As Thweatt-Bates notes:

> The benefit of artificial wombs is the elimination of the problematic embodied reality of pregnancy and childbirth, which thereby allows women's bodies to function more like men's bodies—an *andro*gynous postgender future indeed.[9]

Artificial Womb Technology

Perhaps one of the first scientists to take the idea of artificial wombs seriously was British geneticist, evolutionary biologist, and atheist J. B. S. Haldane.[10] In his 1924 book *Daedalus; or, Science and the Future*, Haldane casts a transhumanist vision for humanity's future. There humans would use directed mutation to orchestrate our own evolution as a species and reproduce through in vitro fertilization—a process he called ectogenesis.

While the biomedical research community has focused significant effort on research and clinical uses for in vitro fertilization, very little work has been done toward developing artificial womb technology. As bioethicist Christine Rosen notes, "Today, we have inched slightly—but only slightly—closer to perfecting the technology that would realize Haldane's vision. . . . A small knot of scientists in the United States and Japan are experimenting with both live animals and human cells to mimic the functioning of the womb."[11]

A significant milestone in artificial womb technology was achieved in the late 1990s by a team of Japanese researchers headed by Yoshinori Kuwabara.[12] Building upon a decade of work, the researchers successfully kept goat fetuses alive for 3 weeks in an artificial womb they built. The womb consisted of an acrylic box filled with liquid designed to mimic amniotic fluid. Salts, glucose, and proteins were dissolved in the liquid. The fluid was kept at 111°F. After performing a C-section to remove the goat fetuses from their mothers' wombs, researchers placed the kids in the artificial womb. Most of the fetuses died; but a few made it to "full term." Unfortunately, all of the goats were deformed and had lung problems.

In 2017—nearly two decades after Kuwabara's pioneering work—a biomedical research team from Children's Hospital of Philadelphia (CHOP) finally achieved what Kuwabara and his collaborators sought to accomplish. They designed and manufactured the first truly viable artificial womb technology. In fact, their success raises the hope that this technology may make its way into a clinical setting soon.[13] Their artificial womb is designed around a polyethylene "bio-bag" that can be opened and then resealed once the fetus is placed in the bag. The bio-bag creates a sterile environment devoid of microbes and other infectious agents. While in the bag the fetus is bathed with a solution that

mimics the amniotic solution. This fluid fills the lungs of the neonate, which is normal for developing infants in the womb until the time of birth. The fluid can be exchanged without opening the bag by tubes connected to ports in the bio-bag. Each time the fluid is exchanged, antibiotics are introduced to maintain a sterile environment.

Temperature and light exposure received by the artificial womb can be controlled. The fetus receives oxygen by a tube that taps into the umbilical cord artery. The tube carries fetal blood to an oxygenator where carbon dioxide and oxygen can be exchanged. Instead of using a mechanical pump to circulate the blood (which can damage the heart from the pressure), the blood circulates through the oxygenator by the pumping action of the neonate's heart. Nutrients such as amino acids, lipids, and sugars are provided to the fetus by tapping into the blood circuit.

The researchers demonstrated the performance of their artificial womb technology by using lambs as a laboratory model. Lambs make an ideal surrogate for humans because prenatal lung development is similar for sheep and humans. The team monitored the growth and development of 8 fetal lambs that were taken from the womb via C-section at 105 to 120 days into the pregnancy. This stage of fetal development corresponds to 22 to 24 weeks in a human pregnancy. After 4 weeks in the artificial womb, researchers removed the neonates and compared their health with lambs who were taken by C-section at 133 to 138 days of pregnancy. The researchers found that the lambs placed in the bio-bags were as healthy as lambs that developed in the womb.

The biomedical research team believes that their artificial womb technology is nearly ready to test on human neonates. They hope that artificial wombs can improve the outcome of premature births and perhaps even extend the survival of premature infants born prior to 22 weeks.

Artificial Endometrium

For the most part, researchers working to develop artificial wombs have little interest in using the technology for transhumanist purposes. They intend to improve the outcome of premature births in the later stages of pregnancy. Still, this breakthrough in artificial womb technology excites transhumanists, who see it as a key stepping-stone to the transhumanist goal of full-fledged ectogenesis.

But to accomplish their ultimate goal, transhumanists need more than artificial wombs such as the one developed by the team from CHOP. They need access to technology that would allow for the early stages of embryonic

development *outside* the womb. At this point the technology doesn't exist. But the prospect of having this capability is just coming into view. Conceivably, the impressive artificial womb technology designed by the CHOP researchers could be improved to extend the survival of fetuses born *earlier* than 22 weeks. However, there appears to be a real limit to how far current artificial womb technology can be pushed.

For full ectogenesis to be possible, researchers need to develop techniques to cultivate early-stage embryos outside the womb immediately after in vitro fertilization takes place. Then they need to find a way to keep the embryos growing and developing to the point that a fetus can be transferred into an artificial womb.

Up to this point, few researchers have even attempted to develop laboratory protocols that would support the growth and development of early-stage embryos. In part, this outage is due to legal restrictions against allowing human embryos to grow in vitro beyond a 6-day limit in the US and a 14-day limit in the United Kingdom. As it stands now, embryos created by in vitro fertilization can't survive beyond 7 days (which corresponds to the 256-cell stage) anyway, and have to be implanted in a womb or frozen for later use.

Still, some researchers think they can extend the viability of early-stage embryos through the use of an artificial endometrium. The endometrium refers to the tissue layer that lines the uterine wall. It consists of an epithelial cell layer that rests upon a layer of connective tissue. During pregnancy, the endometrium increases in thickness and in blood vessel supply and forms a surface for the early-stage embryo to implant. Once the embryo implants, the endometrium undergoes changes that generate the placenta (in conjunction with cells of the early-stage embryo called trophoblastic cells).

Work published over a decade ago demonstrated that researchers could take starter cells from the uterine lining to cultivate sheets of cells in the laboratory. In principle, these cell sheets can function as an artificial endometrium.[14] In 2017 a research team from Belgium made significant strides toward an artificial endometrium when they grew three-dimensional endometrial organoids from cells taken from the lining of the uterine wall.[15] These organoids display many of the features of the endometrium, which allows the researchers to study the menstruation cycle and the way the endometrium changes in response to hormones. When exposed to estrogen, the endometrial organoid thickens. It folds when exposed to progesterone and when hormone exposure ceases, cells shed from the organoid's surface.

In principle, artificial endometria could provide a surface for early-stage

embryos to implant after in vitro fertilization, thereby extending the time embryos can grow and develop outside the womb. Already, some researchers have had success extending the survival of early-stage embryos in the laboratory beyond 4 days by using an artificial endometrium of sorts. In 2016, researchers from the University of Nottingham in the UK developed a cell culture method that uses a curved polymer surface to mimic the lining of a uterus. This synthetic lining provides a surface for embryos to implant. Working with a mouse model, they demonstrated that mouse embryos developed well beyond the 64-cell stage after becoming embedded in their artificial endometrium. This method allowed the researchers to study the formation of cell populations in the mouse embryo, with most of their attention focused on cells fated to develop into the animal's head.[16] There is no reason to think that the researchers' technique (or one similar to it) couldn't be applied to human embryos if restrictions on embryo development were to be lifted.

These few pilot phase studies on artificial endometria provide researchers with hope that one day they will possess the techniques to allow human embryos to thrive outside the mother's womb after in vitro fertilization for much longer than current technology (and regulations) allows. For now, most biomedical researchers working in this arena seem to have little interest in using artificial endometrium technologies to support the transhumanist vision. Instead, their primary motivation is to study the physiology of the endometrium and the events of embryo implantation and development that take place shortly after the placenta forms. Still, for many in the transhumanist movement, these types of advances offer hope that one day full ectogenesis will be possible. Christine Rosen describes the increasingly realistic hope that transhumanists have for full ectogenesis this way:

> With scientists impatient to extend research on embryos at the earliest stages of life, and researchers at the other end of pregnancy constantly pushing back viability for prematurely-born infants, at some point these two forces will likely meet. If they do, the result will be a new era in human procreation: a world in which children are created in the laboratory, gestated in some artificial womb-like environment, and brought "to term" without ever really being "born."[17]

A Technical Assessment of Ectogenesis and the Transhumanist Vision

This brief sampling of the scientific literature underscores just how difficult it

is to duplicate the critical events that take place during the early stages of embryo development and placental formation in a laboratory setting.

Fetal Effects

While artificial womb technology may help to keep neonates alive prior to 22 weeks, the biomedical community is a long way from possessing technology that can support the growth and development of a fetus from fertilization to birth outside the womb. The best biomedical researchers can hope for is *partial* ectogenesis, and mostly for the later stages of pregnancy.

But even if full ectogenesis from fertilization to birth were possible, it is questionable that any ectogenetic technology would ever be capable of fully replicating the physical and psychological development that takes place in the natural setting of a mother's womb. A quick survey of a few recent discoveries illustrates this point.

Gene expression. Scientists have limited understanding of the role gene expression plays in the processes of embryonic growth and development. And as biomedical researchers strive to gain insight into this question, they are uncovering surprises. As a case in point, researchers from Singapore and the UK discovered that 75 percent of growth and development appears to be directed by epigenetic modifications to DNA! These modifications alter gene expression, which is central to the process of embryonic growth and development.[18] Keith Godfrey, one of the study's authors, concludes, "This research provides important new evidence that fixed changes in a baby's genes have only a modest influence on its epigenetic profile at birth and that most of the variation between babies arises from interactions between the environment experienced in the womb and the genetic information inherited from the parents."[19]

Because epigenetic modifications to DNA are often triggered by environmental events, the interplay between womb and fetus appears to be critical for proper development. No doubt, this interplay is complex, prompting the question, can this interplay be replicated in an artificial womb in a way that triggers the right epigenetic changes at the right time in the fetus?

Fetal development. Researchers have also learned that hormone exposure has wide-ranging effects on fetal growth and development. And if the right hormones aren't available at the right time, unanticipated effects on embryonic development can result. A study carried out in 2013 by researchers from Cardiff University in the UK illustrates this point.[20] Working with mice, researchers disrupted the expression of the gene that encodes for the insulin-like growth factor-2 (*IGF2*). This hormone regulates the supply of nutrients

to the embryo. When the *IGF2* gene was disrupted, the nutrient supply to the mouse embryos became imbalanced, altering gene expression patterns in the fetal brain tissue. The consequence of this nutrient imbalance persisted into adulthood. The mice were highly anxious as adults. According to researcher Lawrence Wilkinson, a behavioral genetics scientist at Cardiff University, "The growth of a baby is a very complex process and there are lots of control mechanisms which make sure that the nutrients required by the baby to grow can be supplied by the mother."[21]

Adult health. Biomedical researchers refer to the long-term effects of hormone exposure in the womb on children and adults as placental or perinatal programming. Biomedical scientists have come to recognize just how important this programming is to physical and psychological well-being in adults. For example, in another 2013 study, a research team from the University of Edinburgh discovered that mice exposed to glucocorticoids displayed reduced growth in the womb and mood disorders later in life.[22] Glucocorticoids are stress hormones that trigger the stress response. A fetus will potentially be exposed to these hormones during pregnancy when the mother experiences stress, bereavement, or abuse. Fortunately, an enzyme (11b-Hydroxysteroid dehydrogenase type 2) located in the placenta and the fetal brain breaks down glucocorticoids and protects the fetus. The researchers discovered that disabling this enzyme in mice fetuses had a long-term adverse effect on the adult mice.

This study demonstrates the complexity of the mechanisms required to ensure healthy fetal development in the womb. Though both studies were performed with mice, they have implications for human embryonic development and highlight the importance of hormone exposure in the womb. If this exposure becomes imbalanced it will have profound effects on the physical and psychological health of the child after birth that extends into adulthood. Again, these types of studies emphasize the challenge of replicating the complex, dynamic environment of the womb in an ectogenetic system.

Brain development. Increasingly, biomedical researchers are coming to appreciate just how critical the womb is for fetal brain development. In 2005, researchers from McMaster University presented data at the Society of Neuroscience meeting (held in Washington, DC) that showed differences in brain development for premature infants compared to those carried to full term.[23] The research team demonstrated that the frontal areas of the brains of premature infants born at 26 weeks were smaller and underdeveloped after 10 weeks of intensive care when compared to the brains of infants carried in

the womb for 36 weeks. According to lead researcher Sandra Witelson, "These findings indicate that the normal early maturation of the brain may be compromised when it takes place outside of the womb."[24]

Language development. Work reported in 2017 by researchers from the University of Kansas indicate that the beginning stages of language development take place in the mother's womb at least one month before birth.[25] Using a noninvasive technique that employs a biomagnetometer, the research team discovered that infants in the womb responded differently to English and Japanese—indicating that they are already tuned to the language they will soon learn to speak. According to Kathleen Gustafson, the study's principle investigator, "The fetal brain is developing rapidly and forming networks. . . . The intrauterine environment is a noisy place. The fetus is exposed to maternal gut sounds, her heartbeats and voice, as well as external sounds. Without exposure to sound, the auditory cortex wouldn't get enough stimulation to develop properly. This study gives evidence that some of that development is linked to language."[26]

This brief sampling of recent scientific findings illustrates the importance and complexity of events that take place in the womb during growth and development. Though biomedical researchers are gaining insight into these processes, it is safe to say that we lack full understanding. Without complete understanding, artificial wombs will never be truly adequate replacements for the mother's womb. On top of that, it is quite likely that scientists are unaware of additional critical events that take place during fetal growth and development.

As a case in point, consider the work of biomedical investigators from Cincinnati Children's Hospital Medical Center, also published in 2013.[27] Studying mice, researchers learned that light exposure while mouse pups are *in* the womb is critical for the development of their eyes. The researchers discovered that when pregnant mice experienced normal light-dark cycles, they gave birth to pups with normal vision. On the other hand, pregnant mice kept in the dark gave birth to pups that suffered visual impairment due to abnormal retinal development. To their surprise, the researchers learned that fetuses needed direct light exposure, with photons of light entering the womb. Light exposure suppresses the growth of blood vessels in the retina, which is critical for the retina to develop properly. If the mouse fetus does not experience light exposure, the blood vessels feeding the retina grow unchecked and damage this part of the eye.

This unexpected finding led primary investigator Richard Lang to say, "This fundamentally changes our understanding of how the retina develops. . . .

We had always assumed that if light played a role in the development of the eye, it would also happen only after birth."[28] This discovery has practical implications for artificial womb technology. For the best outcome, fetuses placed in an artificial womb need to be periodically exposed to light at the appropriate stage of fetal development. But that's not all. The key point for considering artificial womb technology is this: if we fail to identify all the mechanisms responsible for growth and development in the womb, placing an otherwise healthy embryo into an ectogenetic system can have catastrophic consequences for the child that can last a lifetime.

In the near future, artificial wombs will likely play an important role in improving the outcome of premature births, but it is questionable whether reproductive technology could ever serve as a true surrogate for even the later stages of pregnancy. In response to this point, transhumanists may rightly argue that artificial wombs could protect the developing fetus from harm caused by stress and the mother's psychological state. Artificial wombs could also protect the fetus from exposure to pathogens and teratogens and ensure that the neonate receives the right nutrients at the right time. But despite all of these benefits, it is doubtful that biomedical researchers can replicate all of the positive, necessary biological and psychological influences the mother exerts on the developing child in her womb.

A Christian Perspective on Artificial Womb Technology

So, what are Christians to make of artificial womb and endometrium technologies? And how should Christians engage people in the scientific community—and our culture at large—who see ectogenesis as a stepping-stone to a posthuman future where reproductive technologies provide a tangible solution to perceived injustices women experience due to pregnancy and childbirth?

First, we think there are good reasons for Christians to celebrate advances in artificial womb technology, particularly if it can be used in a clinical setting. This technology promises to dramatically improve the outcome of premature births, especially those classified as critically preterm. Currently, 1 in 10 births occurs prior to 37 weeks of pregnancy and is considered preterm. Of these, 30,000 infants are born before 26 weeks. Infants born this early are at high risk. One-third of all infant deaths are due to extreme prematurity and those that survive suffer from chronic health problems.[29]

Medical practitioners place premature infants in incubators, where they require mechanical ventilation and are fed and receive medication intravenously. The infants go through quite an ordeal during these treatments. And often

the outcome is mixed: 30 to 50 percent of these little patients suffer chronically poor health—if they survive. In principle, artificial womb technology offers a better approach for treating premature births because it more closely mimics the environment of the mother's womb. Placing a premature infant in an artificial womb should be far less stressful on premature babies, while leading to better clinical outcomes. The technology has the potential to alleviate the suffering and distress that premature infants and their families experience during treatments and in years that follow.

Artificial endometria technology should also excite Christians. These model systems will help lead to a better understanding of the physiology of the uterine lining. This understanding will translate into more effective treatments for diseases such as uterine cancer and endometrial atrophy, alleviating pain and suffering. The use of artificial endometria to study the process of placental formation and the early stages of development will lead to valuable scientific insights into embryonic growth and development. This insight will undoubtedly translate into biomedical advances.

But there is a caveat. As Christians, we believe that experiments designed to study implantation, placental formation, and early-stage embryo development should be limited to *animal* embryos only. Because we regard the human embryo as a person, we are deeply troubled by the prospect of researchers creating human embryos for the sole purpose of studying events in the early stages of embryonic development. Eventually, these embryos must be sacrificed—an act we consider to be morally reprehensible.

Artificial womb technology excites us for another reason. We view it as a pro-life technology. The magnitude of the effort required to develop and continually improve this technology speaks highly of the value most people inherently place on unborn children. Because the technology has the potential to extend the survivability of the fetus outside the womb to earlier than 22 weeks, it has important legal implications. Laws in many states and the District of Columbia restrict abortion to within the first 24 weeks of pregnancy. The basis for this restriction is the viability of the fetus. Right now, a fetus can't survive outside the womb prior to 22 weeks of gestation. But what if artificial womb technology could make it possible for fetuses younger than 22 weeks to survive outside the mother's womb? Using the same logic that undergirds many abortion laws, extending the survival of the fetus outside the mother's womb could be used to justify restricting abortion to the first 4 or 5 months of pregnancy.

Another interesting pro-life application for artificial wombs relates to the fate of the fetus after a pregnancy is terminated by abortion. If this technology

becomes widespread and reasonably cost-effective, it is conceivable that women who choose to abort their babies could voluntarily have the fetus placed in an artificial womb, where it would be allowed to grow to full term and then placed for adoption.

In fact, it is not outside the realm of possibility to think that this practice may one day be legally required whenever a woman terminates her pregnancy.[30] According to ethicist Scott Gelfant, this approach to reproductive choice "could meet the test of Roe vs Wade—that it protects the privacy of the woman while preserving the rights of the fetus."[31] In effect, artificial womb technology may lead to a win-win scenario when it comes to the abortion controversy, although questions of cost will come into play. Who would foot the bill for the "aborted" fetus if he or she were placed in an artificial womb?

But what about the use of these reproductive technologies to free women from the "shackles" of pregnancy and childbirth? As of now, it is hard to imagine how the ultimate transhumanist dream of full ectogenesis could be accomplished. CHOP biomedical researcher Alan Flake, who was instrumental in designing the most successful artificial womb technology to date, says, "It's complete science fiction to think that you can take an embryo and get it through the early developmental process and put it on our machine without the mother being the critical element there."[32]

It is conceivable that one day in the near future partial ectogenesis will be used as a type of human enhancement. After conceiving a child and carrying it for a few months in her womb, a woman might decide to halt her pregnancy and transfer the fetus to an artificial womb to avoid the last several months of pregnancy. According to journalist Colleen Carlston, "These artificial births would be completely safe for the mother, offering no chance of hemorrhaging during birth. Women also would not have to take time away from busy careers for maternity leaves. . . . Other women might want artificial wombs for more superficial reasons, to avoid weight gain or stretch marks."[33]

But as we previously discussed, use of artificial womb technology for this type of human enhancement may be ill-advised. Ectogenetic technology may not ever genuinely be capable of fully replicating the physical and psychological development that takes place in the natural setting of a mother's womb. Though biomedical researchers are learning more and more about these processes, they still lack considerable understanding of developmental mechanisms. It is one thing to use artificial wombs for therapeutic purposes when a child is born prematurely. In that case, even if the artificial womb doesn't completely mimic the conditions of a natural womb, it is still preferred to an

incubator and mechanical ventilator. On the other hand, it is another thing entirely to take a healthy child from a mother's womb and incubate it in an artificial womb to accommodate the demands of the mother's professional career or satisfy her cosmetic needs.

Apart from these technical concerns, using artificial wombs as a human enhancement technology raises several social and ethical issues. The first has to do with access. Given the complexity and sophistication of artificial wombs, it is reasonable to think that this technology will be costly and out of reach for many women. Many ethicists see this as problematic because it will give wealthy women an additional advantage over women who lack the means to take advantage of artificial womb technology. From a Christian perspective, this ethical matter is not as pressing as other concerns. More problematic for us is the impact the technology will have on how society views women and babies. We agree with ethicist and feminist Rosemary Tong, who argues that artificial wombs externalize pregnancy, rendering the process of pregnancy and the resulting child mere commodities.[34] When this change in perspective happens, the mystery and meaning of pregnancy and childbirth are stripped away.

Tong and other ethicists also express concern that the use of artificial wombs for human enhancement will undermine one of the most foundational relationships in any society: the bond between mother and child.[35] We concur. In fact, when this relationship becomes disrupted, it seems to us that it will compromise *all* the relationships within a family. Tong argues that it is the embodied nature of pregnancy that makes a way for parents and their children to connect in a real and fundamental way. If not for this connection, then relationships between generations become more abstract and less meaningful.[36]

It is interesting to us that some feminists decry artificial womb technology. Instead of viewing this technology as the means to free women from the restrictions pregnancy and childbirth impose, they see it as stripping women of their status and power. Sociologist and feminist Robyn Rowland argues that the capacity of women to bear children gives them innate power in a society. She is concerned that artificial womb technology would take control of reproduction away from women and grant it to men, rendering women obsolete.[37]

As Christians, we are less concerned with the amount of innate *power* that women wield in society and more concerned with their innate *value*—value that belongs to them precisely because they are human beings made in God's image. It seems to us that the transhumanist vision of eliminating gender—making women androgynous—devalues women and devalues motherhood. It undermines something beautifully significant that many women and men

hold precious: bringing new life into the world and nurturing the child as parents. Many women don't see pregnancy and childbirth as a burden that they uniquely bear, but as a source of joy and a privilege women uniquely possess.

Ultimately, the use of artificial wombs as a form of human enhancement holds the potential to divest us of our identity as human beings. We agree with philosopher Hans Jordan, who argues that natality defines the human condition in the same way that mortality does.[38] Being born of a human makes us a human. And our birth marks our beginning, just as our death marks our ending. In light of these concerns, Rosen muses, "Perhaps we shouldn't treat the human womb like just another organ to be improved upon. . . . Perhaps some things are so ineffable that they shouldn't be artificially reproduced."[39]

Artificial wombs will one day serve as an invaluable therapeutic tool. Yet, when the technical, social, and ethical concerns are considered, the use of artificial womb technology as a form of human enhancement is destined to disappoint and may lead to a posthuman reality we will come to deeply regret. From our perspective, transhumanists are misguided when they naively trust that technology is the pathway to utopia. The hope that artificial womb technology will provide the means for women to transcend the "limitations" of their gender and counter the societal injustices and inequities they face is nothing more than false hope.

On the other hand, the Christian faith provides genuine hope and the means to overcome the injustices many women experience in our world today. Rather than addressing these inequities by enhancing our biology, Christianity seeks to bring about true justice by spiritual transformation. According to the Christian worldview, the ultimate source of *all* injustice in the world—including the injustices and disadvantages that women experience—is the sinful nature of human beings.

In the Genesis 1 creation account, male and female were both created in God's image; both had the same innate value and worth to God. Both were the crown of creation. But Genesis 2 teaches that the first male and female—Adam and Eve—weren't physically and psychologically identical. After all, Eve was created from a biopsy taken from Adam's side. The Hebrew word describing Eve's creation is *bana*, which means to rebuild; to redesign. Eve was Adam redesigned. She was created to be Adam's aid—his helper. (The same language is used to describe God as an aid or helper.) So this description of Eve's role doesn't imply she was subservient to Adam. Not at all. Eve was to be Adam's counterpart. Adam and Eve were allies, complementing one another in the mission God gave the first human couple; namely, (1) to multiply and fill the

earth, (2) to subdue the earth and bring it under their control, and (3) to be caretakers of God's creation.

As we learn in Genesis 3, things went awry. Adam and Eve ate the fruit from the tree of the knowledge of good and evil because they desired to be like God and disobeyed him. As a consequence, God informed Eve that her pain in childbirth would increase and her desire would be toward her husband, but he would rule over her. Though a bit difficult to understand, this passage has nothing to do with Eve's sexual desire for Adam. Nor does it mean that Adam would be domineering over Eve. Instead, it describes conflict that will take place between them in their marriage. Rather than exemplifying mutual collaboration as allies in fulfilling God's purpose for humanity, the pair will now be at odds with one another—each desiring control over the other. We see this passage as explaining the origin of the conflict between the sexes and, ultimately, the explanation for the injustices women have experienced throughout human history.

Thus, Christians view the injustices women experience as not caused by biology or sociology. It is due to sin.

Christians believe that if the problem is sin, the remedy is Christ's sacrifice for sin on the cross. To put it another way, the solution for sin was dispensed at the cross. Through Christ's atoning death, sinful people who place their trust in Christ are redeemed. Their sins are no longer counted against them. They are forgiven. They are justified (in theological language, legally acquitted of their sin and declared righteous in Christ). They are made new. Desires are reoriented. And, once justified, Christians believe they are taken through a lifelong process of sanctification by the Holy Spirit, who works with each believer to transform him or her more and more into the likeness of Christ. This challenging process eventually produces men and women who increasingly display the fruit of the Spirit: love, joy, peace, forbearance, kindness, goodness, faithfulness, gentleness, and self-control (Galatians 5:22–23).

Upon justification, Christians enter into the community of fellow believers—the church. Ideally, in this community all social distinctions that separate human beings, that create conflict, that lead to disparity and injustice, are addressed and rectified. In a letter to the church at Galatia, the apostle Paul describes the equality that exists among Christians this way:

> So in Christ Jesus you are all children of God through faith, for all of you who were baptized into Christ have clothed yourselves with Christ. There is neither Jew nor Gentile, neither

> slave nor free, nor is there male and female, for you are all one in Christ Jesus (Galatians 3:26–28).

Christians strive to bear the fruit of the Spirit in increasing measure, thus they are aware of the need to live as equals with people they would otherwise be at odds with over racial, ethnic, socioeconomic, and *gender* divides. Because of Christ's work, the mutual interdependence that initially defined Adam and Eve's relationship can gradually be restored and should characterize Christian relationships, including marriages. In a letter written to the church at Ephesus, the apostle Paul describes this recovered mutual interdependence this way:

> Submit to one another out of reverence for Christ. Wives, submit yourselves to your own husbands as you do to the Lord. For the husband is the head of the wife as Christ is the head of the church, his body, of which he is the Savior. Now as the church submits to Christ, so also wives should submit to their husbands in everything. Husbands, love your wives, just as Christ loved the church and gave himself up for her to make her holy, cleansing her by the washing with water through the word, and to present her to himself as a radiant church, without stain or wrinkle or any other blemish, but holy and blameless. In this same way, husbands ought to love their wives as their own bodies. He who loves his wife loves himself. After all, no one ever hated their own body, but they feed and care for their body, just as Christ does the church—for we are members of his body. "For this reason a man will leave his father and mother and be united to his wife, and the two will become one flesh" (Ephesians 5:21–31).

Ideally, injustices arising from social divisions should ease and, hopefully, disappear within the church. Christians believe that as they live and engage the world around them, as much as they have influence, they should work to overcome evil and injustice. As Christians, we believe in true equality. That is, because all people are made in God's image, we recognize that all people have inherent worth and dignity. We celebrate and respect one another's differences as unique gifts bestowed by God. And any injustices that people experience—including those experienced by women—will be healed.

One final point: As we discussed in chapter 11, Christianity *is*

Ideally, injustices arising from social divisions should ease and, hopefully, disappear within the church.

transhumanism. But instead of placing ultimate hope in technology to achieve utopia, Christians believe that the perfect world will be found in the new creation. According to Jesus, there will be no marriage in heaven (Matthew 22:30). There will be no procreation in heaven and no need for marriage. And because humans will have true intimacy with one another and with God in heaven, marriage will become superfluous. Plus, there is no indication from Scripture that we will be androgynous in the new creation. It is reasonable to think that we will retain our gender in heaven. God created human beings as male *and* female.

Our gender is an important part of who we are as individuals, and in community it highlights our complementary need and interdependence on one another. Rather than limiting us or being the source of conflict, gender will be perfected and glorified in eternity. In the new creation, a divine gender equality will exist unlike anything that Riri Williams could ever imagine.

Discussion Questions

1. What do transhumanists mean when they say that gender limits human potential?

2. Is artificial womb technology viable? Why or why not?

3. What is the difference between using artificial womb technology for premature births versus avoiding pregnancy and childbirth?

Endnotes

Special Focus – Artificial Wombs and the Posthuman World

1. Noelene Clark, "Marvel Comics Shaking Up Its Superhero Roster to Attract New Readers," *Los Angeles Times*, June 4, 2015, latimes.com/entertainment/herocomplex/la-et-hc-marvel-comics-axel-alonso-all-new-all-different-lineup-20150603-story.html.

2. Clark, "Marvel Comics."
3. Katie Rogers, "Marvel's New Iron Man Is a 15-Year-Old Black Girl," *New York Times*, July 6, 2016, nytimes.com/2016/07/07/books/marvels-new-iron-man-is-a-15-year-old-black-girl.html; Cameron-Glover, "For Black Women Comic Book Writers Marvel's Riri Williams Is Bittersweet," *Ebony*, August 12, 2016, ebony.com/entertainment-culture/marvel-riri-williams; "Does This Riri Williams Marvel Cover Bother You Too?" *Clutch*, clutchmagonline.com/2016/10/does-this-riri-williams-marvel-cover-bother-you-too/.
4. Dorian Lynskey, "Kapow! Attack of the Feminist Superheroes," *Guardian*, March 25, 2015, theguardian.com/books/2015/mar/25/feminist-superheroes-she-hulk-ms-marvel-thor.
5. Brett Schenker, "Market Research Say 46.67% of Comic Fans Are Female," *The Beat* (February 5, 2014), comicsbeat.com/market-research-says-46-female-comic-fans/.
6. J. Jeanine Thweatt-Bates, "Artificial Wombs and Cyborg Births: Postgenderism and Theology," in *Transhumanism and Transcendence: Christian Hope in an Age of Technological Enlightenment*, ed. Ronald Cole-Turner (Washington, DC: Georgetown University Press, 2011), 103.
7. "Artificial Uterus," Wikipedia, last modified October 22, 2018 (02:42 UTC), en.wikipedia.org/wiki/Artificial_uterus.
8. Anna Smajdor, "The Moral Imperative for Ectogenesis," *Cambridge Quarterly of Healthcare Ethics* 16, no. 3 (July 2007): 336–45.
9. Thweatt-Bates, "Artificial Wombs and Cyborg Births," in *Transhumanism and Transcendence*, 105.
10. Christine Rosen, "Why Not Artificial Wombs?," *New Atlantis: A Journal of Technology and Society* (Fall 2003): 67–76.
11. Rosen, 67–76.
12. Colleen Carlston, "Artificial Wombs: Delivering on Fertile Promises," *Harvard Science Review* (Fall 2008): 35–39.
13. Emily A. Partridge et al., "An Extra-Uterine System to Physiologically Support the Extreme Premature Lamb," *Nature Communications* 8 (April 25, 2017): id. 15112, doi: 10.1038/ncomms15112.
14. Carlo Bulletti et al., "The Artificial Womb," *Annuals of the New York Academy of Sciences* 1221, no. 1 (March 2011): 124–28, doi:10.1111/j.1749-6632.2011.05999.x.
15. Matteo Boretto et al., "Development of Organoids from Mouse and Human Endometrium Showing Endometrial Epithelium Physiology and

Long-Term Expandability," *Development* 144, no. 10 (May 15, 2017): 1775–86, doi: 10.1242/dev.148478.
16. Samantha A. Morris et al., "Dynamics of Anterior-Posterior Axis Formation in the Developing Mouse Embryo," *Nature Communications* 3 (2012): id. 673, doi: 10.1038/ncomms1671.
17. Rosen, "Why Not Artificial Wombs?," *New Atlantis*, 67–76.
18. Ai Ling Teh et al., "The Effect of Genotype and *in utero* Environment on Interindividual Variation in Neonate DNA Methylomes," *Genome Research* 24 (July 2014):1064–74, doi: 10.1101/gr.171439.113.
19. University of Southhampton, "Development in the Womb: New Insight on Epigenetic Influence on Baby," ScienceDaily (website), April 28, 2014, sciencedaily.com/releases/2014/04/140428074640.htm.
20. Mikael Allan Mikaelsson et al., "Placental Programming of Anxiety in Adulthood Revealed by *Igf2*-Null Models," *Nature Communications* 4 (2013): id. 2311, doi:10.1038/ncomms3311.
21. Cardiff University, "Emotional Behavior of Adults Could Be Triggered in the Womb," ScienceDaily (website), August 6, 2013, sciencedaily.com/releases/2013/08/130806132750.htm.
22. British Neuroscience Association, "Fetal Exposure to Excessive Stress Hormones in the Womb Linked to Adult Mood Disorders," ScienceDaily (website), April 7, 2013, sciencedaily.com/releases/2013/04/130407090835.htm.
23. McMaster University Health Sciences, "Womb Needed for Proper Brain Development," ScienceDaily (website), November 22, 2005, sciencedaily.com/releases/2005/11/051122205607.htm.
24. McMaster University, "Womb Needed."
25. Utako Minai et al, "Fetal Rhythm-Based Language Discrimination: A Biomagnetometry Study," *NeuroReport* 28, no. 10 (July 2017): 561–64, doi: 10.1097/wnr.0000000000000794.
26. University of Kansas, "Language Development Starts in the Womb," ScienceDaily (website), July 18, 2017, sciencedaily.com/releases/2017/07/170718084600.htm.
27. Sujata Rao et al., "A Direct and Melanopsin-Dependent Fetal Light Response Regulates Mouse Eye Development," *Nature* 494 (February 14, 2013): 243–46, doi:10.1038/nature11823.
28. Cincinnati Children's Hospital Medical Center, "Light Exposure during Pregnancy Key to Normal Eye Development," ScienceDaily (website), January 16, 2013, sciencedaily.com/releases/2013/01/130116131405.htm.

29. Children's Hospital of Philadelphia, "Unique Womb-Like Device Could Reduce Mortality and Disability for Extremely Premature Babies," ScienceDaily (website), April 25, 2017, sciencedaily.com/releases/2017/04/170425110807.htm.
30. Carlston, "Artificial Wombs," 35–39.
31. Carlston, 35–39.
32. Rachel Becker, "An Artificial Womb Successfully Grew Baby Sheep—and Humans Could Be Next," The Verge (website), April 25, 2017, theverge.com/2017/4/25/15421734/artificial-womb-fetus-biobag-uterus-lamb-sheep-birth-premie-preterm-infant.
33. Carlston, "Artificial Wombs," 35–39.
34. Rosen, "Why Not Artificial Wombs?," 67–76.
35. Rosen, 67–76.
36. Rosen, 67–76.
37. Rosen, 67–76.
38. Rosen, 67–76.
39. Rosen, 67–76.