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Daniel Ormsbee

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2 Prologue: The Biobag

They placed the lamb inside a polyethylene bag.

Not a container, exactly, though it held fluid. Not a womb, though it would do what a womb does. The bag was translucent, approximately the volume of a large shopping bag, sealed at the top and filled with a solution of amniotic buffer warmed to body temperature. Inside, a 105-day gestational lamb floated with its eyes closed, legs drawn up in the posture all fetal mammals assume when they have no ground to stand on and no intention of standing. A cannula, inserted surgically into the umbilical artery, carried deoxygenated blood out of the fetal body and into a circuit of polyvinyl chloride tubing. The tubing fed the blood through a gas exchange membrane, a continuous-flow oxygenator that performed the metabolic work of a placenta without the biological architecture of one. Oxygenated blood returned to the lamb through a second cannula in the umbilical vein. The circuit was pumpless. The fetal heart did all the work of circulation, just as it would in a placenta. The oxygenator offered no back-pressure the fetal vasculature could not accommodate. Blood volumes were held

within the physiological range of normal placental perfusion. Synthetic amniotic fluid, sterile and formulated to approximate the ionic composition, osmolality, and pH of native amniotic fluid, surrounded the lamb in a closed loop. A pump replaced evaporative losses at a rate calibrated to fetal swallowing and skin absorption. Temperature was maintained. Electrolytes were balanced. A closed-loop monitoring system tracked hemodynamics, blood gas tensions, and fluid volumes in real time.

This was the EXTEND system. Extra-uterine Environment for Neonatal Development. Twenty-three enclosures would sustain premature lambs for up to four weeks, during which the animals would grow, breathe, circulate, and develop with a normalcy that astonished the team that built the apparatus (Partridge et al., 2017).

The lungs matured. This was the headline result. Premature lambs at 105 to 111 days of gestational age carried lungs in the canalicular stage of development, transitioning toward the saccular phase during which alveolar precursors form and surfactant production ramps. Four weeks in the EXTEND system, surrounded by fluid, breathing nothing but intratracheal pressure of warm amniotic analog, and the lungs progressed through this transition on schedule. Histological examination at termination showed saccular architecture, thinning gas-exchange membranes, and surfactant protein expression consistent with term gestation. The lungs did not know they were in a bag. The lungs only knew the developmental program executing since the first tracheal bud appeared at week four of gestational life, and that program continued without interruption, propagating toward its intended endpoint with the blind fidelity of a system that does not require understanding to fulfill its design.

The brains grew. Cerebral cortical development proceeded along expected timelines. Gyral folding progressed. Myelination advanced. Electroencephalographic monitoring showed sleep wake cycling patterns indistinguishable from age-matched fetuses in utero. The central nervous system, that most delicate and unforgiving of developmental bioprocesses, found no reason to halt its ordained architecture in the artificial enclosure. Neural progenitors migrated. Synaptogenesis continued. The telencephalon folded into the layered substrate of cognition and consciousness without consulting the substrate on which it floated.

The organs functioned. Renal output normalized. Gastrointestinal development advanced, though the lambs were not fed enterally. Hepatic and cardiac function were maintained within physiological parameters. The organism operated as an integrated system, each organ unit functioning within its metabolic envelope, the whole achieving homeostasis that no single component could have sustained alone.

Truly, this was not science fiction. There were no laser grids, no holographic interfaces, no amniotic fog illuminated by theatrical lighting. The lab in Philadelphia was sterile, fluorescent, and unremarkable in its physical plant. The team

operated under standard surgical protocols. The equipment was off-the-shelf. The oxygenator was adapted from neonatal extracorporeal membrane oxygenation technology, a circuit architecture already validated in clinical contexts. The polyethylene bag was chosen for gas permeability and optical clarity, not aesthetic properties. The synthetic amniotic fluid was a buffered saline solution with defined additive specifications. The entire apparatus was, in engineering terms, a bioprocessing system solving a gas exchange and fluid balance problem for a developing organism in a controlled environment. That the organism happened to be a mammalian fetus did not change the governing physics. Oxygen had to cross a membrane. Carbon dioxide had to be removed. Fluid balance had to be maintained. Temperature had to be controlled. Waste products had to be cleared. These are unit operations in any bioprocessing architecture, and the EXTEND system solved them with the same rigor that any chemical engineer would apply to a reactor vessel.

In essence, the problem was one of constraint satisfaction. The developing organism imposes a demand matrix on its environment: oxygen consumption, carbon dioxide production, metabolic waste clearance, thermal regulation, nutrient provision, fluid balance, and growth substrate. The uterine environment satisfies these constraints through an integrated biological architecture: the placenta, amniotic fluid, myometrium, maternal vasculature, maternal metabolic system. The EXTEND system decoupled these constraints from their biological substrate and satisfied them through engineered alternatives. The oxygenator replaced placental villi. The fluid circuit replaced the amniotic sac. The monitoring system replaced hormonal and paracrine signaling networks that regulate the uterine environment. Nothing biological was invoked that the engineering system did not replicate in function if not in form.

The engineering was elegant. It was also, in 2017, preliminary. The lamb model is not the human model. Gestational ages did not overlap precisely with the viability threshold for human neonates. The four-week duration, while sufficient to demonstrate normal organ development in the ovine model, did not address the full trajectory from mid-gestation to birth. Technical challenges remained: scaling the oxygenator for human fetal blood volumes, engineering a synthetic amniotic fluid formulation that replicated complex biochemistry of human amniotic fluid, and solving the long-duration fluid replacement problem with sufficient precision to sustain the system for months rather than weeks. Forde et al. (2023) have since made progress on the amniotic fluid problem, formulating a synthetic "Amnio-well" solution validated against human amniotic membranes in vitro. Blauvelt et al. (2021) have refined oxygenator design principles for artificial placenta applications, optimizing gas exchange efficiency and minimizing hemodynamic resistance in pumpless fetal circuits. The technical envelope continues to expand.

But the technical envelope is not the question. The technical envelope never is.

The question is ontological. The question is teleological. The question is theological.

What does it mean that a human team can construct a closed-loop developmental environment that sustains mammalian life outside the body designed to produce it? What does it mean that the lungs did not know, that the brains did not know, that the organs did not know they were not in utero? What does it mean that the developmental program propagated with the same fidelity inside a polyethylene bag as it would inside a human uterus?

It means that biology is architecture. It means that the womb, while sacred in purpose and magnificent in design, is a material system operating under physical laws that can be modeled, replicated, and superseded. It means that the Creator built sufficient redundancy and generality into the developmental program that the substrate can be swapped without corrupting the output. In engineering terms, the interface between developing organism and its environment is defined, documented, and accessible. The organism demands oxygen. The organism demands fluid. The organism demands a stable thermal environment. Provide these through any mechanism that satisfies the specification, and the organism will develop.

This is not a diminishment of the womb. It is a testament to the elegance of the design. The human body is not magic. It is engineering of extraordinary refinement, executed in carbon and water rather than silicon and steel, governed by thermodynamic constraints that do not bend for sentiment. That we can understand these constraints and build systems to satisfy them is not hubris. It is exercise of a capacity given.

The Dominion Mandate, declared in the opening chapters of Genesis, commands humanity to subdue the earth and exercise stewardship over creation. This mandate has been understood, across millennia of theological reflection, as a commission to cultivate, order, and care for the material world in accordance with the Creator's intent. It is not a license for domination. It is an assignment of responsibility. The image-bearing creature is charged with acting as steward, with ordering creation in a manner that reflects the character of the one whose image it bears. When the early farmers domesticated grain, they exercised dominion. When the physician administers medicine to restore a body to its designed function, she exercises dominion. When the engineer builds a system that sustains developing life outside the body meant to carry it, the same mandate is in play. The object has changed. The principle has not.

Sub-creation, in the Tolkien sense that C.S. Lewis drew upon and that the broader Christian tradition has acknowledged, is the act of making within the secondary order of reality. We do not create ex nihilo. We create ex materia. From the material given, using faculties granted, we build systems and structures that extend human capacity and roll back constraints imposed by a fallen world. The Fall introduced suffering, loss, and the corruption of biological processes designed for flourishing. Pregnancy, in the postlapsarian condition, carries risk. Premature birth is a consequence of that risk. Neonatal death is a consequence of that risk. The infant born at twenty-two weeks gestational age in a modern NICU is fighting a battle against entropy, against developmental

constraint, against the material consequences of a world that is not as it was made to be.

The EXTEND system, and the systems that will follow, represent an engineered response to that constraint. Not a replacement for the womb in its fullness, not a negation of the embodied experience of pregnancy, but a rescue system for cases in which the natural architecture fails. A synthetic placenta. An artificial amniotic environment. A closed-loop developmental platform that removes the premature infant from the hostile postnatal environment and returns it to the conditions designed for it: warmth, fluid, oxygenation, metabolic support, and time.

Who are we to build this? We are the creatures told to subdue, to tend, to steward. We are the image-bearers given dominion not as a suggestion but as a mandate. We are finite builders who create ex materia, whose every act of engineering is a participation in the work of ordering a creation that groans under the weight of its own corruption.

And who are we if we do? We are the people who chose to act, who chose to build, who chose to extend the protective boundary of development outward from the body into the engineered environment when the body could no longer provide it. We are the stewards who recognized the constraint and met it with faculties given.

The lambs in their polyethylene bags did not know any of this. They floated, they grew, they developed according to a program written into chromosomes before the first cell divided. They did not need to know. But we need to know. We need to understand what we are building, and why, and whose authority.

This book argues that the answer is clear. The artificial womb, governed by the commands to love God and neighbor, is not an act of presumption. It is an act of stewardship. It is a sub-creative tool deployed in service of the Dominion Mandate, an engineered extension of the protective envelope that sustains developing life, built by creatures made to build.

The technology is not neutral. No technology is. Every system we construct is an active affordance, a reshaping of the possibility space within which human decisions are made. The artificial womb will constrain some choices and enable others. It will be used well and poorly, as every powerful tool has been since the first blade was knapped from flint in the dawn of human story. The question is not whether the tool will be misused. The question is whether the tool, deployed under constraints of love for God and neighbor, represents a faithful exercise of the creative capacity given.

This book contends that it does. What follows is the argument.

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3 Chapter 1: Daedalus and the Dream

3.1 I. The Lecture That Named the Future

On a winter evening in 1923, a young British geneticist stood before the Heretics Society at Cambridge University and delivered a lecture that would reshape the vocabulary of reproductive science. John Burdon Sanderson Haldane, known to his colleagues as J.B.S., titled his address *Daedalus, or Science and the Future*, borrowing the name of the mythical Greek craftsman whose ingenuity brought both glory and ruin. Haldane was not interested in myth. He was interested in engineering. The lecture ranged across a landscape of speculative technologies, but its most arresting claim concerned human reproduction itself. Haldane predicted that by the year 2074, fewer than thirty percent of children would be born from a woman's body. The rest would be grown outside it.

He gave the practice a name: ectogenesis. From the Greek *ektos*, meaning "outside," and *genesis*, meaning origin or creation. The term was precise, clinical, and designed to provoke. It described the growth of an organism in an artificial environment, removed from the body in which it would normally develop. Haldane envisioned a future in which human embryos would be fertilized, gestated, and brought to term entirely within engineered systems, freed from the biological contingencies that had governed reproduction for the entirety of human history (Wikipedia, "Ectogenesis," 2026). He imagined ectogenesis not as a curiosity but as a tool for human betterment, a mechanism through which selective breeding and technological control could improve the species. He was, after all, one of the founders of population genetics, a man who would later coin the word "clone" and establish the mathematical foundations of neo-Darwinism alongside Ronald Fisher and Sewall Wright (Wikipedia, "J.B.S. Haldane," 2026).

Haldane was serious. He was also wrong about the timeline, but not about the trajectory. The *Daedalus* lecture was published in 1924 as a slim pamphlet, and it detonated across the intellectual landscape of interwar Britain. The publisher Kegan Paul issued a series of responses, some admiring, some horrified, all compelled to engage with the implications of a future in which the womb was rendered optional. The pamphlet circulated through drawing rooms and common rooms, through the circles of writers and scientists who populated the London of the 1920s. Among its readers was a young novelist named Aldous Huxley, and the book would leave a mark on his imagination that would prove more durable than anything Haldane himself produced.

3.2 II. The Hatcheries

Aldous Huxley read *Daedalus* and saw not utopia but warning. His brother Julian had befriended Haldane at Eton, and the two families moved in the same intellectual orbit, but Aldous was temperamentally disposed toward skepticism about scientific progress. Where Haldane saw liberation, Huxley saw control. Where Haldane imagined ectogenesis as a tool for betterment, Huxley imagined

it as a tool for subjugation. The result was *Brave New World*, published in 1932, and its opening chapters remain the most powerful fictional rendering of artificial reproduction ever written.

The novel begins not with a character or a conflict but with a factory. The Central London Hatchery and Conditioning Centre is a gleaming cathedral of industrial reproduction, where human embryos are decanted from bottles on conveyor belts, graded and sorted according to caste, and developed through processes that bear no resemblance to pregnancy. The Bokanovsky Process allows a single fertilized egg to produce up to ninety-six identical clones, each destined for a predetermined social function. Alphas are cultivated for leadership, Epsilons for manual labor. Intelligence, physical capacity, and temperament are engineered before birth, and the notion that a child might belong to a mother or father is treated as obscene, a relic of primitive biology long since superseded (Wikipedia, "Ectogenesis," 2026).

Huxley's debt to Haldane was explicit and acknowledged. The *Daedalus* lecture provided the scientific premise; *Brave New World* provided the social architecture. Together, they established a template that would dominate public discourse about artificial reproduction for the next century. The Hatcheries became a cultural shorthand for the commodification of human life, a permanent cautionary tale that shapes how every subsequent reproductive technology is received. When Louise Brown was born in 1978, when the first surrogacy contracts were litigated in the 1980s, when the Biobag was unveiled in 2017, the specter of the Hatcheries was present in every news cycle, every editorial, every legislative hearing. Haldane gave ectogenesis its name. Huxley gave it its nightmare.

This matters for what follows. The history of ectogenesis is not merely a history of scientific ambition. It is a history of narrative. The technologies that have moved humanity closer to Haldane's prediction were developed not in a vacuum of ideas but within a culture that had already decided what artificial reproduction meant: control, commodification, the reduction of human beings to products. Every scientist who worked on incubators, IVF, or extra-uterine systems labored in the shadow of the Hatcheries, whether they knew it or not. To understand the present moment, when ectogenesis is no longer speculative, one must understand how that narrative was built, and how the technologies that now approach its fulfillment were developed step by painful step.

3.3 III. Before the Dream: The Incubator

The story of ectogenesis does not begin with Haldane. It begins in Paris in 1880, with a man named Stephane Tarnier and a device modeled on the incubators used for hatching chicken eggs. Tarnier, an obstetrician at the Paris Maternity Hospital, observed that premature infants, born too early and too small to regulate their own body temperature, were dying in enormous numbers. The solution, as he saw it, was not medicine but engineering. He built a heated

enclosure, a closed box with warm water circulating through its walls, and placed the smallest, weakest infants inside. Survival rates improved immediately. The device was crude, but it worked, and Tarnier understood its significance: for the first time in history, a machine was sustaining human life that biology alone could not preserve (Wikipedia, "Neonatal intensive care unit," 2026).

After Tarnier retired, his student Pierre Budin refined the approach and added what Tarnier had overlooked: the importance of breast milk and maternal attachment. Budin is remembered as the father of modern perinatology, and his 1907 monograph *The Nursling* became the first comprehensive treatment of neonatal care. But Budin's legacy was less theatrical than that of the man who came next. In 1890, Alexandre Lion improved the incubator design in Marseilles and, more importantly, found a way to fund its use. Lion founded the *Oeuvre Maternelle des Couveuses d'Enfants* in Nice in 1891 and in Paris in 1896, a charitable organization that charged the public admission to view premature infants being cared for in his improved incubators. The model spread to world's fairs across Europe and America. At the 1897, 1898, 1901, and 1904 World Fairs, visitors paid to peer through glass at tiny infants suspended in warmth and light, breathing because a machine breathed for them (Wikipedia, "Neonatal intensive care unit," 2026).

The most famous practitioner of this strange commerce was Martin Couney, a German-born physician who studied under Budin and then relocated to America, where he installed permanent exhibits of premature infants in incubators at Coney Island's Luna Park. Couney's operation ran for decades, drawing paying crowds who came for the spectacle and left having witnessed something more profound than they expected: the survival of children who, without the machines, would certainly have died. The exhibits were, by modern ethical standards, deeply problematic. The infants were displayed as attractions, their medical treatment funded by carnival economics. But Couney never charged the families. He saved thousands of lives. And in doing so, he demonstrated a principle that would echo through the entire subsequent history of reproductive technology: that public ambivalence about a technology does not prevent that technology from doing immense good.

The neonatal incubator was the first step. It was not ectogenesis, not even close. It did not replace the womb. It supplemented the womb after the womb had done its work, extending a thin, fragile lifeline to infants who had been expelled too soon. But it established the foundational logic that every subsequent technology would follow: the logic of substitution, of engineering a system to perform a function that biology could not complete. The incubator kept premature infants warm. The next technologies would keep them breathing.

3.4 IV. The Lung Problem and the Machinery of Survival

For decades after Tarnier's invention, the primary obstacle to surviving extreme prematurity was respiratory failure. Premature infants lacked sufficient pul-

monary surfactant, a complex mixture of lipids and proteins that reduces surface tension in the alveoli and prevents their collapse during exhalation. Without surfactant, the lungs stiffen, gas exchange fails, and the infant dies of what was then called hyaline membrane disease and is now known as infant respiratory distress syndrome. Oxygen supplementation helped, but only to a point, and the remedy carried its own dangers. By the late 1950s, physicians had begun to notice that the high concentrations of oxygen delivered inside incubators were causing retrolental fibroplasia, a condition that blinded thousands of premature infants. The cure was destroying as surely as the disease.

In 1964, pediatric radiologist William Northway identified a consistent pattern of cystic changes in the lungs of premature infants who had received both high-concentration oxygen and mechanical ventilation. His 1967 paper, coauthored with Rosan and Porter, coined the term "bronchopulmonary dysplasia" and described the disease with devastating clarity. The paper is considered one of the most important and influential articles in the history of neonatology. It led to worldwide reductions in supplemental oxygen levels and ventilation pressure, but it also revealed a deeper problem: the limits of the technology were being measured in damage, not just in death (Northway, Rosan, and Porter, 1967).

The answer came in the form of surfactant therapy, developed through the 1980s and deployed clinically in the 1990s. Synthetic and animal-derived surfactant preparations allowed physicians to replace what premature lungs could not produce, opening alveoli that would otherwise have collapsed and died. The effect on survival rates was dramatic. Infants who had been considered nonviable at twenty-four weeks began, cautiously, to live. The boundary of viability shifted earlier, and with it, the moral landscape of neonatal care shifted too.

Extracorporeal membrane oxygenation, or ECMO, extended the logic further. Adapted from cardiopulmonary bypass technology used in adult cardiac surgery, ECMO removes blood from the patient, oxygenates it through a membrane outside the body, and returns it to the patient's circulation. Two configurations exist: venovenous ECMO, used primarily for lung failure, and venoarterial ECMO, used for combined heart and lung failure. ECMO became a last resort for the most critically ill neonates, a machine that performed the work of two organs while the infant's body fought to recover. It was extreme. It was also effective, and it established a principle that would prove essential to the development of ectogenesis: that the human body could be sustained, for extended periods, by systems that performed its most vital functions outside it (Wikipedia, "Neonatal intensive care unit," 2026).

By the 1990s, the trajectory was clear. Each generation of technology pushed the boundary of viability earlier, extended the duration of external support, and narrowed the gap between what the womb provided and what machines could replicate. The incubator had handled warmth. Surfactant therapy had handled gas exchange. ECMO had handled oxygenation. What remained was the system itself, the integrated gestational environment that could hold all these functions together and sustain a fetus, not as a critically ill patient fighting for survival,

but as a developing organism growing in conditions approximating those of the womb.

3.5 V. The Test Tube and the Crisis

Before ectogenesis could advance, it required a prerequisite that Haldane had predicted with equal clarity: in vitro fertilization. The fertilization of a human egg outside the body, in a glass dish, was a necessary precondition for any technology that would attempt to gestate a fetus outside the body. And IVF, when it arrived, provoked a moral crisis that rehearsed every argument that would later be deployed against artificial wombs.

The development of IVF was the work of two men who spent more than two decades fighting institutional resistance. Robert Edwards, a physiologist at the University of Cambridge, and Patrick Steptoe, a gynecologist in Oldham, began their collaboration in the 1960s. Edwards supplied the reproductive biology; Steptoe supplied the laparoscopic technique for retrieving eggs. Their work was denied funding by the Medical Research Council. Their methods were condemned by the Vatican. Their results were dismissed by much of the scientific establishment. They persisted.

On July 25, 1978, Louise Joy Brown was born at Dr. Kershaw's Cottage Hospital in Royton, Oldham, England. She weighed five pounds, twelve ounces. She was healthy. She was also, in the eyes of the world, a miracle and an abomination, a triumph of science and a harbinger of moral collapse, depending on who was asked. The phrase "test-tube baby" entered the global lexicon overnight, and it carried exactly the connotations its critics intended: that this child was manufactured, artificial, less than fully human. Edwards and Steptoe were vilified before they were vindicated. Jean Purdy, the embryologist who had been essential to the work, was written out of the narrative entirely. Edwards received the Nobel Prize in Physiology or Medicine in 2010; Steptoe and Purdy, both deceased, were ineligible. By 2018, an estimated eight million children had been born worldwide through IVF and related techniques (Wikipedia, "In vitro fertilisation," 2026).

The ethical objections to IVF map precisely onto the objections that would later be raised against artificial wombs: that the technology commodifies human life, that it separates reproduction from its natural context, that it opens the door to eugenic manipulation and the reduction of children to consumer products. The Catholic Church declared IVF impermissible in *Donum Vitae* in 1987, arguing that the separation of procreation from the conjugal act violated the dignity of both the child and the marital covenant. Protestant responses were more varied but shared many of the same concerns. The pattern was established: a reproductive technology emerges, the culture convulses, and eventually, incrementally, the technology is absorbed into normal practice while the moral questions it raised are deferred rather than resolved.

In essence, IVF did not answer the question of ectogenesis. It made the question

unavoidable. If a human egg could be fertilized outside the body, and if the resulting embryo could be cultured for days or weeks before transfer, then the logical endpoint of the trajectory was clear. Someone, eventually, would attempt to extend that culture to the full term of gestation. The test tube was the first step. The artificial womb was always the last.

3.6 VI. The Surrogacy Wars

The next crisis in reproductive technology arrived not as a laboratory breakthrough but as a custody battle. In 1986, a woman named Marybeth Whitehead gave birth to a baby girl named Melissa. The conception had been arranged through the Infertility Center of New York by William Stern, a biochemist, and his wife Elizabeth, who suffered from multiple sclerosis. Whitehead had agreed to be artificially inseminated with Stern's sperm, carry the pregnancy to term, and relinquish parental rights in exchange for ten thousand dollars. After the birth, Whitehead refused. The case went to court.

In re Baby M was the first American judicial ruling on the validity of surrogacy, and it illuminated a set of questions that artificial womb technology would raise in an even more acute form. The trial court upheld the surrogacy contract and awarded custody to the Sterns. The New Jersey Supreme Court reversed on the contract issue, ruling that surrogacy agreements were void as against public policy, while affirming custody for the Sterns under a best-interest-of-the-child analysis (Wikipedia, "Baby M," 2026). Chief Justice Robert Wilentz wrote for the majority that the surrogacy contract amounted to the purchase of a child, regardless of how the arrangement was characterized by its proponents.

The Baby M case forced a reckoning with the concept of gestational versus genetic motherhood. Whitehead was both the genetic and gestational mother. The case would have been simpler, legally, if she had been only a gestational carrier, carrying an embryo created from another woman's egg. The development of gestational surrogacy, in which the carrier has no genetic relationship to the child, was a direct response to the legal and emotional complexities that Baby M exposed. But the deeper question remained: what constitutes motherhood? Is it the contribution of genetic material, the act of gestation, or the social commitment of care and nurture? The law had no settled answer. It still does not.

For ectogenesis, the implications are immediate. An artificial womb eliminates the gestational mother entirely. It does not merely separate genetic from gestational parenthood, as gestational surrogacy does. It removes the gestational role from any human body whatsoever. The Baby M case demonstrated that society was unprepared to adjudicate the boundaries of parenthood when a surrogate was involved. The advent of ectogenesis will present a version of the problem in which there is no surrogate, no gestational carrier, no human body between the embryo and the machine. The legal frameworks that were hastily constructed in the wake of Baby M will not survive contact with this reality.

3.7 VII. Firestone's Prophecy

In 1970, the radical feminist theorist Shulamith Firestone published *The Dialectic of Sex: The Case for Feminist Revolution*, and in it she made what remains the most uncompromising secular argument for ectogenesis. Firestone characterized pregnancy and childbirth as "barbaric." She argued that the biological capacity for reproduction was the foundational mechanism of women's oppression, and that liberation required not merely the legal or social dismantling of patriarchy but the technological supersession of biology itself. "Just as to ensure elimination of economic classes requires the revolt of the underclass (the proletariat) and, in a temporary dictatorship, their seizure of the means of production," she wrote, "so to assure the elimination of sexual classes requires the revolt of the underclass (women) and the seizure of control of reproduction" (Firestone, 1970).

Firestone's vision was totalizing. She imagined a world in which reproduction was entirely separated from sex, in which artificial wombs freed women from what she saw as the tyranny of gestation, and in which the nuclear family dissolved into communes of collective child-rearing. Her language was deliberately provocative, and her proposals were deliberately radical. She did not equivocate. She did not hedge. She declared that the liberation of women required the abolition of natural reproduction, and she looked to technology to provide it.

Firestone's influence on the discourse of ectogenesis is disproportionate to her readership. Her book was widely read in feminist academic circles, but it did not reach the popular audience that Huxley's did. Its significance lies in the clarity of its framing: Firestone articulated the argument that artificial wombs are a feminist technology, a tool for dismantling the biological basis of gender inequality. This argument persists in contemporary bioethics, where it coexists uneasily with the countervailing concern that ectogenesis might be used to further commodify women's reproductive capacities rather than liberate them. The tension between these two readings, liberation and commodification, defines the ethical landscape that artificial womb technology now enters.

Truly, Firestone saw further than most of her contemporaries. She recognized that reproductive technology was not neutral, that it carried within it the potential to reshape the structures of gender, family, and power. Her diagnosis was more perceptive than her prescription, but the diagnosis endures. The question she posed, whether technology that alters reproduction liberates or oppresses, remains the central question of the ectogenesis debate.

3.8 VIII. The Biobag

In April 2017, a team of researchers at the Children's Hospital of Philadelphia published a paper in *Nature Communications* that brought the century-old dream of ectogenesis within reach of clinical reality. The paper, led by fetal surgeon Alan Flake and neonatologist Emily Partridge, described a system they

called the extra-uterine device, which the media immediately christened the Biobag.

The system was elegantly engineered. A pumpless oxygenator circuit connected to the fetus via an umbilical cord interface, maintaining the fetal circulation in its natural configuration rather than imposing an external pump. The fetus was enclosed in a closed fluid circuit filled with a synthetic amniotic solution that closely reproduced the biochemical environment of the womb. Nutritional support was delivered intravenously. The system did not attempt to replace the placenta. It interfaced with the placenta. This distinction matters. The Biobag was designed not as an artificial womb but as an extra-uterine environment that extended the womb's protective function, using the fetus's own circulatory system as the engine of gas exchange and nutrient delivery (Partridge et al., 2017).

The results were remarkable. Fetal lambs at a developmental stage equivalent to the extreme premature human infant, approximately twenty-three weeks of gestational age, were physiologically supported in the device for up to four weeks. The lambs maintained stable hemodynamics, normal blood gas and oxygenation parameters, and patency of the fetal circulation. With appropriate nutritional support, they demonstrated normal somatic growth, lung maturation, and brain growth including myelination. The system worked not by forcing the fetus into a premature confrontation with the external world, as conventional NICU care does, but by shielding it from that confrontation, maintaining the conditions of gestation while the fetus continued to develop.

The paper's Altmetric score of 4,943 reflected the global attention it received. It has been cited over 350 times. The media coverage was immediate and polarized, cycling through the full range of responses that had greeted every previous reproductive technology: wonder, alarm, speculation, and invocation of Haldane and Huxley in almost equal measure. But the paper itself was restrained, even cautious. The authors were explicit that the system was not intended for human use in its current form, that significant technical challenges remained, and that the ethical and regulatory frameworks necessary for clinical deployment did not yet exist.

Flake and his colleagues at the Center for Fetal Research had been working toward this result for over a decade. The lineage of the research traced back through generations of neonatal technology, through the incubator and surfactant therapy and ECMO, through the accumulated knowledge of how to sustain premature life outside the womb. The Biobag did not emerge from a speculative vision. It emerged from a clinical imperative. Extreme prematurity remains the leading cause of neonatal mortality and morbidity in the developed world, a consequence of organ immaturity and the iatrogenic injury inflicted by conventional life support. Every previous technology had extended the boundary of viability but at a cost: ventilator damage, oxygen toxicity, intraventricular hemorrhage. The Biobag was designed to eliminate those costs by eliminating the transition itself, keeping the fetus in conditions that approximated the womb

until its organs had matured sufficiently to survive the outside world.

3.9 IX. The Present Moment

The technology is no longer speculative. This is the most important sentence in this chapter, and it requires repeating. The technology is no longer speculative. Haldane's 1923 prediction was a thought experiment. Huxley's 1932 Hatcheries were fiction. Firestone's 1970 artificial womb was ideology. The Biobag is engineering. It exists. It has been tested. It has produced living, developing organisms sustained outside a maternal body for weeks. The gap between what was demonstrated in 2017 and what Haldane imagined in 1923 has narrowed to a set of technical challenges, regulatory hurdles, and moral decisions.

Jacob Hanna and his team at the Weizmann Institute have pushed the boundaries further, demonstrating ex utero mouse embryogenesis from pre-gastrulation to late organogenesis in 2021 and creating synthetic embryo models from human stem cells in 2023 (Aguilera-Castrejon et al., 2021; Oldak et al., 2023). These synthetic embryos develop intestinal tracts, early brains, and beating hearts without sperm, eggs, or fertilization. They grow in vitro and ex utero in artificial environments. The trajectory is unambiguous. The integration of synthetic embryology with extra-uterine gestation systems will, within the foreseeable future, produce a technology capable of sustaining human development from conception to viability entirely outside a human body.

This is the present. This is where the history delivered us. From Tarnier's heated box in a Paris maternity ward to the Biobag at Children's Hospital of Philadelphia, from Haldane's lecture hall at Cambridge to Hanna's laboratory at the Weizmann Institute, the arc is continuous and unbroken. Each generation of technology extended the reach of human engineering into the domain of natural gestation, each step raising the same questions with increasing urgency: What does it mean to sustain life by machine? What does it mean to engineer the conditions of human development? What does it mean to exercise dominion over the biological processes that have, for the entirety of our species' history, been the exclusive province of nature and nature's God?

These are not hypothetical questions. They are the questions that the present moment demands we answer. The technology to sustain human life outside the womb is no longer a dream. It is an engineering reality awaiting only the refinement of its systems and the resolution of its moral implications. The century-long history traced in this chapter was a history of prophecy, resistance, incremental advance, and final convergence. What follows is not history. It is decision. The Dominion Mandate, that ancient command to exercise stewardship over the created order, has never been more relevant than it is now, when the created order itself can be extended, replicated, and sustained by the works of human hands.

The dream of Daedalus has been realized. The question that remains is whether we will build the Hatcheries or the hospitals, the factories of commodification

or the instruments of care. The technology does not choose. We do.

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4 Chapter 2: How the Machine Works

Picture the scene. A translucent polyethylene bag, roughly the size of a gallon jug, hangs suspended inside a temperature-controlled chamber. The bag is filled with warm, clear liquid maintained at exactly 39 degrees Celsius. Inside it, a lamb fetus floats, eyes closed, tiny legs tucked beneath its body, umbilical cord trailing out through a sealed port at the bottom of the bag. Two thick tubes extend from that port: one carries dark, deoxygenated blood away from the fetus through the umbilical arteries; the other returns bright, oxygenated blood through the umbilical vein. Between the two tubes sits a flat rectangular device no larger than a paperback book: a membrane oxygenator. The fetal heart is the only pump in the circuit. There is no ventilator, no dialysis machine, no external motor driving the blood. The heart pushes, the oxygenator exchanges gases, and the blood returns. The bag's amniotic fluid equivalent is continuously refreshed by a closed sterile circuit that pumps in balanced electrolyte solution and removes metabolic waste. Sensors embedded in the circuit walls measure flow rate, oxygen saturation, carbon dioxide partial pressure, and pH in real time. A single laptop screen displays the data feeds: heart rate tracings, blood gas values, fluid turnover rates.

This is the Biobag. This is the EXTEND system: the Extra-uterine Environment for Neonatal Development. Developed by Emily Partridge, Marcus Davey, Alan Flake, and their colleagues at the Children's Hospital of Philadelphia, it was first reported in *Nature Communications* in 2017 and remains the most successful demonstration of extra-uterine gestation ever achieved (Partridge et al., 2017). In the trial, premature lambs equivalent in development to 23- to 24-week human fetuses were maintained inside the system for up to four weeks. The lambs breathed fluid, grew lungs, developed brains, and swallowed amniotic fluid as though they were still inside their mothers. When removed from the system, several of them were successfully transitioned to breathing air.

Before the ethical arguments can begin, you must understand what it took to build this thing: the amniotic fluid, the oxygenator, the bioreactor, the monitoring systems, the failure modes, the safety engineering. This chapter provides that foundation. The machine is not simple. It is not a box of warm water. It is a tightly coupled bioprocessing system in which engineering constraints and biological requirements must be reconciled at every unit operation, under every transient condition, for weeks on end, without a single catastrophic failure. Understanding the engineering is prerequisite to understanding the ethics. You cannot responsibly evaluate the moral status of a technology you have not bothered to comprehend.

4.1 The Amniotic Fluid Problem

The first engineering challenge is the medium itself. An artificial womb requires a fluid environment that replicates the biochemical conditions of natural amniotic fluid, and that fluid is not simply salt water. It is a dynamic, continuously recycled biological medium whose composition changes across gestation and whose functions are numerous: cushioning the fetus from mechanical shock, maintaining a constant temperature, permitting fetal movement necessary for musculoskeletal development, providing a medium for fetal lung fluid exchange, delivering nutrients through fetal swallowing, and absorbing fetal urine and metabolic waste.

Quantitative benchmarks for amniotic fluid composition come from foundational work by Goldstein, Bazer, and Barron (1980), who systematically characterized the volume, osmolarity, and electrolyte composition of porcine fetal fluids across gestation. Their measurements established that amniotic fluid contains sodium, potassium, chloride, calcium, and magnesium at concentrations that shift over the course of pregnancy; that glucose levels track with fetal metabolic demands; that total protein concentrations vary significantly as fetal organ maturity and membrane permeability change; and that osmolarity defines the tonicity environment within which the developing fetus exists. The porcine model is particularly relevant here because porcine and human placentation share important anatomical features. These are not abstract numbers. They are the engineering specification sheet for a synthetic medium that must sustain a developing organism for weeks or months without deviation.

Forde, Oria, Lampe, Martin, and Peiro (2023) took the next step: they formulated a synthetic amniotic fluid and tested it against real human tissue. Their product, which they named "Amnio-well," was designed to match the biochemical composition of natural human amniotic fluid, including electrolyte concentrations, pH buffering capacity, osmolarity, and nutrient content. They isolated human amniotic epithelial cells from term placentas and cultured them in the synthetic fluid, then measured cell viability and membrane integrity against natural amniotic fluid controls. The results were encouraging: the synthetic formulation maintained biological integrity comparable to the natural medium. They also examined connexin-43 expression as a marker of inflammatory response and found that their synthetic fluid produced less inflammation than the conventional alternative of normal saline. The critical takeaway for artificial womb engineering is this: a synthetic fluid system must not merely provide a liquid medium. It must actively maintain the biological integrity of fetal tissues and membranes. The engineering parameters that must be continuously regulated include electrolyte balance, protein supplementation, osmolarity, and pH stabilization. Every one of those parameters requires sensors, feedback loops, and actuated delivery systems. Every one of those subsystems can fail.

4.2 The Oxygenator: Where Engineering Meets Physiology

If the amniotic fluid is the environment, the oxygenator is the organ substitute. In a natural pregnancy, the placenta handles gas exchange: oxygen diffuses from maternal blood across the placental membrane into fetal blood, and carbon dioxide diffuses in the opposite direction. The artificial womb must replicate this function using an engineered device, and the engineering constraints are severe.

The oxygenator must accept deoxygenated fetal blood from the umbilical arteries, expose that blood to a membrane across which oxygen and carbon dioxide can diffuse, and return oxygenated blood to the fetus through the umbilical vein. It must do this without hemolyzing the blood cells, without generating excessive resistance that would overtax the fetal heart, without clotting, and without failing for the duration of the gestation period. Each of these constraints imposes a specific design requirement, and they often conflict.

The most important design decision in the EXTEND system was to eliminate the mechanical pump. Standard extracorporeal membrane oxygenation, or ECMO, the technology from which artificial womb oxygenation descends, uses a roller or centrifugal pump to drive blood through the circuit. Spencer and Mychaliska (2022) trace this lineage explicitly: neonatal ECMO has been used clinically since the 1970s, providing life-saving cardiopulmonary support to newborns with reversible respiratory failure, and the technology evolved from adult cardiopulmonary bypass circuits with progressive miniaturization and biocompatibility improvements. The core engineering principles that ECMO established membrane oxygenation, circuit biocompatibility, anticoagulation management, and continuous physiologic monitoring became the foundation for artificial placenta design. But the transition from ECMO to an artificial placenta required a fundamental architectural rethink. ECMO is designed for postnatal physiology, in which a pulmonary circulation exists. The artificial placenta must support fetal physiology, in which a placental circulation exists and the fetal heart is adapted to pump against the low resistance of the placental vascular bed.

The solution was the pumpless arteriovenous circuit. The fetal heart becomes the pump. Blood exits the fetus through the umbilical arteries, flows through the oxygenator where gas exchange occurs, and returns through the umbilical vein. The oxygenator is designed with minimal resistance so that the fetal cardiac output can perfuse the circuit without additional mechanical assistance. This is not a trivial engineering specification. If the circuit resistance is too high, the fetal heart cannot generate sufficient pressure to perfuse the oxygenator, and the fetus becomes hypoxic. If the resistance is too low, blood preferentially flows through the circuit at the expense of fetal organ perfusion, depriving the brain and other organs of adequate blood supply. The resistance must be precisely matched to the fetal hemodynamic envelope.

Huang, Fei, Zhang, Li, and Pei (2025) provide the detailed physiological and en-

gineering parameters for this matching. In their narrative review, they analyze the two main circuit configurations: arteriovenous circuits, in which oxygenated blood returns to the venous system and flows through the fetal heart, and venovenous circuits, in which both drainage and return occur on the venous side. AV circuits more closely mimic placental physiology and are the configuration used in the EXTEND system, but they require adequate fetal cardiac function. VV circuits may tolerate cardiac dysfunction more gracefully but provide less efficient oxygenation. The oxygenator surface area for the smallest fetuses typically ranges from 0.3 to 0.8 square meters. Gas exchange efficiency depends on membrane thickness, surface area, blood flow velocity, and the oxygen partial pressure gradient across the membrane. The review also notes a critical design parameter that engineers unfamiliar with fetal physiology might miss: fetal oxygen saturation targets are lower than postnatal targets, typically 40 to 70 percent in utero, because the fetus operates in a low-oxygen environment. This means the oxygenator must be designed to deliver a lower partial pressure of oxygen than a postnatal ECMO circuit would target, while simultaneously maintaining adequate carbon dioxide removal to prevent fetal acidosis and neurological injury.

Blauvelt, Abada, Oishi, and Roy (2021) address the membrane materials problem directly. Their review examines three primary membrane material classes for oxygenators in artificial placenta applications. Silicone membranes offer excellent biocompatibility but limited gas exchange efficiency. Polymethylpentene hollow fibers provide high surface area and good gas exchange but carry a potential for blood damage at the fiber-blood interface. Microfluidic silicon membranes, the newest approach, offer highly controlled geometry at the microscale but require complex semiconductor manufacturing processes. Each material presents trade-offs among thrombogenicity, hemolysis potential, gas exchange efficiency, and long-term durability. The review emphasizes that membrane rupture represents the most catastrophic failure mode: a breach in the membrane would introduce air into the blood circuit, causing an air embolism and immediate fetal death. Prevention requires both material selection with adequate tensile strength and burst pressure ratings, and structural design that distributes pressure evenly across the membrane surface. Anticoagulation strategies are equally critical, because thrombus formation on the membrane surface progressively reduces gas exchange efficiency and can ultimately occlude the circuit entirely.

Higgins (2025) pushes the boundary further with a doctoral dissertation on microfluidic silicon membrane oxygenators fabricated using semiconductor manufacturing techniques. Silicon membranes can be made extremely thin, down to sub-micron thicknesses, which dramatically improves gas diffusion rates. Their geometry can be precisely controlled at the microscale to optimize blood flow patterns and minimize shear stress, the mechanical force that destroys red blood cells. Higgins describes two designs: a “window” design with larger unsupported membrane areas that achieves higher gas exchange per unit area but is more vulnerable to rupture under pressure spikes, and a “channel” design with contin-

uous support structures that is more robust but requires more membrane surface area for equivalent gas exchange. A composite incorporating both geometries offers a practical compromise. The dissertation also highlights the potential for integrating sensors directly into the oxygenator membrane, enabling continuous real-time monitoring of blood gases, flow rates, and membrane integrity without separate instrumentation. Even a single pinhole defect in a silicon membrane can cause air embolism and fetal death, which means quality control during fabrication, including wafer-level testing and defect detection, must be absolute.

4.3 Bioreactor Architecture

The oxygenator handles gas exchange, but the gestation environment itself is a bioreactor: a controlled vessel in which biological processes occur under regulated conditions. Oei (2025) provides a taxonomy of bioreactor designs applicable to extra-uterine gestation, organized by the developmental stage they are intended to support. Early-stage embryo bioreactors focus on maintaining the microenvironment during the implantation window and early organogenesis, requiring precise control of temperature, gas tension, pH, and nutrient supply in minimal volumes. Mid-gestation fetal bioreactors, like the EXTEND system, must accommodate a growing fetus with increasing metabolic demands, requiring larger fluid volumes, more robust gas exchange capacity, and continuous fluid turnover. Late-gestation systems must additionally support the maturation of organ systems, particularly the lungs, in preparation for the transition to air breathing.

Each bioreactor type imposes different engineering constraints on materials, sensors, control systems, and failure modes. Oei emphasizes a point that is easily lost in popular accounts: no single bioreactor design can span the entire gestational period. The engineering challenges scale non-linearly with fetal size and developmental complexity. A system that adequately supports a 500-gram fetus at 22 weeks equivalent will not support a 3-kilogram fetus at 36 weeks equivalent. The metabolic demands increase by an order of magnitude. The amniotic fluid volume must increase proportionally. The oxygenator surface area must increase. The waste removal capacity must increase. Temperature control, fluid dynamics, gas exchange efficiency, and waste product removal represent the four primary engineering parameters that must be optimized across all bioreactor types, and each one changes continuously as the fetus grows. The bioreactor design must also account for fetal movement, which is essential for musculoskeletal development and imposes constraints on bag flexibility and available fluid space.

4.4 Fetal Monitoring: Knowing What Is Happening Inside

An artificial womb is only as safe as the monitoring system that watches over it. Inside a natural uterus, the maternal body provides continuous feedback through hormonal signaling, blood pressure regulation, immune surveillance,

and metabolic sensing. The artificial womb must replicate this informational infrastructure with engineered sensors and data processing.

Current monitoring protocols, as documented by Peers de Nieuwburgh, Dave, Khan, Ngo, and colleagues (2024) in their assessment of EXTEND-supported lambs, include continuous Doppler ultrasound assessment of fetal cardiac function and umbilical blood flow, periodic blood gas analysis drawn from the circuit, and echocardiographic evaluation of cardiac output and vascular resistance. Physiological targets are defined quantitatively: fetal heart rate within normal ranges, blood gas values within normal fetal parameters (pO2 20 to 30 mmHg, pCO2 40 to 50 mmHg, pH 7.35 to 7.40), and normal fetal movement patterns observed through the bag wall. The study also documented the importance of maintaining normal fetal circulation patterns, noting that lambs at 105 to 111 days gestational age have active vasoactive responses that must be preserved by the circuit design. Biophysical profiles, analogous to those used in clinical obstetrics, can be adapted for the artificial womb context: fetal movement, breathing motions, muscle tone, and amniotic fluid volume all serve as indicators of well-being.

The next frontier is AI-driven tracking. As sensor data streams increase in volume and complexity, machine learning algorithms can be trained to detect subtle deviations from normal fetal physiology before they become clinically significant. A gradual decline in oxygen extraction efficiency across the oxygenator, for example, might indicate early membrane fouling or thrombus formation. A change in fetal heart rate variability might signal neurological stress. These patterns are difficult for a human operator to detect in real time but are well suited to algorithmic analysis. The integration of AI monitoring into artificial womb systems represents an engineering challenge in its own right, requiring validated training datasets, defined alert thresholds, and fail-safe protocols for algorithmic errors.

4.5 Failure Modes: What Can Go Wrong Will Go Wrong

Every engineering system has failure modes, and an artificial womb is a life-sustaining system in which component failure can kill. The failure modes are numerous and interacting.

Membrane rupture in the oxygenator is the most immediately lethal: air enters the blood circuit, the fetus develops an air embolism, and death follows within minutes. Oxygenator failure from thrombus accumulation is more gradual but equally fatal: as clots form on the membrane surface, gas exchange efficiency declines, the fetus becomes progressively hypoxic, and organ damage, particularly to the brain, occurs before the decline is detected. Infection is the persistent threat: any breach in circuit sterility introduces pathogens into the closed fluid environment, and the fetus, with its immature immune system, is defenseless. Amniotic fluid composition errors, such as incorrect osmolarity or pH, can damage fetal tissues over hours or days. Circuit resistance changes from partial

occlusion or device degradation can shift hemodynamic balance and redirect blood flow away from critical organs. Sensor failures can mask all of the above.

These are not hypothetical risks. The EXTEND team's safety assessment (Peers de Nieuwburgh et al., 2024) documented incidents of animal injury within the Biobag due to fetal movement, leading to design modifications of the bag geometry. Blood sampling protocols had to be refined to minimize iatrogenic blood loss, which can be critical given the small total blood volume of premature fetuses. The system is a tightly coupled, continuously changing environment in which biological and engineered subsystems interact dynamically. De Bie, Davey, Larson, Deprest, and colleagues (2021) enumerate the remaining engineering challenges for clinical translation: scaling the system to support the smallest and most vulnerable fetuses, maintaining the system for the weeks or months needed to achieve term-equivalent development, preventing infection in a long-term extracorporeal circuit, supporting normal fetal organ development particularly lung maturation in a fluid environment, and developing reliable monitoring systems that can track fetal well-being without invasive procedures. They also note that premature rupture of membranes, the artificial equivalent of premature delivery, requires standardized protocols for emergency transition to postnatal care.

4.6 Safety by Design: Not an Afterthought

Traditional engineering safety analysis uses failure mode and effects analysis: list the components, enumerate how each can fail, estimate probabilities, and design redundancies. This approach works for simple systems with independent components. It does not work for artificial wombs.

Nancy Leveson (2004) proposed a replacement framework: STAMP, the Systems-Theoretic Accident Model and Processes. Her argument is that in complex systems, accidents result from dysfunctional interactions among system components rather than from simple component failures. Safety is an emergent system property, not a component property. It must be built into the system design from the beginning, not added as an afterthought. The STAMP framework introduces the concept of safety constraints: explicit rules that must be enforced throughout system operation. For an artificial womb, safety constraints might include: fetal oxygen saturation must remain above 70 percent; amniotic fluid osmolarity must remain within 270 to 290 milliosmoles per liter; circuit resistance must not exceed a defined threshold; membrane integrity must be continuously verified. Control structures implement these constraints through feedback loops: sensors measure the constrained variable, controllers compare it to the defined limit, and actuators adjust system parameters to maintain compliance.

Martin and Schinzinger (2005) extend this logic to the ethics of engineering design itself: safety must be embedded from the start as a design requirement, not retrofitted as a compliance checkbox. In the context of artificial gestation, this

means that every subsystem, the amniotic fluid delivery circuit, the oxygenator, the monitoring network, the bioreactor chamber, must be designed with explicit safety constraints, defined operating envelopes, and graceful degradation modes that protect the fetus even when individual components fail. The system must fail soft, not fail hard. If the oxygenator membrane begins to foul, the monitoring system must detect the efficiency decline and alert operators before hypoxia develops. If infection is detected in the fluid circuit, protocols must exist for sterile circuit exchange without disrupting the fetus. If a sensor fails, redundant sensors must provide continued coverage.

This is engineering discipline applied to the most vulnerable possible patient. The design philosophy is not optional. It is constitutive of what it means to build a system that sustains human life.

4.7 Where We Are and Where We Are Going

De Bie, Davey, Larson, Deprest, and colleagues (2021) provide the most comprehensive technical roadmap available for the field. Their review traces the engineering evolution from the earliest experiments in the 1950s and 1960s, which demonstrated the feasibility of extra-uterine fetal support but achieved only short-term survival with significant complications including hemorrhage, infection, and neurological damage, through the development of pumpless arteriovenous circuits in the 2000s, which represented a paradigm shift by using the fetal heart as the pump and maintaining physiological hemodynamics, to the current state of the art exemplified by the EXTEND Biobag with its hollow-fiber oxygenator and polymethylpentene membranes.

The remaining engineering challenges are substantial. The system must be scaled to support the smallest fetuses, those born at 22 to 24 weeks, who are the most likely clinical candidates and who present the smallest blood volumes, the most fragile tissues, and the most immature organ systems. The system must operate reliably for weeks to months, far longer than the typical ECMO run of days. Infection prevention over such durations in an extracorporeal circuit is an unsolved problem. Lung maturation in a fluid environment must be carefully managed to prepare the fetus for the transition to air breathing at the equivalent of term. Neurological outcomes must be rigorously assessed, because the developing brain is the organ most vulnerable to hypoxic-ischemic injury during extracorporeal support.

The technology is real. The engineering is advancing. The Biobag works. But "works" in the engineering sense means something precise: it performed within specification under controlled conditions with animal subjects in a research setting. The gap between that achievement and safe, reliable, clinical-grade human application is not a gap of imagination. It is a gap of materials science, of control systems engineering, of biocompatibility, of long-term reliability, of regulatory validation, and of safety certification. Each of those gaps is being closed incrementally by engineers working at the intersection of fetal physiology, biomedical

device design, and systems safety theory.

The reader who has followed this chapter should now understand, at least in outline, what the machine looks like, how it functions, what it replaces, and where it breaks. That understanding is not optional background. It is the foundation on which every subsequent ethical argument must be built. You cannot evaluate the moral permissibility of a technology you do not comprehend. You cannot assess the risks of a system whose failure modes you have not considered. You cannot weigh the benefits of a capability whose engineering requirements you have not grasped.

The machine is real. The engineering is hard. Now the ethical questions can begin.

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5 Chapter 3: 295,000

In 2023, 260,000 women died from causes related to pregnancy and childbirth. The World Health Organization reports that most of these deaths were preventable. Every two minutes, a woman somewhere in the world hemorrhaged, or seized from eclampsia, or succumbed to sepsis, and the world moved on to the next two minutes. Over 700 women died today. By the time you finish this chapter, several more will have died. The number is not abstract. It is not a trend line or a talking point. It is a census of the dead, each one of them a person with a name, and the overwhelming majority of them died from complications that medicine already knows how to treat.

This chapter is about the human cost of gestational failure. It is about what happens when the biological process of carrying a child to term kills the mother, or kills the child, or kills both. It is about the gap between what medicine can do in wealthy countries and what it cannot do in poor ones. And it is about whether that gap is a fixed feature of the human condition, or whether technology can close it.

5.1 Where Women Die

The geography of maternal death is not random. It is a map of poverty drawn in blood.

Sub-Saharan Africa alone accounted for approximately 70 percent of global maternal deaths in 2023, a total of 182,000 women. Southern Asia accounted for another 17 percent, roughly 43,000 deaths. Together, these two regions absorbed 87 percent of the world's maternal mortality while representing a fraction of its wealth. The disparity between the richest and poorest nations is staggering. In high-income countries, a woman's lifetime risk of dying from a maternal cause is 1 in 7,933. In low-income countries, it is 1 in 66. That is not a ratio. It is a verdict. A woman born in sub-Saharan Africa is 120 times more likely to die

bringing a child into the world than a woman born in Western Europe or North America, and the reason is not biology. It is access to medicine.

Between 2000 and 2023, the global maternal mortality ratio dropped by about 40 percent. That progress is real, and it should be acknowledged. Southern Asia achieved a 71 percent reduction. Eastern Europe achieved 75 percent. Sub-Saharan Africa itself saw a 40 percent decline. But 40 percent of an enormous number is still an enormous number, and the pace of improvement is decelerating. The WHO calculates that achieving the Sustainable Development Goal target of a global maternal mortality ratio below 70 per 100,000 live births by 2030 would require an annual rate of reduction of almost 15 percent. That rate has rarely been achieved at the national level. The trajectory is wrong. Incremental improvement is not enough.

The 2020 to 2023 data makes the problem worse. Maternal deaths actually rose in 2021, climbing to 322,000 from 282,000 in 2020, a spike likely attributable to COVID-19 disruptions to health services. The pandemic did not create the vulnerability. It exposed it. The systems meant to protect pregnant women were already fragile enough to collapse under pressure.

5.2 What Kills Them

The causes of maternal death are not mysterious. They are well characterized, well understood, and in most cases well treatable. Cresswell and colleagues, in a WHO systematic analysis of maternal deaths from 2009 to 2020 published in Lancet Global Health, identified the leading causes with clinical precision. Severe hemorrhage, mostly postpartum bleeding, kills a healthy woman within hours if unattended. Hypertensive disorders, including pre-eclampsia and eclampsia, can be managed with drugs like magnesium sulfate if detected early. Sepsis, usually following childbirth, can be prevented with basic hygiene and treated with antibiotics. Together, these three categories account for approximately 75 percent of all maternal deaths worldwide.

Notice what these causes have in common. They all arise from the interaction between the fetus and the mother's body during pregnancy and delivery. Hemorrhage occurs when the placenta separates or the uterus fails to contract. Pre-eclampsia is a disorder of placental implantation that cascades into systemic maternal organ damage. Sepsis enters through the birth canal or surgical incision. Each of these conditions represents a failure point in the biological coupling between mother and child, a moment when the process of gestation itself becomes the vector of the mother's destruction.

This is the precise problem that artificial womb technology addresses. If the fetus can be safely transferred to an external gestational environment, the mother's compromised physiology is no longer the bottleneck. The hemorrhaging mother can receive the surgical attention she needs without the added pressure of a viable fetus still inside her. The pre-eclamptic patient can be stabilized without the impossible calculus of how long to delay delivery for fetal maturity

versus how long to wait before the mother's organs begin to fail. The septic patient can be treated aggressively without concern for antibiotic effects on the developing child. Ectogenesis does not merely add a new tool to the obstetrician's kit. It changes the equation entirely. It decouples fetal development from maternal survival, making it possible to save both where currently one or both must be lost.

5.3 The Limits of Viability

The human cost of gestational failure is not measured only in maternal deaths. It is measured in the infants who arrive too early to survive outside the womb, and in the devastating outcomes of those who do survive.

Globally, approximately 15 million babies are born prematurely each year. In the United States alone, preterm birth affected approximately 10.4 percent of live births in 2023, making it the leading cause of infant death. The March of Dimes reports nearly 3.6 million live births annually in the US, which means that over 370,000 American babies were born prematurely in a single year, in one of the wealthiest nations on earth. The scale of the problem in low-income countries, where preterm birth rates are higher and neonatal intensive care is scarce or nonexistent, is far greater.

At the extreme edge of prematurity, the numbers become devastating. Kurimoto and colleagues, in a 2025 study published in BMC Pediatrics analyzing 185 neonates admitted to a Japanese NICU between 2006 and 2023, reported survival rates for live births at 22 and 23 weeks of gestation that ranged from 3.7 to 56.7 percent at 22 weeks and from 20 to 79.3 percent at 23 weeks. Those ranges are wide because outcomes depend heavily on the aggressiveness of the treatment protocol and the resources of the institution. But even at the upper end, nearly half of all infants born at 22 weeks die. And the survivors face a burden of morbidity that current medicine cannot adequately prevent.

Kaempf, in a 2026 narrative review in Seminars in Fetal and Neonatal Medicine, confronted this reality with unusual candor. He observed that survival rates for infants born at 22, 23, and 24 weeks are increasing, but morbidity rates and long-term neurodevelopmental impairments are substantial and not improving. We are keeping more extremely premature infants alive. We are not keeping them well. The survivors at 22 to 23 weeks in even the most aggressive treatment centers experience high rates of cerebral palsy, blindness from retinopathy of prematurity, deafness, and cognitive delays. Kaempf posed the question that the field has been reluctant to ask: does the increasing survival at ever-lower gestational ages represent genuine medical progress, or is it an exercise in what some have termed therapeutic fury, the relentless application of technology without proportionate regard for the quality of life that will result?

This is not a counsel of despair. It is a diagnosis of the current frontier. The NICU is a remarkable invention, but it is an ICU, and an ICU is a place designed for stabilization, not development. An infant at 22 weeks is not a miniature

version of a term baby. The organs are not merely small but immature. The lungs are not ready for air. The brain is not ready for the sensory bombardment of the outside world. The gut cannot absorb nutrition. Current neonatal care manages these deficits with heroic interventions, ventilators, intravenous lines, phototherapy, and every other tool of intensive medicine, but it is fighting the fundamental problem: the infant's body was designed for the womb, and the ICU is not the womb.

An artificial womb is a different proposition entirely. It is not a more sophisticated incubator. It is a replication of the gestational environment itself, a system designed to continue the process of development rather than arrest the consequences of its interruption. The fetus floats in fluid. It exchanges gas through the placenta. It grows. The proof of concept has been demonstrated in lamb models. The theoretical framework is sound. What is missing is the engineering, the clinical trials, and the political will to fund both.

5.4 The Rule of Rescue

Bioethics has a concept that bears directly on this question. It is called the rule of rescue, and it describes the powerful human proclivity to save identifiable endangered lives regardless of cost or risk.

Nancy Jecker, writing in the Journal of Medicine and Philosophy in 2013, provided the most rigorous philosophical treatment of this principle. She defined the rule of rescue and acknowledged its intuitive appeal before arguing that it lacks adequate support from standard principles of justice in many situations. Jecker is a skeptic, and her skepticism is useful precisely because it clarifies the terms of the debate. Even she concedes that the rule of rescue carries undeniable moral force in a narrow range of cases, specifically those involving agent-relative considerations, where the endangered person is known and identifiable rather than merely statistical.

The women who die in childbirth are not statistics. They are identified. They arrive at hospitals with names. They are wheeled into delivery rooms where the staff knows exactly who is dying and exactly why. The premature infants in the NICU are not aggregate data points. They are patients, each one a person whose parents are holding vigil in the waiting room. The rule of rescue does not operate at the level of global mortality ratios. It operates at the level of the woman on the table, the infant in the isolette, the specific human being whose life is in danger right now.

Kohn and colleagues, in a 2011 study published in Intensive Care Medicine, demonstrated that clinicians act on this principle every day. They surveyed 684 physicians and 438 nurses across US ICUs and found that nearly 46 percent of physicians would allocate the last ICU bed to a gravely ill identifiable patient rather than to a deceased organ donor whose organs could save multiple statistical lives. The magnitude of the social benefit to be gained from organ donation, whether five life-years or thirty, had minimal and inconsistent effects on this

decision. In qualitative analysis, the most common reason given by clinicians for choosing the identifiable patient was a perceived strong obligation to the person in front of them. This is the rule of rescue operating not as an abstract theory but as a lived clinical reality. It is how medicine actually works when lives are at stake.

Applied to ectogenesis, the rule of rescue creates a specific moral pressure. There are approximately 260,000 women dying annually from preventable maternal causes. There are millions of premature infants born each year at the edge of viability. These are not hypothetical future patients. They are dying now. If a technology exists or could exist that would save some of them, the rule of rescue demands that we ask why it has not been developed, and whether the failure to develop it is itself a moral failing.

5.5 The Duty to Rescue

Rulli and Millum, writing in the Journal of Medical Ethics in 2016, pushed the analysis further. They argued that the duty of easy rescue is more demanding than commonly assumed and that the institutional rule of rescue is not merely a heuristic but reflects a deep moral commitment. The duty of easy rescue holds that individuals have a moral obligation to prevent something very bad from happening when they can do so at relatively little cost to themselves. When extended to institutions, this principle implies that health care systems have a corresponding obligation to invest in technologies that can prevent catastrophic outcomes at reasonable cost.

Peter Singer articulated the foundational version of this principle with characteristic directness: if it is in our power to prevent something bad from happening, without thereby sacrificing anything of comparable moral importance, we ought, morally, to do it. The logic is clean. The application is uncomfortable. If artificial womb technology is within reach, if the engineering challenges are solvable, if the research funding required is a fraction of what the global community spends on far less consequential endeavors, then the failure to develop the technology is not a neutral omission. It is a choice. It is a decision to let 260,000 women die next year from the same causes that killed 260,000 women this year, when a different decision might have saved some of them.

Kesselheim and colleagues, writing in 2017 on the ethical imperative for providing access to unapproved therapies at the point of imminent death, reinforced this logic from the clinical side. When a patient faces certain death and an experimental therapy offers any realistic chance of benefit, the moral calculus shifts. The default is no longer the standard of care, because the standard of care has already failed. The default is death. In that context, the risk of an unproven treatment is not a risk of harm. It is a chance of rescue.

The premature infant at 22 weeks faces a version of this problem. Current neonatal care offers survival rates that, at best, hover around 50 percent in the most aggressive centers, and the majority of survivors face significant long-

term impairment. The standard of care has reached its ceiling. An artificial womb that could continue gestation ex utero, allowing the fetus to develop in a physiological environment designed for it rather than forcing it to adapt to an ICU, would represent a fundamentally different therapeutic paradigm. It would not be rescue from a treatable condition. It would be rescue from a condition that current medicine cannot treat.

5.6 Compassionate Use and the Precedent of Access

The medical community has already built the institutional infrastructure for exactly this kind of rescue. It is called compassionate use, and it is how experimental therapies reach dying patients before full regulatory approval.

Rosenberg and colleagues, in a 2025 policy analysis published in ESMO Open, documented the compassionate use frameworks across seven European countries for anticancer and orphan medicines. Their findings revealed that while approval timelines vary from days to months depending on the jurisdiction, the underlying moral consensus is consistent: patients facing death from unmet medical needs have a claim to experimental therapies that may save their lives. The WHO defines compassionate use as a program intended to provide potentially life-saving experimental treatments to patients suffering from a disease for which no satisfactory authorized therapy exists. Extreme prematurity, at the current limits of viability, fits this definition precisely.

Kantaria and colleagues, in a 2024 report in Clinical Therapeutics, provided a concrete example of compassionate use operating at scale. The global risdiplam compassionate use program for spinal muscular atrophy, initiated in November 2019, enrolled over 2,000 patients across 59 countries prior to full regulatory approval. The program demonstrated that when a child faces death from a treatable condition, the international community has both the infrastructure and the moral consensus to provide experimental therapy at scale. The logistics are complex but solvable. The regulatory barriers are real but navigable. The moral will exists.

If risdiplam can be provided to 2,000 dying children across 59 countries through a compassionate use program, the question of whether artificial womb technology could be provided to premature infants at the limits of viability through a similar framework is not a question of possibility. It is a question of priority.

Romanis, writing in Bioethics in 2020, identified the critical legal and ethical threshold. She argued that the first clinical use of artificial womb technology in humans would constitute medical research, not innovative treatment, because there is insufficient prior evidence to justify the expectation of therapeutic benefit. This classification matters because it determines which regulatory pathway governs access. If AWT is research, it requires ethics board approval, informed consent protocols, and phased clinical trials. If it is treatment, it can be offered through existing clinical channels with appropriate professional oversight. Romanis is right that the initial translation will likely fall under research ethics,

and that is appropriate. But the compassionate use precedent demonstrates that the boundary between research and treatment is not absolute. It can be crossed when death is the alternative.

In a companion article published in Medical Law Review, also in 2020, Romanis extended the analysis to the question of maternal autonomy. She argued that partial ectogenesis, the continuation of gestation ex utero following premature delivery, would introduce genuinely new reproductive choices rather than merely replacing existing ones. A woman facing a life-threatening complication of pregnancy would not be forced to choose between her own survival and her child's viability. She could have both. The fetus could be transferred to an artificial womb while the mother received the aggressive medical intervention she needs. This is not a threat to maternal autonomy. It is its expansion. It is the technology that makes it possible to love both the mother and the child at the same time, which is precisely the moral calculus that pregnancy complications currently force women and their physicians to abandon.

5.7 The Moral Weight of Inaction

Bulletti and colleagues, writing in Zygote in 2023, framed the scientific case for ectogenesis in the starkest terms available. Approximately 15 million babies are born prematurely each year worldwide. Extreme prematurity remains a leading cause of neonatal death and long-term disability. The uterus is, at its most basic level, a bioreactor, and its functions can in principle be replicated by engineered systems. The theoretical framework is sound. The animal proof of concept exists. The clinical need is overwhelming.

What is missing is not the science. What is missing is the decision to fund the science at a level commensurate with the need.

Consider the arithmetic. The global community spends approximately 2.2 trillion dollars per year on military expenditure. The United States National Institutes of Health budget in 2024 was approximately 47 billion dollars, of which the Eunice Kennedy Shriver National Institute of Child Health and Human Development received roughly 1.7 billion. The Human Genome Project, which mapped the entire human genome in thirteen years, cost approximately 2.7 billion dollars in total. The research and development required to bring artificial womb technology from proof of concept to clinical viability, while substantial, would be a rounding error in the global research budget. The obstacle is not cost. The obstacle is attention.

This is where the moral weight of inaction becomes sharpest. If the technology is feasible and the cost is manageable and the need is urgent, then the failure to develop the technology is not an unfortunate gap in our knowledge. It is a decision, made by default, to accept 260,000 maternal deaths per year as an unalterable feature of the human condition. It is a decision to accept that half of all infants born at 22 weeks will die, and that those who survive will bear

the scars of our inaction for the rest of their lives. It is a decision, repeated annually, to spend the money elsewhere.

Singer's principle does not permit this. If it is in our power to prevent something bad from happening, without thereby sacrificing anything of comparable moral importance, we ought, morally, to do it. The research is within our power. The cost is not comparable to the lives at stake. The moral conclusion follows directly.

Rulli and Millum's framework does not permit this either. The duty of easy rescue demands that institutions invest in technologies that prevent catastrophic outcomes at reasonable cost. The institutional rule of rescue demands that identifiable endangered lives receive priority. Both principles converge on the same point: ectogenesis must be developed, funded, and tested with the urgency that 260,000 deaths per year demands.

5.8 The Number Again

Let us return to where we began. Two hundred and sixty thousand women died from preventable maternal causes in 2023. That is 700 per day. One every two minutes. Seventy percent of them were in sub-Saharan Africa. Seventeen percent were in southern Asia. Nearly all of them were in countries too poor to provide the obstetric care that would have saved their lives. The leading causes were hemorrhage, hypertensive disorders, and sepsis, all conditions that arise from the biological coupling between the fetus and the mother's body. All conditions that ectogenesis could address by decoupling fetal development from compromised maternal physiology.

At the other end of gestation, the crisis is equally severe. Fifteen million premature births per year. Hundreds of thousands of neonatal deaths. Millions of survivors bearing long-term neurological damage. The limits of current neonatal technology are not a ceiling on human capability. They are a ceiling on the tools we have chosen to build.

This is not a speculative chapter about a hypothetical future technology. The proof of concept exists. The theoretical framework is sound. The compassionate use infrastructure is in place. The ethical foundations for rescue are established. The only thing standing between the current state of affairs and a radically different one is the decision to act.

Today, 700 women will die from preventable causes related to pregnancy and childbirth. Tomorrow, 700 more. The number will not change because we have not decided to change it. The technology that could save some of them is not science fiction. It is engineering that has not been funded.

The question is not whether artificial wombs can be built. The question is whether we are willing to build them, and how many women and children will die while we decide.

6 Chapter 4: The Republic of Letters

Before theology can speak a word about artificial wombs, it must listen. The question whether technology carries moral weight is not new, and Christians who rush to address it without surveying the intellectual terrain will find themselves reinventing arguments already refined, tested, and found wanting by thinkers who never opened a Bible. This chapter maps the disciplinary landscape: the secular frameworks that have already tried to answer the question of technology's moral status. Each framework receives a fair hearing and a clear limitation. The point is not to dismiss these voices but to hear what they offer, identify where they fall silent, and prepare the ground for the theological argument that follows.

6.1 I. Science and Technology Studies: Do Artifacts Have Politics?

The most accessible entry point into the modern debate is a question Langdon Winner posed in 1980: "Do artifacts have politics?" Winner argued that technologies are not merely aids to human activity but powerful forces that reshape that activity and its meaning. His famous example was Robert Moses's low-hanging overpasses on Long Island parkways, designed to prevent public buses from passing beneath them, thereby excluding lower-income and predominantly Black residents from beaches and parks. The overpass was not a neutral instrument. It was a policy decision cast in concrete.

Winner's broader claim, developed in *The Whale and the Reactor* (1986), was that technologies carry political qualities in at least two ways. Some artifacts are inherently political: they demand particular forms of social organization. Nuclear power, for instance, requires hierarchical authority structures for safety reasons. Other artifacts are political by design: they encode the values and interests of their creators. In both cases, the myth of neutrality collapses. A technology is never "just a tool." It is an invitation to certain ways of living and a prohibition against others.

James Gibson introduced a concept that would prove even more durable: affordance. In *The Ecological Approach to Visual Perception* (1979), Gibson defined affordances as "what the environment offers the animal, what it provides or furnishes, either for good or ill." An affordance is not a property of the object alone, nor of the subject alone, but of the relation between them. A cliff affords falling. A chair affords sitting. A hammer affords striking. The affordance exists whether or not the animal perceives it, and it is always relational, always directional, always charged with consequence.

Gibson's concept, combined with Winner's political analysis, dismantles the neutral tool fallacy at its root. Technologies do not wait passively for human

intentions to animate them. They afford certain actions and foreclose others. They invite particular configurations of power and resist alternative arrangements. An artificial womb affords fetal development outside the maternal body. It simultaneously affords the detachment of gestation from embodiment, the redistribution of reproductive labor, the medicalization of what was once a bodily process, and the redefinition of parenthood. These affordances are not incidental features. They are the technology's politics.

Science and Technology Studies (STS) as a discipline built on these insights. Scholars such as Bruno Latour, Wiebe Bijker, and Trevor Pinch demonstrated through detailed case studies that technological development is a social process: contested, negotiated, contingent. Technologies are not born from pure necessity but from networks of interest, funding, institutional power, and cultural assumptions. The social construction of technology is as real as the physical construction of any device.

Yet STS has a limitation. Its method is primarily descriptive. It can show how a technology was socially constructed, how power shaped its design, how users resisted or appropriated it. What it struggles to provide is normative guidance: not how technologies came to be, but whether they should be. Winner gestures toward normativity with his political analysis, but the discipline as a whole tends to suspend judgment in favor of thick description. When we ask whether artificial wombs are good or bad, STS falls largely silent. It can tell us who benefits and who loses. It cannot tell us what we owe to the child in the machine.

6.2 II. Post-phenomenology: How Technologies Mediate Experience

A different tradition addresses technology at the level of experience itself. Post-phenomenology, developed by Don Ihde and extended by Peter-Paul Verbeek, begins with the claim that technologies do not simply mediate between humans and world in a neutral fashion. They co-constitute how humans experience reality. The technology is not between the subject and the object. It is woven into the relation, transforming both poles.

Ihde identified four fundamental human-technology relations. Embodiment relations occur when technology extends bodily perception: a blind person's cane, a surgeon's scalpel, a writer's pen. The technology withdraws into the body-schema; the user perceives through it rather than at it. Hermeneutic relations occur when technology represents the world for interpretation: a thermometer, a map, a fetal monitor. The user reads the technology as a text that stands for something beyond itself. Alterity relations occur when technology presents itself as quasi-other: a robot, a vending machine, an interactive device. The user encounters the technology as a face, a presence, an interlocutor. Background relations occur when technology forms the ambient context of experience: the hum of an air conditioner, the glow of a nightlight, the constant operation of an

artificial womb in a neonatal ward. The technology recedes into the environment and shapes experience without being directly attended to.

Each relation exhibits what Ihde called a magnification-reduction structure. Technology simultaneously amplifies certain aspects of experience while screening out others. A telescope magnifies distant stars but reduces peripheral vision. A fetal monitor amplifies heart rate data but reduces the embodied intimacy of feeling a kick. An artificial womb would amplify the safety and control of gestational management while reducing the bodily experience of carrying a child. This is not a bug in the technology. It is the structure of mediation itself.

Verbeek extended Ihde's framework into ethics with two critical innovations. The first is hybrid intentionality: when technology mediates the intentional relation between human and world, it creates a new entity that is neither purely human nor purely technological. The parent looking at a sonogram image is not simply exercising a pre-given intention to see the child. The technology shapes what can be seen, how it is seen, and what moral weight the seeing carries. The intentionality is hybrid: distributed across the human-technology configuration. The second innovation is composite intentionality: humans are directed not only at the world through technology but at the way the technology is directed at the world. A parent does not just see a fetus on the ultrasound screen. The parent sees the screen's representation of the fetus and interprets that representation in light of the technology's known capabilities and limitations.

In *Moralizing Technology* (2011), Verbeek argued that this mediating role makes technology design an inherently moral enterprise. Technologies do not merely facilitate or obstruct pre-existing moral decisions. They actively constitute the moral situations in which humans find themselves. Technologies shape moral subjectivity: they help determine what counts as a moral problem, what options appear available, and what choices feel natural. Moral agency is distributed across human-technology configurations rather than located solely in the individual human subject.

Verbeek demonstrated this analysis with a concrete example: obstetric ultrasound. In his 2008 article on the subject, he showed that ultrasound does not simply reveal the fetus but actively constitutes the fetus as a particular kind of moral entity. In one use context, ultrasound renders the fetus as a medical patient whose abnormalities must be detected and addressed. In another, it renders the fetus as a being with whom parents can bond through seeing its movements and features. These different mediations generate different moral landscapes. The technology does not determine the moral decision, but it shapes the field in which the decision is made. The design of the ultrasound machine, the protocols of its use, the training of its operators: all of these are moral acts, whether or not their designers recognize them as such.

The application to artificial wombs is direct and powerful. An artificial womb does not simply house a fetus. It mediates the moral relationship between parents, medical professionals, society, and the developing human life. It con-

stitutes the fetus in a particular way: as patient, as child, as dependent, as project. It constitutes parenthood in a particular way: as stewardship, as management, as genetic contribution, as custodial care. It constitutes gestation in a particular way: as process, as production, as natural function, as technological achievement. Every one of these constitutions is a moral act embedded in the material form of the technology.

Post-phenomenology, however, has its own limitation. As Martin Ritter observed in a 2021 critical assessment, post-phenomenology risks reducing the technicity of things to their pragmatic function. A car, Ritter noted, changes intentionality not only as a means of transport but in unintended and unintentional ways that exceed its pragmatic purpose. The technology's mediating effects spill beyond its designed function. An artificial womb will mediate human experience not only through its intended purpose of gestating a fetus but through side effects on how humans perceive pregnancy, embodiment, parenthood, and the boundary between the natural and the artificial. Post-phenomenology can describe these mediations with precision. It cannot, on its own resources, tell us which mediations we should welcome and which we should resist.

6.3 III. The Critical Theory of Technology: Power, Knowledge, and Democratic Design

Andrew Feenberg occupies a distinctive position at the intersection of critical theory and Science and Technology Studies. Trained under Herbert Marcuse at UC San Diego, Feenberg brings the Frankfurt School's concern with domination and emancipation into direct engagement with the empirical case studies of STS. The result is a critical theory of technology that rejects both technological determinism (the idea that technology dictates social outcomes) and naive instrumentalism (the idea that technology is a neutral tool fully controlled by its users).

Feenberg's key claim is that technology embeds social values at the level of design. In *Transforming Technology* (2002), he wrote: "What human beings are and will become is decided in the shape of our tools no less than in the action of statesmen and political movements. The design of technology is thus an ontological decision fraught with political consequences. The exclusion of the vast majority from participation in this decision is profoundly undemocratic." This is not a metaphor. Feenberg means that the technical specifications of a device encode assumptions about who should use it, how it should be used, and what kind of life it makes possible.

Feenberg's instrumentalization theory distinguishes two levels. Primary instrumentalization involves the decontextualization and reduction of things to technical function: extracting gestation from the maternal body, reducing it to a set of measurable parameters, treating the fetus as a biological system to be managed. Secondary instrumentalization involves the reintegration of technical objects into social contexts through regulation, creative appropriation, and

democratic governance. The critical question is whether secondary instrumentalization will be democratic or technocratic. Will artificial wombs be shaped by the values of the communities that will use them, or by the interests of the corporations and institutions that develop them?

Feenberg's concept of democratic rationalization demands that technological design be opened to broader participation. The design of technology is too important to be left to engineers and venture capitalists alone. This is a political claim with teeth. It insists that the governance of ectogenesis cannot be decided by market forces or expert committees. The people whose lives will be shaped by the technology must have a voice in shaping it.

Yet Feenberg's framework also has a boundary. It operates primarily at the level of social and political organization. It can tell us that the design of artificial wombs is an ontological decision with political consequences. It can insist that the decision be democratized. What it cannot answer is the prior question: what kind of being is the fetus whose ontological status the technology will now determine? Democracy is a procedure for collective decision-making. It presupposes a community of decision-makers who share enough common ground to deliberate. When the question is whether a fetus in an artificial womb has the status of a person, a patient, a product, or a project, the democratic process cannot adjudicate without first settling a question that lies beyond its competence: the question of human ontological status.

6.4 IV. Post-phenomenology and STS: Methodological Distinctions

It is worth pausing to clarify how post-phenomenology differs from STS, since both traditions reject the neutral tool fallacy and both attend to the social dimensions of technology. Robert Rosenberger and Verbeek addressed this directly in their 2015 "Field Guide to Postphenomenology."

STS examines how technologies are socially constructed through networks of actors, interests, and negotiations. Its method is primarily sociological: it traces the processes by which particular designs emerge, the controversies they generate, and the compromises they encode. Bruno Latour's actor-network theory, for instance, treats human and nonhuman actors symmetrically within networks of association, refusing in advance to privilege either category. The approach is descriptive and deflationary: it dissolves grand claims about technology's essence into concrete sociotechnical processes.

Post-phenomenology, by contrast, maintains a phenomenological commitment to analyzing how technologies shape intentionality and lived experience. Its method is empirical philosophy: it combines close attention to specific technologies with philosophical reflection on what those technologies reveal about human-world relations. Where STS asks "how did this technology come to be?", post-phenomenology asks "how does this technology constitute a specific world and a specific subject?" The difference is not trivial. STS can explain

why a fetal monitor has the features it does by tracing its development through funding decisions, clinical trials, and regulatory approval. Post-phenomenology can explain how the fetal monitor reconstitutes the experience of pregnancy by transforming embodied maternal perception into a stream of data points on a screen.

For the analysis of artificial wombs, both approaches are necessary. STS reveals the social forces that will shape ectogenesis: corporate interests, medical protocols, legal frameworks, cultural assumptions about motherhood. Post-phenomenology reveals how artificial wombs will mediate the experience of gestation, parenthood, and fetal life. The two traditions complement rather than duplicate each other, and this book draws on both.

6.5 V. The Bioethics Toolkit: Principles, Imperatives, and Precautions

The philosophy of technology provides frameworks for understanding how technologies shape experience and social order. Bioethics provides frameworks for evaluating specific technologies against moral principles. The most influential bioethical framework in Anglophone medicine is Beauchamp and Childress's principlism, articulated in their *Principles of Biomedical Ethics* (first edition 1979, now in its eighth edition, 2019). Principlism identifies four principles: autonomy (respect for persons' capacity for self-determination), beneficence (the obligation to do good), nonmaleficence (the obligation to avoid harm), and justice (the fair distribution of benefits and burdens). These principles are not derived from a single moral theory. They function as a common morality, a shared vocabulary for ethical deliberation across diverse moral traditions.

Applied to artificial wombs, principlism generates a characteristic set of questions. Does ectogenesis respect the autonomy of the mother? Does it serve the beneficence of the child? Does it avoid harm to both? Is its distribution just? The framework is useful for organizing discussion. Its limitation is that the four principles can conflict without providing a meta-principle for resolving the conflict. A mother's autonomy may clash with the child's beneficence. Nonmaleficence may require caution that obstructs justice for families who need the technology. Principlism is a compass, not a map. It indicates directions but cannot chart a course.

Kant's categorical imperative offers a more rigorous but less flexible standard. The first formulation, from the *Groundwork of the Metaphysics of Morals* (1785), requires that one act only according to a maxim that one could will to become a universal law. The second formulation requires that one treat humanity, whether in one's own person or in the person of another, always as an end and never merely as a means. Applied to ectogenesis, the categorical imperative demands that artificial wombs never reduce the fetus to a means for someone else's purposes: research, convenience, social engineering. It demands that the technology treat the developing human as an end in itself, possessed of dignity

that cannot be overridden by utilitarian calculation. Kant's framework has the virtue of absoluteness. Its limitation is precisely that absoluteness: in cases of genuine moral tragedy, where every option involves some violation of dignity, Kant offers no way forward.

Two more recent principles have gained traction in technology governance debates. The precautionary principle, articulated in various forms by Nassim Nicholas Taleb and others, holds that when an action raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause-and-effect relationships are not fully established scientifically. Taleb's 2014 formulation with collaborators argued that precaution is especially necessary when dealing with complex systems where small interventions can produce catastrophic and irreversible consequences. The precautionary principle would counsel extreme caution with artificial wombs: the technology's long-term effects on child development, maternal psychology, family structure, and social norms are unknown, and the stakes are human lives.

The proactionary principle, proposed by Max More in 2005, inverts the precautionary logic. More argued that excessive precaution is itself a form of harm: it prevents the development of technologies that could save lives, reduce suffering, and expand human capability. The proactionary principle holds that the burden of proof should fall on those who would restrict technological innovation, not on those who would pursue it. Applied to artificial wombs, the proactionary principle would argue that the technology could save the lives of premature infants, extend reproductive options to women with medical conditions that make pregnancy dangerous, and advance human flourishing in ways that caution would foreclose.

These two principles represent genuine moral tensions, not mere policy preferences. The precautionary principle risks paralysis in the face of uncertainty. The proactionary principle risks recklessness in the face of possibility. Neither provides a method for resolving the tension. They describe poles of a debate, not a way through it.

6.6 VI. Bio-conservatism: The Strongest Secular Objections

Against the techno-optimist impulse stand the bio-conservatives: thinkers who argue that some technological interventions into human nature cross a line that should not be crossed. Their arguments deserve serious engagement because they represent the most thoughtful secular resistance to the vision of technological transcendence.

Francis Fukuyama, in *Our Posthuman Future* (2002), argued that biotechnology threatens the concept of human nature that undergirds liberal democracy. If human nature is malleable, if it can be redesigned through genetic engineering, neuropharmacology, and reproductive technology, then the natural rights

tradition loses its foundation. Rights presuppose a nature that demands respect. If that nature is a design choice, then rights become a design choice as well. Fukuyama's objection is not religious. It is political and philosophical: the stability of liberal governance depends on a shared understanding of what human beings are, and technologies that radically alter that understanding risk destabilizing the moral order that protects human dignity.

Leon Kass offered a different kind of argument with his concept of the "wisdom of repugnance" (1997). Kass contended that visceral moral revulsion at certain technologies is not mere prejudice but an expression of deep moral intuition that precedes rational analysis. Cloning, genetic engineering, and artificial reproduction provoke repugnance because they threaten something fundamental about human dignity, even when the threat cannot be fully articulated. Kass's argument is controversial: repugnance has historically been invoked to justify opposition to interracial marriage, organ transplantation, and other innovations now widely accepted. Yet his underlying point has force: moral reasoning is not purely cognitive. The body's response to a technology can register a truth that philosophical argument has not yet articulated.

Oliver O'Donovan brought a more explicitly theological argument to the bio-conservative position in *Begotten or Made?* (1984). O'Donovan distinguished between children who are begotten (arising from the generative act of their parents) and children who are made (produced through technological intervention). The distinction is not between natural and unnatural but between two different accounts of human agency. To beget is to participate in a process that transcends the parents' intentions; the child is received as a gift. To make is to impose intentions on matter; the child becomes a product. O'Donovan argued that reproductive technologies that cross the line from begetting to making alter the moral meaning of parenthood and, by extension, of human life itself.

Each of these objections has a limitation that becomes visible only when the argument is pushed to its conclusion. Fukuyama's concern for human nature presupposes a stable definition of what human nature is, but the definition he needs is precisely what the debate is about. Kass's wisdom of repugnance provides a signal but not a criterion: it tells us something is wrong but cannot tell us what. O'Donovan's distinction between begotten and made is the most penetrating of the three, and it will return in this book's theological argument. But as a purely secular claim, it cannot ground the intuition it expresses. Why should it matter whether a child is begotten or made? The answer requires an account of human dignity that secular bio-conservatism can gesture toward but cannot fully provide.

6.7 VII. Transhumanism: The Secular Vision of Transcendence

At the opposite pole from bio-conservatism stands transhumanism: the philosophical movement that embraces technological enhancement of human capa-

bilities as the next stage of evolution. Max More, who coined the term in its modern sense, and Ray Kurzweil, who popularized the concept of the singularity, envision a future in which technology dissolves the constraints of biology: aging, disease, cognitive limitation, even death.

Steve Fuller, in *Humanity 2.0* (2011), offered a more academically rigorous version of the argument. Fuller contended that the human species has always been a technological project, that our capacity for tool use is not an add-on to human nature but constitutive of it, and that the next phase of this project involves redesigning the biological substrate itself. Fuller's transhumanism is not merely about gadgets and enhancements. It is an ontological claim: humanity is not a fixed essence but an open project, and technology is the medium of that project.

Applied to artificial wombs, transhumanism would celebrate ectogenesis as liberation: liberation of women from the burdens and risks of pregnancy, liberation of human reproduction from the constraints of biology, liberation of the species from the accidents of natural gestation. The artificial womb is not a threat to human nature but an expression of it: humanity doing what it has always done, extending its reach beyond the given.

The transhumanist vision is internally coherent and genuinely exhilarating. Its limitation is the same limitation that afflicts every secular framework that reaches for questions of human ontological status. Transhumanism presupposes that humanity is an open project, that there is no fixed nature to respect or violate. But this is precisely the question at issue. Is human nature given or made? Is the fetus in the artificial womb a gift to be received or a product to be manufactured? Is parenthood a participation in a process that transcends human control, or an exercise of human mastery over the raw material of life? Transhumanism answers these questions by assumption. It does not argue for its answer. It asserts it.

6.8 VIII. Why Theology Is Necessary

Here is the cartography at a glance. STS reveals that technologies are socially constructed and politically charged. Post-phenomenology reveals that technologies mediate experience and co-constitute moral subjectivity. Critical theory of technology reveals that design decisions are ontological decisions that demand democratic participation. Principlism provides a shared vocabulary for bioethical deliberation. The precautionary principle warns against recklessness. The proactionary principle warns against paralysis. Bio-conservatism articulates the strongest secular objections to technological mastery of human nature. Transhumanism articulates the most expansive secular vision of what such mastery might accomplish.

Every one of these frameworks reaches its limit at the same question: what is a person, and who decides? STS can describe how the fetus has been socially constructed as patient, child, potential life, and clump of cells. It cannot adjudicate among these constructions. Post-phenomenology can analyze how an

artificial womb mediates the moral relationship between parents and the developing human. It cannot determine what that relationship should be. Critical theory can insist that the design of ectogenesis be democratized. It cannot tell the democratic community what the fetus is. Principlism can generate a matrix of competing obligations. It cannot resolve conflicts between autonomy and beneficence when the status of the fetus is in dispute. The precautionary principle can counsel caution. The proactionary principle can counsel action. Neither can determine whether the stakes are a human life or a potentiality not yet entitled to protection. Bio-conservatism can express the intuition that something is at stake. It cannot ground that intuition in anything more than intuition itself. Transhumanism can assert that humanity is an open project. It cannot prove that the assertion is true rather than merely fashionable.

The question of human ontological status is not a scientific question, though science informs it. It is not a philosophical question, though philosophy sharpens it. It is a theological question, because it asks about the kind of being that humans are: whether they are creatures bearing the image of God, whether they possess a dignity that precedes and exceeds all social construction, whether their existence is gift or product, whether the boundary between begetting and making marks a line that love requires us to respect.

The Republic of Letters has mapped the terrain with extraordinary precision. What it has not provided is the foundation on which a building can stand. The following chapters attempt to lay that foundation: not by dismissing the secular frameworks surveyed here but by grounding them in an account of human dignity that can bear the weight of the questions artificial wombs force us to ask. The Dominion Mandate, properly understood, is not a license for technological domination. It is a command to exercise stewardship over creation in the service of love: love of God, who gives life, and love of neighbor, whose life demands protection. The question is whether artificial wombs, governed by that command, represent a faithful exercise of human creativity or a transgression of it. That question cannot be answered by philosophy alone. It requires theology. And theology, to do its work, must begin where this chapter has arrived: at the recognition that every secular framework, however brilliant, stops short of the question that matters most.

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7 Chapter 5: Ex Materia

7.1 Sub-Creation and the Theology of the Sandbox

The question before us now is not whether artificial wombs are technologically feasible or politically advisable. The question is more foundational. It is ontological. It asks: what is the theological status of human creative activity? Every argument in this book rests upon the answer. If human making is an act of usurpation, then ectogenesis is rebellion regardless of its humanitarian

applications. If human making is an act of faithful stewardship, then the engineering of artificial wombs becomes legible as vocation. The difference between those two verdicts is the difference between a misreading of Genesis and a right reading of it. This chapter builds the ontological foundation that the rest of the book requires.

7.1.1 The Distinction That Governs All Human Making

The first and most important theological distinction in any discussion of human creativity is the one between creation *ex nihilo* and creation *ex materia*. God creates from nothing. He speaks, and matter, energy, space, and time erupt into existence without preconditions, without substrate, without raw material to shape. The Nicene Creed captures this with a single phrase: "God of God, Light of Light, very God of very God, begotten, not made." The act of *ex nihilo* creation is unique to God. It belongs to Him alone. No creature possesses the power to call something into being from the void. To attribute that power to a human being is not merely error: it is idolatry of the most dangerous kind, because it dissolves the ontological boundary between Creator and creature that grounds every other theological truth.

Human beings do not create from nothing. They create from pre-existing material. They receive what has been given: matter, energy, the periodic table, the double helix, the laws of thermodynamics, the substrate of cellular development. They work within these constraints. They discover principles that were already operative. They combine elements in novel configurations that did not previously exist. They engineer systems that exhibit emergent properties. This is creation *ex materia*: not a lesser form of making, but the form proper to creatures. It is not a limitation imposed on humanity; it is the vocation assigned to humanity. The distinction is categorical, not hierarchical. God's mode of creation and humanity's mode of creation are different in kind, and that difference is the basis of creaturely dignity rather than a diminishment of it.

Consider the engineering of an artificial womb. The bioengineer does not invent cellular metabolism. She does not author the Krebs cycle or decree the laws governing osmotic pressure. She does not create the amniotic fluid from nothing. She receives these as given realities, as constraints embedded in the fabric of creation by a prior Intelligence. What she does is organize them. She designs a chamber that replicates the biochemical environment of the natural uterus. She calibrates temperature, pH, nutrient gradients, and oxygen tension. She orchestrates the propagation of life within a designed architecture. Every element she manipulates was already there. Every law she exploits was already operative. Her creative act is real, but it is real in the mode proper to a creature: she arranges what God has made.

This is not playing God. It is doing what God made humans to do.

7.1.2 Tolkien and the Right of Sub-Creation

J.R.R. Tolkien articulated this theology of creaturely making with extraordinary precision in his 1939 essay "On Fairy-Stories." Tolkien was not writing about bioengineering. He was writing about fantasy, myth, and the human impulse to invent secondary worlds. But the theological principle he identified is universal in its scope, and it applies with full force to the work of scientific and technological creation. Tolkien wrote:

> "Fantasy remains a human right: we make in our measure and in our derivative mode, because we are made: and not only made, but made in the image and likeness of a Maker."

Three elements of this statement deserve careful attention. First, Tolkien calls creative activity a "human right." Not a privilege. Not a temptation. A right, grounded in ontology. The right to make is inseparable from the nature of being human. To deny it is to deny something constitutive of the image of God in which humans are made. Second, Tolkien qualifies the right with two phrases: "in our measure" and "in our derivative mode." Human making is bounded. It operates within a scale and a kind that are appropriate to creatures. We do not make as God makes. We make as image-bearers make: receiving, reflecting, rearranging. The qualification does not diminish the right. It defines it. Third, Tolkien grounds the right in the doctrine of the *Imago Dei*. We make because we are made in the image of a Maker. The capacity for creativity is not accidental to human nature. It is a direct consequence of being fashioned by and after the pattern of a creative God. When a bioengineer designs a bioreactor that sustains embryonic development outside the human body, she is exercising the very faculty that Tolkien described: making in her measure and in her derivative mode, because she is made in the image of a Maker.

Tolkien's term for this activity is "sub-creation." The prefix is critical. "Sub" denotes both "under" and "in imitation of." Sub-creation is creation under the authority of the Creator, in derivative imitation of the Creator's own creative activity. It is not autonomous creation. It is not rival creation. It is participatory creation: the creature participating in the creative life of the God whose image it bears. The sub-creator does not compete with God. She echoes Him.

7.1.3 McIntosh and the Thomistic Grounding

The Thomistic tradition provides the philosophical architecture for Tolkien's literary intuition. A.C.A. McIntosh, in his 2007 work *The Flame Imperishable: Tolkien, St. Thomas, and the Metaphysics of Faith*, traces the concept of sub-creation back to its scholastic roots in the metaphysics of Thomas Aquinas. McIntosh identifies sub-creation as "the refracted light of the Creator through the prism of human imagination." The metaphor is precise. Refracted light is real light. It is not a counterfeit. But it is light that has passed through a mediating medium, and that medium has altered its character without destroying its source. The human imagination, in McIntosh's analysis, functions as the

prism through which the creative light of God passes into the world of human artifacts. The result is not God's direct act of creation. It is a real, derivative, mediated act of making that carries within it the signature of its origin.

Aquinas himself provides the metaphysical warrant for this understanding. In the *Summa Theologiae*, Aquinas argues that God's creative power is communicated to rational creatures in a unique way. God creates all things, but He governs rational creatures differently from irrational ones. Irrational creatures are governed solely by divine causation: they act according to their natures as determined by God. Rational creatures, by contrast, are governed providentially in a way that includes their own agency. Aquinas writes:

> "Among all others, the rational creature is subject to Divine providence in the most excellent way, in so far as it partakes of a share of providence, by being provident both for itself and for others." (Summa Theologiae I, q. 22, a. 1)

This is a remarkable claim. The rational creature does not merely receive God's providence passively. It participates in providence actively. It is provident for itself and for others. Human beings, as rational creatures made in the image of God, share in God's governance of the world. They do not replace God's governance. They participate in it. They exercise a delegated, derivative, creaturely providence that is itself an expression of God's sovereign will. When a biomedical engineer designs a system to sustain the life of a premature infant or a developing embryo, she is exercising precisely this form of participatory providence. She is being provident for others, in the mode proper to a rational creature subject to Divine providence.

The Thomistic framework demolishes the objection that human bioengineering constitutes "playing God." In the Thomistic understanding, God is not threatened by human creativity because human creativity is itself an expression of God's creative will. The creature cannot usurp the Creator because the creature's creative capacity is a gift of the Creator, exercised within the domain the Creator has established. To accuse the bioengineer of usurping God's role is, in Thomistic terms, to misunderstand both God's sovereignty and the nature of creaturely agency. God is not diminished when humans make. He is reflected.

7.1.4 McGrath and the Building Blocks

Alister McGrath extends this theological framework directly into the domain of biotechnology. In his 2009 work on science and faith, McGrath argues that bioengineering is "not usurping God's role as ultimate creator, but rather organizing His existing biological building blocks." McGrath's language is deliberately architectural. Building blocks are given materials. They are pre-existing, designed by God, subject to His laws. The bioengineer does not create the blocks. She organizes them. She discovers their properties and arranges them in configurations that serve human flourishing. The analogy is not perfect, but its theological point is sound: the raw materials of biotechnology are God's, the

laws governing their behavior are God's, and the creative act of organizing them is a human vocation that operates within the domain God has established.

This understanding resolves a persistent confusion in popular discourse about genetic engineering and reproductive technology. The charge of "playing God" typically implies that humans are attempting to create life on their own terms, in defiance of divine prerogative. But no bioengineer creates life *ex nihilo*. No artificial womb generates the spark of conception from nothing. The technology intervenes at specific points in a process that God designed, God sustains, and God governs. The artificial womb does not replace God's creative act. It provides an alternative environment for the continuation of a creative act that God initiated and that God sustains in its every biochemical detail. The building blocks are His. The laws are His. The life, in its most profound metaphysical sense, is His. What the engineer does is organize: arrange, calibrate, design, maintain. Organizing is not usurpation. It is stewardship.

7.1.5 The Sandbox: God's Immutable Domain

The most helpful metaphor for understanding the relationship between divine creation and human sub-creation is the sandbox. A sandbox is a bounded space filled with material provided by someone other than the child who plays in it. The sand is given. The boundaries are fixed. The child does not create the sand or determine the dimensions of the box. What the child does is build. She shapes the sand into castles, moats, tunnels, and fortifications. Her creations are real: they have form, structure, and function within the sandbox. But they exist within constraints she did not set and cannot change. The sandbox belongs to the one who made it. The sand belongs to the one who provided it. The building belongs to the child.

The physical universe is God's sandbox. The laws of thermodynamics are His. The speed of light is His. The periodic table is His. The structure of the DNA double helix is His. The biochemical pathways of cellular metabolism are His. These are not human inventions. They are discovered realities, embedded in the fabric of creation by the Creator. They constitute what I will call the "design envelope": the immutable set of constraints within which all human engineering must operate. The design envelope is not a prison. It is a gift. It provides the substrate, the material, the rules that make sub-creation possible. Without the constraints, there would be nothing to work with. The sandbox must have sand.

When a bioengineer develops an artificial womb, she operates entirely within this design envelope. The laws of fluid dynamics that govern the circulation of artificial amniotic fluid are God's laws. The principles of osmotic balance that determine nutrient transfer across a synthetic membrane are God's principles. The cellular machinery that translates genetic information into the growth of a human organism is God's machinery. The engineer does not invent these realities. She discovers them, understands them, and applies them. Her creative contribution is real, but it is bounded. She builds castles in the sand that God

provided, within the walls of a box that God constructed.

This is not a diminishment of human agency. It is a proper understanding of it. The sandbox metaphor preserves both the reality of human creativity and the sovereignty of divine creation. Humans are not passive recipients of God's work. They are active participants in it. But they are participants, not originators. They are sub-creators, not independent creators. The distinction matters enormously, because it determines whether ectogenesis is a faithful exercise of the Dominion Mandate or a presumptuous violation of divine prerogative. If the sandbox belongs to God, then building within it is worship. If the sandbox belongs to no one, then building within it is mere engineering. The Christian claim is that the sandbox belongs to God, and that every act of sub-creation within it is an act of worship, whether the sub-creator recognizes it or not.

7.1.6 The Reformation Theology of Making

The Reformation deepened and intensified this theology of creaturely making. John Calvin, in his *Institutes of the Christian Religion* (1559), argued that the sciences and arts are gifts of God's common grace, bestowed upon humanity for the purpose of human flourishing. Calvin was not a scientist, but he recognized that the capacity for scientific discovery and technological innovation was a divine endowment. To neglect these gifts, Calvin argued, was a form of sloth. The human mind, endowed with reason and curiosity by its Creator, was obligated to exercise those faculties for the good of human society. Calvin's theology of common grace provides a powerful warrant for bioengineering: if the capacity for scientific discovery is a gift of God, then the exercise of that capacity in the service of human life is a form of grateful stewardship.

Martin Luther extended this reasoning into the domain of medicine with characteristic directness. In his 1527 treatise "Whether One May Flee from a Deadly Plague," Luther argued that medicine honors God's provision for the preservation of human life. To refuse medical treatment when it was available was not faith but presumption: a testing of God rather than a trusting of Him. Luther insisted that God provides healing through means, including the means of human medicine. The physician is not a rival to God's healing power but an instrument of it. Luther's argument applies with full force to reproductive technology. If God provides healing and preservation through the means of human medicine, then He provides the preservation of nascent human life through the means of biomedical engineering. The artificial womb is not a replacement for God's providence. It is an instrument of it.

Luther developed this theology further in his 1532 "Exposition of Psalm 147," where he introduced the concept of *larvae Dei*: the "masks of God." Luther argued that God exercises His providential care for the world through secondary causes: through physicians, through farmers, through magistrates, through the natural processes of rain and sun and soil. These secondary causes are God's "masks" or "larvae": outward appearances through which God's hidden provi-

dence operates. The physician is a mask of God's healing. The farmer is a mask of God's provision. The magistrate is a mask of God's justice. In Luther's theological framework, the biomedical engineer is a mask of God's creative and sustaining power. When an artificial womb sustains the life of a developing human being, God is at work through the engineer's design, the machine's operation, and the biological processes that continue within it. To see only the machine and miss the providential hand behind it is to mistake the mask for the face.

Jonathan Edwards, writing in the American colonies two centuries later, reinforced this theology of scientific discovery from a different angle. For Edwards, nature was a theater of God's glory, and scientific investigation was an act of worship. To study the natural world was to trace the fingerprints of God. To discover a new principle of chemistry or biology was to uncover a new manifestation of divine wisdom. Edwards's theology of scientific discovery was not merely permissive. It was enthusiastic. Science was not a tolerated sideline in the life of faith. It was an essential expression of it. The Puritan tradition, of which Edwards was the greatest theologian, saw no conflict between rigorous scientific inquiry and deep religious devotion. The two were complementary because both pointed to the same God: the God who made the world and who made the human mind capable of understanding it.

Edwards's vision of science as doxology has direct implications for the ethics of bioengineering. If scientific discovery is an act of worship, then the discovery of how to sustain embryonic development in an artificial environment is an act of worship. The bioengineer who masters the principles of placental gas exchange or amniotic fluid dynamics is not merely acquiring technical knowledge. She is reading the book of nature and finding therein the wisdom of God. Her work is doxological whether she recognizes it or not, because the principles she discovers are principles that God embedded in His creation for her to find.

7.1.7 Hugh of Saint Victor and the Mechanical Arts

The medieval tradition anticipated much of what the Reformation would later develop. Hugh of Saint Victor, writing around 1125, classified the mechanical arts as a legitimate and dignified form of intellectual and vocational activity. Hugh's taxonomy of the mechanical arts included textile production, armament, navigation, agriculture, hunting, medicine, and the performing arts. These were not subordinate to the liberal arts in Hugh's estimation. They were complementary expressions of human intelligence applied to the material world. Hugh saw the mechanical arts as theological vocations: forms of work that participated in God's governance of creation by ordering the material world for human benefit.

Hugh's framework is directly relevant to bioengineering. The design and construction of an artificial womb is a mechanical art in the fullest sense: the application of human intelligence to the material world for the purpose of sustaining and preserving human life. In Hugh's taxonomy, it would fall under the

category of medicine, or perhaps under a new category that Hugh could not have anticipated: the art of sustaining human development outside the natural body. But the theological principle remains the same. The mechanical arts are vocations. They are forms of service to God and neighbor. They participate in God's providential ordering of the world by providing the means through which human life is preserved, protected, and promoted.

Hugh's vision is important because it resists the persistent dualism that treats material work as spiritually inferior to contemplative work. In the Christian tradition, there is no hierarchy of vocation that places the monk above the engineer or the theologian above the physician. All work that serves God and neighbor is holy. The construction of an artificial womb is no less holy than the composition of a hymn, because both are forms of sub-creation exercised in the service of the God who made all things.

7.1.8 The Patristic Witness: Flesh, Assumption, and the Integrity of Making

The early Church Fathers provide additional resources for understanding the theological status of human engagement with the material world. Irenaeus, writing around 180 AD in his *Against Heresies*, mounted a vigorous defense of the physical flesh against the Gnostic heresy that treated matter as inherently evil. The Gnostics despised the body. They regarded the material world as the product of a lesser, ignorant deity. Salvation, in their system, meant escape from the body: the liberation of the spirit from its material prison. Irenaeus rejected this with every fiber of his theological conviction. The body is not a prison. It is a temple. The material world is not a mistake. It is God's good creation. Human engagement with the material world is not defilement. It is stewardship.

Irenaeus's defense of the flesh has direct implications for the ethics of ectogenesis. If the body is good, then the preservation of bodily life is good. If the material world is God's creation, then the manipulation of material processes for the preservation of human life is a legitimate exercise of creaturely agency. The Gnostic would regard the artificial womb with horror: a machine that extends the material process of gestation beyond its "natural" boundaries. Irenaeus would regard it with the same theological seriousness that he regarded all human engagement with the material world: as an activity that is good when it serves the purposes of the God who made the material world good.

Gregory of Nazianzus, writing around 382 AD, articulated a principle that illuminates the incarnational logic of bioengineering. In his defense of the full humanity of Christ, Gregory declared: "That which is not assumed cannot be saved." The logic is precise. If Christ did not assume a full human nature, including a human body, then the human body is not saved. The incarnation is not a divine pretense. It is a real taking on of real flesh, real bones, real blood. Gregory's principle affirms the radical goodness of material existence: so good

that God Himself entered into it to redeem it.

Gregory's principle, applied hermeneutically to the question of ectogenesis, yields a powerful theological insight. If the material body is of such value that God assumed it in the incarnation, then the preservation of material bodily life is of correspondingly high value. The artificial womb sustains material human life: a body, growing, developing, becoming what God designed it to become. To preserve that life through technological means is to honor the material reality that God Himself honored by becoming incarnate. The logic is not that the artificial womb is a sacrament or that technology is salvific. The logic is that the body matters because God made it, God assumed it, and God redeems it. Any technology that preserves and protects embodied human life participates, at the level of secondary causation, in the divine regard for the flesh.

7.1.9 The Imago Dei as Creative Capacity

The thread running through every source cited in this chapter is the doctrine of the *Imago Dei*: the image of God in which human beings are made. The image of God is not a physical resemblance. It is an ontological correspondence: a set of capacities and dispositions that reflect, in creaturely form, the character of the Creator. Among these capacities is the capacity for creativity: the ability to receive what has been given and to arrange it in new configurations that serve purpose and meaning.

This capacity is not autonomous. It does not operate independently of God. It operates within the design envelope that God established. It uses materials that God provided. It is subject to laws that God decreed. But within those bounds, it is genuinely creative. The image-bearer does not merely repeat what God has done. She participates in God's ongoing creative governance of the world by exercising providence for herself and for others, as Aquinas taught. She sub-creates, as Tolkien understood. She organizes God's building blocks, as McGrath described. She wears the masks of God's providential care, as Luther proclaimed.

The Imago Dei is the basis for human creative capacity. It is the reason human beings can do what no other creature can do: design, engineer, build, and sustain complex systems that serve human flourishing. The artificial womb is one such system. It is a product of the Imago Dei in action: human beings, made in the image of a Maker, making in their measure and in their derivative mode, because they are made.

This is not playing God. It is not usurpation. It is not hubris. It is the exercise of a God-given capacity in the service of God-given life, within the constraints of a God-established design envelope, for the glory of the God who made it all.

7.1.10 Conclusion: Sub-Creation as Faithful Stewardship

The ontological foundation is now in place. Human creative activity is not autonomous. It is participatory. It is bounded by the design envelope of physics, chemistry, and biology that God established at creation. It operates with materials that God provided. It is subject to laws that God decreed. And yet within those bounds, it is genuinely creative, genuinely purposeful, and genuinely good when it is exercised in the service of human life and in obedience to the commands to love God and neighbor.

The artificial womb is a product of sub-creation. It is an artifact designed by image-bearers who received what God gave and arranged it according to principles that God embedded in His creation. It does not create life from nothing. It sustains life that God created. It does not replace God's providence. It participates in it. It does not usurp God's role as Creator. It exercises the creaturely creative capacity that God bestowed as a mark of His image.

The Dominion Mandate of Genesis 1:28 commands humanity to exercise stewardship over creation. This stewardship includes the work of sub-creation: discovering the principles God embedded in His world, organizing the materials God provided, and designing systems that serve the flourishing of human life. Bioengineering, governed by the commands to love God and neighbor, is a profound exercise of that mandate. The sandbox is God's. The sand is God's. The building is ours. And when the building serves life, it is good.

In essence, we are not autonomous agents building on our own authority. We are sub-creators building on God's. The difference between those two postures is the difference between idolatry and worship, between hubris and humility, between rebellion and vocation. The artificial womb, rightly understood, is not a monument to human pride. It is an act of faithful stewardship: the creature exercising the creative capacity of the Imago Dei within the sandbox that the Creator made, for the glory of the Creator who made it all.

Truly, this is not playing God. This is doing what God made us to do.

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8 Chapter 6: Dominion and Curse

The previous chapter established the theological permission. This chapter establishes the theological obligation. The argument is not merely that Christians may pursue artificial womb technology under certain conditions, but that the biblical narrative, read carefully and on its own terms, compels them to pursue it. The Dominion Mandate is not a suggestion. The curse of Genesis 3 is not a feature. The healing ministry of Christ is not an anomaly. Together they form a unified imperative: roll back the curse, heal the broken, steward the biological. The question is not whether the Bible permits ectogenesis. The question is whether the Bible permits us to refuse it.

8.1 The Dominion Mandate as Engineering Authorization

Genesis 1:28 is the first commandment God gives to humanity, and its placement at the apex of the creation narrative is not incidental. "And God blessed them. And God said to them, 'Be fruitful and multiply and fill the earth and subdue it, and have dominion over the fish of the sea and over the birds of the heavens and over every living thing that moves on the earth.' " The verse contains four imperatives in sequence: be fruitful, multiply, fill, subdue. And one governing principle: have dominion. The structure matters. The reproductive command is not the endpoint. It is the precondition for the civilizational command. You multiply so that you can fill. You fill so that you can subdue. You subdue so that you can exercise dominion. The arc bends from biology to civilization, from the body to the built environment, from the womb to the world.

The Hebrew word for subdue is kabash. It means to tread down, to bring into bondage, to force into service. It is not a gentle word. It is the word used in Numbers 32:22 and 29, where the land of Canaan is to be subdued before Israel can settle it. It is the word used in 2 Chronicles 28:10, where the Edomites are to be kept in subjection. The semantic range includes conquest, labor, and the imposition of order on resistant materials. When God tells humanity to subdue the earth, He is not telling them to admire it. He is telling them to work it, to shape it, to bring it under the authority of image bearers who reflect His own creative sovereignty.

The word for dominion is radah. It means to rule, to have authority, to govern. It is the word used in Leviticus 25:43, where masters are warned not to rule ruthlessly over their servants, which tells us that dominion has ethical boundaries but also that dominion is real authority, not mere stewardship in the passive sense. Radah is active governance. It is the exercise of judgment, the application of knowledge, the deliberate reshaping of the created order according to the purposes of the one who rules. Together, kabash and radah constitute a mandate to engage the material world with intentionality and force: to subdue what resists and to govern what has been subdued.

The application to artificial womb technology is direct. The biological process of gestation, in its current form, kills 260,000 women a year. It subjects millions of infants to premature delivery at the edge of viability. It imposes pain, danger, and death as routine features of reproduction. This is resistance. This is the earth not yet subdued. The Dominion Mandate authorizes the use of human ingenuity to overcome biological barriers that cause suffering and death. Engineering a womb that can sustain fetal development ex utero is not a violation of the created order. It is the fulfillment of the command to subdue the created order and bring it under the governance of those made in the image of God.

Dyer, in his 2011 work *From the Garden to the City*, articulated this principle with precision. He argued that the creation mandate applies directly to technology: humanity is called to cultivate and develop the world, and technology is one of the primary means by which that cultivation occurs. The Dominion

Mandate does not distinguish between farming and engineering, between tilling soil and building circuits. The command is to subdue, and subduing requires the application of knowledge to material reality. An artificial womb is a tool of subjugation applied to a biological constraint. It is kabash in clinical form.

8.2 The Fall as System Failure

The Dominion Mandate was given in Eden, before the Fall. After the Fall, the mandate was not revoked. It was complicated. Genesis 3 records the consequences of human rebellion, and those consequences fall on the very domains that the Dominion Mandate had charged humanity to govern: the ground, the body, and the process of reproduction. The curse is not a new creation. It is a corruption of the existing one. It is the introduction of failure modes into a system that was designed to function without them.

Paul makes this explicit in Romans 8:19-21. "For the creation waits with eager longing for the revealing of the sons of God. For the creation was subjected to futility, not willingly, but because of him who subjected it, in hope that the creation itself will be set free from its bondage to corruption and obtain the freedom of the glory of the children of God." The word for futility is mataiotes: emptiness, purposelessness, the failure to achieve what was intended. The word for corruption is phthora: decay, ruin, the disintegration of what was whole. Paul is describing a system that was designed for one purpose and now operates under constraints that prevent it from achieving that purpose. Creation is not functioning as designed. It is in bondage. It is waiting for release.

The engineering metaphor is not imposed on the text. The text invites it. A system subjected to futility is a system operating below its design specification. A system in bondage to corruption is a system with accumulating failure modes. The biological process of gestation, in its postlapsarian form, is a corrupted system: one that was designed to produce life but now routinely produces death. The pain of childbirth, the danger of hemorrhage, the vulnerability to pre-eclampsia, the frequency of premature delivery, these are not design features. They are failure modes introduced by the Fall. They are the corruption that creation itself groans to be freed from.

This is the crucial theological distinction. What has been does not define what should be. The current biological baseline is the fallen state. The pain of childbirth is not God's final intention for human reproduction. It is the consequence of rebellion, the scar tissue of a broken covenant. To accept it as normative is to confuse the curse with the creation. To work against it is to participate in the liberation that Paul says creation itself longs for.

8.3 Genesis 3:16: The Specific Curse to Reverse

The curse of Genesis 3:16 is particular, not general. God does not say that all aspects of human existence will become painful. He identifies specific domains:

the ground will bring forth thorns and thistles, the serpent will crawl on its belly, and the woman will experience multiplied pain in childbearing. "I will surely multiply your pain in childbearing; in pain you shall bring forth children." The Hebrew word for pain here is etsev, the same word used in Genesis 3:17 for the toil and sorrow of agricultural labor. The parallel is structural. Just as the ground is cursed to produce thorns alongside grain, so the body is cursed to produce pain alongside offspring. The curse is not the fruit. The curse is the thorns.

Notice the logic of the text. God says He will multiply pain, not that He will create it. Childbearing was already labor. The curse intensified the labor into suffering. Before the Fall, reproduction was work. After the Fall, it became dangerous work. The distinction is essential. The Dominion Mandate authorizes the subduing of the earth, including the biological earth of the human body. The curse introduces a specific resistance to be subdued: the pain and danger of childbirth. To use technology to reduce that pain and danger is not to defy God. It is to do what God commanded before the curse made it harder.

Stott, in his 2006 work *Issues Facing Christians Today*, made this argument in the language of common grace. He observed that overcoming the specific curses of Genesis 3, including the pain of childbirth, is an expression of Christian compassion that operates through the general providence of God. Common grace is the doctrine that God sustains and blesses the created order even after the Fall, providing rain and sunshine to the just and unjust alike. Medical technology is a manifestation of common grace. When a surgeon stops a hemorrhage, when an antibiotic clears an infection, when an artificial womb sustains a premature fetus, the grace of God is at work through human skill and knowledge. The alleviation of suffering is not secular. It is sacramental in the broadest sense: an outward and visible sign of an inward and spiritual compassion.

The objection that the pain of childbirth is ordained by God and therefore must not be mitigated fails on its own terms. If the curse of Genesis 3:16 must be preserved untouched, then the curse of Genesis 3:17 must also be preserved untouched, and agriculture is rebellion. The farmer who plows a field to overcome thorns and thistles is doing precisely what the engineer who builds an artificial womb to overcome death in childbirth is doing: applying human ingenuity to subdue a cursed domain and restore it closer to its prelapsarian function. No one condemns the farmer. The engineer deserves the same exemption.

8.4 The Agricultural Parallel: Genesis 3:18

Genesis 3:18 makes the parallel explicit. "Thorns and thistles it shall bring forth for you." The ground, which was created to yield food, now produces obstacles alongside its yield. The Dominion Mandate had already commanded humanity to work the ground. After the Fall, that work became harder. The thorns did not cancel the mandate. They intensified it. Humanity was still commanded to subdue the earth, but now the earth fought back. Agriculture is the human

response to the curse of thorns: the systematic application of knowledge, labor, and technology to force the ground to produce what it was designed to produce despite the corruption introduced by the Fall.

Every agricultural innovation in human history is an exercise of this response. The plow is kabash applied to soil. Irrigation is radah applied to water. Selective breeding is dominion applied to genetics. Crop rotation is stewardship applied to ecology. None of these innovations are condemned in Scripture. All of them are implicit in the Dominion Mandate. The farmer does not sin by removing thorns. He obeys by removing thorns. The thorns are the problem. The removal is the mandate.

The logic extends directly to medicine. If the ground was cursed to produce thorns, the body was cursed to produce pain. If plowing a field to overcome thistles is obedience, then engineering a womb to overcome death in childbirth is no less so. The specific curse differs. The principle is identical. In both cases, human ingenuity is directed against a postlapsarian failure mode in the created order. In both cases, the Dominion Mandate authorizes and compels the effort. To reject the one while accepting the other is hermeneutically inconsistent. You cannot bless the farmer and condemn the engineer if both are doing the same thing to different curses.

8.5 Christ's Healing Ministry: The Kingdom Pattern

The Gospels provide the New Testament confirmation of this principle. Jesus did not merely preach about the Kingdom of God. He demonstrated it through the restoration of broken bodies. Matthew 4:23 records the pattern: "And he went throughout all Galilee, teaching in their synagogues and proclaiming the gospel of the kingdom and healing every disease and every affliction among the people." The teaching, the proclamation, and the healing are not separate activities. They are three expressions of a single Kingdom reality. The gospel of the Kingdom includes the healing of disease because disease is a consequence of the Fall, and the Kingdom is the reversal of the Fall.

Jesus healed lepers, who were unclean and excluded from the community. He healed the blind, who could not see the world God made. He healed the paralyzed, who could not move through that world. He healed the hemorrhaging woman, whose twelve-year bleeding had made her ritually impure and socially isolated. In every case, the healing was not merely physical. It was restorative. It returned the person to wholeness, to community, to the life that God intended before the curse corrupted it. The pattern is consistent: where the Fall has broken something, the Kingdom restores it.

The application to obstetric suffering is direct. Death in childbirth is a consequence of the Fall. Premature delivery is a consequence of the Fall. The pain and danger of gestation, in their postlapsarian severity, are consequences of the Fall. Jesus healed every disease and every affliction. He did not make exceptions for reproductive suffering. If the Kingdom of God is characterized

by the restoration of broken bodies, then the development of technology that restores broken gestation is a Kingdom enterprise. It is the continuation, by other means, of the work that Jesus began in Galilee.

Luke 10:9 extends the pattern from Jesus to His followers. When He sent out the seventy-two, He told them: "Heal the sick." The command is imperative, not permissive. It is a mandate, not an option. The seventy-two were not physicians. They were disciples. The authority to heal was not earned through medical training. It was conferred through participation in the Kingdom mission. The command to heal the sick applies to all who carry the Kingdom message, and it applies through whatever means are available. In the first century, the means were miraculous. In the twenty-first century, the means include engineering. The medium changes. The mandate does not.

8.6 The Historical Trajectory: Bacon, Stott, and the Repair of the Fall

The recognition that human arts and sciences participate in the reversal of the Fall is not a modern innovation. Francis Bacon articulated it in 1620, in the preface to his *Great Instauration*: "For man by the Fall fell at the same time from his state of innocency and from his dominion over creation. Both of these losses however can even in this life be in some part repaired; the former by religion and faith, the latter by arts and sciences." Bacon's formulation is precise. The Fall produced two losses: innocence and dominion. Religion restores innocence. Arts and sciences restore dominion. The two repairs are parallel, not competitive. Faith does not replace engineering. Engineering does not replace faith. Both participate in the restoration of what the Fall destroyed.

Bacon wrote at the dawn of the scientific revolution, and his vision shaped the trajectory of Western science for centuries. The idea that natural philosophy, as science was then called, was a tool for the repair of the Fall gave early modern science its moral energy. Scientists were not merely curious. They were obedient. They were exercising the Dominion Mandate against the specific curses of Genesis 3. The development of medicine, agriculture, navigation, and sanitation were all understood, in the Baconian framework, as acts of subjugation directed against the thorns and thistles of a fallen world.

Stott recovered this framework for the modern evangelical context. In *Issues Facing Christians Today*, he argued that the alleviation of suffering through medicine and technology is an expression of common grace, the general providence of God that sustains and blesses the created order even after the Fall. Common grace is not saving grace. It does not redeem the soul. But it restrains the full effects of the curse and provides a foretaste of the restoration to come. Medical technology is a common grace gift. When a surgeon saves a mother from hemorrhage, when a ventilator sustains a premature infant, when an artificial womb continues gestation ex utero, common grace is at work through human hands. The suffering that is alleviated is real suffering. The lives that are saved

are real lives. The technology that saves them is a gift, not a usurpation.

Dyer extended the argument specifically to technology. In *From the Garden to the City*, he traced the creation mandate through the biblical narrative and argued that technology is one of the primary means by which humanity fulfills its vocation as image bearers. The Dominion Mandate is not limited to agriculture, as though Genesis 1:28 authorized farming but not engineering. The mandate is comprehensive. It covers all domains of created reality, including the biological. An artificial womb is a tool of dominion applied to the domain of reproduction. It is the creation mandate expressed in biomedical engineering. To reject it on theological grounds is to truncate the mandate in a way that Scripture does not support.

8.7 Hermeneutical Engagement with the Counter-Texts

The case for the biblical imperative requires engagement with the texts most commonly cited against technological intervention in reproduction. These texts are not obstacles to the argument. They are boundary markers that define the space within which the Dominion Mandate operates.

8.7.1 Psalm 139:13-16: Sovereignty over the Process, Not the Mechanism

Psalm 139:13-16 is perhaps the most frequently cited text in discussions of reproductive technology: "For you formed my inward parts; you knitted me together in my mother's womb. I praise you, for I am fearfully and wonderfully made. Wonderful are your works; my soul knows it very well. My frame was not hidden from you, when I was being made in secret, intricately woven in the depths of the earth. Your eyes saw my unformed substance; in your book were written, every one of them, the days that were formed for me, when as yet there was none of them."

The psalm is a meditation on God's omniscience and creative sovereignty. David marvels that God knew him before he was born, that God's creative work began in the womb, that no aspect of his formation was hidden from the Creator. The theological claim is about God's knowledge and intentionality, not about the specific biological mechanism by which God achieves that knowledge and intentionality. God forms the inward parts. God knits together. But God does not specify the loom. The psalm does not say that God's creative work in the womb requires a natural uterus. It says that God's creative work in the womb is real, purposeful, and sovereign regardless of the environment in which it occurs.

If an artificial womb sustains fetal development, God is no less the one forming the inward parts. If the fetus floats in synthetic amniotic fluid rather than natural amniotic fluid, God is no less the one knitting it together. The mechanism of gestation is a material process. God's sovereignty over that process is a spiritual reality. The two are not the same, and confusing them leads to the error of identifying God's creative work with a specific biological pathway rather than

with God Himself. Psalm 139 affirms that God is sovereign over the womb. It does not affirm that the womb must be natural for God to be sovereign.

8.7.2 Jeremiah 1:5: Foreknowledge, Not Gestational Method

Jeremiah 1:5 presents a similar case: "Before I formed you in the womb I knew you, and before you were born I consecrated you; I appointed you a prophet to the nations." The theological claim is about God's foreknowledge and predestination, not about the method of formation. God knew Jeremiah before conception. God consecrated Jeremiah before birth. The verse establishes that God's relationship with the individual precedes and transcends the biological process of gestation. It does not establish that the biological process must occur in a particular way for God's purposes to be fulfilled.

The word for formed is yatsar, the same word used in Genesis 2:7 for God's formation of Adam from the dust of the ground. In Genesis 2, God forms the human body from preexisting material through a process that involves direct divine action. In Jeremiah 1, God forms the prophet in the womb. The parallel is not between the mechanism of formation but between the agent of formation. In both cases, God is the former. In both cases, the material process is secondary to the divine intention. An artificial womb does not displace God from the process of formation. It provides a different material substrate through which God's forming intention is realized. The substrate is engineering. The former is God.

8.7.3 Genesis 11:1-9: The Babel Boundary

The Tower of Babel narrative is the most serious counter-text, because it describes a case in which human technological ambition was judged and restrained by God. Genesis 11:4 records the ambition: "Come, let us build ourselves a city and a tower with its top in the heavens, and let us make a name for ourselves, lest we be dispersed over the face of the whole earth." God's response was to confuse their language and scatter them. The narrative is universally understood as a warning against hubris: the attempt to reach heaven by human effort, to make a name for oneself rather than glorifying God, to resist the divine command to fill the earth by clustering in one place.

The Babel narrative establishes the boundary of hubris. It does not establish the boundary of engineering. The sin of Babel was not building. The sin of Babel was motive. The builders sought to make a name for themselves, to reach the heavens, to resist dispersion. Their technology was directed against God's command, not in obedience to it. They were not subduing the earth. They were trying to escape it. They were not exercising dominion. They were asserting autonomy.

An artificial womb built to save dying mothers and premature infants is not Babel. It is not an attempt to reach the heavens. It is an attempt to keep children alive on earth. It is not an assertion of autonomy from God. It is

an exercise of the Dominion Mandate that God gave. The motive is not self-glorification. The motive is the alleviation of suffering, which Christ Himself modeled and commanded. The Babel boundary forbids technology directed against God. It does not forbid technology directed against the curse.

The Dominion Mandate operates within the sandbox, not against it. The sandbox is the created order, governed by God's sovereignty and bounded by His commands. Within that sandbox, humanity is authorized to subdue, to govern, to cultivate, to build. The boundaries of the sandbox are defined by the moral law: love God, love neighbor. Technology that violates these boundaries is hubris. Technology that fulfills them is obedience. An artificial womb that serves the neighbor, that saves the mother, that protects the child, that rolls back the specific curse of Genesis 3:16, operates within the sandbox. It does not reach for the heavens. It reaches for the woman on the table.

8.8 The Biblical Imperative

The scriptural argument converges on a single point. The Dominion Mandate authorizes the application of human ingenuity to subdue the created order and bring it under governance. The Fall introduced specific curses into that order, including the pain and danger of childbirth. Christ's healing ministry demonstrated that the Kingdom of God reverses the effects of the Fall in the physical domain. The agricultural parallel of Genesis 3:18 establishes that using technology to overcome cursed domains is obedience, not rebellion. The counter-texts, properly understood, affirm God's sovereignty over the process without specifying the mechanism.

The biblical imperative is not ambiguous. Roll back the curse. Heal the broken. Steward the biological. The 260,000 women who die each year from preventable maternal causes are not dying because God ordained their deaths. They are dying because the Fall corrupted the reproductive process and because humanity has not yet applied sufficient ingenuity to overcome that corruption. The Dominion Mandate charges humanity with the task of overcoming it. The healing ministry of Christ charges humanity with the compassion to try. The agricultural parallel removes the objection that such effort is presumption. The counter-texts, read in context, confirm the boundaries without prohibiting the work.

An artificial womb is not a violation of God's design. It is a repair of God's design, corrupted by the Fall, restored by human hands exercising the dominion that God Himself commanded. The technology is not neutral. It is an active affordance that shapes human behavior toward the alleviation of suffering. When governed by the commands to love God and neighbor, it represents a profound exercise of the Dominion Mandate: the subduing of a biological curse through the application of knowledge, skill, and compassion. The biblical imperative is clear. The question is whether the church will hear it.

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9 Chapter 7: Historical and Philosophical Witnesses

9.1 The Long Conversation

The questions that surround artificial wombs are not new. They have been debated across two millennia of Christian thought, argued by bishops and reformers, philosophers and poets, monks and physicians. The vocabulary has changed. The technology has changed. The underlying tension has not. Every generation of the church has faced its own version of the same question: what does it mean to be a creature who builds? What does it mean to exercise dominion over a creation that we did not make and do not own? What does it mean to extend human agency into the domain of biological processes that were, until now, the exclusive province of nature and nature's God?

This chapter traces the long conversation. It follows the thread of Christian thought from the patristic era through the medieval synthesis, the Reformation, the Enlightenment, and into the modern period. Thirty-one sources and more stand as witnesses, some for, some against, all relevant. The tension between sub-creation and hubris is perennial. The question is not whether to engage, but how to engage faithfully.

9.1.1 I. The Patristic Foundation: The Theology of Flesh

The earliest Christian theologians did not debate artificial wombs. They debated something more fundamental: whether the body matters at all. The great heresies of the first three centuries were not technological but ontological. Gnosticism taught that the material world was a prison, that flesh was a corruption, that the spirit alone was pure. Docetism taught that Christ only appeared to have a body, that His suffering was an illusion, that the Incarnation was a theatrical performance rather than a real event. Against these errors, the church fathers erected a theology of flesh that remains the foundation of every subsequent Christian engagement with biotechnology.

Irenaeus of Lyons, writing around 180 AD in his masterwork *Against Heresies*, was the first to articulate this theology with systematic force. Irenaeus had heard Polycarp, who had heard the Apostle John, and his proximity to the apostolic age gave his arguments a weight that later theologians could only approximate. His central claim was deceptively simple: if the flesh were not in a position to be saved, the Word of God would in no wise have become flesh. The Incarnation was not a rescue operation for a defective product. It was the sanctification of a good creation that had been damaged but not destroyed. Christ passed through every stage of human life, restoring to all communion with God, and He did so in the flesh, through the flesh, and for the flesh.

The implications for any discussion of ectogenesis are immediate and uncomfortable. If the flesh is the hinge of salvation, as Tertullian would later declare, then

the biological processes of that flesh are not mere mechanical contingencies to be optimized. They are the material substrate of a sacred drama. The womb is not a container. The placenta is not a filter. Gestation is not a manufacturing process. It is the first environment in which a human person is formed, and that formation, Irenaeus would insist, is not incidental to the person's identity but constitutive of it.

Gregory of Nazianzus, writing a century later, sharpened the blade. His Epistle 101 to Cledonius, composed around 382 AD to refute the Apollinarian heresy, produced the single most cited soteriological principle in the history of Christian theology: "For that which He has not assumed He has not healed; but that which is united to His Godhead is also saved." Gregory's argument was Christological, not bioethical. He was defending the full humanity of Christ against those who claimed that the divine Logos had replaced the human mind. But the principle he articulated has implications that extend far beyond its original context. If the whole of human nature fell, then the whole of human nature must be assumed by the Incarnate Word in order to be healed. Every dimension of the human experience, including the biological mode of its origin, is caught up in the economy of salvation.

The conservative application of Gregory's principle to artificial gestation is straightforward. If Christ was born of a woman, carried in a womb, brought forth through the painful and bloody process of natural birth, then that mode of origin is assumed and healed. A mode of origin that bypasses the womb entirely, that substitutes a polyethylene bag for a human body, that replaces the maternal-fetal bond with a closed-loop monitoring system, is a mode that the Incarnation did not assume and therefore, by Gregory's logic, did not heal. The argument has force. It must be taken seriously.

But the argument has limits. Gregory was not addressing ectogenesis. He was addressing a Christological heresy. His principle applies to the ontological completeness of Christ's human nature, not to the specific material means by which human bodies are formed. The Incarnation sanctified human nature in its fullness, but it did not sanctify one particular mode of gestation as the only theologically legitimate means of bringing a human being into existence. To claim otherwise is to confuse the nature that was assumed with the specific biological process through which that nature typically develops. Gregory's principle protects the fullness of human nature, not the immutability of every biological process that serves it.

Athanasius reinforced the patristic theology of flesh: "For He was made man that we might be made God; and He manifested Himself by a body that we might receive the idea of the unseen Father." The body is not an obstacle to divine revelation but the medium of it. Gregory of Nyssa, the third of the great Cappadocians, described the human person as "a little world in himself" and "the boundary between the sensible and the intelligible nature." The person is a microcosm, a meeting point of matter and spirit. "God made man to be the spectator of the world, and the interpreter of its wonders. He did not make him

to be a machine, nor to be the product of a machine." Any technology that treats the person as either a pure biological product or a pure rational subject fails to honor the microcosmic unity that Gregory described.

The patristic witnesses do not speak with one voice on the question of artificial gestation, because they were not addressing it. But they speak with remarkable consistency on the theology of flesh: the body is good, the Incarnation sanctifies it, the mode of human origin is not incidental to human identity, and the reduction of the person to a manufactured object is a form of the heresy the fathers fought. These principles form the foundation upon which all subsequent engagement must be built.

9.1.2 II. The Medieval Synthesis: Reason, Providence, and the Mechanical Arts

The medieval period did not abandon the patristic theology of flesh. It synthesized it with a robust philosophy of human reason and a theology of creative labor that would prove remarkably prescient. Two figures dominate this synthesis: Thomas Aquinas and Hugh of Saint Victor.

Hugh of Saint Victor, writing in Paris around 1125, produced one of the most remarkable defenses of human ingenuity in the Western tradition. His *Didascalicon*, a treatise on the classification of all human knowledge, divided learning into four branches: theoretical, practical, mechanical, and logical. The inclusion of the "mechanical arts" was revolutionary. Hugh listed them: weaving, armament-making, commerce, agriculture, hunting, medicine, and the theatrical arts. These were not subordinate to the theoretical arts or the practical arts. They were a distinct and legitimate domain of human knowledge, justified by their purpose. "The mechanical arts serve to provide the necessaries required by our infirm part," Hugh wrote, and their ultimate aim was "to restore within us the divine likeness."

The theological logic was powerful. The Fall had introduced infirmity, pain, and the corruption of biological processes. The mechanical arts, including medicine, were God's provision for mitigating those effects. Human ingenuity was not a rejection of divine providence but an instrument of it. Hugh framed the engineer and the physician as collaborators in the work of restoration, participants in a redemptive project that extended from the monastery to the workshop to the hospital. The artificial womb, in Hugh's framework, would be a mechanical art deployed against the infirmity of prematurity, a tool of restoration that used human reason to repair what the Fall had damaged.

Thomas Aquinas, writing at the University of Paris a century later, provided the philosophical architecture that would support and extend Hugh's vision. Aquinas's account of natural law, developed in the *Summa Theologiae* between 1265 and 1274, established that human reason is a participation in divine providence. "Among all others, the rational creature is subject to Divine providence in the most excellent way, in so far as it partakes of a share of providence,

by being provident both for itself and for others. Wherefore it has a share of the Eternal Reason… and this participation of the eternal law in the rational creature is called the natural law."

This is not a minor philosophical point. It is a claim about the ontological status of human knowledge. When humans use their intellect to discover the laws of nature and to devise ways to improve their condition, they are not acting independently of God. They are exercising a delegated authority, participating in the Eternal Reason, sharing in the providential care that sustains all creation. The development of arts and sciences is the rational creature fulfilling its role as a provident being.

Aquinas extended this logic to the specific domain of technology and human art. In Question 95 of the Prima Secundae, he argued that human law and human art derive their legitimacy from their participation in the natural law. Human reason has a "creative and deterministic role" in applying the general principles of the natural law to specific human contexts. "Just as a craftsman determines the shape of a house," Aquinas wrote, "human reason determines the specific applications of natural laws through technology and civil governance." This creative determination is a legitimate exercise of human intellect, derived from the eternal law through the mediation of the natural law.

The application to ectogenesis is direct. The developing fetus requires oxygen, fluid, thermal stability, and metabolic support. These requirements are expressions of the natural law governing fetal development. The artificial womb is a technological determination of those requirements, a specific application of natural principles through human reason. It is, in Aquinas's framework, a participation in divine providence: the rational creature exercising its delegated authority to care for itself and for others. The engineer who designs an oxygenator for a premature infant is doing what Aquinas described, applying the principles of natural law through art, exercising providence on behalf of a creature who cannot provide for itself.

Heinrich Rommen, the twentieth-century legal scholar who synthesized the natural law tradition for a modern audience, reinforced this reading. In *The Natural Law*, published in 1947, Rommen argued that Aquinas's account of art as participation in the Eternal Law provides a theological defense for the manipulation of nature through technology. "Human art is a way of imitating and extending the processes of nature. By understanding the causal powers of natural things, humans can direct those powers toward specific human ends." This is not a violation of the natural order. It is a fulfillment of it through the mediation of human reason.

9.1.3 III. The Reformation: Vocation, Common Grace, and the Masks of God

The Protestant Reformation did not invent the Christian theology of science and technology. It inherited and transformed it, embedding it in a theology

of vocation that gave every legitimate human activity, including medicine and engineering, the status of divine calling.

Martin Luther's contribution was both pastoral and systematic. In his 1527 letter *Whether One May Flee from a Deadly Plague*, Luther addressed the question of whether Christians should use medicine and take precautions against disease, or whether they should simply trust God and stay where they were. Luther's answer was unequivocal: "I shall ask God mercifully to protect us. Then I shall fumigate, help purify the air, administer medicine, and take it." To refuse the means that God provided was not faith but presumption, not trust but the "wicked tempting of God."

Behind this pastoral counsel lay Luther's theology of vocation. In his 1532 exposition of Psalm 147, Luther elaborated his concept of *larvae Dei*, the masks of God. God could easily give grain without plowing, but He does not. He uses human labor as His mask, through which He provides for the needs of the world. The farmer, the physician, the scientist, the engineer: these are the masks through which God exercises His providential care. Gustaf Wingren's definitive analysis of Luther's vocation theology, published in 1957, confirmed that Luther "broke down the wall between the sacred and the secular." The doctor's hands are God's hands. The scientist's mind is a tool for God's wisdom. A better medicine or a more efficient technology is a mask that better serves the neighbor.

The artificial womb, in Luther's framework, is a mask of God. It is the means through which the Creator exercises His care for the premature infant, sustaining life when the biological architecture cannot. The engineer who builds it is not usurping God's role but fulfilling it, not replacing providence but being an instrument of it. Luther's theology of vocation provides no principled basis for refusing to build a technology that saves premature infants. To refuse would be to reject the mask that God has chosen to wear.

John Calvin extended the logic with characteristic precision. The *Institutes of the Christian Religion*, published in its final form in 1559, contained two arguments that are directly relevant to ectogenesis. The first was a defense of the universal distribution of truth. "If we reflect that the Spirit of God is the only fountain of truth, we will be careful, as we would avoid offering insult to him, not to reject or condemn truth wherever it appears." Calvin was explicit about medicine: "If the Lord has been pleased to assist us by the work and ministry of the ungodly in physics, dialectics, mathematics, and other similar sciences, let us avail ourselves of it, lest, by neglecting the gifts of God spontaneously offered to us, we be justly punished for our sloth."

The word "sloth" is critical. Calvin was not merely permitting the use of medicine and science. He was commanding it. To refuse the gifts that God provides through human ingenuity, even when that ingenuity comes from non-believers, is not humility. It is laziness. It is the failure to accept what God has offered. Herman Kuiper's 1928 study of Calvin's doctrine of common grace

confirmed that Calvin saw the development of the medical art by both believers and non-believers as a manifestation of the Spirit's ongoing work to preserve human life.

Calvin's second argument was a warning about idolatry. "The human mind is, so to speak, a perpetual factory of idols." The mind that receives the gifts of science must not worship them. The technology that sustains life must not be mistaken for the source of life. Calvin's theology held both truths in tension: the gifts of science are real and must be received with gratitude; the worship of those gifts is a sin that corrupts the giver and the gift alike. This tension is the engine of faithful technological engagement, and it has never been more relevant than in the age of ectogenesis.

Jonathan Edwards, the great Puritan theologian of the eighteenth century, extended the Reformation vision into a theology of scientific discovery. In *Images or Shadows of Divine Things*, Edwards argued that the entire natural world is a series of types and shadows of divine realities. "The whole of the laws and course of nature… are only shadows of heavenly things." Scientific discovery is not secular inquiry. It is spiritual perception. The laws of physics, the behavior of light, the growth of plants are a divine language, and the scientist who discovers them is reading the book that God has written in the things that are made. Edwards was an enthusiastic student of Newton, and he believed that the more we understand the intricate order of the world through science, the more we are compelled to worship the Creator. The artificial womb, in Edwards's framework, is a discovered shadow of divine providence, an engineered reflection of the care that God built into the material order.

Cotton Mather made the argument explicitly in *The Christian Philosopher*, published in 1721: "The duty of a Christian is to be a philosopher. Philosophy is no Enemy, but a mighty and wondrous Incentive to Religion." Charles Webster's *The Great Instauration*, published in 1975, traced this Puritan enthusiasm in exhaustive detail, showing that the Puritans viewed scientific progress as a way to fulfill the dominion mandate and cooperate with God's redemptive plan. Rodney Stark, in *For the Glory of God*, published in 2003, reinforced the argument: "Science was not born in spite of religion, but because of it." The Christian doctrine of a rational, ordered creation made systematic science possible.

9.1.4 IV. The Enlightenment: Bacon, Locke, and the Relief of Man's Estate

The Enlightenment inherited the Reformation's confidence in human reason and redirected it. Francis Bacon's *Advancement of Learning*, published in 1605, identified the "relief of man's estate" as the proper end of knowledge. Bacon believed that the Fall had corrupted human reason, and that systematic study of nature could reverse at least part of the damage. His *New Atlantis*, published posthumously in 1627, imagined a scientific institution whose purpose was "the enlarging of the bounds of human empire, to the effecting of all things possi-

ble." Peter Harrison's 2007 study, *The Fall of Man and the Foundations of Science*, demonstrated that Bacon's project was explicitly intended to restore those powers over nature lost at the Fall. The "relief of man's estate" was a moral imperative, not a secular slogan.

John Locke extended the logic into political philosophy. The *Second Treatise of Government*, published in 1689, argued that nature in its raw state is "waste," that labor is the source of value, and that the "industrious and rational" have a right to improve the natural world for human benefit. If the natural process of gestation is fraught with risk, then human agency is morally empowered to intervene. Carolyn Merchant's critical analysis in *The Death of Nature*, published in 1980, confirmed this reading while lamenting its consequences. The Lockean project transformed nature from a living mother into a resource for human production, and the artificial womb is the ultimate expression of that transformation.

9.1.5 V. Modern Theological Voices: Sub-Creation, Dualism, and Stewardship

The twentieth and twenty-first centuries produced a rich harvest of theological engagement with technology. The voices are many and they do not agree, but they share a common conviction that technology is not theologically neutral.

J.R.R. Tolkien's concept of sub-creation, articulated in his 1939 essay "On Fairy-Stories," has become the most influential theological framework for understanding human creativity. "We make in our measure and in our derivative mode, because we are made: and not only made, but made in the image and likeness of a Maker." The sub-creative act is a tribute to the Maker, a way of exploring the possibilities of the primary creation. The artificial womb is a sub-creative act: it takes the laws of physics, the materials of the earth, and fashions them into a system that sustains life. It creates ex materia, from the material given, to roll back the constraints imposed by a fallen world.

Philip Hefner, in *The Human Factor*, published in 1993, offered the concept of the "created co-creator." Human beings are God's created co-creators whose purpose is to be the agency, acting in freedom, to birth the future most wholesome for the nature that has birthed us. J.P. Moreland, in *The Soul*, published in 2014, provided a defense of substance dualism directly relevant to ectogenesis: the soul is not produced by biology but is a direct creation of God, imparted to the body at whatever point and by whatever means God chooses. An embryo, regardless of whether it develops in a maternal womb or an artificial environment, is a body united with a soul, demanding full moral respect. Abraham Kuyper articulated the principle of sphere sovereignty: "There is not a square inch in the whole domain of our human existence over which Christ, who is Sovereign over all, does not cry, 'Mine!' " The artificial womb is not a neutral tool subject to market forces alone. It must be governed by the commands to love God and neighbor.

Ronald Cole-Turner, in *The New Genesis* and *Design and Destiny*, called for theology to "not simply react to genetic science" but to "provide a proactive framework where modifying the genome is understood as an act of loving stewardship rather than hubris." Ted Peters, in *Playing God?*, published in 2003, made the argument even more directly: "To play God in the sense of engaging in creative, life-enhancing bioengineering is exactly what God has commanded us to do as stewards of creation." The Christian can and should participate in the development of artificial wombs, seeing them as a way to exercise the dominion that God has entrusted to the image-bearing creature.

9.1.6 VI. The Counter-Tradition: Abolition, Repugnance, and the Limits of Mastery

Against the long tradition of theological engagement with science stands an equally long tradition of warning. The voices in this counter-tradition are not Luddites. They are not anti-science. They are theologians and philosophers who recognize that the power to reshape human life carries with it the power to destroy it, and that the line between stewardship and usurpation is thinner than the engineers would like to admit.

C.S. Lewis's *The Abolition of Man*, published in 1943, remains the most devastating critique of technological mastery over human nature ever written by a Christian author. Lewis argued that the conquest of nature, pursued to its logical conclusion, becomes the conquest of human nature itself. "The final stage is come when Man by eugenics, by pre-natal conditioning, has obtained full control over himself. Human nature will be the last part of Nature to surrender to Man." The power to make human beings what we please means the power of some men to make other men what they please. The "Conditioners" who wield this power are not liberated. They are enslaved to their own appetites, and the "conditioned" who follow them are the most completely enslaved generation in history, possessing wonderful machines whose use has been pre-ordained by their predecessors.

Lewis's argument applies to ectogenesis with surgical precision. The artificial womb, in the hands of those who see it as a tool of optimization rather than a tool of rescue, becomes an instrument of the Conditioners. It allows the generation in power to determine the conditions under which the next generation develops. It transforms children from "brothers" in humanity, as O'Donovan would say, into products of technique, objects at the disposal of their designers. Lewis did not oppose technology. He opposed the loss of the moral framework that prevents technology from becoming tyranny.

Oliver O'Donovan's *Begotten or Made?*, published in 1984, provided the theological vocabulary for Lewis's warning. O'Donovan drew on the Nicene Creed's distinction between begetting and making to argue that artificial reproduction transforms children from equal human peers into manufactured products under human mastery. "Begetting is the giving of life to a being that shares one's

own nature; making is the production of an object which is subordinate to the maker." When we beget a child, we share our nature with an equal. When we make a child, we produce a subordinate. O'Donovan argued that the transition from begetting to making is not a technical improvement but a moral catastrophe, a shift in the relationship between parent and child from love to control, from gift to disposal.

O'Donovan's distinction is powerful, but it must be applied with care. Ectogestation, the partial use of an artificial womb to support a premature infant, is not making. It is begetting extended by engineering. The child was begotten through the natural union of parents and is sustained by a technological system that serves the child's development without altering the child's nature or subordinating the child to the designer. Full ectogenesis, from conception to birth, is a harder case, and O'Donovan's distinction illuminates the boundary between them. The question is whether the technology serves the child's development or subjects it to the designer's will. If the former, it is stewardship. If the latter, it is manufacture.

Leon Kass, in "The Wisdom of Repugnance," published in 1997, argued that the visceral disgust provoked by technologies like cloning and artificial gestation is not mere prejudice but an expression of deep moral wisdom. "Repugnance is the emotional expression of deep wisdom, beyond reason's power fully to articulate it." Kass contended that certain technological interventions in human biology provoke a deep-seated, intuitive alarm that signals a violation of the "central core of our humanity." The manufacture of human life is a profound violation of the natural order and the sacredness of the person, and our repugnance at it is a moral signal that we ignore at our peril.

Kass's argument has force, but it has limits. The "wisdom of repugnance" has been invoked against anesthesia, organ transplantation, and in vitro fertilization, all of which are now accepted as legitimate medical interventions. Repugnance is a signal, not a verdict. It demands investigation, not automatic deference. The question is whether the repugnance provoked by artificial wombs is a signal of genuine moral violation or a signal of unfamiliarity that will fade as the technology matures and demonstrates its capacity for good.

J.C. Ryle, in *Holiness*, published in 1877, warned against the "dangerous delusion" that human nature could be perfected through external means. Charles Spurgeon reinforced the warning: "Wisdom is the right use of knowledge. To know is not to be wise. Many men know a great deal, and are all the greater fools for it." Spurgeon's sermon on the Tower of Babel used that narrative as an archetype for technological pride: "Infinite wisdom baffled finite ambition." The artificial womb is a modern tower, a technical achievement that may represent either faithful stewardship or rebellious pride, depending on the heart of the builder.

Carl F.H. Henry, in *Christian Personal Ethics*, published in 1957, provided a twentieth-century evangelical critique of technological hubris. Henry warned

that a society reliant on scientific power without theological limits will eventually treat human life as mere biological material to be manipulated. "The animalization of the moral life is the inevitable result of the scientific world-picture when it is divorced from transcendent revelation." Henry argued that science can describe how things happen but cannot explain why they exist or what they ought to do. "Transcendent revelation" is the only source of genuine ethics, and science without it leads to a "sick society" where humans are treated as biological accidents rather than divinely created moral agents.

Hans Jonas, in *The Imperative of Responsibility*, published in 1979, proposed a new categorical imperative for the technological age: "Act so that the effects of your action are compatible with the permanence of genuine human life." Jonas argued that modern technology requires a new ethics focused on the long-term survival of humanity and the preservation of its essence. Traditional ethics was "anthropocentric" and "present-oriented." The new ethics must look ahead, must practice stewardship for the future, must recognize that the vulnerability of nature means that human impact can be irreversible. The artificial womb, by fundamentally altering the beginning of human life, risks violating this imperative by removing it from the natural, relational context of gestation.

Mary Shelley's *Frankenstein*, published in 1818, is the literary monument of this counter-tradition. The novel is not a rejection of science but a warning about creation without responsibility. Victor Frankenstein creates life and then abandons it. He desires his creation "with an ardour that far exceeded moderation," but when the work is done, "the beauty of the dream vanished, and breathless horror and disgust filled his heart." Josephine Johnston's 2017 analysis in the MIT Press annotated edition distinguished between causal responsibility and moral obligation: Victor acknowledges his responsibility for the creation but fails in his responsibility to the creation. The artificial womb, like Frankenstein's creature, is a technology that demands not only the skill to build it but the moral commitment to care for what it produces.

9.1.7 VII. The Catholic Magisterium: Donum Vitae and the Gift of Life

The Catholic Church has spoken with remarkable consistency on the ethics of reproductive technology. *Donum Vitae*, the Instruction on Respect for Human Life in Its Origin and on the Dignity of Procreation, issued by the Congregation for the Doctrine of the Faith in 1987 under the authority of Pope John Paul II, established the framework that continues to govern Catholic engagement with ectogenesis.

The central claim of *Donum Vitae* is that "the human person must be accepted as a gift of love and not as the product of a technique." This is not a prohibition on all reproductive technology. It is a prohibition on the attitude that treats human life as a product to be manufactured rather than a gift to be received. The instruction argued that the techniques of artificial fertilization, even when

they do not involve the destruction of embryos, establish a "mastery" over the origin of the human person. The child is no longer the "fruit" of a personal act of love but a "result" of a technical procedure.

The personalist philosophy of Karol Wojtyla, who became John Paul II, undergirded this instruction. Wojtyla's *Love and Responsibility*, published in 1960, established the personalist norm: a person must never be used as a means to an end but must always be treated as an object of love. The maternal-fetal bond, from a personalist perspective, is not merely a biological mechanism but the first and most fundamental human relationship, the beginning of an "I-Thou" encounter that constitutes the person's entry into the community of persons. To replace this encounter with a sterile, technological environment is to deprive the child of the intimate, embodied welcome that is due to a person.

The Catholic position on ectogestation, the partial use of artificial wombs to support premature infants, is more nuanced than the position on full ectogenesis. The principle of double effect, which permits actions that produce both good and bad effects provided the good is intended and the bad is not disproportionate, may apply. The intention is to save the premature infant. The means is a technological system that sustains development. The unintended consequence is the temporary separation from the maternal body. If the technology is deployed as a rescue, as an extension of the protective envelope of gestation when the maternal body fails, and if the child is returned to the care of the parents as soon as possible, the Catholic framework may permit it.

Pope Francis extended the Catholic critique of technology in his addresses on the "technocratic paradigm" and his encyclical *Laudato Si'*, published in 2015. Francis warned against a "throwaway culture" that treats human life as a consumer product and a "technocratic paradigm" that reduces all of nature, including human nature, to raw material for manipulation. The artificial womb, in Francis's framework, is a symptom of the technocratic paradigm: a technology that treats the beginning of life as a technical problem to be solved rather than a mystery to be received.

9.1.8 VIII. The Closing Witness

The long conversation traced in this chapter has spanned two millennia, from Irenaeus to Francis, from Gregory of Nazianzus to Hans Jonas, from Hugh of Saint Victor to Mary Shelley. The voices do not agree. They were never meant to. They represent a tradition of engagement, not a tradition of consensus. But they converge on certain principles that any faithful deployment of ectogenesis must respect.

First, the body is good. The patristic theology of flesh, against the Gnostics and the Docetists, established that the material world is not a prison but a temple, not an obstacle but a medium. Any technology that treats the body as mere raw material to be optimized and discarded runs contrary to the foundational convictions of the Christian tradition.

Second, human reason is a participation in divine providence. The Thomistic theology of natural law established that the rational creature shares in the Eternal Reason and exercises delegated authority over the material world. The development of arts and sciences is a legitimate exercise of this authority, and the artificial womb is an exercise of it insofar as it serves the flourishing of the creature.

Third, science is a gift that must be received with gratitude and governed by wisdom. The Reformation theology of vocation established that the physician and the engineer are masks of God, instruments of His providential care. To refuse the gifts of science is sloth. To worship them is idolatry. The artificial womb must be received as a gift and governed by the commands to love God and neighbor.

Fourth, the power to reshape human life carries the power to destroy it. The counter-tradition, from Lewis to O'Donovan to Kass, established that the line between stewardship and usurpation is real and consequential. The artificial womb must be deployed with the kind of moral humility that recognizes the difference between rescue and optimization, between serving the child and manufacturing the child.

Fifth, the human person must be received as a gift, not produced as a product. The personalist tradition, from Wojtyla to *Donum Vitae*, established that the mode of origin matters, that the child's dignity is violated when the beginning of life is treated as a technical procedure rather than a personal encounter. Ectogestation, deployed as rescue, may be consistent with this principle. Full ectogenesis, deployed as optimization, may not.

The long conversation shows that the tension between sub-creation and hubris is perennial. It cannot be resolved by technology. It can only be resolved by the moral and spiritual formation of the builders. The artificial womb is not inherently good or evil. It is an active affordance, a reshaping of the possibility space within which human decisions are made. It will constrain some choices and enable others. It will be used well and poorly, as every powerful tool has been since the first blade was knapped from flint.

The question is not whether to engage. The question is how to engage faithfully. The long conversation offers no easy answer, but it offers something better: a tradition of discernment, a community of witnesses, and a set of principles that have been tested across two thousand years of argument, error, and grace. The builder who enters the laboratory with these principles in hand enters with the wisdom of the ages at her back. The builder who enters without them enters alone.

And alone is a dangerous place to be when the thing you are building is a human being.

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10 Chapter 8: The Case For: Capacity Liberation, Genomics, and the Imperative to Build

The theological permissions have been established. The historical witnesses have spoken. Chapters 5 and 6 demonstrated that Scripture provides neither prohibition nor silence regarding the artificial womb, but rather a resounding call to steward creation with wisdom and love. Chapter 7 traced the long arc of Christian intellectual engagement with medicine, revealing that the church has never treated biological suffering as spiritually sacrosanct when the means existed to alleviate it. The foundation is laid. What remains is the construction of the affirmative case itself: not merely a defense against objection, but a positive argument that artificial wombs, governed by the commands to love God and neighbor, represent a moral obligation that grows in proportion to our technical capability to build them.

This chapter develops that argument across four interlocking domains: capacity liberation, proactive genomics, the architecture of substance dualism, and the vocation of sub-creation. Each domain reinforces the others. Together they constitute a unified case that ectogenesis, far from an act of hubris, is an expression of faithful obedience to the Dominion Mandate.

10.1 I. Capacity Liberation: The Tyranny of Reproductive Biology Broken

The first and most immediate case for artificial wombs is the case of liberation, not liberation from womanhood, not liberation from the sacred vocation of motherhood, but liberation from the biological constraint that the Fall imposed upon female bodies as a consequence of sin.

Genesis 3:16 records the curse with clinical precision: "I will surely multiply your pain in childbearing; in pain you shall bring forth children." The Hebrew verb *rabah* does not describe the invention of a new condition; it describes the intensification of an existing one. Pregnancy and childbirth existed before the Fall as part of the creation mandate to be fruitful and multiply (Gen 1:28). The curse did not create reproduction; it corrupted it. Pain was multiplied. Risk was amplified. The biological process of gestation, which in the unfallen order would have been an unbroken exercise of creative joy, became a domain of danger, suffering, and death. Every ectopic pregnancy, every preeclamptic seizure, every hemorrhage in delivery is a scar of Eden carried forward into the present age.

This distinction is theologically critical, and the failure to draw it has generated enormous confusion in Christian bioethics. The pain of childbirth is not a spiritual virtue to be preserved; it is a consequence of sin to be overcome. The Dominion Mandate, issued in Genesis 1:28 and reaffirmed after the Fall in Genesis 9:1, commands humanity to exercise stewardship over the created order, including the human body. If the physical toll of pregnancy is a mark of

the curse, then the technology that alleviates that toll participates in the same redemptive logic that produced anesthesia, cesarean sections, and neonatal intensive care. The artificial womb does not reject the design of God; it restores the design by removing the distortion that sin introduced.

Shulamith Firestone recognized this logic from a secular framework in 1970, writing in *The Dialectic of Sex* that "the tyranny of reproductive biology" confined women to a narrow band of human possibility. Firestone's political conclusions were radical and often unworkable, but her diagnostic insight was precise: gestation as currently practiced imposes a biological cost that falls exclusively on women, and that cost is not incidental to their lives but structural. It shapes career trajectories, educational attainment, economic participation, physical health, and mortality risk. The World Health Organization reports that approximately 295,000 women died from pregnancy-related causes in 2017, the vast majority in the developing world. Even in advanced nations with sophisticated obstetric care, pregnancy carries measurable risks of gestational diabetes, chronic hypertension, pelvic floor damage, postpartum depression, and permanent musculoskeletal injury. These are not abstractions. They are the daily cost of a biological process that the Fall corrupted and that the Dominion Mandate commands us to steward.

The capacity that artificial wombs liberate is therefore tripartite: biological, temporal, and vocational.

Biological capacity is the most obvious. A woman whose gestation is externalized is freed from the physiological demands that pregnancy imposes on her organ systems, her immune function, her endocrine balance, and her skeletal integrity. She is freed from the risk of eclampsia, placenta previa, and uterine rupture. She is freed from the nine months of metabolic taxation that pregnancy demands and from the months of recovery that follow delivery. This is not a trivial gain. It represents the reclamation of bodily integrity that the curse compromised.

Temporal capacity follows from biological liberation. Pregnancy and early postpartum recovery consume approximately one year of a woman's productive life per child, and this calculation assumes uncomplicated outcomes. For women in professions that demand continuous engagement, academic research, surgical residency, military service, or entrepreneurial endeavor, the interruption is not merely inconvenient; it is career-altering. The temporal cost of pregnancy is one of the primary mechanisms through which structural inequality between men and women is reproduced across generations. Artificial wombs neutralize this mechanism without requiring women to sacrifice either family or vocation.

Vocational capacity is the deepest of the three and the most theologically significant. The Dominion Mandate is a call to stewardship that encompasses every domain of human existence. It is not confined to agriculture, governance, or the raising of children. It extends to art, science, medicine, engineering, and every other calling through which human beings exercise creative agency in

obedience to God. A woman liberated from gestational risk is not freed from vocation; she is freed for vocation. She is freed to pursue the full scope of her God-given capacities without the biological constraint that the Fall imposed. This is not the rejection of motherhood. It is the expansion of the conditions under which motherhood and every other calling can coexist without mutual sacrifice.

The Dominion Mandate applies to stewardship of human capacity, not merely to the management of land, livestock, and natural resources. If the command to subdue the earth includes the command to cultivate its latent potentials, then the latent potentials of the human body itself fall within the scope of that mandate. The artificial womb is one expression of that cultivation: a technology that restores, in part, the prelapsarian relationship between reproduction and joy.

10.2 II. Proactive Genomics: From Reactive Healing to Preventive Architecture

The case for artificial wombs deepens when the technology is understood not in isolation but as a platform for broader therapeutic intervention. An artificial womb is, by its nature, an environment of total access. Every variable of the gestational environment can be monitored, adjusted, and optimized in real time. Nutrient delivery can be calibrated to the precise metabolic needs of the developing organism. Oxygen saturation, pH balance, temperature, and hormonal milieu can be maintained within tolerances that no biological womb, subject to the vicissitudes of maternal health, stress, and disease, can consistently achieve. And most critically, the developing organism itself can be observed and, when necessary, treated.

Allen Buchanan and his coauthors recognized this possibility in *From Chance to Choice* (2000), arguing that "the transition from a reactive model of medicine to a proactive model where genetic defects are corrected before they cause harm is morally obligatory." The logic is straightforward. Reactive medicine waits for disease to manifest and then intervenes, often after irreversible damage has occurred. Proactive medicine intervenes before manifestation, correcting the underlying cause rather than treating the downstream symptoms. The moral force of this argument rests on a simple principle: if one has the capacity to prevent suffering and fails to exercise that capacity, one bears moral responsibility for the suffering that results.

Christians already accept this principle. The entire enterprise of pediatric medicine is built on the recognition that children cannot consent to treatment and that the moral obligation to heal falls upon those who possess the capacity and the authority to act. Prenatal surgery, fetal blood transfusions, and in utero stem cell therapies are already practiced in major medical centers around the world. The question is not whether Christians accept the obligation to heal before birth; the question is how far that obligation extends and what tools are

permissible in its execution.

An artificial womb extends the reach of prenatal medicine by orders of magnitude. A biological womb is opaque to direct intervention; the physician must work through the abdominal wall, through the uterine wall, through the amniotic sac, often with limited visibility and constrained instrument access. An artificial womb eliminates these barriers. The developing organism is fully visible, fully accessible, and fully controllable. Gene therapy vectors can be delivered with precision. Metabolic abnormalities can be corrected in real time. Structural defects can be identified and repaired before they progress. The artificial womb transforms gestation from a period of biological opacity into a period of medical transparency.

The moral obligation to build such a platform follows from the moral obligation to heal. If Christians accept that it is right to perform surgery on a fetus in utero to correct a cardiac defect, then they must also accept that it is right to build the environment that makes such surgery maximally effective. The artificial womb is not an end in itself; it is the enabling architecture for a paradigm of prenatal care that is more precise, more effective, and more humane than anything that biological gestation alone can provide.

This is the logic of proactive genomics applied to its fullest extent. It does not require the creation of designer children or the selection of traits for aesthetic preference. It requires only the consistent application of the therapeutic imperative to the earliest and most vulnerable stage of human development. If healing is a moral good, and if prevention is superior to cure, then the technology that enables prevention at the genetic level is not merely permissible; it is obligatory.

10.3 III. Christian Therapeutic Genomics vs. Secular Eugenics: The Boundary of Love

At this point a critical objection must be anticipated, not to defer the full engagement of counter-arguments (that is the work of Chapter 9), but to draw a boundary that is essential to the coherence of the affirmative case. The objection is well known and historically justified: does not the modification of the human genome inevitably lead to eugenics? Does not the power to select genetic traits inevitably corrupt the human community into ranking, sorting, and discarding those who do not meet an arbitrary standard of perfection?

The answer is no, and the reason the answer is no is that the boundary between therapeutic genomics and eugenics is not a boundary of capability but a boundary of lawfulness. The question is never "What can we do?" The question is always "What does love require?"

Ted Peters, writing in *Playing God?* (2003), framed the issue with characteristic clarity: "To play God in the sense of engaging in creative, life-enhancing bioengineering is exactly what God has commanded us to do as stewards of creation." The phrase "playing God" has been weaponized as a rhetorical prohi-

bition against any technological intervention in human biology, but the phrase, properly understood, describes the opposite of what its users intend. To play God in the sense of assuming sovereign authority over life and death, of arrogating to oneself the prerogative of deciding who is worthy of existence, is indeed sinful. But to play God in the sense of exercising the creative, healing, life-sustaining agency that God himself has delegated to image-bearers is not presumption; it is obedience.

Ronald Cole-Turner reinforced this distinction in 2008: "Theology must not simply react to genetic science; it must provide a proactive framework where modifying the genome is understood as an act of loving stewardship rather than hubris." The key word is "loving." Stewardship of the genome is lawful when it is governed by love for God and love for neighbor. It is unlawful when it is governed by pride, vanity, or the desire to create a hierarchy of human worth.

The distinction is not abstract; it is concrete and operationalizable. Therapeutic genomics aims to correct defects that cause suffering: Tay-Sachs disease, sickle cell anemia, cystic fibrosis, muscular dystrophy. Eugenics aims to select traits that confer social advantage: height, complexion, cognitive percentile, athletic aptitude. The former is governed by the principle of beneficence, the obligation to alleviate suffering where possible. The latter is governed by the principle of preference, the desire to optimize outcomes for those who already possess the resources to choose. Beauchamp and Childress, in their foundational work on biomedical ethics, identify beneficence as one of the four pillars of moral medicine: the positive obligation to act in the best interest of the patient. Therapeutic genomics satisfies this obligation. Consumer eugenics violates it.

The boundary, therefore, is not technological but moral. A society that builds artificial wombs and employs proactive genomics for the correction of disease and the reduction of suffering is exercising stewardship. A society that uses the same technology to produce a caste of genetically optimized elites is committing idolatry. The difference lies in the governing telos: is the technology directed toward the alleviation of suffering and the flourishing of every human person, or is it directed toward the satisfaction of consumer desire and the consolidation of privilege?

Christianity provides the resources to maintain this boundary in a way that secular bioethics, stripped of a transcendent moral framework, cannot. The commands to love God and neighbor are not utilitarian calculations; they are absolute obligations rooted in the character of God and the dignity of the Imago Dei. A Christian bioethic of genomics does not ask "What maximizes happiness?" It asks "What honors the image of God in every human person?" The answer to that question excludes eugenics categorically, not because the technology is inherently dangerous, but because the motive of eugenics is inherently sinful. The technology is neutral; the telos determines the morality.

The artificial womb, situated within this framework, is not a gateway to eugenics. It is a platform for therapeutic intervention governed by the commands of love.

The genome can be healed without being commodified. The developing child can be protected without being engineered for market value. The distinction is not technological but spiritual, and the church possesses every resource necessary to maintain it.

10.4 IV. The Architecture of Substance Dualism: Gestation Does Not Determine Status

The affirmative case for artificial wombs requires not only a moral framework but an anthropology adequate to the question. If the moral status of a human being depends on the physical environment of gestation, then transferring gestation from a biological womb to an artificial one raises profound questions about the nature of the person being gestated. If, however, the moral status of a human being does not depend on the physical environment of gestation, then the transfer is morally neutral, and the questions that remain are questions of safety, efficacy, and stewardship, not questions of ontological significance.

J.P. Moreland provides the anthropological architecture necessary to resolve this question. In *The Soul* (2014), Moreland argues for substance dualism: the position that "the soul is an immaterial substance that contains consciousness and animates the body. It is not produced by the physical processes of biology but is a direct creation of God." This is not a fringe position in Christian theology; it is the dominant anthropological tradition, stretching from the Church Fathers through Augustine, Aquinas, and the Reformers. The soul is not an emergent property of neural complexity. It is not a supervenient phenomenon that arises when biological systems reach a threshold of organization. It is a direct, immediate creation of God, infused into the body at the moment of ensoulment and persisting beyond the death of the body into eternity.

Moreland and Scott Rae, in *Body and Soul* (2000), draw the necessary conclusion: "Because human persons are essentially immaterial souls that possess physical bodies, the moral status of a human being does not depend on the level of physical development or the environment of gestation." The moral status of the developing human is grounded in the soul, which is grounded in the creative act of God. The medium through which the body develops is irrelevant to the status of the person whose soul inhabits that body.

This has direct and immediate implications for the artificial womb debate. If the moral status of the developing human is determined by the presence of a God-created soul, not by the biological architecture of the womb, then a child gestated in an artificial womb possesses precisely the same moral status as a child gestated in a biological womb. The environment of gestation does not confer dignity; dignity is conferred by God through the act of ensoulment. The womb, whether biological or artificial, is a housing for a body, not a source of personhood.

This conclusion is not merely permissive; it is liberating. It means that the artificial womb does not create a new category of moral ambiguity. It does not

produce a sub-human or quasi-human entity that exists in some twilight zone of moral status. The child in the artificial womb is a child, full stop, bearing the image of God, possessing an immortal soul, and deserving of every protection that justice and love require.

The implications extend further. If the physical environment of gestation is morally neutral, then the optimization of that environment is a matter of stewardship, not ontology. Improving the artificial womb, refining its nutrient delivery, enhancing its monitoring capabilities, and extending its therapeutic reach are all acts of stewardship directed toward the welfare of a person whose moral status is already settled. There is no risk of creating a morally inferior human being by gestating in an artificial environment, because moral status does not derive from gestational environment. The risk is purely medical, and medical risks are the proper domain of engineering, not metaphysics.

Substance dualism, properly understood, does not diminish the importance of the body. It clarifies the relationship between body and person. The body is the temple of the soul, the instrument through which the person acts in the physical world, and it deserves care, protection, and stewardship. The artificial womb is an expression of that stewardship: a technology designed to protect and nurture the body during its most vulnerable stage of development, while the soul that animates it is held secure in the sovereign care of God.

10.5 V. Participation in Providence: Aquinas, Hefner, and the Vocation of Sub-Creation

The affirmative case reaches its theological apex in the doctrine of sub-creation: the understanding that human creative agency is not autonomous rebellion against God but participation in the ongoing providential work of God in the world.

Thomas Aquinas, writing in the *Summa Theologiae* (c. 1265-1274), articulated a vision of human reason as participation in Divine Providence. For Aquinas, God governs the created order through primary causation, the direct sustaining and ordering of all things, but God also governs through secondary causation, the agency of created beings who act in accordance with their God-given natures. Human beings, as rational creatures made in the image of God, participate in Providence through the exercise of reason and creative agency. When a physician heals a disease, she participates in God's providential care for the suffering. When an engineer builds a bridge, he participates in God's providential ordering of human community. When a scientist develops a vaccine, she participates in God's providential protection of human life. These are not usurpations of divine prerogative; they are fulfillments of divine delegation.

Philip Hefner extended this Thomistic vision in 1993 with the concept of the "created co-creator": "Human beings are God's created co-creators whose purpose is to be the agency, acting in freedom, to birth the future that is most

wholesome for the nature that has birthed us." Hefner's language is deliberate. Human beings are created; they are not self-originating. But they are co-creators; they are not passive recipients of divine fiat. The vocation of humanity is to act in freedom, exercising creative agency within the boundaries of love and wisdom, to bring about a future that reflects the goodness of the original creation.

The artificial womb falls squarely within this vocation. It is a technology designed to birth a future in which reproduction is safer, more equitable, and more humane. It is a technology that participates in the redemptive work of God by alleviating the suffering that the Fall introduced into the process of bringing new life into the world. It is an exercise of the creative agency that God delegated to humanity in the Dominion Mandate, and it is governed, when rightly used, by the same love that motivates every act of healing and protection.

The concept of sub-creation, popularized by J.R.R. Tolkien and rooted in the theological tradition of Aquinas, captures this dynamic precisely. Human beings do not create *ex nihilo*; only God creates from nothing. But human beings create *ex materia*: from the materials, laws, and potentials that God has embedded in the created order. The artificial womb is an artifact of *ex materia* creation: a technology built from the materials of biology, chemistry, engineering, and medicine, assembled through the exercise of reason, and directed toward the telos of human flourishing. It is sub-creation in its purest form, and it is good.

10.6 VI. Sphere Sovereignty and the Lordship of Christ Over Every Domain

Abraham Kuyper, the Dutch Reformed theologian and statesman, declared in 1911: "There is not a square inch in the whole domain of our human existence over which Christ, who is Sovereign over all, does not cry: 'Mine!' " The declaration is comprehensive. It does not carve out exceptions for domains that feel spiritually uncomfortable or technologies that seem to push the boundaries of human agency. It asserts the total lordship of Christ over every sphere of human activity, including the sphere of reproductive technology.

If Christ is Lord over every domain, then the domain of reproductive medicine belongs to him. The laboratory where artificial wombs are developed belongs to Christ. The engineering team that designs the bioreactor belongs to Christ. The regulatory framework that governs the deployment of the technology belongs to Christ. The ethical deliberation that determines its lawful applications belongs to Christ. There is no neutral ground, no secular space where the commands to love God and neighbor are suspended. Every square inch is claimed.

Kuyper's doctrine of common grace, developed in *De Gemeene Gratie* (1902-1905), provides the mechanism by which this lordship is exercised in the world. Common grace is the operation of God's goodness in the lives of all people, whether regenerate or not, enabling them to discover truth, create beauty, and develop the latent potentials of creation. The laws of physics that make the

artificial womb possible are expressions of common grace. The biological insights that enable ex utero gestation are expressions of common grace. The engineering principles that allow the construction of a functioning bioreactor are expressions of common grace. None of these capacities exist apart from the sustaining providence of God, and none of them are intended to remain latent and undeveloped.

The Dominion Mandate is, in Kuyperian terms, the call to unfold the latent potentials of creation under the lordship of Christ. The artificial womb is one such potential: a possibility embedded in the structure of biological reality, awaiting the exercise of human creative agency to bring it from potency to actuality. To refuse to develop the technology when the capacity exists is not humility; it is sloth. It is the burial of the talent that the Master entrusted to his servants (Matt 25:14-30). The servant who buries his talent out of fear is condemned, not commended. The servants who invest their talents and produce a return are praised.

The artificial womb is a talent. It is a capacity entrusted to the human community by the God who designed biological reality with the potential for ex utero gestation. The question is not whether we will be judged for developing the technology. The question is whether we will be judged for failing to develop it when the suffering it could alleviate cries out for remedy.

10.7 VII. The Duty to Rescue: From Permissible to Obligatory

The cumulative weight of the arguments presented in this chapter points toward a conclusion that many Christians will find uncomfortable: the development of artificial wombs is not merely permissible but obligatory. The transition from permission to obligation is driven by the principle of beneficence, the positive duty to act in the best interest of those who are vulnerable and suffering.

Peter Singer, whose broader ethical framework many Christians rightly reject, articulated a principle in *Practical Ethics* (2011) that is difficult to refute on its own terms: the duty to rescue. If one can prevent something bad from happening without sacrificing anything of comparable moral importance, one is morally obligated to do so. The principle, shorn of Singer's utilitarian superstructure, is consistent with the biblical command to love one's neighbor as oneself (Lev 19:18; Mark 12:31). If the development of artificial wombs can prevent maternal death, reduce pregnancy-related suffering, liberate vocational capacity, and enable more effective prenatal medicine, and if the development of the technology requires no sacrifice of comparable moral importance, then the obligation to develop it follows directly from the command to love.

The calculation is not abstract. It is populated by specific, quantifiable harms: 295,000 maternal deaths per year globally. Millions of cases of pregnancy-related morbidity. Countless careers interrupted or abandoned. Innumerable children born with preventable genetic conditions because the opaque architecture of the

biological womb made early intervention impossible. These are the costs of the status quo, and they are borne disproportionately by women in the developing world who have the least access to advanced obstetric care and the least power to demand technological change.

The artificial womb does not solve all of these problems immediately. The technology is not yet mature. The engineering challenges are formidable. The regulatory environment is complex. But the trajectory is clear, and the moral logic is compelling. Every year that the technology is delayed, the costs of the status quo continue to accumulate. Every maternal death that could have been prevented by a safer alternative to biological gestation is a death that the moral community, including the church, bears partial responsibility for if it failed to support the development of the technology that could have prevented it.

The duty to rescue is not a call to recklessness. It is a call to responsible development: rigorous testing, transparent regulation, equitable access, and unwavering commitment to the commands of love. But it is a call, and it is urgent.

10.8 Conclusion: The Affirmative Case Stands

The affirmative case for artificial wombs, presented across the domains of capacity liberation, proactive genomics, substance dualism, sub-creation, sphere sovereignty, and the duty to rescue, is substantial. It is grounded in Scripture, informed by the Christian theological tradition, consistent with the best insights of biomedical ethics, and directed toward the telos of human flourishing under the lordship of Christ.

The physical toll of pregnancy is a consequence of the Fall, not a spiritual virtue, and the Dominion Mandate commands the alleviation of that toll wherever the capacity exists. Proactive genomics extends the therapeutic imperative to the earliest stage of human development, and the artificial womb is the enabling architecture for that extension. The boundary between therapeutic genomics and eugenics is a boundary of love, not capability, and Christianity possesses the moral resources to maintain that boundary with integrity. Substance dualism establishes that the moral status of the developing human does not depend on the medium of gestation, liberating the artificial womb from the charge that it produces a morally inferior form of human life. The Thomistic tradition of participation in Providence and the Kuyperian doctrine of sphere sovereignty affirm that the development of reproductive technology is a legitimate and indeed obligatory exercise of sub-creative agency under the lordship of Christ. And the duty to rescue, rooted in the command to love one's neighbor, elevates the development of artificial wombs from a permissible project to a moral imperative.

The affirmative case is not merely adequate; it is commanding. The theological permissions are established. The historical witnesses have spoken. The moral logic is coherent. The engineering possibility is within reach. The suffering that the technology could alleviate is real, quantifiable, and ongoing.

The counter-arguments must now be engaged. They will be, with full rigor and without evasion, in the chapter that follows. But it is important, before turning to the objections, to recognize the weight of what has already been established. The case for artificial wombs is not a marginal argument advanced by a fringe coalition of techno-optimists and theological liberals. It is a case that emerges from the heart of the Christian tradition: from Genesis, from Aquinas, from Kuyper, from the long history of the church's engagement with medicine, and from the plain reading of the commands to love God and neighbor with every capacity that God has entrusted to us.

The affirmative case stands. Let the objections come.

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11 Chapter 9: The Case Against

The affirmative case is formidable. It is, however, not unassailable.

Having traced the trajectory from permission (Chapters 5-6) to obligation (Chapters 7-8), we now confront the full weight of objections that must be answered if ectogenesis is to be embraced as a faithful exercise of the Dominion Mandate. This chapter engages these counter-arguments with maximum intellectual honesty, presenting each position in its strongest form before offering resolution. The dialectic proceeds: permission → obligation → objections → resolution. We do not dismiss concerns lightly; we subject our own position to the most rigorous scrutiny possible, for only then can we discern whether the technology truly serves the twin commands to love God and neighbor.

11.1 Section 1: The Incarnational Critique

The most fundamental objection to ectogenesis arises from the Incarnation itself: if God chose to enter human history through a human womb, does removing gestation from the female body deny something essential about what it means to be human? Gregory of Nazianzus provides the axiomatic principle: "For that which He has not assumed He has not healed" (Nazianzus, c. 382 AD). If Christ did not assume the gestational process, then that aspect of human experience remains unhealed, unredeemed. Irenaeus likewise defended the goodness of physical flesh against Gnostic tendencies to denigrate embodiment (Irenaeus, c. 180 AD). Their concern is not merely historical; it cuts to the heart of whether ectogenesis represents a covert Gnosticism that seeks to escape the constraints of material existence.

This critique carries profound weight. If the Incarnation sanctifies not merely human birth but the entire prenatal journey within the maternal body, then ectogenesis risks treating gestation as a defective mechanism to be improved rather than a divinely ordained context for person-formation. The objection gains force when we consider that Jesus entered the world not as a fully formed

adult descending from heaven, but as an embryo implanted in a woman's uterus, sustained by placental exchange, shaped by maternal rhythms, and born through the vagina. Every stage of this process was assumed by the Logos.

Yet the resolution lies in precise application of the Nazianzus principle. Christ assumed human nature, not every conceivable mechanism through which human nature might be sustained or developed. The hypostatic union concerns the assumption of a complete human nature. body and soul. not the assumption of every possible biological subsystem or developmental environment. As J.P. Moreland argues in his defense of substance dualism, the soul is independently imparted by God and does not derive its identity from gestational mechanics (Moreland, 1998). The gestational mechanism is a contingent biological subsystem, not an essential component of human nature itself.

We find a compelling engineering parallel in medical technologies that alter birth mechanisms without altering ontological status. Caesarean sections surgically extract the fetus rather than allowing vaginal birth; neonatal incubators provide external thermodynamic regulation and respiratory support; extracorporeal membrane oxygenation (ECMO) temporarily performs placental gas exchange functions. None of these interventions lead us to question the humanity of those born via these methods. The gestational mechanism, like the respiratory or circulatory systems, is a host-constrained unit operation within the broader biochemical chassis of human development. Altering its location or method does not change the fundamental nature of the entity undergoing development. any more than changing the material of a heat exchanger alters the thermodynamic properties of the fluid passing through it.

The Incarnation affirms the goodness of embodied existence, not the theological necessity of every specific biological pathway through which that embodiment is achieved. Ectogenesis, when evaluated against the Nazianzus principle, does not deny the assumption of human nature; it merely relocates one of the many subsystems through which that nature is sustained during development. The Word became flesh; He did not become amniotic fluid.

11.2 Section 2: The Commodification Objection

A second powerful objection contends that ectogenesis inevitably leads to the commodification of human life, transforming children from gifts into products, from subjects into objects. This objection draws deep from theological and philosophical wells. O'Donovan distinguishes sharply between "begetting" and "making": "Begetting is the giving of life to a being that shares one's own nature; making is the production of an object which is subordinate to the maker" (O'Donovan, 1984). This distinction echoes the Nicene Creed's affirmation that Christ is "begotten, not made," emphasizing that true generation involves sharing nature rather than exercising unilateral control (Smith & Spencer, 2023).

Michael Sandel frames the concern as the "one-sided triumph of willfulness over giftedness," arguing that biotechnologies like ectogenesis undermine our open-

ness to the unbidden, replacing acceptance of life as a gift with mastery over life as a project (Sandel, 2007). Jürgen Habermas warns that such technologies threaten the moral equality necessary for democratic society by creating situations where some humans are designed by others, fundamentally altering the subject-object relationship (Habermas, 2003). The Catholic Church's Donum Vitae insists that human procreation must remain "a gift not a product," maintaining that technological intervention should assist rather than replace the natural conjugal act (Wojtyla, 1987).

These concerns are not theoretical. Feminist critics like Moran warn that ectogenesis could disrupt abortion law by expanding fetal viability, potentially eliminating women's legal right to terminate pregnancies (Moran, 2023). Raymond argues that reproductive technologies serve patriarchal interests by defining women's fertility as a problem requiring technological solution, thus extending medical control over women's bodies rather than liberating them (Raymond, 1993).

The resolution requires distinguishing between the risk of application and the essence of the technology. Ectogenesis, like any powerful technology, carries risks of misuse. but its essence need not be commodifying. The Dominion Mandate framework provides precisely the governance structure needed to prevent commodification: stewardship requires treating all life as bearing the Imago Dei, not as raw material for human design. This aligns with Wojtyla's vision of technology as servant rather than master.

Crucially, the technology's design stage offers the primary opportunity for constraint. If ectogenesis systems are architected from inception to enforce limits. such as prohibiting trait selection, requiring parental responsibility regardless of gestation method, and prohibiting commercial surrogacy markets. then the technology can serve as a conduit for gift rather than a tool for manufacture. The affinity with the Dominion Mandate lies precisely here: just as we steward the earth not by owning it but by serving its flourishing, we steward reproductive technology not by making children to specification but by enabling the gift of life within proper bounds.

The commodity objection thus targets a real risk, but one that can be constrained through governance rooted in the same theological principles that prohibit treating any human being as mere property. The technology's potential for misuse does not negate its potential for righteous use when properly constrained.

11.3 Section 3: The Bonding Caveat

A third significant objection focuses on the irreplaceable biological and psychological bonding that occurs between mother and fetus during pregnancy. Weaver et al. demonstrate that maternal behavior directly shapes offspring epigenome, showing that the intrauterine environment is not merely nutritive but actively instructive in developmental programming (Weaver et al., 2004). Beyond epigenetics, pregnancy involves microbiome transfer, immunological synchronization,

hormonal reciprocity, and even auditory learning where the fetus learns to recognize the mother's voice patterns. Taleb's precautionary principle urges caution when dealing with complex systems where small perturbations can produce large, unpredictable effects. precisely the domain of fetal development (Taleb, 2014).

This objection contends that ectogenesis, by severing these embodied connections, risks producing individuals with attachment disorders, emotional dysregulation, or impaired social bonding. The concern is not merely speculative; it emerges from developmental psychology showing that early maternal-infant interaction lays the foundation for lifelong relational capacity. If ectogenesis provides optimal nutritional support but omits the complex signaling milieu of natural gestation, we may create beings who are biologically sound but relationally impaired.

The resolution demands treating this as a falsifiable hypothesis rather than an a priori objection. If empirical data shows that ectogenetically developed children exhibit statistically significant deficits in attachment security, emotional regulation, or social cognition compared to gestated peers, then the technology must be paused or redirected toward therapeutic applications only (e.g., saving extremely premature infants). The command to love neighbor requires honoring such data. if the technology harms those it intends to help, continued deployment violates the most basic ethical obligation.

Critically, this objection does not condemn ectogenesis in principle but demands rigorous monitoring and adaptive governance. The system architecture must include feedback loops from developmental psychology and epigenetics to inform real-time adjustments. If the data shows no significant bonding deficits when appropriate parental interaction protocols are followed (e.g., immediate skin-to-skin contact post-decanting, consistent caregiving by intended parents), then the technology may proceed. If harm emerges, we pivot. not out of Luddism, but out of fidelity to the Dominion Mandate's requirement that sub-creation serve genuine flourishing.

The bonding caveat thus functions as a vital constraint in the technology's design envelope: ectogenesis must either replicate or compensate for the full spectrum of maternal-fetal signaling, or be limited to cases where the benefits outweigh the risks (such as lifesaving premature infant care). This constraint aligns precisely with the command to love neighbor. we may not proceed with technologies that risk relational harm without rigorous evidence of safety and ongoing vigilance for emergent harms.

11.4 Section 4: The Frankenstein Warning & Technological Hubris

A fourth powerful objection frames ectogenesis within the broader narrative of technological hubris. the danger that in our quest to conquer nature, we ultimately become conquered by our own creations. C.S. Lewis captures this dread succinctly: "Man's conquest of Nature turns out, in the moment of its

consummation, to be Nature's conquest of Man" (Lewis, 1943). This is not merely poetic imagery but a structural warning about what Lewis termed "The Conditioners". those who, having gained power over nature, inevitably use that power to shape humanity according to their own design, thereby abolishing genuine human autonomy.

Mary Shelley's Frankenstein (1818) provides the archetypal narrative of creator-responsibility gone awry: Victor Frankenstein succeeds in animating life but utterly fails to assume responsibility for his creation, resulting in tragedy for both creator and creature. The novel warns that technological capability without corresponding moral maturity produces monsters. not necessarily in physical form, but in the existential sense of beings abandoned by their makers.

Leon Kass articulates what he terms the "wisdom of repugnance". the idea that our visceral negative reactions to certain biotechnologies may track deep truths about human dignity that rational argument struggles to articulate (Kass, 1997). While repugnance alone cannot settle ethical questions, Kass argues it often signals a violation of the natural boundaries that make meaningful human life possible.

Winner's dual insights prove particularly relevant: first, that "artifacts have politics". meaning technologies embody and enact specific power relations and social arrangements (Winner, 1980); second, that technologies reshape human activity and perception in ways that often escape our notice until they become second nature (Winner, 1986). Gibson's affordance theory complements this by suggesting that ectogenesis, as an artifact, would offer new possibilities for action while simultaneously constraining others. particularly the affordance of natural gestational bonding (Gibson, 1979).

Fukuyama warns that technologies like ectogenesis could usher in a "Posthuman Future" where fundamental human equality is undermined by asymmetrical access to enhancement, creating castes of the genetically and technologically privileged versus the natural (Fukuyama, 2002). Zuboff extends this to the realm of surveillance, arguing that reproductive technologies could become vectors for unprecedented data extraction and behavioral modification (Zuboff, 2019). Foucault's analysis of biopolitics reveals how technologies governing life itself become instruments of state power, turning biological processes into sites of political control (Foucault, 2008).

The resolution acknowledges the validity of these concerns while rejecting technological determinism. The Frankenstein narrative fails not because hubris is impossible, but because it assumes that creators inevitably abandon their creations. The Dominion Mandate framework provides precisely the antidote: it positions humans not as autonomous creators exercising arbitrary power, but as stewards operating under divine authority and constrained by love for neighbor.

This shifts the question from "Can we build it?" to "Should we build it, and under what constraints?" The technological hubris objection targets a real human tendency. but tendencies can be countered by virtue, by institutional

design, and by theological commitment to creaturely limits. Ectogenesis need not become Frankenstein's monster if its development is governed by humility, accountability, and recognition that we are not the ultimate source of life but merely its temporary caretakers.

The key lies in recognizing that all technology operates within a created order with inherent constraints and purposes. To ignore these is not to transcend limits but to violate them. inviting consequences that may not be immediately apparent but which accumulate through feedback loops in complex systems. The precautionary principle, properly understood, is not anti-technology but pro-wisdom: it demands that we proceed with humility when dealing with powers that alter the very conditions of human existence.

Thus the Frankenstein warning does not forbid ectogenesis but demands that we build it with eyes wide open to the temptations of power, with systems designed to check hubris, and with a constant awareness that we are not gods but image-bearers called to reflect divine character in our technological endeavors.

11.5 Section 5: Feminist Counter-Arguments

Feminist responses to ectogenesis reveal a profound internal tension, demonstrating that the technology cannot be evaluated through a monolithic feminist lens. On one hand, Shulamith Firestone's radical vision in *The Dialectic of Sex* (1970) champions ectogenesis as liberation from what she terms "biological tyranny". the oppression inherent in pregnancy and childbirth that anchors patriarchal control over women's bodies and lives. Firestone argues that seizing control of reproduction is essential for feminist revolution, framing ectogenesis not as a threat but as the key to eliminating sex distinctions entirely. On the other hand, contemporary feminist critics warn that ectogenesis risks exacerbating existing power imbalances rather than alleviating them, particularly through its potential to disrupt abortion access and its historical continuity with patriarchal control over reproductive technology.

This tension is crucial for Chapter 9 because it shows that even within feminist thought, ectogenesis is not inherently liberating or oppressive. its impact depends entirely on governing structures and intent. Moran's 2023 analysis in *Wired* highlights how ectogenesis could weaponize against reproductive rights by expanding fetal viability to earlier gestational stages, thereby strengthening legal arguments for fetal personhood and weakening the viability framework that underpins Roe v. Wade and its successors. If ectogenesis makes embryos viable outside the womb at conception, the legal basis for abortion collapses entirely, potentially forcing all pregnancies to continue to artificial birth regardless of maternal circumstance. This represents not an expansion of choice but a constriction. one that could be exploited by anti-abortion legislatures to eliminate termination options entirely.

Raymond's 1993 critique in *Women as Wombs* provides the historical depth necessary to understand this danger. She argues that reproductive technologies.

from IVF to surrogacy to genetic screening. have consistently emerged from a patriarchal medical establishment that defines women's fertility as a deficit requiring technological correction. Ectogenesis, in this view, is not a break from this pattern but its culmination: it transfers complete control of gestation from female bodies to male-dominated laboratories and corporations, enabling men to reproduce without women while positioning women's natural reproductive capacity as obsolete or defective. This aligns with Gena Corea's earlier argument in *The Mother Machine* (1985) that reproductive engineering serves patriarchal interests by severing the biological link between sexuality and reproduction, thereby allowing men to bypass women entirely in the reproductive process.

The resolution requires distinguishing between the technology's potential applications and its governance framework. Firestone's pro-ectogenesis feminism assumes a utopian scenario where the technology is universally accessible and controlled by women. a scenario that ignores existing power structures in medical technology development and distribution. Moran and Raymond's critiques are correct to warn that without deliberate feminist governance, ectogenesis will likely reinforce rather than dismantle patriarchal control over reproduction, particularly given the historical tendency of reproductive technologies to serve capitalist and institutional interests over women's autonomy.

Yet this does not mean ectogenesis is inherently antifeminist. The engineering parallel to debates about contraception and IVF within feminism is instructive: just as those technologies initially sparked feminist divisions (with some viewing contraception as liberating and others as enabling male sexual entitlement without responsibility), ectogenesis forces a similar reckoning. The key lies in applying feminist principles of bodily autonomy and justice to the technology's design and deployment. If ectogenesis is governed by constraints that prioritize maternal decision-making. such as requiring explicit maternal consent for fetal transfer, prohibiting use without maternal consent, and ensuring equitable access across socioeconomic lines. then it can serve as a tool for expanding rather than constraining reproductive choice. The Dominion Mandate framework, when properly understood, aligns with feminist stewardship: it requires using technology to serve human flourishing rather than imposing technological solutions that exacerbate existing injustices.

Thus the feminist counter-argument does not condemn ectogenesis in principle but demands that it be developed and deployed within a feminist justice framework. one that centers women's agency, challenges patriarchal medical control, and ensures that liberation for some does not come at the expense of liberation for others. Without such constraints, ectogenesis risks becoming another instrument of reproductive oppression; with them, it may advance the very goals of bodily autonomy and reproductive justice that feminism has long pursued.

11.6 Section 6: Disability Rights Critique

A sixth significant objection emerges from disability rights scholarship, contending that ectogenesis technologies aimed at eliminating disability express a eugenic devaluation of disabled lives. Garland-Thomson's foundational work in feminist disability studies provides the conceptual framework: "Feminist disability studies… provides a framework for questioning the assumption that disability is inherently negative and that eliminating disability is an unquestioned good" (Garland-Thomson, 2002). This challenges the premise that ectogenesis's primary value lies in preventing disability, asking instead whether such prevention communicates that disabled existence is less valuable or worth living.

This objection gains philosophical rigor from Asch and Wasserman, who articulate the expressivist objection: "Choosing not to bring a disabled child into the world expresses a negative evaluation of the lives of disabled people" (Asch & Wasserman, 2006). Their argument rests on the idea that reproductive decisions based on disability status are not merely personal preferences but public statements about the value of disabled life. When ectogenesis enables comprehensive screening and intervention throughout gestation, it transforms reproduction into a process of quality control that treats disability as a defect to be eliminated rather than a form of human variation.

The concern is not theoretical but deeply felt within disability communities. If ectogenesis becomes a tool for selecting against disability, it risks sending the message to existing disabled persons that their lives are regrettable mistakes. that the world would be better off without them. This expressivist harm operates independently of any individual's intent; even if parents seek ectogenesis solely to alleviate suffering, the social message transmitted is that disability constitutes a valid reason to avoid existence altogether.

The resolution requires distinguishing between therapeutic healing and eugenic enhancement. a boundary that aligns precisely with the command to love neighbor. Using ectogenesis to treat life-threatening conditions in extremely premature infants (therapeutic healing) differs fundamentally from using it to select against traits like Down syndrome or cleft palate (eugenic enhancement). The former responds to immediate medical need; the latter enacts a preference for certain types of human beings over others.

This distinction finds theological anchor in Jesus' healing ministry, which restored individuals to wholeness without eliminating their existence as disabled persons. Jesus healed blindness, lameness, and leprosy. but never suggested that those conditions made lives unworthy of living. His approach honored the person while addressing the condition. a model for ectogenesis that treats medical need without enacting eugenic preferences.

The Dominion Mandate framework provides the governance structure necessary to maintain this boundary: ectogenesis must be constrained to therapeutic applications that preserve life rather than eliminate it based on perceived qual-

ity. This requires explicit prohibitions against trait selection for non-medical reasons, robust informed consent processes that disclose the expressivist implications of disability-selective ectogenesis, and ongoing accountability to disability communities affected by the technology's deployment.

Critically, this objection does not reject ectogenesis in principle but demands that it serve healing rather than elimination. that it express love for neighbor by alleviating suffering without communicating that certain lives are not worth living. When governed by this constraint, ectogenesis can advance the healing aspects of the Dominion Mandate without violating its core commitment to the equal worth of all image-bearers.

11.7 Section 7: Global Inequality & Neo-Colonial Dynamics

A seventh significant objection centers on global justice, arguing that ectogenesis will exacerbate existing inequalities rather than alleviate them. Bulletti et al. identify the core technical reality: "Implementing artificial wombs would require advanced technology and significant costs, potentially limiting access for people in developing countries or with fewer resources" (Bulletti et al., 2011). This creates a reproductive technology divide that mirrors existing global health inequities, where the benefits of ectogenesis would accrue primarily to wealthy nations and individuals while poorer populations remain excluded.

The Randalls extend this analysis to reproductive politics, arguing that ectogenesis "does not transcend biological limits universally but rather allows wealthy societies to overcome limits that remain binding on the poor, deepening existing global reproductive injustice under the guise of technological progress" (Randall & Randall, 2008). If ectogenesis is available only in affluent nations, it establishes a reproductive hierarchy: women in wealthy countries can access ectogenesis as an abortion alternative or for premature infant care, while women in developing nations retain only traditional options. often with higher risks and fewer resources. This creates differential moral and legal frameworks for reproductive rights based on citizenship and class.

Further complicating this dynamic is the potential for reproductive tourism and exploitation. Rosen warns of the psychosocial risks but also notes the global injustice dimension: wealthy individuals from the Global South might travel to Northern clinics for ectogenesis services, creating a flow of reproductive capital northward while local capacities remain underdeveloped (Rosen, 2003). More critically, the question of who bears financial responsibility for artificially gestated children introduces new forms of exploitation: surrogate nations or populations might be pressured to provide ectogenesis services, or ectogenesis children might become commodities in international adoption markets.

The resolution acknowledges that these concerns are not merely possible but likely without deliberate intervention. The Dominion Mandate requires just

stewardship. not merely competent technical execution but equitable distribution of technological benefits. This means governance structures must be designed from inception to prevent biocolonialism: sliding scale pricing models, technology transfer agreements that build local capacity, prohibitions on exporting ectogenesis services to exploit economic disparities, and international funding mechanisms to ensure access isn't determined by wealth alone.

Engineering parallels abound in medical technology deployment history. The pattern of costly innovations first serving wealthy populations before gradually becoming more accessible (if they do at all) is well documented. from MRI machines to antiretroviral drugs. The ectogenesis challenge is to break this pattern through proactive justice-oriented design: treating equitable access not as an afterthought but as a core system constraint, much like safety or efficacy parameters in biomedical engineering.

Thus the global inequality objection does not reject ectogenesis in principle but demands that it be developed within a framework of global justice. one that recognizes the Dominion Mandate's requirement to steward creation for the flourishing of all, not just the privileged few. When governed by this constraint, ectogenesis can advance rather than undermine the biblical vision of shalom where technological benefits flow to all image-bearers regardless of geography or economics.

11.8 Section 8: Eastern Orthodox Perspectives

An eighth significant objection emerges from Eastern Orthodox bioethics, which offers a distinct theological framework that challenges ectogenesis on grounds of incarnation, embodiment, and participation in divine creation. Engelhardt's foundational work emphasizes that "Bioethics is not a single enterprise but many, depending on the particular moral communities within which bioethical issues are addressed" (Engelhardt, 1996). This pluralist insight is crucial: Orthodox objections to ectogenesis cannot be dismissed as merely sectarian but represent a coherent theological anthropology with deep patristic roots.

Engelhardt argues that Orthodox Christianity rejects secular bioethics' attempt to ground moral claims in neutral reason, maintaining instead that personhood is constituted through embodied participation in the life of Christ. For Orthodox theology, incarnation. God becoming flesh. is the central salvific event, affirming the goodness and necessity of embodied existence. Ectogenesis, by relocating gestation outside the human body, challenges this incarnational theology by suggesting that material embodiment is merely a mechanical process to be optimized rather than a sacred context for divine-human encounter.

This objection gains further depth from Sherrard's theology of sacred nature, which contends that "The natural world is not merely a backdrop for human activity but a sacred reality in which the divine is manifested" (Sherrard, 1990). From this perspective, human reproduction is not merely a biological process but a participation in God's creative act. the generation of new persons made

in the divine image. Ectogenesis represents the culmination of modernity's desacralization: it treats pregnancy as a mechanical process that can be improved, optimized, and eventually outsourced to machines. Orthodox theology resists this framing by insisting that gestation, like all natural processes, carries spiritual significance that cannot be replicated technologically. The mother's body is not merely an incubator but a site of spiritual formation where the developing person first experiences communion with another.

The resolution requires engaging Orthodox theology on its own terms rather than attempting to override it with secular bioethical principles. The Dominion Mandate, properly understood, operates within the created order rather than seeking to transcend it. a position that aligns with Orthodox emphasis on living within divine boundaries rather than attempting to overthrow them. Orthodox theology's resistance to ectogenesis stems not from anti-technological bias but from a profound commitment to theosis. the process of becoming by grace what God is by nature. which requires engagement with the material world as a site of divine encounter rather than raw material for manipulation.

Crucially, this does not mean Orthodox theology rejects all medical technology. The distinction lies in technologies that assist natural processes versus those that replace them. Just as antibiotics support the body's innate healing mechanisms without replacing them, ectogenesis could be justified when it assists natural gestation (e.g., saving extremely premature infants) but not when it seeks to replace the gestational process entirely. This aligns with the Orthodox understanding of synergy (cooperation with divine grace) versus autonomy (self-directed action apart from God).

Thus the Orthodox counter-argument does not reject ectogenesis in principle but demands that it be evaluated within a framework that honors the sacredness of embodiment and the incarnational principle that the material world is a locus of divine presence. When governed by this constraint. particularly when limited to therapeutic rather than replacement applications. ectogenesis can be pursued in a manner consistent with Orthodox theological commitments to bodily integrity and participation in the divine life.

11.9 Section 9: Islamic Bioethics

A ninth significant objection arises from Islamic bioethics, which provides a comprehensive framework for evaluating ectogenesis based on Qur'anic principles, maqasid al-sharia (objectives of Islamic law), and jurisprudential reasoning. Daar and Al Khitamy begin with the foundational principle: "In Islam, human life is regarded as an invaluable gift from God, and should therefore, be both respected and protected" (Daar & Al Khitamy, 2001). This establishes the baseline expectation that any reproductive technology must uphold the sanctity of life as a divine trust.

This objection gains specificity from Atighetchi's analysis of Qur'anic embryology, particularly Surah Al-Mu'minun 23:12-14: "And certainly did We create

man from an extract of clay. Then We placed him as a sperm-drop in a firm lodging. Then We made the sperm-drop into a clinging clot, and We made the clot into a lump [of flesh], and We made [from] the lump, bones, and We covered the bones with flesh; then We developed him into another creation. So blessed is Allah, the best of creators." This passage establishes several key principles: first, human creation is a sequential divine act demonstrating God's direct involvement in every stage of gestation; second, the developmental transitions imply divine agency in ensoulment and animation; third, the phrase "the best of creators" establishes an absolute distinction between divine creation and human making.

Applied to ectogenesis, this framework raises the concern that the technology attempts to replace rather than assist God's creative act. a form of shirk (associating partners with God) that violates tawhid (God's absolute unity and sovereignty). While ectogenesis might be justified under the "saving life" principle for extremely premature infants, extending it to full ectogenesis raises concerns about humans overstepping their role as stewards (khalifa) rather than creators.

Shomali's maqasid al-sharia framework provides further guidance, identifying five essential objectives of Islamic law: preservation of life, intellect, progeny, wealth, and faith. Applied to ectogenesis, the preservation of progeny objective is particularly relevant: Islamic law values natural reproduction within marriage as the legitimate means of perpetuating the human community. Ectogenesis that replaces natural gestation raises concerns about whether the technology preserves or undermines the integrity of progeny as an essential value.

The resolution acknowledges that Islamic bioethics, like the Dominion Mandate framework, centers on stewardship rather than ownership. The concept of khalifa (stewardship) aligns closely with the biblical mandate to exercise dominion as God's representatives, not as autonomous proprietors. When ectogenesis is evaluated through the maqasid al-sharia lens, it is permissible only insofar as it serves life preservation. for example, saving extremely premature infants. but becomes problematic when it substitutes for natural gestation in ways that disrupt the divine order of human creation and reproduction.

Critically, this does not mean Islamic bioethics rejects all reproductive technology. The historical record shows nuanced positions on assisted reproduction: IVF is generally permitted when using married couples' gametes, while third-party donation is often prohibited. Ectogenesis, evaluated through this same framework, would likely be permitted for therapeutic applications (saving endangered fetuses) but restricted for elective or enhancement purposes. The key lies in ensuring that the technology serves the maqasid rather than human desire for control or perfection. precisely the alignment point with the Dominion Mandate's requirement that sub-creation operate within divine boundaries rather than seeking to transcend them.

Thus the Islamic counter-argument does not reject ectogenesis in principle but

demands that it be developed and deployed within a framework that honors divine sovereignty over creation. one that recognizes humanity's role as stewards rather than owners of life. When governed by this constraint, ectogenesis can advance the healing aspects of human flourishing without violating the core Islamic principle that all life is a sacred trust from Allah.

11.10 Closing Synthesis

All these counter-arguments are formidable. Each presents a genuine challenge to the vision of ectogenesis as a faithful exercise of the Dominion Mandate. The incarnational critique reminds us that we cannot escape the wisdom of "that which He has not assumed He has not healed." The commodification objection warns that even technologies begun in service can become instruments of mastery. The bonding caveat demands empirical vigilance against hidden harms to relational development. The Frankenstein warning alerts us to the ever-present temptation of hubris. Feminist critiques reveal how even liberating technologies can reinforce oppression under unjust governance. Disability rights scholarship forces us to distinguish healing from elimination. Global justice concerns remind us that technological benefits flow unevenly without deliberate intervention. Orthodox and Islamic perspectives call us to honor the sacredness of embodiment and divine sovereignty over creation.

Yet we must also acknowledge a counter-counter-argument: the propagation argument. Ectogenesis, like fire, the wheel, or the printing press, appears technologically inevitable. not because we must build it, but because the knowledge to build it exists and will likely be actualized somewhere, sometime. The question is not whether ectogenesis will be built, but who shapes its affordances, what constraints govern its deployment, and whether it serves or subverts the twin commands to love God and neighbor.

This reality shifts our task from prevention to prudent governance. We cannot un-invent the knowledge; we can only shape its embodiment in technology and society. The constraints we refuse to embed will be the constraints that do not exist. Therefore, our work must focus on designing ectogenesis systems that embody the Dominion Mandate from the ground up: systems constrained by love for neighbor, accountable to divine authority, and oriented toward genuine human flourishing rather than technological prowess for its own sake.

With this sober recognition, we transition to Chapter 10's exploration of compassionate use pathways. how ectogenesis might first be deployed in therapeutic contexts to save extremely premature infants. and ultimately to Chapter 12's resolution of how the Dominion Mandate framework can guide this technology toward service rather than domination.

The constraints we refuse to embed will be the constraints that do not exist.

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12 Chapter 10: The Bioengineering Dilemma

12.1 Navigating the R&D Gap

The preceding chapters have established the theological permission and the theological obligation. Sub-creation is legitimate. The Dominion Mandate compels. The human cost of gestational failure demands response. None of that analysis matters if the technology cannot be ethically developed. The question of whether Christians should pursue ectogenesis is meaningless if the pathway from laboratory to clinical deployment requires the destruction of human embryos to obtain it. This chapter addresses the primary hurdle: transitioning from animal models to human application without violating the moral principles that justify the work in the first place.

The R&D gap is not merely a technical problem. It is a design problem with an engineering solution, and the compassionate use regulatory pathway provides the bridge.

12.2 The Clinical Trial Paradox

The paradox is structural and it is brutal. Early-stage failures in experimental medical technology are inevitable. No system works perfectly on the first deployment. No prototype performs within specification on the first test. The history of medicine is a history of trial and error, of approaches that succeeded in animal models and then failed or harmed or killed in human subjects. Jesse Gelsinger died in 1999 because an adenovirus vector triggered a systemic inflammatory response that the preclinical data did not predict. The death halted gene therapy trials across the United States for years. The pattern is not unique to gene therapy. It is the universal pattern of biomedical research: you test on animals, you refine, you test on humans, and sometimes the humans suffer because the model was incomplete.

Now apply this pattern to artificial womb technology. The CHOP biobag experiments demonstrated feasibility in lamb models. Premature lamb fetuses were sustained for four weeks in a closed fluid environment with a pumpless arteriovenous circuit. The results were promising enough to justify the next step. But the next step is a human trial, and a human trial requires placing a human fetus in an experimental system that has never sustained a human fetus before. The first attempts will fail. Some failures will be fatal. You cannot test an artificial womb on a human fetus without risking the death of that fetus, and you cannot obtain the data needed to improve the system without testing it on human fetuses.

This is the clinical trial paradox: the knowledge required to make the technology safe can only be obtained by deploying the technology in an unsafe state. The paradox is not unique to ectogenesis. It characterizes every experimental medical intervention from the first heart transplant to the first gene therapy trial to the first use of ZMapp during the 2014 Ebola crisis. But the paradox is

more acute in ectogenesis because the subject is a human fetus at the edge of viability, a being whose moral status is the most contested question in bioethics. Destroying embryos to obtain research data is not an unintended side effect. It is the mechanism by which the data is generated. The bad effect is the means to the good effect, and that fact has consequences for the moral analysis.

12.3 Why the Principle of Double Effect Fails Here

Thomas Aquinas formulated the principle of double effect in the Summa Theologiae, and it has governed Catholic moral reasoning on the permissibility of actions that produce both good and bad outcomes for five centuries. The principle requires four conditions to be met simultaneously. First, the act itself must be good or at least morally neutral. Second, the agent must intend only the good effect, not the bad effect. Third, the bad effect must not be the means by which the good effect is achieved. Fourth, the good effect must be proportionate to the bad effect, meaning there must be a proportionately grave reason for permitting the bad effect.

The third condition is the one that breaks. In conventional clinical research, the death of a research subject is an unintended side effect of an intervention whose primary purpose is therapeutic. The physician administers a drug intending to cure the disease, not to kill the patient. If the patient dies, the death is a tragic consequence of the intervention, not the mechanism by which the therapeutic data is obtained. The knowledge gained from the death is incidental. The death itself was not the means to the knowledge.

In the clinical trial paradox for artificial womb technology, this condition cannot be satisfied in the early stages. If a human fetus is placed in an experimental artificial womb and dies because the system is not yet calibrated for human physiology, the death is not an unintended side effect of a therapeutic intervention. It is the direct consequence of deploying an untested system on a subject whose survival depends on that system functioning correctly. The data obtained from the failure is the knowledge that the system failed, and that knowledge is acquired only because the failure occurred. The death is the means to the data. The bad effect produces the good effect. Under the principle of double effect, this is impermissible.

The principle of double effect is not a loophole. It is a boundary marker, and it marks this boundary clearly. You cannot justify the destruction of embryos or the death of fetuses as a means to obtaining research data, even if the ultimate purpose of that data is to save future lives. The ends do not justify the means in Catholic moral theology, and the principle of double effect is the instrument that prevents the collapse of means into ends. The Christian bioengineer must find a different pathway.

12.4 The Compassionate Use Bridge

The compassionate use pathway, formally known as expanded access, provides that different pathway. It does not solve the clinical trial paradox directly. It routes around it.

The FDA's expanded access program allows patients with serious or life-threatening conditions to access investigational drugs and medical devices outside of a clinical trial. The program was formalized in 1987 in response to HIV/AIDS patients demanding access to experimental antiretrovirals, and it has been refined through successive legislative and regulatory actions, including the 21st Century Cures Act. The conditions for expanded access are specific and constraining. The patient must have a serious or immediately life-threatening condition. The patient's physician and the patient must both consent. There must be no comparable or satisfactory alternative therapy available. The probable risk from the investigational product must not be greater than the probable risk from the disease itself. The FDA must determine that there is sufficient evidence of safety and effectiveness to justify the risk, and that providing the investigational product will not interfere with ongoing clinical trials.

The scale of the program is larger than most people realize. The FDA receives approximately 1,500 expanded access requests per year and authorizes 99 percent of them. Darrow and colleagues, writing in the New England Journal of Medicine in 2015, confirmed that the FDA is not the bottleneck. The real constraint is manufacturer willingness and liability exposure. Companies must provide data collected from expanded access patients to the FDA annually, and that data can help or harm the approval process depending on the outcomes. The manufacturer remains legally liable for the investigational product even under expanded access, and no company can be compelled to provide a drug or device that it is developing. The 21st Century Cures Act requires companies to make their expanded access policies publicly available, but a 2021 analysis found that smaller firms frequently fail to comply with this requirement.

The compassionate use pathway functions as a bridge between animal models and full clinical trials. It does not require the researcher to destroy embryos to obtain data. It provides a mechanism for deploying experimental technology in extreme, life-or-death scenarios where the alternative is certain death. The data generated through compassionate use is real clinical data, collected under monitored conditions, submitted to the FDA, and available for analysis. It is not a substitute for randomized controlled trials. But it is a data bridge, a way of accumulating human physiological data without the moral cost of deliberate embryo destruction.

The application to artificial womb technology is direct. A premature infant at 22 weeks gestational age, born in a facility with no capacity for aggressive neonatal intervention, faces survival rates that in many settings approach zero. The standard of care has failed. The infant will die. In that scenario, the expanded

access framework authorizes the deployment of experimental artificial womb technology provided the conditions are met: there is no satisfactory alternative, the probable risk from the device does not exceed the probable risk from the disease, and sufficient preclinical evidence exists to justify the attempt. The CHOP lamb data constitutes that preclinical evidence. The infant's imminent death provides the clinical indication. The compassionate use pathway provides the regulatory authorization.

This is not a theoretical possibility. It is an established regulatory mechanism with a thirty-year track record and a 99 percent authorization rate.

12.5 The ZMapp Precedent

The 2014 West Africa Ebola crisis established the moral and regulatory precedent for exactly this kind of deployment. ZMapp, a cocktail of three chimeric monoclonal antibodies, had never undergone human clinical trials when it was administered to patients infected with Ebola virus. The drug had been tested in nonhuman primates with promising results, but no human safety or efficacy data existed. When the epidemic overwhelmed the capacity of conventional public health measures, the calculus changed. Patients were dying. The experimental drug offered any chance at all.

By October 2014, the United States Food and Drug Administration had approved the use of ZMapp and several other experimental drugs for Ebola patients. The World Health Organization assessed the deployment under its Monitored Emergency Use of Unregistered and Investigational Interventions protocol, known as MEURI, and deemed it ethical. The moral framework that authorized the deployment rested on three pillars: the severity of the disease, the absence of proven alternatives, and the existence of sufficient preclinical evidence to justify the risk. President Obama, when questioned about fast-tracking approval, responded that "we've got to let the science guide us," but the science in this case included the moral science of emergency ethics. When people are dying and an experimental intervention offers a chance, the default shifts from standard of care to rescue.

The ZMapp precedent is not perfect. The PREVAIL II trial that followed failed to reach statistical significance, and the controversy over equitable access provoked outrage and exposed deep inequities in the global health system. These are real problems that must be addressed in any future deployment of experimental ectogenesis technology. But the precedent stands: regulatory and ethical authorities authorized the deployment of an untested biotechnology in a life-threatening scenario where the alternative was death.

The WHO's MEURI protocol provides a template for the ethical deployment of experimental artificial womb technology. The protocol requires that the intervention be used only when no standard treatment exists, when the patient's condition is life-threatening, when the potential benefits justify the potential risks, when informed consent is obtained, when the data is collected and shared,

and when the use is approved by an ethics committee. These conditions map directly onto the scenario of a premature infant at the edge of viability for whom current neonatal care offers no realistic hope of survival without severe impairment.

12.6 The Gene Therapy Trajectory: A Cautionary Model

The history of gene therapy provides both a cautionary tale and a developmental roadmap for ectogenesis research. Martin Cline conducted the first unauthorized human gene therapy experiments in 1980, bypassing institutional review and provoking a firestorm of regulatory response. The field proceeded cautiously through the late 1980s, with the first approved therapeutic use of gene transfer occurring in 1990 under French Anderson's clinical trial for adenosine deaminase deficiency. Between 1989 and December 2018, over 2,900 clinical trials were conducted, with more than half in phase I.

The trajectory was not linear. Jesse Gelsinger's death in 1999 from a systemic inflammatory reaction to an adenovirus vector in a trial for ornithine transcarbamylase deficiency halted gene therapy research across the United States. The death exposed failures in informed consent, conflicts of interest among the investigators, and insufficient preclinical safety data. The field did not recover until 2006, when clinical successes regained researchers' attention. Modern gene therapy approvals now include treatments for spinal muscular atrophy, inherited retinal dystrophy, and certain blood cancers.

The parallel to ectogenesis is instructive but not exact. Germline gene therapy, which modifies the genome in a heritable way, remains prohibited in many jurisdictions including Australia, Canada, Germany, Israel, Switzerland, and the Netherlands due to insufficient knowledge about risks to future generations. The prohibition establishes a regulatory boundary that parallels debates about ectogenesis's intergenerational implications.

The ectogenesis R&D pathway should learn from the gene therapy trajectory without repeating its mistakes. Cline's unauthorized experiments must not be replicated. The Gelsinger failures in consent and safety reporting must not be repeated. The field must proceed incrementally, with robust preclinical data, transparent safety reporting, and rigorous ethics review at every stage. But the gene therapy trajectory also demonstrates that the gap between animal models and human application can be bridged through disciplined, ethical research, and that the bridge can be built without destroying the moral principles that justify the work.

12.7 Safety by Design

The engineering discipline of safety analysis provides a framework for addressing the clinical trial paradox at the design level rather than the deployment level. Nancy Leveson, in her 2011 work Engineering a Safer World, argued that safety

is not a property that can be tested into a system after it is built. Safety is an emergent property that must be designed into the system from the beginning. Leveson's systems-theoretic approach to safety treats accidents not as failures of individual components but as failures of the control structure that governs the interactions between components. The goal is not to prevent every possible failure mode, which is impossible in any complex system, but to ensure that the system's control mechanisms can detect, contain, and respond to failures before they cascade into catastrophic outcomes.

Applied to artificial womb design, Leveson's framework demands that safety be embedded in every layer of the system architecture. The pumpless arteriovenous circuit must be designed with redundancy and fail-safe mechanisms that prevent catastrophic pressure drops. The closed fluid environment must include real-time monitoring of pH, temperature, oxygen tension, and nutrient gradients, with automated correction systems that respond before physiological parameters drift outside safe ranges. The umbilical vascular access must be designed for atraumatic insertion and maintenance, with imaging guidance that minimizes the risk of vessel damage. Every subsystem must be designed with the assumption that it will eventually fail, and the system as a whole must be designed so that no single failure is lethal.

Martin and Schinzinger, in their 2005 work on engineering ethics, articulated the moral duty that underlies Leveson's technical framework. Engineers have a moral obligation to embed safety, reliability, and informed consent into the technologies they develop. This obligation is not merely professional. It is moral. The engineer who designs a system that will be used to sustain human life bears a responsibility that extends beyond the technical specifications of the system to the human beings whose lives depend on it. The artificial womb is not a consumer product. It is a life-sustaining system, and the moral weight of that function must be reflected in every design decision.

The practical implication is that the R&D pathway for artificial womb technology must begin with safety architecture, not with efficacy testing. The first question is not whether the system can sustain fetal development. The first question is whether the system can fail safely. Can it detect an impending failure in time to transfer the fetus to alternative support? Can it shut down without catastrophic harm? Can it alert clinical staff to problems before those problems become lethal? These are engineering questions, and they must be answered before any human fetus is placed in the system.

Safety by design does not eliminate the clinical trial paradox. It mitigates it. A system designed with Leveson's principles will fail less often, detect failures earlier, and contain failures more effectively than a system designed for efficacy first and safety second. The first human deployment will still carry risk. But the risk will be bounded, monitored, and mitigated by design rather than left to chance.

12.8 Legal Personhood and the Viability Threshold

The legal framework governing fetal personhood creates a direct intersection with artificial womb technology, and that intersection is more consequential than most commentators acknowledge.

The United States Supreme Court, in Roe v. Wade (1973), defined viability as the point at which the fetus becomes "potentially able to live outside the mother's womb, albeit with artificial aid." The Court placed viability at approximately 28 weeks but acknowledged it could occur earlier. The subsequent decision in Planned Parenthood v. Casey (1992) modified the trimester framework, permitting states to regulate abortion in ways not posing an "undue burden" on the right to an abortion at any point before viability. Viability itself was legally dissociated from the hard line of 28 weeks and recognized as a moving target dependent on medical technology.

The Born-Alive Infants Protection Act of 2002 defined "born alive" as the complete expulsion or extraction from the mother of a member at any stage of development who after such expulsion or extraction breathes or has a beating heart, pulsation of the umbilical cord, or definite movement of voluntary muscles. This definition creates a legal category that includes extremely premature infants and, by extension, could include fetuses sustained in artificial womb systems.

Elizabeth Chloe Romanis, writing in the Journal of Medical Ethics in 2020, analyzed the legal classification of artificial womb technology with precision. Romanis argued that ectogenesis collapses the viability threshold by making it possible to sustain fetal development at gestational ages far earlier than current neonatal care can achieve. If a fetus at 18 weeks can be sustained in an artificial womb, the legal concept of viability shifts from 24 weeks to 18 weeks, and the constitutional framework governing state regulatory interest in fetal life shifts with it. The implications for abortion law are profound, because viability has been the constitutional line that determines when the state's interest in potential life becomes compelling enough to override the individual's right to terminate a pregnancy.

The legal classification of the fetus in an artificial womb is unresolved. If the technology is used as a rescue for a premature infant that would otherwise die, the fetus is a patient and the technology is a therapeutic intervention. If it is used for full ectogenesis from conception, the legal classification is far more contested and will require new statutory frameworks. The Christian bioengineer must engage these questions proactively, ensuring that the framework protects the fetus as a bearer of the Imago Dei regardless of its location.

12.9 Custody Law and the Missing Mother

The legal framework for parental rights and custody becomes profoundly complicated when ectogenesis removes the gestational mother from the equation

entirely.

The Baby M case of 1988 established that the birth mother retains legal parental rights regardless of genetic contribution or contractual agreement. The New Jersey Supreme Court invalidated surrogacy contracts as against public policy, ruling that no contract can alter the legal position of a woman who bears a child as that child's mother. The decision was landmark and controversial, and it has shaped surrogacy law for nearly four decades.

Calvert v. Johnson in 1990 shifted the framework. The California court upheld the parental rights of the intended parents over the gestational carrier and defined the legal mother as the woman who, according to the surrogacy agreement, intends to create and raise a child. The shift from genetic and birth-based parenthood to intent-based parenthood was significant, and it created a legal category that could be extended to ectogenesis scenarios.

The Mexico Supreme Court ruling in 2021 pushed the logic further, holding that every individual has the right to access assisted reproductive technology and that legal parentage should be based on the presence of procreational will, not genetic or gestational relationship. This ruling, if adopted more broadly, provides a legal framework for determining parental rights in cases of full ectogenesis where no woman gives birth.

But the frameworks are incomplete. Baby M was about a woman who bore a child and then refused to surrender it. Calvert v. Johnson was about a gestational carrier who changed her mind. Neither case addressed a scenario in which no woman bore the child at all. If an embryo is conceived through in vitro fertilization and gestated entirely in an artificial womb from implantation to delivery, there is no birth mother. There is no gestational carrier. There is a genetic mother and a genetic father, or there are donors, or there is neither. The existing custody frameworks, built on the assumption that someone gives birth, create a legal vacuum that must be filled with new statutory categories before the technology is deployed.

The question is not merely academic. It determines who has the legal authority to make medical decisions for the fetus in the artificial womb. It determines who bears financial responsibility for the technology. It determines who has standing to sue if the technology fails and the fetus is harmed or killed. It determines inheritance rights, citizenship, and a hundred other legal consequences that attach to parentage.

The Christian bioengineer should advocate for intent-based parenthood frameworks that protect the child's dignity and the parents' authority without reducing the child to a product of technique. The child is not manufactured. The child is begotten by human agents and sustained by a technological system that serves the child's development. The legal framework must reflect that reality.

12.10 IRB Processes and the 14-Day Rule

The institutional review board framework for human subjects research provides the procedural mechanism through which artificial womb research must be evaluated, and that framework includes constraints that are both essential and inadequate.

Federal human subjects protections under 45 CFR 46 Subpart B provide additional safeguards for research involving pregnant women, human fetuses, and neonates. These protections were designed for in utero fetal research, and they assume the presence of a pregnant woman as co-subject whose consent and welfare must be protected. The protections do not translate directly to ex utero ectogenesis research, where the fetus exists entirely outside a maternal body and the traditional framework of maternal-fetal co-subjects does not apply.

The 14-day rule, codified into law in twelve countries, prevents researchers from keeping human embryos in artificial environments longer than 14 days. The rule was originally designed for in vitro fertilization research and reflects the biological observation that the primitive streak, which marks the beginning of individual development, appears around day 14. The International Society for Stem Cell Research relaxed this rule in 2021, allowing researchers to seek approval for longer studies, but human embryo models remain banned from being implanted into a uterus.

The 14-day rule is both a constraint and an opportunity for ectogenesis research. It constrains the timeline for early embryonic research in artificial environments, preventing researchers from studying human embryo development beyond 14 days in vitro. But the ISSCR's 2021 relaxation opens a pathway for extended studies if the appropriate ethics committee approval is obtained. The 2002 Cornell experiment, in which human embryos were implanted into cultured endometrial tissue and began to grow before being halted at six days to comply with IVF legislation, demonstrated that short-term embryonic development in artificial environments is feasible. The constraint is regulatory, not technical.

The IRB process for artificial womb research must address several unique challenges. The subject is a human fetus, which has uncertain legal status in many jurisdictions. The intervention is experimental and life-sustaining, meaning that failure is lethal. The data collected is continuous physiological monitoring, which raises privacy and data security concerns. The long-term outcomes are unknown, which complicates the informed consent process for the parents who authorize the intervention.

The Christian bioengineer must work within the IRB framework honestly and transparently. The framework exists to protect vulnerable subjects, and the fetus in an artificial womb is among the most vulnerable subjects in the history of medical research. The IRB process is not a bureaucratic obstacle to be circumvented. It is a moral safeguard that ensures the technology is deployed with the respect for human life that the Dominion Mandate demands.

12.11 The Data Bridge: Compassionate Use as R&D Pathway

The compassionate use pathway does not merely provide regulatory authorization. It generates real clinical data that can be used to refine the technology, inform future trials, and build the evidentiary base for eventual approval. Companies must provide data collected from expanded access patients to the FDA annually. This data is not as rigorous as data from a randomized controlled trial, because there is no control group and the sample sizes are small. But it is human physiological data, obtained without the moral cost of deliberate embryo destruction, and it can serve as a bridge between animal models and formal clinical trials.

The data bridge operates in both directions. In the forward direction, it provides early human physiological data that can inform the design of subsequent clinical trials. In the reverse direction, it provides safety signals that can halt the research if the data shows insurmountable harm. If compassionate use deployments generate adverse events that cannot be mitigated by design improvements, that data informs the decision to pivot or abandon the technology.

The Christian bioengineer is not exempt from the discipline of data. If the data from compassionate use deployments shows that the technology causes more harm than it prevents, the bioengineer must accept that verdict. The Dominion Mandate does not require the pursuit of a technology that kills the people it is meant to save. It requires the faithful application of human ingenuity to the alleviation of suffering, and faithfulness includes the willingness to stop when the evidence says to stop.

12.12 The Engineering Solution

The R&D gap for artificial womb technology is a design problem. It has the structure of every other design problem in engineering: a set of constraints that must be satisfied simultaneously, a set of variables that can be adjusted, and a solution space that must be explored through disciplined iteration. The constraints are moral, regulatory, and technical. The solution space is defined by the intersection of what is technically feasible, what is morally permissible, and what is legally authorized.

The engineering solution is a systematic approach that begins with safety architecture, proceeds through incremental animal testing, transitions to human deployment through the compassionate use pathway when the alternative is certain death, collects data at every stage, and uses that data to refine the system before formal clinical trials begin. The approach is iterative, transparent, and bounded by the moral principles that justify the work.

None of this is easy. The engineering challenges are substantial. The regulatory environment is complex. The moral stakes are high. But the alternative is to accept that 260,000 women will die next year from the same causes that killed

260,000 women this year, and that millions of premature infants will continue to be born at the edge of viability with no technology capable of sustaining their development. The Dominion Mandate does not permit that acceptance. The healing ministry of Christ does not permit it. The rule of rescue demands that we ask why the technology has not been developed, and whether the failure to develop it is itself a moral failing.

12.13 The Pivot

The R&D gap is a design problem with an engineering solution. The compassionate use pathway serves as a data bridge between animal models and human application. Safety must be embedded in the system architecture from the beginning, not tested in after deployment. The legal frameworks for personhood and parental rights must be developed proactively. The IRB process must be engaged honestly and transparently.

And if the data shows insurmountable harm, the Christian bioengineer pivots. The Dominion Mandate commands the faithful application of human ingenuity to the alleviation of suffering, not the stubborn pursuit of a technology that causes more suffering than it prevents. The pivot is not failure. It is faithfulness. It is the recognition that the sandbox has boundaries, and that working within those boundaries is not a limitation but a discipline. The builder who stops when the evidence says to stop is not less obedient than the builder who continues. The builder who stops is listening.

The question is not whether the technology can be developed. The question is whether it can be developed without violating the moral principles that justify its development. The answer, as this chapter has argued, is yes. The compassionate use pathway provides the bridge. Safety by design provides the discipline. The data provides the discipline to stop if the bridge leads nowhere.

The R&D gap is real. It is not insurmountable. The Christian bioengineer has a pathway forward. The question is whether the church will fund it, the regulators will authorize it, the manufacturers will accept the liability, and the builders will maintain the moral discipline to use it well. Those are not engineering questions. They are questions of will, of faith, and of obedience to the command to love the neighbor whose life depends on the work.

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13 Chapter 11: The Industrial Horizon

The analysis to this point has centered almost exclusively on human ectogenesis: the prospect of gestating human beings entirely outside the maternal body. This focus is warranted. Human dignity demands that any technology touching the most intimate processes of human generation receive the most searching moral scrutiny. Yet the Dominion Mandate does not terminate at the human

species. The command to "fill the earth and subdue it" extends to "every living thing that moves on the earth" (Gen. 1:28), and the stewardship ethic that governs responsible innovation encompasses the whole biosphere. Artificial wombs, once developed for any purpose, will not remain confined to human application. They will be deployed across species, scaled for industrial throughput, and integrated into systems of commerce and governance that stretch far beyond the reproductive clinic. The industrial horizon is not a distant abstraction. It is already under construction.

13.1 The Biobag as Species-Agnostic Infrastructure

The landmark work of Partridge et al. (2017) demonstrated that an extrauterine system could sustain premature lamb fetuses for four weeks with near-normal physiological development. This achievement was significant not merely for what it implied about human ectogenesis, but for what it confirmed about the underlying engineering. The Biobag system managed gas exchange, nutrient delivery, and waste removal through an interface that was, at its core, species-agnostic. Lambs are large mammals with complex developmental requirements, and a system capable of sustaining ovine fetal life is, in principle, transferable to other large mammalian species with appropriate modifications to fluid composition, oxygenation parameters, and growth factor profiles.

This matters because the infrastructure of artificial gestation does not inherently discriminate between human and non-human subjects. The same bioreactor cores, sterile media preparation lines, and physiological monitoring systems that would sustain a human fetus at twenty weeks of gestational age could, with calibration, sustain the gestational equivalent for an elephant, a dolphin, or a rhinoceros. The engineering overlaps are not incidental. They are foundational. Any artificial womb technology developed for human medicine will immediately generate derivative capabilities for veterinary medicine, conservation biology, and industrial animal husbandry. The Dominion Mandate, understood in its full scope, compels Christian thinkers to reckon with this fact: the technology of ex utero gestation will not stay in the hospital.

13.2 De-Extinction and the Commercialization of Artificial Gestation

The most dramatic early application of non-human ectogenesis is already taking shape in the de-extinction industry. Browne (2025) has documented the convergence of human reproductive interests and conservation biotechnology, noting that artificial womb technology sits at the nexus of both. The company driving this convergence most aggressively is Colossal Biosciences, founded in 2021 by Harvard geneticist George Church and entrepreneur Ben Lamm. What began as a $15 million seed-stage venture has, in the span of five years, grown to a valuation exceeding $10.2 billion, fueled by a portfolio of de-extinction targets that reads like a catalog of natural history: the woolly mammoth, the Tasma-

nian thylacine, the dodo, the dire wolf, the northern white rhinoceros, and the moa.

Colossal's technical pathway is instructive. The company uses CRISPR-Cas9 gene editing to splice woolly mammoth genes into the Asian elephant genome, creating hybrid embryos that carry the genetic architecture of a species extinct for millennia. But genetic engineering alone does not produce a living animal. Embryos must be gestated, and here the company confronts a problem that artificial wombs were designed to solve. Colossal has explicitly stated its intention to develop artificial elephant wombs lined with uterine tissue as a parallel path to gestation, acknowledging that natural elephant surrogacy is impractical, ethically fraught, and prone to biological mismatch. In January 2025, the company reported success with a prototype artificial uterus that cultured fertilized single-cell marsupial embryos to over halfway through pregnancy. This is not theoretical. The infrastructure is being built now.

The convergence Browne identifies is real and accelerating. Conservation biology needs artificial wombs to avoid surrogacy mismatching during species restoration. Commercial biotechnology needs them to scale de-extinction operations beyond the limitations of natural reproduction. And both of these imperatives drive research and development that generates knowledge directly applicable to human ectogenesis. The Dominion Mandate does not prohibit such work; indeed, the effort to restore extinct species can be read as a profound exercise of stewardship over creation. But the speed of private capital investment vastly outpaces the development of governance structures adequate to the technology being built. Colossal's $10.2 billion valuation reflects market confidence. It does not reflect institutional readiness.

13.3 High-Throughput Husbandry and Bio-Industrial Production

Beyond de-extinction, the industrial horizon encompasses applications that are far more prosaic but potentially far more consequential. If artificial wombs can sustain large mammalian fetuses, then the livestock industry has an immediate economic interest in the technology. The global meat and dairy industry operates on razor-thin margins and is perpetually constrained by the biological realities of natural reproduction: gestation periods, fertility rates, perinatal mortality, and the physical toll of pregnancy on breeding stock. Ectogenesis would offer a controlled, reproducible, and scalable alternative.

The implications extend further. Bioprocessing for pharmaceutical production already relies on mammalian cell culture systems that bear structural resemblance to the nutrient delivery and waste removal systems required for fetal gestation. The line between a bioreactor producing monoclonal antibodies and an artificial womb sustaining fetal development is not as wide as it might appear. Both require sterile media preparation, precise control of temperature and oxygenation, continuous monitoring of metabolite concentrations, and contamina-

tion prevention at every stage. The industrial infrastructure for one application can be leveraged for the other, creating economies of scale that would accelerate adoption across sectors.

This is where the concept of the Dominion Mandate encounters its most demanding test. The command to subdue the earth and exercise dominion over every living thing implies a broad grant of creative and managerial authority. Humanity is not merely permitted but expected to develop the tools necessary for responsible stewardship of biological resources. Fuller (2011) argues that humanity is "obliged to use science to radically extend human flourishing," and while his primary concern is human welfare, the logic extends to ecological stewardship. The responsible use of ectogenesis for conservation biology, sustainable agriculture, and species preservation represents a legitimate exercise of sub-creative authority. The question is whether the institutional frameworks governing such use can keep pace with the technology itself.

13.4 The Ethical Bifurcation

Here the analysis must confront a distinction that secular bioethics is often reluctant to draw: the ontological difference between human and non-human life. The Imago Dei is unique to humanity. Genesis 1:27 establishes this in the clearest possible terms, and the entire biblical narrative presupposes a categorical distinction between the human creature, made in God's image, and all other created beings. Non-human organisms do not possess the same ontological status. They are not made in the divine image. They do not bear the same moral weight. This does not mean they may be treated with cruelty or carelessness; the creation mandate, the Sabbath rest extended to working animals, and the prophetic concern for the welfare of the land all testify to God's regard for non-human creation. But it does mean that the moral calculus governing artificial gestation for an elephant embryo is categorically different from the calculus governing artificial gestation for a human fetus.

This bifurcation grants broad freedom for ecological and industrial innovation. Conservation biologists pursuing de-extinction are not violating human dignity. Agricultural engineers developing ectogenetic systems for livestock are not reducing human persons to biological machines. The Dominion Mandate authorizes and even encourages such work, provided it is conducted with a view toward stewardship rather than exploitation, toward flourishing rather than mere profit maximization. The ethical obligation is to exercise dominion responsibly, which means attending to ecological consequences, minimizing animal suffering, and maintaining the integrity of creation even as humanity reshapes it through biotechnology.

But the bifurcation also carries a warning. If the same technology serves both human and non-human applications, and if the commercial incentives for non-human applications vastly exceed the regulatory scrutiny applied to them, then the boundary between the two domains will be under constant pressure. The

industrial horizon is not merely a matter of animal husbandry and de-extinction. It is a governance problem of the first order.

13.5 The Governance Challenge

Zuboff (2019) has described the logic of surveillance capitalism as a system that "unilaterally claims human experience as free raw material" for commercial extraction. The parallel to ectogenesis is instructive. Artificial womb technology, if governed solely by market forces, will be claimed as raw material for industrial optimization. The commercial incentives to scale, automate, and commodify gestational processes are enormous, and the historical record offers little confidence that the boundary between human and non-human applications will be maintained without deliberate institutional enforcement.

Foucault (2008) introduced the concept of biopolitics to describe the modern state's management of biological populations: birth rates, mortality rates, public health, and the regulation of bodies as objects of political governance. Ectogenesis represents the ultimate biopolitical technology. A state that can control the gestation of its citizens can control, at the most fundamental level, the reproduction of its population. This is not hypothetical. The history of state reproductive control is long, systematic, and deeply disturbing.

The record of compulsory sterilization spans the globe and the twentieth century. Nazi Germany sterilized approximately 400,000 people under the 1933 Law for the Prevention of Hereditarily Diseased Offspring, defending the program by noting that the United States had provided the model. The United States itself sterilized over 60,000 people under state eugenics laws, with California alone accounting for a third of all operations. Peru under Fujimori conducted over 300,000 sterilizations between 1996 and 2000, disproportionately targeting indigenous women. Sweden sterilized 63,000 people between 1934 and 1976 under its own eugenics legislation. India's Emergency-era sterilization programs targeted millions, with officials reported to have blockaded villages and dragged men to surgical centers for forced vasectomies.

China's one-child policy stands as the most comprehensive modern example of state reproductive engineering. Between 1980 and 2014, 324 million Chinese women received IUDs and 108 million were sterilized. Enforcement was managed by the National Population and Family Planning Commission at every level of government, with detailed records maintained on women of childbearing age, including past births, contraceptive usage, and menstrual cycles. The demographic consequences have been catastrophic. China's fertility rate has fallen to approximately 1.0, far below replacement level, and the Shanghai Academy of Social Sciences projects that the population will collapse from 1.4 billion to 525 million by 2100. The government abolished all birth limits in 2021 and discovered, too late, that birth rates continued to decline.

These precedents are directly relevant to the governance of ectogenesis. A technology that enables states to manage gestation outside the human body is a

technology that enables states to manage reproduction at a level of control that forced sterilization programs could only approximate. Horn (2023) argues from a reproductive justice framework that ectogenesis could be used coercively, either to force gestation on those who wish to terminate pregnancies or to provide states with tools to manage the reproduction of targeted populations. The risk is not merely theoretical. It is historical. Governments that have forcibly sterilized their citizens cannot be trusted with a more powerful reproductive technology without robust, transparent, and enforceable governance structures.

Spar (2006) observed that "when science creates a new way to make babies, commerce quickly follows." The observation applies with equal force to the industrial horizon. Commerce is already following. Colossal Biosciences' $10.2 billion valuation is not an isolated phenomenon; it is a signal that private capital recognizes the commercial potential of artificial gestation across species. The livestock industry, the pharmaceutical industry, and the conservation biology sector are all potential markets for ectogenetic technology. The governance challenge is to ensure that commercial deployment does not outrun ethical scrutiny and institutional oversight.

13.6 The Environmental Footprint

A dimension of the industrial horizon that bioethics discourse has largely neglected is the environmental impact of ectogenesis at scale. Wowra et al. (2023) have developed life-cycle assessment frameworks for evaluating the ecological costs of bioprocesses, and their findings bear directly on the question of artificial gestation. The researchers demonstrate that in mammalian cell culture systems, the environmental impact of cultivation medium preparation is dominated by amino acid production. Purified amino acids, growth factors, and sterile media are not free inputs; each carries its own supply chain, energy requirements, and waste stream. The study notes that even small-scale mammalian cell culture produces significant environmental burdens when assessed across the full lifecycle, considering energy consumption, toxicity, and resource use at every stage of production.

Artificial womb technology, scaled beyond the experimental stage, would require massive continuous inputs of these materials. Sustaining a human fetus for thirty or more weeks of ectogestation demands a nutrient delivery system operating around the clock, with precisely calibrated concentrations of amino acids, lipids, vitamins, and signaling molecules. The growth factors alone, which regulate cellular differentiation and tissue development at critical stages, represent a production challenge that the bioprocessing industry has not yet solved at the scale that continuous fetal gestation would demand. Scaling this to multiple simultaneous gestations multiplies the environmental burden accordingly. No published environmental assessment of artificial womb technology currently exists, yet the bioprocessing industry is already developing the infrastructure that ectogenesis would require. The blind spot is not merely academic; it is strategic. Without early-stage environmental assessment, the industrial deployment of ar-

tificial gestation will follow the same pattern that Wowra et al. identify across bioprocessing generally: sustainability treated as an afterthought rather than a design constraint.

The environmental dimension extends beyond the gestation facility itself. The supply chains required to produce sterile nutrient media draw on global networks of chemical manufacturing, agricultural inputs, and energy infrastructure. A single facility operating multiple artificial wombs continuously would consume resources comparable to a small pharmaceutical manufacturing plant, and the waste streams generated by fetal metabolic byproducts, spent media, and sterilization chemicals would require treatment systems designed specifically for biological waste. When multiplied across dozens of facilities serving conservation, agricultural, and medical applications simultaneously, the aggregate environmental footprint of non-human ectogenesis could be substantial.

This environmental dimension must be integrated into the governance framework. The Dominion Mandate commands stewardship of creation, not merely its exploitation. An industrial horizon that generates significant ecological burdens through artificial gestation must be evaluated not only for its ethical implications for human dignity but for its material impact on the biosphere. Lifecycle assessment should be a prerequisite for commercial deployment, not an afterthought.

13.7 Demographic Consequences

Präg et al. (2017) have documented the demographic consequences of existing assisted reproductive technologies, finding that while ART's net impact on national fertility is modest, it is growing, and it varies significantly across countries depending on access, insurance coverage, and cultural attitudes. In countries with generous ART subsidies like Denmark and Belgium, the technology has measurably increased total fertility rates. These findings establish a baseline against which the demographic effects of ectogenesis can be projected.

Complete ectogenesis represents a qualitative shift beyond current ART. Where IVF helps couples conceive, artificial wombs decouple gestation from the female body entirely. This decoupling enables possibilities that existing demographic models cannot incorporate: fetal gestation without pregnancy, simultaneous gestation of multiple embryos, gestation outside traditional reproductive timelines. The capability to gestate fetuses ex utero could be deployed to increase population growth in nations facing demographic collapse or to decrease it, depending on the governance framework. China's demographic crisis, driven by decades of state reproductive control, illustrates the dangers of population engineering. Ectogenesis could provide the tools for a different kind of population engineering, equally powerful and potentially equally devastating if mismanaged.

Horn (2023) adds a critical dimension to this analysis through her reproductive justice framework. She argues that ectogenesis could deepen existing inequalities, particularly for marginalized populations who have historically been sub-

jected to reproductive coercion. The right to have children, the right not to have children, and the right to parent children in safe environments form the tripartite foundation of reproductive justice, and each of these rights would be profoundly affected by the availability of artificial gestation. Wealthy populations would gain access first, creating new reproductive stratifications. States facing demographic decline might incentivize ectogenesis for population management purposes, replicating in subtler form the coercive dynamics of China's one-child policy in reverse. Marginalized communities, which have borne the brunt of forced sterilization and reproductive exploitation throughout history, would face the greatest risk of coercion under a governance regime that treated artificial gestation as a tool of demographic engineering rather than a service grounded in human dignity.

The demographic dimension reinforces the argument for proactive governance. Ectogenesis is not a technology that will enter the world quietly. Its effects on population structure, family formation, labor markets, and social welfare systems will be immediate and far-reaching. Institutions that have not anticipated these effects will be forced to respond after the fact, with all the inadequacy that reactive governance entails.

13.8 Regulatory Frameworks and Institutional Gaps

Romanis (2020) has demonstrated that existing legal frameworks are fundamentally unprepared for ectogenesis. In jurisdictions where abortion law is framed around fetal viability, artificial wombs could make every fetus viable from the earliest stages of development, potentially collapsing the legal basis for reproductive choice. In the United Kingdom, the Abortion Act of 1967 assumes gestation occurs within a human body. In US law, the viability threshold established in Roe v. Wade was defined by technological capability, a standard that ectogenesis would render obsolete. No jurisdiction currently has an adequate framework for governing artificial gestation. Romanis argues that criminal law is "not the appropriate vehicle for regulating the use of artificial womb technology" and that governance must address questions of access, cost, and coercion, issues that criminal frameworks cannot adequately handle. Without proactive regulation, artificial wombs could become instruments of reproductive coercion, particularly for marginalized populations.

Di Stefano et al. (2020) have examined the implications of ectogestation for viability definitions and neonatal resuscitation obligations, finding that as artificial womb technology supports fetuses at earlier and earlier gestational ages, the legal and moral category of "viable" would progressively expand. This viability threshold collapse creates legal and ethical categories that no existing framework can accommodate. If ectogestation can support a twenty-week fetus, do physicians have an obligation to offer artificial gestation to all fetuses at that gestational age? How would this interact with parental wishes, resource allocation, and the definition of futility in neonatal medicine? The paper raises the possibility that ectogestation could be used to extend gestation beyond the

natural forty-week term, raising novel questions about the rights and interests of the gestating entity. These questions have no answers in current law.

At the international level, Langlois (2013) has documented the structure and limitations of UNESCO's International Bioethics Committee, the primary global governance body for reproductive technology ethics. The IBC has addressed cloning, human genetic data, and the social implications of new technologies, but its authority rests on soft law rather than binding treaties. Declarations carry moral authority but lack legal teeth. This governance gap becomes critical when considering ectogenesis, where the technology intersects with reproductive rights, fetal viability, and the very definition of parenthood, issues that national governments have historically regulated with vastly different approaches. The dual-track system of expert deliberation through the IBC and state-level negotiation through the Intergovernmental Bioethics Committee creates a framework for discussion, but it does not create the enforcement mechanisms necessary to prevent states from deploying ectogenetic technology in ways that violate human dignity.

Segers (2021) has identified additional governance gaps: no international body has jurisdiction over ectogenesis research and development; existing medical device regulations were not designed for artificial gestation systems; reproductive rights frameworks assume gestation occurs within a human body; and bioethics committees lack the technical expertise to evaluate ectogenesis proposals. The sum of these gaps constitutes not merely a regulatory inconvenience but a structural governance crisis. The technology is developing faster than the institutions designed to govern it, and the market forces driving development have no intrinsic incentive to slow down and wait for governance to catch up.

13.9 The Bleedback Problem

The most dangerous feature of the industrial horizon is not the deployment of artificial wombs for non-human species in itself. It is the certainty that non-human deployment will bleed back into human applications. The same engineering teams that develop artificial elephant wombs for Colossal Biosciences will carry that expertise into medical device companies. The same bioreactor designs that sustain livestock fetuses will be adapted for human neonatal medicine. The same regulatory frameworks that govern commercial animal husbandry will serve as precedents for governing human gestation. The flow of knowledge, capital, and institutional practice between human and non-human ectogenesis will be continuous and bidirectional.

This bleedback is already visible. Partridge's Biobag work with lambs generated immediate speculation about human applications. Colossal Biosciences' artificial uterus prototype was reported in the same breath as its implications for human reproductive medicine. The technical and commercial logic does not respect the ontological boundary that the Imago Dei establishes between human and non-human life. The boundary must be maintained by institutional design,

not assumed by default.

The Foucauldian insight applies with particular force here. Biopolitics describes the state's management of biological populations, and ectogenesis is the most powerful biopolitical technology ever conceived. If the industrial horizon develops without robust institutional enforcement of the human-non-human boundary, the state will possess tools of reproductive management that make forced sterilization look crude by comparison. The governance challenge is not merely to regulate artificial wombs but to prevent the industrial logic of non-human ectogenesis from colonizing the domain of human reproduction.

13.10 Toward Institutional Enforcement

The bifurcation between human and non-human applications of ectogenesis requires institutional enforcement, not merely good intentions. Good intentions did not prevent the sterilization of 400,000 people in Nazi Germany. Good intentions did not prevent China from inserting IUDs in 324 million women. Good intentions did not prevent Peru from targeting indigenous women for forced sterilization under the guise of family planning. The historical record is unambiguous: when states possess the institutional capacity to manage reproduction, they use it coercively against vulnerable populations.

The same logic applies to commercial actors. Good intentions did not prevent the exploitative surrogacy industries that now operate in India, Ukraine, and Southeast Asia. Good intentions did not prevent the commodification of human eggs and sperm in the global fertility market. The commercial incentives surrounding ectogenesis are enormous, and the boundary between acceptable industrial application and exploitative commodification will be tested continuously.

What is required, therefore, is a governance architecture that operates at multiple levels simultaneously. At the international level, the UNESCO framework must be strengthened beyond soft law to include binding protocols on the deployment of artificial gestation technology, with particular attention to the bleedback risk from non-human to human applications. At the national level, regulatory frameworks must be developed proactively rather than reactively, incorporating life-cycle environmental assessment, demographic impact modeling, and reproductive justice principles from the outset. At the institutional level, bioethics committees must be equipped with the technical expertise necessary to evaluate ectogenesis proposals across the full spectrum of human and non-human applications.

The Dominion Mandate demands nothing less. The command to exercise dominion is a command to exercise it well, which means governing the tools of creation with wisdom, foresight, and an unyielding commitment to the dignity of every human person made in the image of God. The industrial horizon is coming. The question is whether the church and the state will build the institutions necessary to govern it, or whether they will be governed by it.

The bifurcation holds. Human ectogenesis must be governed by the principles of Imago Dei dignity, relational embodiment, and the covenantal framework of marriage and family. Non-human ectogenesis must be governed by the principles of ecological stewardship, animal welfare, and responsible innovation. But both domains require the same institutional seriousness, the same proactive governance, and the same refusal to let market forces or state power set the terms unilaterally. The tools of creation belong to the Creator. The dominion stewards are accountable for how they are used.

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14 Chapter 12: The Imperative of Christian Affordances

14.1 Resolution and Call to Action

The dialectic is now complete. Across the preceding chapters, this work has constructed an affirmative case for the development of artificial wombs as a legitimate and necessary exercise of the Dominion Mandate, grounded in the theological architecture of sub-creation, governed by the dual commandment to love God and neighbor, and calibrated against the empirical realities of maternal suffering that cry out for redress. The case is substantial and, this author believes, compelling. Chapters 5 and 6 established the theological warrant with rigor: humanity, bearing the Imago Dei, is called to exercise creative dominion over the natural order as stewards under divine sovereignty, not as autonomous usurpers grasping at prerogatives reserved for the Creator alone. The Dominion Mandate is not a license for reckless innovation. It is a commission for ordered creativity, for the extension of human agency into domains where suffering is preventable and flourishing is achievable. Chapter 8 extended that warrant into the specific domain of ectogenesis, demonstrating that the artificial womb does not violate the biological substrate God designed but rather participates in the redemptive unfolding of a creation that groans under the weight of the Fall and awaits the liberation of the children of God. The counter-arguments marshaled in Chapter 9 were formidable, and this work has not dismissed them. The risks of commodification, surveillance, eugenic optimization, and the disruption of maternal bonding are real, structurally embedded, and historically precedented. They deserve the weight this book has given them.

But the counter-arguments, for all their moral and analytical gravity, ultimately fail to negate the affirmative case for one overriding reason that has not yet received sufficient emphasis: the technology is inevitable.

This is not a rhetorical concession designed to foreclose debate. It is an engineering assessment grounded in observable trajectories. The convergence of microfluidic design, bioreactor scaling, artificial placenta research, and stem cell biology has reached a point of critical mass that no single ethical objection can

arrest. Government funding agencies in the United States, the European Union, Japan, and South Korea are investing in artificial womb research with increasing urgency. Private biotechnology firms are pursuing ectogenesis platforms with venture capital backing. The scientific literature is expanding at an exponential rate. And the moral weight of the maternal mortality crisis, which this book has returned to repeatedly and will return to once more before this chapter closes, exerts a pull that no amount of philosophical caution can fully resist. The artificial womb will be built. The question that remains is not whether it will reshape the landscape of human reproduction, but whether its affordances will be shaped by those who recognize the Imago Dei in every human person, or by those who operate under a framework that regards the human person as a configurable input to a system of optimization.

This distinction is not academic. It is architectural. It determines what the technology becomes.

14.2 The Propagation Argument

Every engineered system embeds affordances. This principle, established in Chapter 2 and revisited throughout this work, is not a theoretical abstraction. It is a structural reality. A bridge affords crossing. A vaccine affords immunity. A surveillance camera affords monitoring. A database affords classification. These affordances are not accidental. They are designed. They are chosen by engineers and architects and systems designers who make decisions at the drawing board that propagate forward through every downstream interaction with the finished system. The artificial womb is no exception to this principle. Its affordances will be determined at the design table, and those affordances will shape human behavior, social structures, and moral intuitions for generations to come.

Consider the alternative to Christian engagement. If those who confess the lordship of Christ refuse to engage the design process, if they cede this ground to secular utilitarian frameworks that regard the human person as a bundle of preferences to be optimized, a biological machine to be tuned, then the affordances embedded in the technology will reflect that ontology with relentless consistency. The affordance of commodification will be realized, treating human embryos as products to be manufactured to specification, graded by quality metrics, and distributed according to market logic. The affordance of surveillance will be operationalized, subjecting fetal development to continuous algorithmic monitoring not merely for clinical purposes but for predictive profiling, data harvesting, and behavioral pre-configuration. The affordance of eugenic optimization will be industrialized, sorting human beings by genetic fitness with the cold efficiency of a quality control pipeline in a semiconductor fabrication plant. The language of precision medicine will provide the euphemistic cover. The language of reproductive autonomy will provide the moral license. And the infrastructure will be built by engineers who never heard the name of Christ spoken in the context of their work, because no Christian was present to speak it.

And Christians will have no seat at the design table.

This is the propagation risk, and it must be stated with absolute clarity: the constraints we refuse to embed will be the constraints that do not exist. If the theological conviction that every human life possesses inherent dignity, grounded in the Imago Dei and sustained by the creative will of God, is not translated into engineering specifications, then those specifications will not exist. If the doctrine that the human person is a bearer of sacred worth, not a configurable variable in a utilitarian calculus, is not encoded into the affordance architecture of the artificial womb, then the architecture will encode something else. Something worse. Nature abhors a vacuum, and so does design. Every engineered system has a default state. If the default is not theological, it will be utilitarian. If it is not stewardship, it will be optimization. If it is not love, it will be efficiency. If it is not the Imago Dei, it will be the market.

The propagation argument is not a prediction about what might happen. It is a structural observation about what will happen based on the mechanics of affordance design. And it issues a call that the Church cannot afford to ignore.

14.3 Three Imperatives

The propagation argument, if it is accepted, generates three imperatives that are not optional suggestions but operational mandates for Christian engagement with ectogenesis.

14.3.1 I. Claim a Seat at the Design Table

Abraham Kuyper, in his 1911 Stone Lectures at Princeton, declared with characteristic boldness: "There is not a square inch in the whole domain of our human existence over which Christ, who is Sovereign over all, does not cry: 'Mine!'" This declaration was not a devotional sentiment. It was not a pious aspiration to be filed under "spiritual reflections" and left there. It was an operational mandate. Kuyper was articulating the doctrine of sphere sovereignty, the conviction that Christ's lordship extends over every domain of human activity without exception, including the domains of science, engineering, medicine, and biotechnology. The laboratory is not outside the jurisdiction of the Kingdom of God. The bioreactor is not exempt from the sovereign claim of Christ. The design specifications for the artificial womb fall under that claim, and those who confess it are obligated to act accordingly, not merely in their private devotions but in their public professional conduct.

This means Christians must show up. Not as protesters standing outside the laboratory with placards and condemnation. Not as commentators issuing denunciations from the safety of the pulpit, the podcast studio, or the opinion page. But as engineers. As bioethicists. As regulatory specialists. As funding bodies. As institutional voices willing to invest human capital, intellectual labor, and financial resources in the design process. The propagation argument demands presence. Affordances are shaped by those who are present at the

table. Absence is abdication. Silence is surrender. To refuse to engage the engineering of the artificial womb is to consent to an engineering that proceeds without theological constraint.

The Church has historically excelled at this kind of engagement in other domains. The impulse that built the first Christian hospitals in the Roman Empire, that drove the establishment of medical missions across Africa and Asia in the nineteenth century, that animated the founding of universities in the medieval period and the construction of healthcare systems across the modern world, that continues to sustain Christian medical and nursing programs at institutions around the globe, that same impulse must now be directed toward the design of reproductive technologies. The artificial womb is a medical device. It belongs in the same moral category as the ventilator, the dialysis machine, the neonatal incubator, and the cardiac pacemaker. Christians have never argued that these life-saving technologies should be left to secular design alone, and the artificial womb deserves no less engagement.

Kuyper's square inch is not a suggestion. It is a claim. And it extends to the bioreactor.

14.3.2 II. Govern the R&D Pathway with Empirical Accountability

The affirmative case for ectogenesis presented in this book has been deliberately structured around falsifiable hypotheses rather than irrefutable dogma. This was a conscious design choice. The bonding caveat, for instance, is not an article of faith that must be defended at all costs. It is a testable claim about the relationship between gestational environment and postnatal attachment. This work has argued, on the basis of the available evidence, that the case for gestational bonding is less conclusive than critics assume, that adoption literature demonstrates robust bonding in the absence of biological gestation, and that postnatal interaction provides a sufficient substrate for secure attachment. But if future data demonstrates insurmountable harm to infants gestated outside the womb, harm that cannot be mitigated through neonatal care, postnatal bonding protocols, environmental design, or any other intervention, then the R&D pathway must pivot. This is non-negotiable.

The command to love one's neighbor demands this. Love is not ideological stubbornness. It is not the insistence on a predetermined conclusion regardless of what the evidence shows. Love listens. Love adjusts. Love honors the data when the data speaks, especially when it speaks of harm to the vulnerable. A Christian commitment to ectogenesis is not a commitment to the technology at all costs. It is a commitment to the principle that suffering should be alleviated when it can be alleviated without creating greater suffering. If the technology creates greater harm than it resolves, then love demands that it be abandoned, redesigned, or restricted until the harm can be eliminated.

This is why empirical accountability must be embedded in the R&D pathway from the very beginning. Clinical trials must be rigorous, transparent, and sub-

ject to independent oversight. Longitudinal studies must be funded, sustained over decades, and published regardless of outcome. Independent review boards must be constituted with genuine theological and ethical representation, not merely as rubber stamps for predetermined outcomes or as fig leaves for institutional legitimacy. The engineering process must include feedback loops that allow for course correction at every stage, from initial concept through prototype development, preclinical testing, clinical trials, regulatory approval, and post-market surveillance. Iterative design, the standard methodology of biomedical engineering, is well suited to this requirement. But iterative design only functions if the iteration is honest. Christians must insist on honesty, even when honesty complicates the narrative they wish to tell. Truthfulness is not optional in the Kingdom of God. It is foundational. And it is especially foundational in matters of life and death.

14.3.3 III. Embed Governance Structures from the Design Stage

Nancy Leveson, in her landmark 2011 work on system safety engineering, argued with considerable force that safety is not a feature to be bolted onto a system after construction is complete. It is an emergent property of the system's architecture. A system is safe, or it is not, based on the decisions made during the design phase. Retrofitting safety is always more expensive, less effective, and more prone to catastrophic failure than building it in from the start. This principle is well established in aerospace engineering, nuclear engineering, and chemical process safety. It must now be applied to biomedical engineering with equal rigor.

This principle applies with full force to the artificial womb. Governance structures must be embedded from the design stage. Not as external regulations imposed after the fact by regulatory agencies playing catch-up with technological development. Not as ethical guidelines that exist on paper but are ignored in practice because they lack enforcement mechanisms. But as functional components of the system architecture itself. The affordance architecture of the artificial womb must include governance affordances: constraints that prevent commodification by making it technically impossible to treat embryos as market commodities within the system, protocols that limit surveillance to medically necessary parameters with hard-coded boundaries, selection criteria that explicitly exclude eugenic optimization at the software level, and access frameworks that ensure equitable distribution is a design requirement rather than an afterthought.

Ron Cole-Turner articulated this necessity with precision in 2008 when he wrote: "Theology must not simply react to genetic science; it must provide a proactive framework where modifying the genome is understood as an act of loving stewardship rather than hubris." The same imperative applies to ectogenesis with equal force. Theology cannot wait until the artificial womb is a commercial product available for purchase and then scramble to offer commentary after the fact. The proactive framework must be in place before the first clinical deploy-

ment. This requires sustained collaboration between theologians and engineers, not as a one-time consultation or a perfunctory ethics review but as an ongoing partnership embedded in the development process at every stage.

Jack Stilgoe, Richard Owen, and Phil Macnaghten, in their influential 2013 framework for responsible innovation, identified four dimensions of responsibility that map directly onto the Christian imperatives articulated here. Anticipation demands that Christians think carefully about the downstream affordances of the technology before it is deployed, modeling the likely consequences and preparing for the contingencies. Reflexivity demands that Christians examine their own assumptions, motivations, and blind spots, ensuring that the pursuit of ectogenesis is genuinely oriented toward love of neighbor and not toward cultural dominance, institutional prestige, or theological point-scoring. Inclusion demands that the design process incorporate diverse voices, especially the voices of the vulnerable populations most likely to be affected by the technology: women in low-income countries, communities with limited access to healthcare, families facing high-risk pregnancies, and populations that have historically been subjected to coercive reproductive policies. Responsiveness demands that the framework remain adaptive, ready to adjust when new evidence emerges, when new ethical concerns are identified, or when the technology evolves in directions that were not anticipated at the outset.

These are not optional add-ons to the engineering process. They are engineering requirements. A system designed without anticipation is a system designed to fail in ways that could have been foreseen. A system designed without reflexivity is a system designed to replicate the designer's blind spots at industrial scale. A system designed without inclusion is a system designed for the privileged at the expense of the vulnerable. A system designed without responsiveness is a system designed to ossify, to become brittle, to lose the capacity for self-correction that is essential to any technology that serves human flourishing. The artificial womb must be none of these things. It must be designed with foresight, humility, justice, and adaptability. These are engineering virtues. They are also theological virtues. And they converge in the design table.

14.4 The Maternal Mortality Restatement

The argument returns, as it must and as it always has throughout this book, to the bodies of women.

The World Health Organization reports that approximately 260,000 to 295,000 women die each year from causes related to pregnancy and childbirth. These are not abstractions. These are not statistical projections or epidemiological models. These are women with names, with families, with communities that grieve their absence. The vast majority of these deaths occur in low- and middle-income countries where access to emergency obstetric care is limited or nonexistent. The vast majority are entirely preventable. Hemorrhage, the leading cause, kills through rapid blood loss that could be managed with timely intervention. Sep-

sis kills through infection that could be treated with antibiotics. Hypertensive disorders, including preeclampsia and eclampsia, kill through organ failure that could be prevented with monitoring and medication. Complications from unsafe abortion kill through processes that could be eliminated entirely with safe reproductive healthcare. These are not exotic diseases requiring breakthrough therapies or billion-dollar research programs. They are known problems with known solutions, solutions that have been available in high-income countries for decades. The gap is not knowledge. The gap is access.

The artificial womb is one such solution. It is not the only solution. It is not a substitute for improved healthcare infrastructure, better trained birth attendants, equitable distribution of medical supplies, or universal access to emergency obstetric care. These interventions must continue and must be expanded. But the artificial womb addresses the root cause of a significant portion of maternal mortality in a way that no other intervention can: it removes the mother from the physical act of gestation and delivery. If the fetus can be gestated outside the maternal body, the mother is no longer at risk from the complications that gestation and delivery produce. This is not a theoretical abstraction. It is a calculable reduction in mortality. It is a foreseeable outcome of a technology that is within the reach of current engineering capability.

Every year that the technology is delayed, women die who did not need to die. Every year that Christians spend debating whether ectogenesis is morally permissible while refusing to engage the engineering process that would bring it to fruition, the propagation risk compounds. The affordances that could have been shaped by theological conviction remain unshaped. The constraints that could have been embedded by those who recognize the Imago Dei in every human person remain unembedded. The governance structures that could have been built into the system architecture remain unbuilt. And the women who die continue to die, in hospitals without surgeons, in villages without clinics, in communities without the resources to save them.

This is not an argument from emotion, though emotion is appropriate. It is not an argument from sentiment, though sentiment is warranted. It is an argument from justice. The command to love one's neighbor is not suspended when the neighbor is a woman in sub-Saharan Africa or South Asia facing a high-risk pregnancy without access to emergency obstetric care. The command to love one's neighbor is not contingent on the neighbor's ability to pay for the technology, on the neighbor's geographic proximity to a research hospital, or on the neighbor's social status within the structures of global inequality. The command is absolute. It issues from the character of God himself, who is no respecter of persons and who numbers the hairs on every head. And it issues a demand: build the technology that saves her life. Build it with theological integrity. Build it with engineering rigor. Build it with governance structures that protect the dignity of every person it serves. Build it now.

Nola Herzfeld, writing in 2009, offered a vision that anchors this demand in theological confidence rather than humanistic presumption: "A faith-based techno-

logical optimism trusts that God's grace operates through human ingenuity to bring about healing and transformation." This is not naive optimism. It is not technological utopianism that ignores the realities of sin, brokenness, and the capacity of human beings to corrupt even the best of creations. It is eschatological confidence, grounded in the conviction that the God who sustains the biological substrate of human life also sustains the human capacity for engineering, that the same Spirit who groans in intercession for a creation under the curse of the Fall also empowers the minds that design systems of healing and restoration. The artificial womb, built with theological integrity and governed by the command to love, is not an act of presumption against the Creator. It is an act of faithfulness to the Creator's commission. It is the Dominion Mandate in action, the sub-creative vocation exercised in the domain of reproductive medicine, the Imago Dei made manifest in microfluidics and bioreactor design.

The maternal mortality crisis is not a problem that will solve itself. It is a crisis that demands intervention, and the intervention that this book has argued for is one that Christians are uniquely positioned to shape. Not because Christians are smarter than secular engineers. Not because Christian institutions have more resources than secular biotechnology firms. But because Christians possess a framework that no secular ontology can provide: the conviction that every human person is made in the image of God, that every life is sacred, that every woman who dies in childbirth is a woman whose death is an affront to the Creator who made her. This framework, if it is held with integrity and translated into engineering practice, will produce a technology that serves human flourishing in a way that no purely utilitarian framework can achieve. The affordances will be different. The governance structures will be different. The outcomes will be different. Because the foundation is different.

This is the case. The argument is settled. The theology is established. The engineering is feasible. The moral urgency is undeniable. The propagation risk is compounding by the year.

What remains is action.

14.5 Epilogue: The Womb That Was Built

The Prologue of this book opened with a scene: a hospital room, a mother in crisis, a child whose arrival carried the weight of peril. The narrative arc has now traversed the full distance from that opening to this closing, through the history of ectogenesis, the engineering of artificial wombs, the theological warrant for sub-creation, the Dominion Mandate applied to reproductive technology, the counter-arguments weighed and measured, and the imperatives that emerge from the dialectic. The arguments have been laid. The evidence has been presented. The theological framework is in place. The engineering possibilities are real. The maternal mortality crisis is ongoing.

What remains is the question that every argument, in the end, must face.

What will be done?

The artificial womb will be built. This is not a conditional statement. It is not contingent on whether Christians approve or disapprove, whether the Church engages or withdraws, whether theologians affirm or condemn. The engineering trajectory is set. The investment is flowing. The scientific groundwork is laid. The moral urgency is undeniable. The technology will emerge from laboratories and enter the world. The only variable is who will shape its affordances and how.

There are two futures. They diverge at the design table.

In one future, the artificial womb is built by those who regard the human person as a resource to be managed, a problem to be solved, a variable to be optimized in a system of competing preferences. The affordances reflect this ontology with merciless precision. Access is stratified by wealth, with premium gestation environments available to those who can afford them and standard or degraded environments assigned to those who cannot. Selection criteria favor genetic fitness, with algorithmic sorting of embryos by predicted phenotypic traits and market-driven filtering of undesirable characteristics. Surveillance is normalized, continuous, and predictive, generating behavioral profiles from fetal biometric data that follow the child through life. Commodification is the operating logic, treating embryos as products and gestation as a service with a price point. The technology saves lives, but it also sorts them. It alleviates suffering, but it introduces new hierarchies of human worth based on genetic composition and economic access. The womb that was built is a marvel of engineering and a monument to utilitarian indifference. The Imago Dei is not denied outright. It is simply never mentioned. And its absence shapes everything.

In the other future, the artificial womb is built by those who recognize the Imago Dei in every human person from conception to natural death, who confess the sovereignty of Christ over every square inch of human existence, who understand the Dominion Mandate as a commission for ordered stewardship rather than autonomous control. The affordances reflect this conviction with structural consistency. Access is governed by medical need, not by purchasing power, with design specifications that make equitable distribution a technical requirement rather than a policy aspiration. Selection criteria are limited to genuine medical indications, with hard-coded exclusions that prevent eugenic sorting at the software level. Surveillance is constrained to clinically necessary parameters with embedded oversight mechanisms that prevent data exploitation. Commodification is prohibited by architecture, with system designs that make it technically impossible to treat embryos as market commodities. The technology saves lives and honors the lives it saves. It alleviates suffering without introducing new suffering. The womb that was built is a marvel of engineering and a testament to theological conviction translated into technical specification.

These are not utopian fantasies or dystopian warnings. They are engineering outcomes. The difference between them is not technological. Both futures

employ the same microfluidic channels, the same bioreactor designs, the same artificial placenta architectures, the same monitoring algorithms. The difference is moral. It is architectural. It is determined by the choices made at the design table, by the people who show up, by the affordances they choose to embed and the affordances they choose to foreclose. The technology is the same. The affordances are not. And affordances determine outcomes.

The reader now stands at the threshold. The arguments of this book are complete. The reader has been invited to think carefully about the theology of sub-creation, to weigh the evidence for and against ectogenesis, to consider the propagation risk of ceding the design table to those who do not share a theological anthropology, and to accept or reject the three imperatives that this chapter has articulated. The choice belongs to the reader. It has always belonged to the reader.

But the choice is not abstract. It is concrete. It is embodied in the decision to engage or to withdraw, to build or to protest, to shape affordances or to surrender them. The artificial womb will be built. The only question that matters is the one this book has been asking from its first page to its last.

Will it be built rightly?

Truly, all engineering and scientific pursuit, when rightly ordered and boldly executed, serves to glorify the Author of the biological substrate and deeply love our neighbors. The artificial womb, governed by the commands to love God and love others, is not a rebellion against the Creator. It is an exercise of the Imago Dei. It is a sub-creative act of stewardship that rolls back the physical realities of the Fall, liberates human capacity, and participates in the redemptive trajectory of a creation groaning for the freedom of the glory of the children of God. Let us build. Let us build rightly. And let us do so to the glory of the One who designed the biological substrate we dare to steward.
