Queering Oocytes: Laboratory, Body, Cell

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To Abu Eli, Grandpa Stanley, Abuelo Oscar, and Grandma Doris
Abstract

Recent advances in stem cell technology enable new possibilities for biological reproduction among same-sex couples and transgender people who have undergone medical or surgical transition. Despite this promise of revolutionary queer futurity, biomedical science has been harnessed to marginalize the reproductive capacity of the poor, colonized, and people of color for eugenic and capitalist aims. This study draws upon firsthand experiences working in a reproductive biology laboratory and integrates perspectives from feminist science and technology studies, Black feminism, and queer and transgender studies. The work explores how the formation of scientific knowledge (re)produces racialization of reproductive bodies, capitalist manipulation of reproductive potential, and normative temporalities of reproductive bodies. Examining the dynamic plasticity of sexing and gendering gametes within the laboratory reveals a mechanism by which researchers instill their own internalized sex and gender norms onto their research subjects, essentializing sex and gender hierarchies across species, tissue, and cell boundaries. *In vitro* gametogenesis, an assisted reproductive technology on the horizon of human use, invites a politics of multiplicity through which to understand all mammalian tissues as potentially reproductive. This novel reproductive future elucidates the interconnections between human and animal reproduction within and beyond the laboratory context and enables groundbreaking new opportunities for interspecies reproductive intimacy and queer reproductive futurity. Ultimately, the work takes an ambivalent view of emergent reproductive technologies, acknowledging their reinforcement of eugenic and economizing racial logics even as they queer human and animal bodies, tissues, and cells and revolutionize kinship and reproductive capacity for bodies deemed non-normative.
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Introduction: The Lab on the Hill

On my third day in Göttingen, Germany, I set out on my first trip to the lab to begin my summer research internship at the Max Planck Institute (MPI). I mounted my 7-speed rental bike, bicycle, strapped on my helmet, and followed Google Maps’ verbal navigation instructions until I reached an incline so steep that I was forced to step off the bike and catch my breath. My graduate student mentor, Sophie, had warned me that the Institute stood atop a “hill” in an email ahead of time. This was a mountain. I pedaled/ran/walked ungracefully to the top, my shirt and fleece sweater both soaked through by the time I got to the top.

In the waning dusk light, I was struck by the Institute’s imposing form. It was industrial and uniform, each building consisting of corners and edges and rectangles, whites and greys and beiges interrupted by large square windows. It was functional, with outdoor staircases connecting different levels of buildings and different buildings to one another as they marched up to the hill’s summit. That night, I met Sophie and other colleagues at a dinner at the Institute canteen marking the end of a conference. After days hearing mostly German in Göttingen as I recovered from my cross-Atlantic flight, it was refreshingly familiar to hear English – tinged with an astonishing variety of European, Asian, African, and Latin American accents – spoken among the Institute researchers. I had my first German bread and my first German beer and desperately tried to memorize as many names as possible before my first day of work.

The next time, I left myself more time to make it up the hill, budgeting for plenty of breaks when it got too steep. I made my way to Tower 5, the second-furthest building from the Institute’s entrance, and climbed four flights of stairs to reach the Smith\(^1\) Lab for the first time.

\(^1\) pseudonym
Positioning the Laboratory, Positioning the Researchers

The lab’s positioning on a hilltop sequestered from the town below was a defining feature of my experience doing research there. I cannot comment on the reasoning for constructing the Institute in this location – or in Göttingen, for that matter – in 1971. However, I am painfully aware that its physical position relative to residential spaces mandated that Institute employees possess a certain fortitude and tenacity to get there every day – physical, mental, emotional, or otherwise. Even those who lived quite close by had to scale the hill – by bicycle or by foot – to reach the Institute at the summit. Those who lived further away more often took the bus, but its leisurely pace and questionable reliability made this option an unpopular choice. Very few people in Göttingen had their own cars; this was especially true of masters and PhD students, who made up most of the laboratory. Thus, getting to the lab was at least somewhat inconvenient for every member of the laboratory. Moreover, the lab first and foremost studies mammalian oocytes and their specialized cell division process called meiosis. This kind of work required long days, often beginning at 0700 and ending after 2000 or 2100 due to the many hours spent waiting for oocytes to progress to the next phase of their division process. On many occasions, I biked home with only my dim bicycle light to guide me through the darkness. My colleagues often encouraged me to head home early or come in later, assuring me that they would help complete any tasks I couldn’t finish myself, but I was insistent that I be the one to execute every step of the research process.

What compelled me to go to such lengths and expend such physical effort for a summer research internship? In assessing my motivations, I am compelled to situate myself amid my research interests and career ambitions as well as within the scholarly community that informs this thesis. Contextualizing my research efforts and the personal motivations behind them requires an acknowledgement that “science is a contestable text and a power field” (Haraway 1988, 577). My experiences working in laboratories over the last eight or so years have laid bare the fact that
science’s “truth claims” are as much a product of the people doing the science as the observations made, though I imagine most of my dearest mentors in science would deny this vehemently for fear that it would undermine the perceived rigor of their experiments. Science is rhetoric. It is a story told to lab colleagues, principal investigators, peer reviewers, grant reviewers, popular science publications, and the general public aimed to convince others that “one’s manufactured knowledge” grants them their “desired form of very objective power” (Haraway 1988, 577-578). I aimed to approach my internship – and aim to approach this piece of writing – with “feminist objectivity” at the forefront of my mind and behavior. My observations, discoveries, and experimental strategies in the laboratory were each informed by who I am as a subject and how that subjectivity manifested in my techniques of knowledge production alongside other scientist subjects with their own bodies producing knowledge in their own ways. Especially in studying oocytes, a project that relied so heavily on the prosthesis of a microscope to render information meaningful, my standpoints as a scientist were mediated by the tools I used to observe and the particular laboratory environment around me. My descriptions, measurements, and hypotheses only make sense if I position myself relative to the living subjects I studied. I want to make clear the strengths and shortcomings of my unique vantage point and its enmeshment in conversations with other scientists and thinkers as well as with oocytes themselves; this is how any semblance of “objective” knowledge is produced. Thus, I hope to emphasize that my view is “from a body,” and I hope that my account will too be interpreted “from a body” (Haraway 1988, 589).

Framing my subjectivity acknowledges “how a place on the map is also a place in history within which…I am created and trying to create” (Rich 1986, 212). I am first situated within my body. I have been told that my body is a Jewish body, a male body, a Latinx body, a white body. I assert that I am queer – my gender identity is non-binary though my presentation is most often read as masculine. My sexuality is fluid, though I am committed to a woman partner such that others
most often read my relationship as heterosexual. Notably, I did not come out as queer to any of my colleagues throughout my time in the Smith Lab. It began as a reflex to entering a new environment. Unsure of the political viewpoints of my new colleagues, I thought it safer to pass as straight and cis, a privilege conferred by my whiteness, my masculine gender presentation, and my partner’s gender identity. In doing so, left part of me still packed in the huge suitcase I brought to Germany.

In the spring semester of my junior year as an undergraduate at Duke University, I was looking for a change of pace; I and my colleagues were preparing to submit a manuscript reflecting the sum of my last two and half years of research in my cell biology laboratory at Duke. As a major in Biophysics with a penchant for reproductive biology, I sought to integrate these interests amid Germany’s vibrant biophysics community. I consulted a German biophysicist recently hired as a faculty member at Duke; he recommended the Smith lab and helped me make initial contact, after which I interviewed and managed to secure myself an internship position. Notably, none of my scientific work at the MPI, nor this thesis analyzing that science, would have been possible without funding I received as part of a research grant that came as part of my merit scholarship at Duke. This thesis is a product of my own intellectual curiosity but is also indebted to the individuals and funding agencies who have chosen to support my inquiry.

While doing research at the Institute, I was simultaneously applying to combined MD/PhD programs at American medical schools with an eye toward a PhD in reproductive and developmental biology with translational relevance to human reproductive healthcare. I chose to pursue oocyte research at the MPI in part for the optics of how it would fit within my broader research portfolio. I knew that travelling to Germany to work with a leader in reproductive biology and high-resolution live imaging would convey my independence and resourcefulness as a scholar and scientist as well as dual commitments to the work’s subject matter and methodology. Looking back now at the conclusion of my application process, I can affirm that interviewers and program
directors were routinely impressed that I’d gotten the opportunity to work with Dr. Smith and contributed meaningfully to a project in her laboratory.

I was driven to bike to the top of that hill every morning out of a deep curiosity for both the biology and social relevance of human reproduction. From a scientific perspective, I had previously investigated gametogenesis — the process by which sexually reproducing organisms generate cells containing only half their genomes with the potential to combine with other such cells to produce an embryo — in model organisms including yeast and roundworms, but never in mammals. I was excited to probe the complexities of mammalian reproductive biology for their translational relevance to human reproductive medicine. I hoped to inform myself on the most modern techniques and most salient ideas in mammalian oocyte research today as a future physician-scientist with aspirations to conduct similar work in my own laboratory throughout my career. Informed by my own queer identity, I was also motivated to call attention to inequities in reproductive healthcare for those who have been marginalized through the mechanisms of racialization and cis-heterosexism. I saw the reproductive biology laboratory as an environment in which I could locate and contextualize racist, sexist, cisgender, and heterosexual conceptions of human reproduction in order to learn how best to strategically contest them. I hoped that as a queer voice in an overwhelmingly heterosexual and cisgender space, I could destabilize the normative reproductive scripts that I observed and draw upon my training in feminist and queer theory as well as biology to introduce new perspectives on how reproductive capacity is evaluated and understood (Collins 1986). I strove to learn how I could distinguish my own medical and scientific practices from the ones I observed to better serve the reproductive health needs of the marginalized throughout my career, with particular interest in enabling novel queer reproductive opportunities. Despite these lofty aspirations, I left the laboratory most days feeling deeply ambivalent about my participation in my
work. I knew that by participating in existing bioscientific frameworks, I was contributing to the racialization and cis heterosexism central to the scientific practices I observed.

I have taken the time to rigorously position myself within the context of my research activities and area of study in keeping with the tradition of feminist science and technology studies and feminist studies more broadly – I recognize that the knowledge production is a function of the individuals producing that knowledge and cannot escape the realm of human discourse or interpretation (Haraway 1988, Latour and Woolgar 1979). Entering the laboratory prompts intimacies among researchers and non-human animal subjects – between entities recognized as whole bodies and tissues and cells rendered parts of a whole – with power to reaffirm as well as question bodily and species boundaries (Hayward 2008, Hayward 2010). In the study of reproduction especially, the natural, the technoscientific, the human, and the non-human animal blur together, producing new intimacies, new knowledges, and new bodies all at once. Human and animal bodies, cells, and tissues become porous and enmeshed (Chen 2012, Deleuze and Guattari 1987). Discrete, rigid boundaries of the known give way to uncertainty, questions, and competing claims (Latour and Woolgar 1979, Murphy 2017). Within this dense, interconnected biocultural milieu and knowledge field, researchers must be vigilantly “aware of when [they] are projecting cultural imagery onto what [they] study” (Martin 1991, 501).

Of course, I am not the only one for whom getting to the lab was such a profound inconvenience. Each one of us managed to reach the hilltop daily to complete the day’s experiments; many of my lab mates came in on weekends and worked days even longer than mine. What compelled them?

Some told me that they saw Dr. Smith as a pioneer in live cell imaging of mammalian oocytes (she was indeed the first investigator to successfully study mouse oocyte meiosis in detail in real time); they hoped to leverage their specialized and sought-after training under Dr. Smith into
post-doctoral or principal investigator positions down the road. Many of these same individuals claimed that oocyte meiosis simply provided a fascinated biological problem that they were excited to investigate. These individuals seemed motivated to advance their careers and scientific acumen – oocyte research, with all its challenges, provided an excellent opportunity to harness their tenacity and creativity as they prepared for the next stage in their careers.

Others’ incentives seemed based in a project of liberation not unlike mine. They constantly articulated their position that declining fertility in aging “women” placed inequitable constraints on their opportunities for family building on a timeline compatible with their career goals. This struck me as a distinctly feminist position; they hoped to learn more about age-related changes in oogenesis in the hopes of clarifying approaches for therapeutic intervention that might keep oocytes healthier for longer, allowing women to have children later in life after they had presumably attained long-term job stability and achieved the capacity to support a family. This liberating feminist reproductive fantasy was steeped in a very specific Western, wealthy, white woman referent, a view of female sex/gender that “becomes descriptive for the social and sexual arrangements of the dominant social order rather than an analytic category” (Hartman 1997). I explore the mechanisms by which reproductive science establishes deviance and debility by establishing specific racialized, sexed, and gendered reproductive forms as normative in Chapter 1 and Chapter 2.

My motivation might be distinguished from my colleagues’ as a distinctly queer rather than feminist position, not simply because I myself identify as such or because I feel driven to enable new queer reproductive futures, but more deeply because of my perspective that oocytes have much to reveal not only about female reproductive biology, but can lend profound insight into how all bodies reproduce (or do not reproduce). This is an attitude of multiplicity – a recognition that human and animal bodies, tissues, and cells are interconnected and relationally constituted objects with broad potential as research subjects, therapeutic agents, and beyond. My perspective acknowledges and
embraces emerging stem cell and germline biology research findings that paint a new picture of cell, tissue, body, and species identity. I see a reproductive future that harnesses the techniques of regenerative medicine to embrace the multiplicity within all human and animal tissues, opening new kinship structures and destabilizing normative heterosexual and cisgender visions of reproduction and family. I expand on the specifics of this vision in Chapter 3, highlighting current possibilities for rethinking reproduction and identifying gaps in bioscientific knowledge required to make my envisioned reproductive future a reality.

Reproductive Racialization, Sex/Gendering, and Queerly (Re)producing the Future

In the three essays that follow, I interrogate modern laboratory practices in reproductive biology research, tracing their historical origins and implementations on human and animal populations and exploring their future ramifications for reproductive medicine and human kinship. My chief method is autoethnography engaged with my bioscientific knowledge production within the Smith Lab. Throughout the thesis, I aim to identify how existing social hierarchies reproduced themselves within the laboratory’s research methodologies. In turn, I examine practices of data collection, analysis, and interpretation to better understand how these are used to buttress the social hierarchies that framed our research approaches in the first place. In continuing to think through scientists’ divergent motivations for pursuing our shared research, I seek to identify the intended beneficiaries of the science in which we were engaged, contextualizing the purposes of reproductive biology research in relation to constructs of race, sex, gender, class, age, ability, and other axes of difference.

Chapter 1 engages with three interconnected apparatuses of racialization that coexisted throughout my experiences working in the Smith Lab: eugenics, economization, and chrononormativity. I draw from Foucault’s understanding of racialization as the creation of biological
breaks that are used to differentiate between individuals and apply this perspective to human beings and mouse research subjects alike (Foucault 1976). The chapter identifies linkages between historical and modern practices of reproductive manipulation in animal and human populations to the laboratory practices of comparative reproductive physiology and differential economic valuation of research subjects and their reproductive tissues (Clarke 1998; Murphy 2017). I analyze technologically assisted reproduction as a mechanism to construct and uphold normative reproductive temporality in desired populations (Roberts 1997; Franklin 2013) and examine how my own data on reproductive aging in mouse oocytes was shaped to reinforce normative white, wealthy, cisgender, heterosexual reproductive temporality (Halberstam 2005; Berlant 2007). In connecting racialization within the reproductive biology laboratory to the institutions of animal breeding for agricultural meat production, forced sterilization as state policy, the development and implementation of birth control, scientific funding, the use of assisted reproductive technologies, and the global trade in reproductive tissues, I explore the cyclic reinforcement of racialization within and outside of laboratory spaces (Latour and Woolgar 1979; Kühl 1994; Ordover 2003; Takeshita 2012; Rosenberg 2016; Waldby 2019).

I build on this analysis in Chapter 2, taking sex and gender as my main objects of inquiry. Drawing from the work of Anne Fausto-Sterling and Emily Martin, I consider the implications of sexing and gendering gametes isolated from their biological contexts (Fausto-Sterling 2000, Martin 1991), asserting that sex/gendering occurs at the level of cells and tissues before conception as well as during and after. Throughout the chapter, I seek to articulate and explain how the researchers around me progressively un-sexed and un-gendered the oocytes they isolated from mice only to swiftly re-sex/gender them when presenting their experimental findings. I name interlocking forms of violence: reproduction to reproductive functioning and sex/gendering reproductive cells and tissues. Highlighting the ubiquity of reproduction throughout all forms of life and some forms of
non-life, I articulate how these violent forms have played a role in creating a biological classification system based on reproductive structures and governing how research subjects are selected for study across the biological and social sciences (Haraway 1989, Schiebinger 1995). Separating reproductive tissues from their biological milieu obscures their multiplicity and facilitates pornotroping those reproductive tissues to fit within normatively sex/gendered narratives of reproductive capacity and reproductive value (Spillers 1987).

Chapter 3 explores the emergent assisted reproductive technology of *in vitro* gametogenesis (IVG), distinguishing it from the existing procedures that make up *in vitro* fertilization (IVF). Thinking alongside Shulamith Firestone and her envisioned techno-utopic abolishment of sex-class through extracorporeal gestation, I outline the mechanisms by which IVG destabilizes hegemonic links between sex/gendered bodies and sex/gendered gametes, introducing novel queer reproductive possibilities that perturb the boundaries dividing species, bodies, soma and germline, bodies, tissues, and cell types (Deleuze and Guattari 1987; Chen 2012; Ibtisham et al. 2017; Yamashiro et al. 2018). Furthermore, IVG enables new kinship forms that intervene in normative reproductive generational temporality (Palacios-González, Harris, and Testa 2014). Despite introducing novel forms of genetic relatedness, IVG ultimately still privileges biological kinship and thus fails to intervene in eugenic notions of heredity and lineages. Moreover, it facilitates, and perhaps exacerbates, the global trade in economized reproductive tissues by rendering all human tissues potentially reproductive (Waldby and Cooper 2008; Carter-Walshaw 2019).

**Setting the (Microscopic) Stage**

On my first day of work, after filling out an imposing stack of yellow forms translated from German, my mentor Sophie took me on a tour to get me oriented. The lab was organized in concentric squares: at the center was a “technical zone” containing shared centrifuges, analysis
devices for molecular biology, and refrigerators and freezers holding communal reagent stocks. The next square, immediately outside the technical zone, contained four hallways. Two of these, on opposite ends of the technical zone, were lined with individual scientists’ lab benches hangers for lab coats, sinks, and chemical hoods. The third hallway was lined with shelves filled with pipette tips, buffer solutions, miniprep kits, mouth pipettes, and other supplies intended for replenishing personal supplies at the bench. The final hallway connected to the staircase used to exit the building. Each of these four hallways separated the technical zone from a third concentric square consisting of various workrooms. On the two sides with the lab benches, these rooms took the form of office spaces situated between two lab benches; the office contained a desk, computer, and shelving for each of the four scientists at the two closest benches. One side also contained a room filled with autoclaves and lab equipment waiting to be sterilized – all the lab members legitimately called it “Leah’s² Kitchen” after the laboratory technician who could usually be found there. The workroom space along the supply hallway was dominated by the Oocyte Room – a large space filled with 14 dissecting microscopes, a prep bench for setting up oocyte dishes and injecting apparatuses, a needle puller (to pull needles for injecting oocytes), and three injection rigs. Adjacent to the oocyte room was a tissue culture room with three tissue culture hoods, two chemical hoods, and a few rotating tube holders. The workrooms along the fourth hallway – the one connecting to the stairway – constituted the “dry lab.” Two rooms were filled with workstations, computers with enhanced processing power for processing raw microscopy data and performing more complex computational analysis techniques. Next door were offices for Dr. Smith, the principal investigator, and Deborah³, her administrative assistant, as well as a conference room for laboratory meetings. Finally, there was the actual kitchen, which featured a sliding glass door leading out to a balcony overlooking the

² pseudonym  
³ pseudonym
Institute, a stove, oven, dishwasher, and fridge, tables and chairs, drawers for keeping personal non-perishable food (including one for me!) and an impressive espresso machine – I miss those cappuccinos dearly. The entire space maintained a refined beauty – floor-to-ceiling sliding glass doors separated the technical zone from the lab bench hallways on either side as well as the lab bench hallways from the adjacent office workrooms. This design facilitated constant communication between researchers. Comments made in passing often reinforced certain hypotheses over others, suggested modifications to experimental designs, shared exciting findings, or simply warned that the principal investigator was in a bad mood that day.

In the stairwell leading to the Smith Lab entrance hung a beautiful fluorescence confocal microscopy image of a mouse oocyte in meiosis I. This is the very cell type and stage that I studied most closely during my time in the lab. My goal in this autoethnographic thesis is to interrogate not only the human laboratory dynamics around me, but also the subject matter of my research. Thus, I have outlined the basics of mammalian oogenesis here, starting with the very foundational information and moving to highlight the field’s unanswered questions in greater detail. The vast majority of cells in an organism’s body contain two copies of the genome: a DNA blueprint for that individual’s development and functioning throughout their life. In order to sexually reproduce, an organism must generate cells that contain only one copy of the genome: eggs and sperm, which can combine to produce an embryo. The cell division processes that occurs to generate both eggs and sperm (meiosis) is adversely affected by aging, making aged organisms more prone to producing eggs and sperm containing too much or too little DNA, making them generally unable to produce a healthy embryo. This aging effect is especially pronounced in oogenesis (the process that generates eggs); many changes have been documented in the microscopic structures that differ between aged and young developing egg cells. My work sought to characterize the order in which these changes
accumulate in oocyte meiosis throughout the aging process in order to better understand fertility
decline and identify mouse models that best recapitulate the human oocyte aging process.

Oocytes are hegemonically conceptualized as precursors to eggs, the sex cells produced by
bodies sexed as female. An oocyte has the capacity to divide twice after a single duplication of its
DNA, giving rise to a haploid ovum containing just one copy of the genome through meiotic cell
division. Spermatocytes also undergo meiosis to give rise to haploid spermatozoa, but here their
similarities end. Spermatozoa are only slightly larger than bacterial cells and contain little more than
mitochondria to produce energy, flagella for motility, a haploid genome, and an enzyme cap called
an acrosome which facilitates fusion between the cell membranes of the spermatozoon and ovum
upon fertilization. Moreover, in mammals, spermatozoa are produced rapidly in the testis
throughout an animal’s period of sexual maturity, progressing through meiosis continuously and
without any periods of arrest. In stark contrast, mammalian oocytes are all produced during
embryonic development and remain in the ovary until the onset of puberty. Oocytes arrest their
meiosis early in the first division cycle, immediately after synapsing their homologous chromosomes
to physically link them together and exchange some of their genetic material. They remain in this
arrested state surrounded and supported by granulosa cells in ovarian follicles (cumulus cells in
mouse ovaries), where they receive nutrients and signaling molecules in order to grow to over
100,000 times the volume of a spermatozoon and produce an abundance of cytoplasm and cellular
components. If an ovum derived from this oocyte produces a zygote, a single-celled embryo, by
fusing with a spermatozoon, the ovum’s ample cytoplasm and cellular components will support the
embryo’s early development. Only upon hormonal cycling at sexual maturity do oocytes resume
their meiotic cell division to produce a mature ovum capable of fertilization. Herein lies oocytes’
central biological quandary.
For an ovum to yield a viable embryo after fertilization, it must contain at least one copy of each autosome (non-sex chromosome). In humans, most ova that yield viable offspring contain exactly one copy of each autosome and a single sex chromosome. However, ova containing two copies of specific autosomes, no sex chromosomes, or multiple sex chromosomes may also yield viable offspring (these outcomes are often medicalized and stigmatized as disorders such as Down’s Syndrome, Turner’s Syndrome, or Klinefelter’s Syndrome). To achieve these specific karyotypes compatible with life, chromosome segregation must be highly regulated in both spermatogenesis and oogenesis (variations of meiosis specific to a particular kind of gamete). Oocytes and spermatocytes alike contend with this by capturing their synapsed chromosomes at protein complexes called kinetochores where microtubules (polymers involved in cellular trafficking and structure) attach after the nuclear envelope breaks down. Then, molecular motors arrange the microtubules into a barrel-shaped spindle, an apparatus of microtubules which pulls homologous chromosomes apart from one another during the first meiotic division and sister chromatids apart from one another during the second meiotic division. This process of pairing chromosomes and then pulling the pairs apart helps avoid aneuploidy (an abnormal number of chromosomes in the gametes or resulting zygote). In mammalian oogenesis, this process is uniquely precarious, as the oocyte must contend with its own immense volume. When an oocyte breaks down its nuclear envelope, it risks losing control of pairs of homologous chromosomes or sister chromatids (depending on which meiotic division is underway) if it fails to efficiently capture each chromosome with a microtubule before they diffuse into the cytoplasmic void. Accordingly, 88% of all autosomal aneuploidies result from mis-segregation during oogenesis (MacLennan et al 2015).

Remarkably, young oocytes maturing and undergoing meiosis near the beginning of a mammal’s reproductive life mis-segregate their chromosomes only 2-3% of the time, whereas in humans, those oocytes that have remained dormant in the ovary for 40 years or longer feature
aneuploidy rates of over 35% (Chiang, Schultz, and Lampson 2012). Thus, researchers have strived to identify structural and functional changes in aged oocytes that could drive this steep increase in aneuploidy rate. Aged oocytes feature notable changes in the appearance of their kinetochores, the protein complexes that allow spindle microtubules to bind to chromosomes for alignment and segregation. In aged oocytes, kinetochores on sister chromatids, which are intended to split apart only during the second meiotic division, can be observed having already split while chromosomes are being aligned on the metaphase plate in the first meiotic division (Zielinska et al 2015). This first division is intended to segregate homologous chromosomes rather than sister chromatids; prematurely split kinetochores pose a great risk to the oocyte as they may permit various forms of mis-segregation that each lead to aneuploidy.

Though this severe kinetochore phenotype has been well characterized in human and mouse oocytes alike, it is unknown precisely when in the life course the kinetochore phenotype begins relative to the onset of increased rates of aneuploidy in the ova. Furthermore, how kinetochore phenotypes arise relative to other aging phenotypes (such as the morphology of the spindle and actin cytoskeleton) is unknown (Smoak et al. 2016). Lastly, though human oocytes occasionally came through the Smith lab when IVF clinics had additional oocytes, the scientists had no control over their quality or the ages of the people from which the oocytes came. Thus, identifying a mouse strain that effectively recapitulated the severity of human kinetochore phenotype changes with advanced age while retaining enough oocytes to facilitate efficient experimentation at that advanced age became a central goal of the laboratory.

I spent my time modifying a technique for fluorescent labelling and microscopic visualization of subcellular structures in oocytes with the aim of characterizing the developmental time points at which aging-related changes in oocytes first arise, and in what order these age-related changes accumulate. I conducted my analyses within one candidate mouse strain and compared my
results with those of colleagues performing similar analyses on other strains to identify an optimal model system in which to study human oocyte aging. The laboratory’s explicit goal for the project was to be the first to develop and characterize a human oocyte aging model and establish that model across similar oocyte meiosis laboratories worldwide to facilitate global coordination of reproductive aging research.

In processing my experiences within the Smith Lab, I am principally interested in recognizing the reproductive biology laboratory as a biocultural site that produces and reproduces existing social hierarchies of race, sex, gender, and sexuality. The processes of knowledge production in reproductive biology laboratories are based in separating and differentiating between, human and animal bodies as individuals and as species. Cells, tissues, and bodies are descriptively overdetermined within racialized, sexed, and gendered categories in the pursuit of rigorous characterization and comparison. Yet, the reproductive biology laboratory as an institution does not entirely foreclose novel queer reproductive futurities. Scientific approaches that embrace multiplicity and enmeshment between cells, tissues, bodies, and species will always exist within researchers’ own biocultural frames of knowledge production yet retain some potential to disrupt extant social orders. There is a queer reproductive future: queering oocytes is the first step toward enabling that future.
Reproductive Research, Manipulation, and Racialization

Imagining queer reproductive futurity grounded in technoscientific advancement demands interrogating how research efforts in the reproductive sciences have contributed to existing inequities in reproductive healthcare. In the 171-year history of reproductive biology as a field, researchers, medical professionals, and government policy makers have systematically racialized human and animal bodies by assigning them differential reproductive value. This chapter examines historical and contemporary reproductive biology research initiatives in the West to highlight three dominant mechanisms of racialization that span laboratory, commercial, and state spaces: eugenics, economization, and chrono-normativity. I draw from the histories of animal breeding, forced and incentivized human sterilization, birth control, and assisted reproductive technologies to foreground my own experiences working in a mammalian reproductive biology laboratory in the summer of 2019. I present my firsthand experiences incubating eugenic racism, economizing human and animal bodies, and enforcing chrono-normative conceptions of appropriate reproductive temporality through my research on reproductive aging in mouse oocytes.

Comparative Reproductive Physiology and Eugenic Population Management

At the turn of the twentieth century in Britain, some of the earliest reproductive biologists pioneered the practice of comparative reproductive physiology: a research technique that would become fundamental to all subsequent studies in reproductive biology and to the management of

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4 Here, it is necessary to clarify my meaning in using the term “racialization.” I draw from Foucault’s understanding articulated in his 1976 Lecture at the College de France, in which he describes racism as “primarily a way of introducing a break into the domain of life that is under power’s control: the break between what must live and what must die” (Foucault 1976). Racialization establishes “biological-type caesura[es]” that divide the species into “subspecies.” In Foucault’s articulation of biopower, this is about which subspecies are made to live and which subspecies are made to die. Certainly, this is engaged with which subspecies are made to reproduce and which are let die through inadequate access to resources or, importantly, from being denied the reproductive capacity necessary to sustain their populations.
animal and human populations. Walter Heape of the Cambridge University Department of Zoology pioneered comparative studies of reproductive morphology and physiology, describing menstrual, uterine, and ovarian function in monkeys, rabbits, sheep, and other mammals. He claimed that “by means of [science] the infinitely minute variations in animals are recognized and seized upon, and by its exercise successful mating is divined” (Heape 1906, 26). F. H. A. Marshall followed in Heape’s footsteps to construct “the first full physiology of mammalian reproduction.” Alongside comparative physiology of the estrus cycle in sheep, ferrets, and dogs, Marshall collaborated with his PhD advisor on “prolonged interspecies breeding experiments” to investigate theories of heredity (Clarke 1998, 71). These studies and others like them stabilized species distinctions and expanded their purview to the arena of reproduction. Species “distinguish[es] different forms-of-life” into a taxonomy, indexing differences in “reproductive commensality, morphological uniformity, and…genetic similarity” as “constitutive of” its “boundaries” (Rosenberg 2016, 55). Reproduction and species are indeed co-constitutive. French comparative anatomist Georges-Louis Leclerc, comte de Buffon was the first to coin “reproduction” “to name the process of organisms coming into being” in the mid-eighteenth century. Buffon saw reproduction as “a process of maintaining a species in time, …perpetuat[ing] the stability of form in organisms across generations” (Murphy 2017, 32). Any research initiative explicitly focused on characterizing morphological and physiological reproductive differences across species – or within them – is directly invested in situating reproduction as a site for making and reinforcing boundaries between different kinds of bodies.

In identifying and rigorously characterizing variation in reproductive features across mammalian taxa and refining the implementation of assisted reproductive technologies in animals, Heape and Marshall provided powerful fodder to the growing Western movement toward intensive breeding – pure breeding that aimed to standardize animal bodies better suited “better suited to the
emergent grain-meat complex” (Rosenberg 2019, 37). Though speciation – “locating a form-of-life” within a taxonomy – is distinct from the process of racialization – “sorting…bodies according to visions of collective, social, and national health,” – they overlap in the locus of animal breeding, in which animals are racialized into breeds through direct human management of animal reproductive capacity. Pure breeding first and foremost valued prepotency – an animal’s ability to pass on its traits perfectly to its offspring (Rosenberg 2016). Here, the link between animal breeding and human eugenics is explicit, as prepotency is the fundamental premise underlying the practice of promoting reproduction among individuals and populations exhibiting desirable characteristics – the assumption is that those characteristics will be perfectly reproduced in the next generation (Rosenberg 2019). This is a clear articulation of Foucauldian biopolitics, a power that “consists in making live and letting die” to shape the population (Rosenberg 2016, 52).

Similar practices of directly managing reproductive capacity in pursuit of prepotent pure-breeding populations were central to American and European eugenics movements of the early 1930s. Two interrelated concepts of racism coexisted within these movements: ethnic racism, “the application of hierarchal standards to the taxonomy of human racial groups,” and eugenic racism, “the demarcation of certain elements within a particular race, followed by attempts to reduce these elements through discriminatory policies” (Kühl 1994, 70-71). These two racial logics drew differently from “anthropological” and “population genetic” concepts of race developed from scientific studies of heredity, a discipline indistinguishable from the reproductive sciences until at least 1919 and “within the interlocked web of…evolution…development, and reproduction” thereafter (Clarke 1998, 69). Despite their differences, both racist ideologies sought to define distinct groups of human beings by distinguishing between them at the level of reproductive capacity. Mainline eugenicists and racial anthropologists in the U.S., Scandinavia, and Germany drew from both ethnic and eugenic racism in believing that whites were evolutionarily more advanced than
other races, but could be further improved “by supporting the procreation of capable individuals and preventing the reproduction of inferior persons” (Kühl 1994, 75-77). Reform eugenicists in the United States identified “differential fertility” and the “high differential [population] growth of Indians and Mexicans as problematic,” “lament[ing] the fact that genetically inferior populations of the rural South and West were reproducing faster than “hereditarily more valuable stock in the Northeast.” This was the intellectual legacy of Heape and Marshall’s comparative physiology studies at the inception of the reproductive sciences.

Nazi reproductive scientists performed extensive experiments on captive human subjects in concentration camps with the explicit goal of facilitating racial genocide. Just as state capitalist demands stimulated the development of novel breeding approaches and assisted reproductive technologies in the context of animal breeding for agriculture, Nazi Germany’s capital constraints stimulated inquiry into non-surgical sterilization techniques suitable for mass implementation. In Auschwitz, Ravensbrück, and elsewhere beginning in 1941, Dr. Carl Clauberg experimented with injections of toxic solutions containing high concentrations of iodine and silver nitrate into the cervixes of Jewish and Roma women – the injections caused severe inflammation and scarring that blocked off the fallopian tubes, thus preventing pregnancy (Lifton 1986, 267-271). Clauberg embodies the connection between basic reproductive biology research and sterilization – and, in turn, positive and negative eugenic ideologies. In the late 1920s and early 1930s, Clauberg was a pioneer in the study of female reproductive hormones, and collaborated with the German “Schering-Kahlbaum Pharmaceutical Company” to produce “Progynon and Proluton” – modified forms of estrogen and progesterone for use in manipulating the human ovulation and menstrual cycles to treat infertility (Lifton 1986, 45).

As the Nazis’ eugenic program began to implement mass killings in 1941, American mainline eugenicists feared that “Nazi anti-Semitism would dominate the perception of eugenics in the
United States.” As an alternative, they advocated for “more ‘acceptable’ measures, such as sterilization, marriage restrictions for handicapped people, anti-miscegenation laws, and special support for the procreation of ‘worthy’ couples, redirecting “public attention to these ‘exemplary’ eugenic measures” (Kühl 1994, 73). Thus, within eugenics communities and in the public eye, manipulating reproductive capacity to shape the racial makeup of human populations was promoted as a benign alternative to extermination despite the shared racist motivations of the two approaches. Manipulating reproductive capacity allowed eugenicists to somewhat shroud their ethnic racism in favor of eugenic racism, an ideology with more support from state governments and the general populace, as evidenced by widespread compulsory sterilization laws (Ordover 2003, 92-96).

I observed eugenic racist logic routinely cultivated, expressed, and propagated within the space of the reproductive biology laboratory. My main project in the lab was designed to systematically document the trajectory of age-related fertility decline across the mouse strains maintained for the laboratory. It is well known that declining oocyte quality is a leading factor in decreased fertility, and that oocytes in subfertile or infertile humans, mice, and other mammals sexed female exhibit stark changes in subcellular morphology (Chiang, Schultz, and Lampson 2012). These morphologic changes – aging phenotypes – are most apparent in key structures that form during meiosis – the cell division process that yields haploid ova from diploid oocytes. Severe meiotic aging phenotypes yield elevated rates of aneuploidy – improper segregation of chromosomes such that the resulting ovum contains too much or too little genetic material. Errors in oocyte meiosis are responsible for 90% of all aneuploidies in human embryos, which in turn cause failed uterine implantation and miscarriage – so changes in oocyte subcellular morphology account for much of the human age-related fertility decline (MacLennan et al 2015; Cimadomo et al 2018).

Though the aging phenotypes of both mouse and human oocytes are well defined, the sequential timing of when such aging phenotypes arise throughout the life history of the animal
remains an open question. In addition, the Smith Lab strived to streamline their reproductive aging research enterprise in pursuit of an optimal mouse model for human oocyte aging, the first of its kind in the world. During my time in Göttingen, the lab – in particular, “unskilled” animal house technicians, not the scientists themselves – maintained three common mouse strains used in labs around the world for diverse experimental applications: two inbred (CD1 and FVB/N) and one outbred (129S6). The Smith\textsuperscript{5} Lab also continuously generated first-generation hybrid animals between two other common strains, one outbred (CBA) and one inbred (B6) to make a hybrid CBA/B6 strain. All four strains (CD1, FVB/N, 129S6, and CBA/B6) were used throughout the laboratory for different oocyte experiments.

Until my time in the lab last summer, there had been no sustained effort to systematize or regulate which strains were used for which experiments: scientists selected a strain based on suggestions from their colleagues or stuck with the oocytes that seemed to work well for their needs. The Smith lab wished to identify which strain could most robustly model human oocyte aging and proceed to perform all aging experiments in that strain once its trajectory of aging phenotypes had been rigorously characterized. An optimal oocyte aging model would possess oocytes that decline severely in quality with advanced age such that aging phenotypes are easily distinguishable from “normal” morphology in young oocytes. However, this model would also ideally maintain a relatively robust supply of oocytes throughout its lifetime such that aged mice would yield at least a few oocytes per ovary. Importantly, these criteria of an optimal oocyte aging model align with human researchers’ needs while remaining at best agnostic to mouse health, and potentially deleterious. From preliminary observations, aged mice from the CD1 and FVB/N strains seemed to exhibit severe aging phenotypes in their oocytes, but often contained no viable oocytes per ovary by advanced ages, due perhaps to their genetic homogeneity. In contrast, the outbred 129S6 strain was

\textsuperscript{5} pseudonym
known to yield a sufficient oocyte supply at advanced ages, though the severity of their oocyte aging phenotypes had not been documented. The first-generation hybrid CBA/B6 strain held promise as a potential intermediate that might split the difference between the features of the inbred and outbred strains (Personal Communication 2019). I considered including representative images of each strain to help the reader visualize my research subjects, but ultimately decided that doing so would merely reinforce pernicious notions of ancestry as phenotypically relevant and subject to reproductive manipulation.

In executing my project, my task was to quantitatively compare the morphologies of meiotic subcellular structures (chromosomes, kinetochores, and microtubules) in oocytes harvested from mice of various age groups in the mouse strain I was assigned to characterize: the outbred 129S6 mice. In particular, I identified oocytes featuring unstable or misaligned chromosome bivalents (homologous chromosome pairs in oocytes prior to the first meiotic division), premature splitting of sister kinetochores, and insecure kinetochore-microtubule attachments, as each of these phenotypes are known to give rise to aneuploid ova (Zielinska et al 2015, Zielinska et al 2019). Other graduate students and post-docs were assigned to characterize the other strains. This study, like Heape’s and Marshall’s over a century ago, depended explicitly on comparisons of reproductive physiology between organisms. The project was invested in establishing and reinforcing boundaries between mouse strains, conceptualizing reproductive differences as constitutive of speciated/racialized breeds. Developing distinct mouse strains for laboratory research and maintaining the strains within the Smith Lab animal house demonstrates reproductive scientists’ willingness to reproductively isolate mouse bodies to drive human knowledge production through experiment. The Smith Lab’s efforts to create the hybrid outbred/inbred CBA/B6 strain does not transgress this norm; the hybrid strain was produced for the express purpose of exploiting bodily characteristics conferred through hybridity. This reminds me of the ways that babies and children racialized as “mixed” are fetishized
and commercialized for their attractiveness, as evidenced by the popular Instagram accounts @Mixedracebabiesig and @BeautifulMixedKids. In developing and experimenting with the CBA/B6 mice, scientists ossified preconceived distinctions between the CBA and B6 mice used to create the strain and created a hierarchy of ancestry that privileged presumed physiological benefits of hybrid ancestry over pure breeding or outbreeding – the notion of hybrid vigor. Insofar as experiment is a “selective practice of attention and inattention,” choosing to focus on comparative reproductive physiology across policed boundaries of animal strain reveals scientists’ reliance on establishing phenotypic differences between bodies to study reproductive function as opposed to identifying robust features shared throughout the aging process of all the animals available for study (Murphy 2017, 89). This attention to strain as biologically significant is especially egregious in the face of an adage often repeated throughout the lab – an adage to which I will return in my discussion of the politics of data collection: “If the conclusions drawn from the data are not robust to small variations in the experimental apparatus, the result likely isn’t real.” Comparing and producing mice for experimental applications based on their physical characteristics was a project of finding phenotypic opportunities for racialization, motivated by the pursuit of knowledge within a capitalist bioscientific industry. Such opportunities for racialization are precisely Foucault’s caesurae: imagined breaks in the continuum of morphology linking all mice to one another and to each of us as humans (Foucault 1976).

**Economized (Re)productivity**

To frame the American and Nazi German contexts in the 1930s and 1940s as unique or exceptional ignores the manner in which racializing logics continued to dominate reproductive manipulation initiatives implemented worldwide since the Holocaust (Arendt 1963). Nazi genocide prompted a “retreat from eugenics,” requiring “a new way” to provide “racist accounts of
differential human evolution” (Murphy 2017, 11). Keynesian macroeconomic theory would cast the economy as this “new way” to justify racist population control. Keynes, himself an avid eugenicist, “argued against the automatic balancing of national budgets and instead advocated for active countercyclical fiscal policies,” providing ample justification for active intervention and modification at the level of the population to promote and sustain economic growth. Paradoxically, such growth could be tracked through gross domestic product (GDP), a metric feigning objective mass progress by measuring “all the goods and services produced within a domestic economy, irrespective of who owns the units of production (Murphy 2017, 20-22).

Quantified perspectives on population management were supported by laboratory science. American biologist and population scientist Raymond Pearl devised the S-curve to represent the growth of human and animal populations. This representation facilitated de-individuation and evaluation of collective reproductive output at the level of discrete populations. High fertility became the variable in need of adjustment for the sake of economy,” justifying practices to modulate the reproductive capacity of “nonwhite people and poor people” in recently colonized nations so as not to “derail the American good life of capitalism and white supremacy.” This was an “economized reformulation” of Foucauldian biopolitics: “some must not be born so that future others might live more abundantly (consumptively)” (Murphy 2017, 36-46).

Insofar as production was cast as the driver of economic progress, reproduction was integral as a means to “keep replacing the means of production” in order for “capitalist society to maintain itself over time” (Murphy 2017, 33). In a manner akin to the work of eugenicists mere years and decades earlier, Western nations deployed reproductive technoscience in order to selectively restrict the reproduction of poor, nonwhite, and often recently colonized groups while encouraging reproduction for white, middle- and upper-class populations deemed more economically productive. State sponsored actors such as the U.S. Agency for International Development as well as private
foundations aligned with capitalist goals collaborated to fund and deploy contraceptive strategies and assisted reproductive technologies in support to economize life, tying reproduction “to the very fate of the macroeconomy” “through the social science figure of population” (Murphy 2017, 46).

In the United States, the economization of life had direct consequences for reproductive manipulation of Black communities. After emancipation, the growth of Black communities was no longer aligned with U.S. capitalist economic interests as it had been under slavery, and Black bodies were instead viewed as economically un-productive. Margaret Sanger couched her birth control advocacy in the early twentieth century as a movement for women’s sexual freedom and emancipation from the burdens of reproductive labor. In doing so, she contested eugenic racism but embraced economized views of human life, believing “that racial degeneration resulted from social factors, especially economic pressures, rather than inherent genetic defects.” Sanger held “uncontrolled fertility responsible for bringing children into conditions of poverty” and was invested in “helping Negroes to control their birthrate…to maintain better standards of health and living for those already born, and to create better opportunities to help themselves, and to rise to their own heights through education and the principles of a democracy” (Roberts 1997, 94-95). These sentiments indicate a devaluing of Black lives as dispensable in pursuit of collective national prosperity: “some must not be born so that future others might prosper” (Murphy 2017, 46).

The technological advance of the birth control Pill only reinforced the “interdependent relationship between scientific development and the maintenance of the Western world order” measured “by capitalist standards.” Reproductive scientists depended on state and industrial practitioners of population control for their “increasing support” of reproductive research, and the population control movement “relied on scientific activities for the technological instruments to implement fertility regulation” (Takeshita 2012, 38). Margaret Sanger sought the help of Gregory Pincus to develop the contraceptive pill in 1951, seeking a “universal contraceptive that would
reliably limit the fertility of the poor” (Takeshita 2012, 38). Pincus was a reproductive biologist who had followed in the footsteps of Walter Heape to study the mammalian egg and artificial parthenogenesis – embryogenesis from the fusion of two ova – in the 1930s and 1940s prior to his involvement with hormonal contraceptives.

Pincus and his collaborators performed the bulk of their clinical testing in Puerto Rican women beginning in 1956. The island had been “regarded as having an overpopulation problem” and thus made the perfect laboratory configuration – what McCormick called a “‘cage of ovulating females’ necessary to carry out clinical tests.” So many Puerto Rican women experienced “intolerable…headaches, bloating, and nausea” that the “local chief investigator concluded that the oral contraceptive could not be a universally acceptable drug.” Despite these concerns, Pincus and his colleagues had acquired the necessary data to obtain FDA approval for use in treating menstrual disorders 1957 and as the first oral contraceptive in 1960 (Takeshita 2012, 39-40). The “knowledge-producing effort” of such experimentation was one in which “nothing was improved, but the larger surround” of “forms and phantasies of economization” and “instruments and infrastructures of expectation” were still established (Murphy 2017, 81). After completing this contraceptive work, Pincus resumed his studies of fertilization and conception. In 1959, Min-Chueh Chang achieved the “first live births following IVF in mammals” while working in Pincus’ lab (Franklin 2013, 144).

Sterilization and birth control both manipulated populations by reducing their birth rate; assisted reproductive technologies have been deployed to selectively sustain or increase the birth rate of populations whose reproduction was deemed to fit within state economic interests. Since its first use in humans in 1978 (and in animals since 1959) in vitro fertilization (IVF) technology has both transgressed historical understandings of procreation and kinship while reinforcing the status quo of healthcare inequity (Roberts 1997; Franklin 2013; Kenney and Müller 2017). In the United States, only 12.8 percent of Black women use advanced reproductive technologies to conceive, compared
to 27.2 percent of white women despite the fact that “Blacks have an infertility rate one and one-half times higher than that of whites” (Roberts 1997, 262-266). Reasons for this disparity are systemic and multifaceted. IVF cycles cost $12,000-$17,000 USD apiece, and conception often requires multiple cycles. As of 2019, only 16 U.S. states “have passed laws that require insurers [Medicaid or private companies] to either cover or offer coverage for infertility diagnosis and treatment,” including IVF (National Conference of State Legislatures 2019). The U.S. government has opted to “treat infertility at public expense,” which ironically “conflicts with the ongoing campaign to reduce the numbers of children born on welfare.” There is no legal consensus on “whether infertility qualifies as an illness and disability for purposes of coverage under insurance policies and the Americans with Disabilities Act.” I will return to the questions of infertility as disability, or reproduction as a right, in the third chapter.

Regional and transnational patterns of oocyte donation that have emerged over the last two decades reveal modern reproductive technoscience’s continued investments in economizing fertility and racializing human bodies. When a fertility doctor deems an IVF patient to have an insufficient supply of oocytes to facilitate a successful harvest, or after multiple unsuccessful, costly rounds of IVF, they may recommend using a donor egg in subsequent IVF treatments. Donated oocytes travel up gradients of wealth and age – oocytes from poorer, younger bodies are donated to older, wealthier people. Donors have often been incentivized to donate oocytes through monetary compensation, either through subsidized “egg-sharing,” in which people already undergoing treatment are compensated for donating a proportion of their oocytes to someone else, or through direct payment for oocyte harvesting – especially within the United States. In Germany, one of four European countries that bans egg donation entirely in line with its 1990 Embryo Protection Act, infertile couples and reproductive medicine professionals alike clamor for reforms, calling to commercialize oocytes as in neighboring European countries in order to help more people conceive
safely (DW.com, 2020). Furthermore, bodies harboring donor oocytes are racialized through the global bioeconomy: Ecuador provides prized oocytes from light-skinned donors to neighboring Latin American countries, Vietnamese women sell oocytes and gestational surrogacy to hopeful Thai parents, and white Australian women travel to South Africa to obtain white Afrikaans oocytes in South Africa. Northwest Europeans purchase oocytes from Southeastern European bodies, and Israelis rely on Romanian oocytes for their “white” genetics in order to avoid using oocytes from Palestinians (Waldby 2019, 84-95). Thus far, “the use of new reproductive technologies [has reflected] an already existing racial cast system” (Roberts 1997, 298).

The racialization of mouse strains and mouse bodies I observed in the Smith Lab was similarly based upon an economized view of reproductive capacity. The nature of laboratory science renders experimental reagents susceptible to commodification as intellectual property throughout the world of biomedicine, meaning that a novel mouse model for human oocyte aging could provide substantial revenue for the laboratory. Furthermore, publishing systematic studies yielding deeper understanding of the reproductive aging process — understanding coveted by reproductive clinicians and scientists alike — would help sustain the laboratory’s influx of grant money from funding institutions. Funding for a scientific enterprise can be recognized as a locus for strong social reinforcement of specific research initiatives — and the practitioners of such a research enterprise — at the expense of others. This is a symptom of the libidinal economy in which scientists operate, driven by a cyclic demand for credibility, capable of interconverting different types of capital for the scientist: “money, data, prestige, credentials, problem areas, argument, papers, and so on” (Latour and Woolgar 1979, 200). Scientists’ activities in the laboratory are governed not only by their intellectual interests, but also by the availability of funding, regularity of publication, reception by the scientific community, and general funding attitudes of governments (Latour and Woolgar 1979, 191). Scientists in a capitalist economy must continuously produce credible information to sustain
the flow of funding through their laboratory. Thus, reproductive scientists economize their research subjects in pursuit of funding, normalizing the economized racist implementation of the reproductive biology knowledge they produce.

Within the space of the laboratory, a mouse’s oocyte count – or a strain’s mean oocyte count – came to occupy the same role for myself and my colleagues as reproductive scientists as did GDP for Keynesian macroeconomists seeking to evaluate the nation’s fiscal health. Oocyte count was a representative metric that could be used to mark an individual’s health as a reproductive agent. In my project seeking to identify a mouse model for reproductive aging, oocyte count could also mark the utility of the strain within which the mouse was racialized – a proxy for its worth to the researcher as a subject worthy of study. Oocyte count was a powerfully deindividuating value – it lent itself well to graphical visualizations that elided individual variation to establish a quantitative norm.

![Figure 1: Side-by-side box-and-whisker plots of the number of oocytes isolated per mouse across four age groups. N = 8 for 6-9-week age group, 5 for 50-59-week age group, 3 for 60-69-week age group, and 26 for 80+-week age group. * indicates p < 0.01. *** indicates p < 0.001.](image)

My work recapitulated Raymond Pearl’s population S-curve in constructing a quantitative representation of life. The box-and-whisker plots in Figure 1 aim to represent the spread of oocyte counts among mice in each group, but ultimately, they are overwhelmed by the precipitous
downward trend observed between age groups. This emphasis on between-group variation rather than within-group variation is common to both the eugenic and economizing logics at work in the reproductive biology laboratory. Individual mice are represented only in terms of where they are placed along my graphical representation of variation – how far they deviate from the norm. Much like GDP was used by economists and policy makers as a simple metric marking the nation’s economic wellbeing, the plot above positions oocyte count per mouse as simple metric of reproductive potential marking the mouse body’s utility for the researcher and the strain’s broader economic utility as an object of study for the laboratory. In much the same way that GDP obscures the sources of production to comment broadly on economic output within a nation, oocyte count fails to consider whether the oocytes can actually complete meiosis to produce ova and is thus at best a crude metric for the fertility of an individual mouse, much less a mouse strain. Furthermore, visions of research progress toward “curing” the “problem” of infertility were couched in altering the population average of oocyte count. Once the trajectory of normative age-related decline in oocyte count was rigorously defined, increasing the mean oocyte count of aged mice through genetic or pharmacological intervention could be celebrated as a success. This echoes the manner in which reproductive biologists, economists, and policy makers collaborated to “solve” the issue of population growth by reducing the fertility of economically undesirable populations and increasing the fertility of desirable populations.

**Chrono-normative Reproductive Temporality – Race, Class, Gender, and Sexuality**

Specific notions of temporality can be found within the histories of eugenic and economizing reproductive manipulation in humans and animal populations. Animal breeders in agriculture were invested in maximizing the productivity of their animals in order to most efficiently generate capital, either in terms of progeny to be slaughtered for meat or products such as milk and
eggs. The value assigned to prepotency in pure breeding established a temporal progress narrative toward an increasingly economically valuable population coupled with increased reproductive isolation and greater phenotypic separation across breeds (Rosenberg 2016, 60). With more aggressive inbreeding over generations, truer breeding and greater phenotypic stasis could be achieved. Reproductive capacity and rapid maturation to sexual maturity were also paramount for economizing animal bodies, as larger litters that could be produced more quickly provided greater return on investment. Thus, the prototypical breeding animal would mature quickly, produce a large litter, and perfectly pass on its physical characteristics to its offspring. It is no coincidence that these temporal contingencies of rapid regeneration and true-breeding prepotency through genetic homogeneity are mandatory characteristics of laboratory animals for research in the biomedical sciences.

Human reproductive manipulation for the goal of economic progress also operated through temporality. Frank Notestein’s principal contribution to General William Draper’s 1959 report on behalf of the U.S. presidential committee on military assistance was his model of demographic transition, which “pegged temporal changes in fertility and death rates to economic development.” The model positioned human populations on a timeline based on birth and death rates, with high birth and death rates ascribed to “traditional, premodern, or agrarian societies” and reduced birth and death rates catalyzed by “public health,” “industrialization,” and “changing attitudes” ascribed to modernity. Along with Raymond Pearl’s S-curve of population growth, this positioned “populations with high birth rates” as “out of time with the forward orientation of white American economic futures” (Murphy 2017, 11). Appropriate human reproduction was assigned a normative temporality and any human populations deemed “out of time” were subject to reproductive manipulation to shift their population curves.
Eugenic and economizing logics of reproductive manipulation in the laboratory transcended mouse bodies by identifying and reinforcing normative temporal scripts for reproduction through mouse experiments. For Murphy, experiments are “conjectural future-making assemblages” that “reorient and reshuffle…the boundary between what is thought to be known and what is beyond imagination” (Murphy 2017, 80). My oocyte aging experiments certainly fit that mold. The premise of characterizing the trajectory of morphologic degradation from a “young” state to an “aged state” requires stabilizing the assumption that mature oocytes begin as uniformly healthy and capable of giving rise to fertilizable ova and then monotonically decline in quality over time such that at some point they cross a threshold of inadequacy and are no longer able to reliably yield functional gametes. Within this paradigm, all that is left for the scientist to do is interpolate. The end points of the fertility curve were defined for me – fertile on one end, infertile on the other – and I was expected to place oocytes of different maternal ages on a spectrum between them. Consistent with this model of reproductive aging, Figure 1 shows how oocyte count declines precipitously with increased mouse age. This temporal frame is both derived from and actively reinforces dominant cultural understandings of normative human reproductive temporality – people with ovaries are constantly reminded of the biological clock, a “linear, unidirectional, and non-repetitive” temporal framework that dictates perceived reproductive potential for individuals, their physicians, and the state (Waldby 2019, 120). The experiment’s design foreclosed alternate futures in which fertility was uncoupled from the aging process or followed a trajectory distinct from a precipitous drop. Our approach relied upon and reified existing norms governing how mammalian reproduction is organized and how reproductive capacity changes with time.

As I characterized my mouse strain’s reproductive aging phenotypes, I was encouraged to provide “representative images” of young and aged oocytes when presenting my data. This view of
oocyte aging singled out individual oocytes – not even whole mice – as “typical” specimens representing their strain and age group.

Presenting representative oocytes established a phenotypic norm that further discretized morphologic temporality. This enabled my colleagues to more granularly place their individual mouse oocytes from different strains as “forward” or “backward” in reproductive aging time in relation to the stereotypical specimens I selected for each age range. This created and enforced hyper-specific temporally normative morphology, meaning that oocytes could be labeled phenotypically deviant from their age group not only in aggregate, but also as individual entities.

Furthermore, my project was built upon the central premise that the temporality of mouse reproduction was a useful and informative analogy for the temporality of human reproduction. This reflects the scientists’ willingness to deputize a highly specific temporal reproductive script to marginalize mouse and human embodiments alike. In captivity, laboratory mice typically live between 1.3 and 3 years (68 to 156 weeks), with some strains living on average twice as long as others. Mouse reproductive lifespan is also known to be highly variable across strains, with some as short as 30 weeks and others lasting over two years. Mouse strains’ reproductive lifespans are not highly correlated with their average lifespans, meaning that some mice produce litters a mere few

Figure 2: Airyscan-processed laser scanning fluorescence microscopy images of immunofluorescence stained 129S6 oocytes fixed in formaldehyde in metaphase of meiosis I. Leftmost image is a 6-9-week young oocyte, middle is a 50-59-week aged oocyte, and rightmost is a 80+-week aged oocyte. Chromosomes labeled with Hoechst stain in magenta, kinetochores labeled with primary anti-CENP-A antibodies and secondary antibodies tagged with AlexaFluor 488 in green, and microtubules labeled with primary anti-α-tubulin antibodies and secondary antibodies tagged with AlexaFluor 647 in greyscale.
months before they die while others experience a post-reproductive period of over two years (The Jackson Laboratory Staff, 1966). Such variation between strains – variation catalyzed by decades of forced reproductive isolation by breeders for scientific purposes – makes comparison between the reproduction of mice and humans on the collective species level a dubious prospect. As the Smith Lab recognized, it might be possible to identify a specific mouse strain with a reproductive lifespan and reproductive aging trajectory akin to those of humans. However, such a comparison between humans and even a single mouse strain would require that human reproductive temporality be uniform across the population. This is not the case.

Human bodies deemed hereditarily inferior or insufficiently productive are denied access to normative temporality of the life course, and with it, normative reproductive temporality. Many blatant examples of this can be found in the history of forced sterilization and birth control that I outlined earlier in this chapter, in which fertility was manipulated in populations deemed biologically inferior or economically unproductive. Another mechanism of exclusion from normative temporality is captured in Lauren Berlant’s concept of slow death, which accounts for “the dispersed management of the biological threat posed by certain populations” marked by endemic, permanent factors – “to the reproduction of the normatively framed general good life of a society” (Berlant 2007, 756). “Health itself can then be seen as a side effect of successful normativity” – those deemed non-normative across a variety of axes (race, socioeconomic status, and body type being particularly salient), are subject to a set of social, economic, political, and environmental insults that render their bodies debilitated and subject to die earlier those deemed normative (Berlant 2007, 765). This in turn prevents marginalized communities from accessing normative life courses afforded to those shielded from debilitating stressors. Meanwhile, bodily debility is cast as endemic to the population experiencing it, displacing the harm from the realm of human injury or illness, to which all are susceptible, and placing it within the domain of personal culpability for the marginalized. This is
especially evident in the early history of the AIDS epidemic in the United States, in which AIDS was first labeled a gay and lesbian disease (despite low rates of infection in lesbians), and then expanded to encompass the “Four H” group of at-risk populations: homosexuals, heroin users, hemophiliacs, and Haitians. Despite mounting evidence of universal human susceptibility to AIDS, physicians, scientists, and policy makers held onto their view of AIDS as endemic to non-normative bodies – as if to justify their deaths as a side-effect of inclusion in minoritized groups (Patton 1985). Christina Sharpe calls attention to the constant proximity of Blackness to death “In the Wake” of chattel slavery. She accounts for the factors that made it possible for three members of her immediate family to die in close succession, and years later, another three within the course of a year, most of whom were young. Sharpe’s work acknowledges that Black people’s deaths at the hands of police injury, illness, poverty, malnourishment, sexual violence, and other biocultural circumstances share a common relation to racism and slavery’s legacy (Sharpe 2016). Black people in the United States have a lifespan five to seven years shorter than white people; that disparity grows to 20+ years in highly segregated areas (LaVeist 2003, Khazan 2018). In the United States, there was a 14-year gap in lifespan between the richest 1% and the poorest 1% of the population between 2001 and 2014 (Chetty et al. 2016). Trans people, especially trans women of color and trans Black women, are routinely murdered in the United States and around the world: victims’ ages range from 30 to 35 on average. There were 331 confirmed murders of trans people worldwide in 2019, with 26 coming in the United States. The majority of those victims were Black trans women (Human Rights Campaign 2019). Enforcing a specific notion of reproductive temporality inaccessible to bodies marked as non-normative is a racist, classist, and cis heterosexual project.

People whose lives are ended by the debilities of marginalization are not permitted to access chrono-normative reproductive temporality. Normative “repro-time,” “the time of reproduction…ruled by a biological clock for women and by strict bourgeois rules of respectability
and scheduling for married couples,” permeates the entire life course and beyond, spanning the ways in “which values, wealth, goods, and morals are passed through family ties from one generation to the next,” connecting “the family to the historical past of the nation and…the future of both familial and national stability.” As normative temporal scripts are reserved for those members of society deemed biologically fit and economically productive, those deemed non-normative are forced to inhabit a distinct temporality – a “queer time” (Halberstam 2005, 4-5). In making this critique, I do not wish to reinforce the conception that a long life free of debility is necessarily positive; instead, I wish to highlight the way that positioning any temporal script as normative marginalizes those without access to that life course. In the search for a mouse strain to recapitulate human reproductive aging, the scientists in the Smith Lab drew together mouse reproductive temporality with human repro-time, a very specific temporality which is straight, cisgender, wealthy, and white. Modeling human reproductive temporality is a fallacy doomed to fail, as human reproductive temporality is not a thing (Berlant and Warner 1998). Instead, the lab aimed to locate and enforce white, wealthy, cis, straight repro-time as universal across species boundaries and among human bodies and populations.

Throughout the study, subjective choices made throughout data collection, interpretation, and presentation were organized to prioritize consistency with chrono-normative narratives of wealthy, white, cisgender, straight reproductive aging.

First, I noticed that my graduate student mentor Sophie had a great preference for a specific microscope in the laboratory — not a specific microscope technique, or model, but a specific microscope — she preferred Zeiss LSM (Laser Scanning Microscope) 800-2 over LSM 800-4. Sophie herself maintained both of the microscopes of this model as part of her lab job, ensuring that both remained in working condition with their identical camera setups and identical acquisition

6 pseudonym
settings. Yet, she claimed that number 2 “produced clearer images” that “always were easier to analyze and looked better in figures.” I was flattered that she felt my oocytes, prepared by a mere internship student, were worthy of time booked on her favorite microscope, but also mystified by how she could possibly hold this preference. To be clear, I do not think there was any material difference between the microscopes, the cameras, or any other aspect of the setup. Unlike most other biology laboratories, the Smith Lab did not regard their microscopes as “black boxes” (Latour and Woolgar 1979) — Sophie was familiar with their inner workings and opened them up on occasion for repairs. As intimate as she was with the “physiognomy” of the apparatus, perhaps she knew something I didn’t about the state of each machine and its history of manipulation. Either way, her preference for LSM 800-2 flew in the face of another comment she’d made routinely throughout my time working with her: “If the conclusions drawn from the data are not robust to small variations in the experimental apparatus, the result likely isn’t real.” Like her counterparts in high-energy physics mourning the demise of their beloved detector (Traweek 1988, 59). Sophie had an emotional relationship to her favorite microscope; she used it almost exclusively to collect her data because she believed in its capacity to reveal biological detail that other microscopes might miss. I suspect that Sophie’s cognitive dissonance is a matter of selective attention and inattention: when considering the integrity of her data, she is motivated to ensure its quality and ease of analysis above all else, but while designing experiments, she recognizes that she must obtain widely reproducible, clear results so that others believe her findings.

As we designed our approach for labeling kinetochores, the protein complexes that anchor chromosomes to microtubule spindle fibers that will pull them across the cell to segregate them during meiotic division, we selected centromere protein A (CENPA) as our target for visualization. Out of over 100 proteins making up the kinetochore, CENPA was selected because it is the innermost protein of the kinetochore, associated directly with the DNA of the chromosome.
Theoretically, this meant that it might be the most sensitive marker for detecting kinetochore splitting, an aging phenotype thought to account for the increased rate of aneuploidy in aged oocytes (Wan et al. 2009). Challenges with immunofluorescence staining for CENPA emerged in an early pilot run of the sample preparation protocol; the antibody targeting CENPA often bound to off-target substances in the cell, yielding a relatively high level of background staining. This yielded a poor signal-to-noise ratio in the final microscopy images, leading to challenges in working with the lab’s automatic spot detection algorithm with which to identify and measure the kinetochores (Figure 3). This meant that I would often have to “correct” the algorithm, un-labeling what I deemed to be mislabeled fluorescence signals and replacing them with what I thought were the actual kinetochores, using nothing more than context clues to guide my decision-making. Despite these issues, my mentor Sophie felt that the guesswork was worth it, explaining that tagging the innermost protein would potentially allow detection of kinetochore splitting at earlier ages than had

Figure 3: Airyscan processed laser scanning microscopy images of a immunofluorescence stained 6-9-week young 129S6 oocyte fixed in formaldehyde in Metaphase of Meiosis I. The spot detection algorithm in Imaris (3D cellular visualization software) has been applied to both images. Left panel shows chromosomes in magenta and kinetochores in green, with green opaque spheres labeling kinetochores recognized by the spot detection algorithm. Note possible kinetochore spots at the bottom left and bottom center with no opaque spheres labeling them. Right panel shows chromosomes in magenta and kinetochores in green, with green opaque spheres labeling auto-detected kinetochores and white spheres labeling manually detected kinetochores. White lines connect kinetochores on homologous chromosomes.
been previously reported – a tantalizing finding that might help explain the progressive nature of oocyte aging phenotypes.

This approach troubled me greatly day-to-day during my time in the lab, but upsets me even more now, looking back. Each decision I made introduced a greater degree of human subjective choice into the data analysis process – though all the data was double-blinded throughout analysis, I could tell that the spot detection algorithm was even less effective in aged oocytes, where the background signal tended to be much higher than in young oocytes. This meant that I was more likely to inappropriately locate and measure the aged kinetochores in relation to their surrounding structures in aged oocytes, our subjects of greatest interest. While sitting in front of the computer, selecting and unselecting possible kinetochores, I knew that each decision I made would shape the stories that I would tell my colleagues about precisely how 129S6 mouse oocytes age. In the lab presentations, there would be little discussion of those painstaking decisions, just “spot detection algorithm with manual correction as needed.” Unless our data directly contradicted existing oocyte aging literature (it did not, for the most part), no peer reviewer would likely bat an eye.

In selecting “representative” images (Figure 2) for presentations, I was often encouraged to select the oocyte that most clearly represented the aging phenotypes found at that time point. It is important to note that the oocytes that most clearly represent aging phenotypes do not often accurately represent the severity of those phenotypes in the other oocytes within the sample – typically, the “representative” oocytes exaggerate. This means that while my data might faithfully articulate the severity of aging phenotypes across aged oocytes, my representative figures would influence the way that “statements” in discussions regarding oocyte aging trajectories would “see their credibility increase (or decrease) a few points” (Latour and Woolgar 1979, 17). This over-exaggeration of aging phenotypes in oocytes may continue to reinforce myths about female fertility “dropping off a cliff” with age. The oft-quoted statistic that one third of women cannot conceive
after age 35 is based on church records from 18th century France. Today, ample clinical data suggests that fertility decline in modernity is a far more gradual process, with 82% of people sexed female ages 35-39 able to conceive within a year of trying (Dunson, Baird, and Colombo 2004).

Furthermore, I was told to ignore or gloss over instances of deviation from normative reproductive temporality that arose in the data. In addition to their abundance of oocytes and lack of aging phenotypes, young oocytes are expected to progress through meiosis without incident. The first step of meiosis that can easily be observed by researchers through a light microscope (without fluorescent labeling) is nuclear envelope breakdown (NEBD), in which the nucleus breaks down to release the chromosomes inside for capture by the spindle microtubules. The expected proportion of isolated oocytes progressing to NEBD would be highest in young oocytes and decline over time as oocytes declined in quality.

![Figure 4: Bar graph showing the NEBD rates of 129S6 oocytes across four age groups. * indicates p < 0.01. ** indicates p < 0.001.](image)

However, as shown in Figure 4, this is not the case. The proportion of oocytes progressing to NEBD was actually significantly higher in the 50-59-week old oocytes, and the highest of the age
groups I analyzed. At this age, 129S6 mice routinely produce small litters or none at all. Despite this surprising finding and its statistical significance (p < 0.01), my lab colleagues seemed unimpressed and doubtful about the finding’s relevance. This is especially instructive when contrasted with a finding more consistent with normative reproductive temporality. Figure 5, a comparison of the proportion of oocytes featuring misaligned chromosomes, shows the same level of significance (p < 0.01) between young and 50-59-week aged oocytes. My colleagues were excited by this result, as previous studies had not shown the chromosome misalignment phenotype – highly correlated with aneuploidy – to manifest as early as 50-59 weeks in the reproductive aging process. The principal difference between the reception for the NEBD rate (Figure 4) and chromosome misalignment rate (Figure 5) results is that the chromosome misalignment result is consistent with a normative reproductive aging narrative, and the NEBD rate result is not.

Figure 5: Bar graph showing the chromosome misalignment rates of 129S6 oocytes across three age groups. * indicates p < 0.01. ** indicates p < 0.001.

I do not mean to suggest that the Smith Lab or any of my scientist colleagues acted in bad faith to intentionally craft a narrative around their findings, nor do I mean to imply that the Smith
Lab is in any way unique for the way they construct their data. Instead, the microprocesses of data collection, interpretation, and presentation in the Smith Lab, like the majority of laboratories in the reproductive sciences for over a century, has been spurred to produce knowledge in line with social and political currents around them in order to maintain their influx of funding with which to continue their work. The reproductive sciences are precariously positioned within the funding arena. They address subjects of population management and infertility, both topics central to national interests in cultivating economically productive, “healthy” workforces. They also engage in the making of “Brave New Worlds” – novel reproductive possibilities that push the boundaries of the “natural” and “unnatural” in generating new human life and unraveling its mysteries – which breeds discomfort among the general populace, private industry, and government agencies. A dominant strategy for researchers in the reproductive sciences has been to emphasize their “safer” work in public-facing communications while simultaneously pursuing more groundbreaking, yet controversial studies (Clarke 1990, 27-30).

In the Smith Lab, this was very much the case. My project fit neatly within the “safe” side of the lab, targeted toward better understanding the causes of aging women’s infertility – only within a white, wealthy, cisgender, heterosexual temporal frame. However, another group of researchers were interested in developing tools with which to manipulate protein expression in oocytes and early embryos in real time – tools that would allow physicians to modulate human traits with even greater flexibility and sustain eugenic logics of trait selection in human offspring. On the lab webpage, such tools are marketed solely for research purposes, but their clinical relevance is emphasized day-to-day among the researchers themselves (Personal Communication 2019, Max Planck Institute for Biophysical Chemistry). In press releases announcing Dr. Smith’s prestigious awards from private and public institutions the reproductive aging and infertility studies dominate descriptions of the
lab’s research interests; the work on protein expression manipulation tools is relegated to a sentence or two at the end (citations redacted to preserve anonymity).

The reproductive aging characterization experiments that I performed on my 129S6 mice were “not actually set up to produce surprising findings or new rearrangements of the world but instead [were] oriented to preserving the conditions under which corporates operate” (Murphy 2017, 164). Reproductive biology research laboratories developing the next frontier of assisted reproductive technologies must take distinct approaches to their subject matter and research practices to foster more equitable reproductive futures. Researchers must take intentional steps to avoid eugenic or economizing reasoning and contest temporal normativity in reproduction.
un- and re-sex/gendering oocytes

To study oocytes, I first had to isolate them from the mice that bore them. Mastering the isolation protocol was my very first task in the lab. Every day for my first two weeks, I sacrificed mice, dissected them to locate and harvest their ovaries, and then punctured the ovaries to release their precious oocytes for cleaning and selection.

Oocyte isolation began with my graduate student mentor, Sophie, requesting the appropriate number of mice in our strains of interest for preparation by animal facility staff. The following morning, I would prepare petri dishes and M2 oocyte media for my isolation, then go to the animal facility with a body-temperature media-filled plastic tube in hand, ready to obtain ovaries. There, Sophie explained, we had two options for sacrificing the mice: “you can asphyxiate her in the carbon dioxide chamber (oxygen deprivation) and then break her neck, or you can break her neck and then cutting off her head with these scissors.” After completing dual methods of euthanasia, I would work quickly to harvest the ovaries while the carcass remained as close to normal body temperature as possible. I began by spraying down the mouse’s fur in the abdominal area with alcohol to sterilize it before making a small incision with scissors to cut through the skin, but leave the membrane surrounding the abdominal cavity (peritoneum) intact. Then, I would grasp the flap of skin made by the incision with one gloved hand and hold the mouse’s tail with the other, pulling them in opposite directions to tear the skin off the abdomen and torso, exposing the thoracic and abdominal organs. Next, I would cut into the peritoneum (abdominal cavity) and move the intestines and fat aside to reveal the ovaries, pulling them into better view with my tweezers before dissecting away the fat cap and slicing through the fallopian tubes, then place each ovary carefully into the tube of warm media containing dbcAMP, an analog of a natural messenger molecule that keeps oocytes dormant and prevents them from resuming meiosis to make ova.
Keeping the tube warm in the palm of my hand, I would return quickly to the laboratory and sit at a dissecting microscope to clean off any remaining fat and fallopian tube from the ovary, then transfer the cleaned ovary to a new dish with fresh M2 medium containing dbcAMP. Next came puncturing; using two small, thin hypodermic needles, I would repeatedly stab each ovary to lyse every follicle, paying special attention to protruding, bulbous ones most likely to contain mature oocytes. I would continue this painstaking puncture process until only connective tissue was left behind. Then, I would search for mature oocytes, identifiable under the dissecting microscope by their large size, nearly spherical shape, and centrally located nucleus.

This searching process, and all subsequent oocyte manipulation during experimentation, was conducted using a mouth pipette – an apparatus consisting of a mouthpiece into which I would suck or blow, rubber tubing, a one-way filter to prevent sucking oocytes into the user’s mouth, and an adapter to accommodate a glass capillary. In context of the ways that early research in reproductive biology was immediately deployed for the efficient production of meat in animal breeding practices, it is notable that sucking oocytes into the mouth pipette filter was called “eating” them. The capillaries on the mouth pipettes were pulled to narrow the tip opening to just larger than the diameter of a mature oocyte so that they could be used to pick up oocytes one-by-one or separate oocytes from the cumulus cells surrounding them in a process called “stripping.” While in ovarian follicles, cumulus cells nurture the oocytes, providing them with nutrients and signaling molecules to support their growth as they prepare to resume meiosis and undergo ovulation. However, in M2 media designed to support oocytes rather than cumulus cells, they often die rapidly – as Sophie put it, “if a live oocyte is surrounded by dead or dying cumulus cells, she’s likely to die too, so you have to strip her quickly to give her the best chance of surviving.” Notably, just like an intact mouse, an oocyte surrounded by its cumulus cells remained a “she.”
Following Sophie’s guidelines, I would strip every large oocyte I could find, repeatedly sucking it – her – up into my mouth pipette and expelling it back into the media until every cumulus cell was gone, then evaluating the positioning of the nucleus to determine whether the oocyte was properly mature. In mice, mature oocytes with centrally located nuclei are most likely to progress smoothly through meiosis, so they are used exclusively for all experimentation (Clift & Schuh 2015).

Newly naked, the oocytes were exposed to the solution around them for the first time. Suddenly, they were individual cells separated from any other tissue that might render them recognizable as belonging to an ovary or to a mouse. With this change came a stark shift in vocabulary. “After stripping, the oocyte has to be kept warm or it’ll die quickly and we won’t have any for the experiment, so transfer it immediately to your collection dish and turn on the warming plate,” Sophie warned. Upon losing their last physical, visible ties to a whole gendered, sexed organism, or even a feminized organ, the oocytes were suddenly freed of their previous anthropomorphizing, reductionist characterizations within human sex and gender categories. No longer was “she” an “oocyte,” but rather “it” was a “cell.” After additional manipulation – fixation to preserve the appearance of subcellular structures, injection with mRNA to stimulate protein expression, drug treatment, or imaging – the oocytes were even termed a collective “sample,” a term that overlooked their recent organismal origin. Isolating the oocytes from their biological contexts opened a window for (re)interpretation as multipotential entities.

Engaging repeatedly in this ritual throughout my time in the laboratory gave me ample opportunities to recognize gamete isolation as a powerful site of observation, interpretation, and dynamic social construction. The un-gendering, un-sexing7 process I witnessed called my attention

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7 In order to analyze the processes of un-sexing and un-gendering – or sexing and gendering, for that matter – it is useful to first engage with the meanings of “sex” and “gender” as well as their relationships to one another. I draw on Anne Fausto-Sterling’s perspective, which views both sex and gender as layered, multifaceted, co-constitutive biocultural constructs. Sex alone is made up of “chromosomal sex, indifferent fetal sex, differentiated fetal gonadal sex, fetal hormonal sex, genital sex, fetal internal reproductive sex, brain
to the socio-scientific apparatus responsible for naming, characterizing, and contextualizing biological material and in so doing, defining its specific utility as a research subject. I will focus my attention on two interrelated forms of violence central to reproductive biology research, each exemplified by the process of oocyte isolation: the reduction of organisms to their reproductive functions and the sexing and gendering of gametes and other sub-organismal reproductive structures. Together, these work to support and maintain the heterosexism and transphobia underlying all Western medical and scientific reproductive biology literature produced to date. These interlocking forms of violence coincide in the pornotroping of human and animal reproductive cells and tissues – their disembodied enfleshment leaves them susceptible to knowledge production practices that fit within scientists’ normatively sex/gendered reproductive scripts. Any queer-centric or more equitable approach to reproductive biology research and reproductive healthcare must begin by deconstructing how gametes are described in scientific literature to reimagine what they are and what they can do.

sex, pubertal hormonal sex, pubertal erotic sex, and pubertal morphological sex.” Gender is similarly complex as both a social institution and an individual characteristic, and includes “body image, social gender fortification, juvenile gender identity, and adult gender identity (Fausto-Sterling 2012, 3). Each of these components of sex/gender can vary independently, giving rise to great diversity in individual sex/gender presentations. In Sexing the Body, Fausto-Sterling articulates the way that sex/gender permeates the many layers of society using a metaphor of “Russian nesting dolls.” Each doll is another layer of complexity and possibility, spanning molecular, “cellular, organismal, psychological, interpersonal, cultural, and historical” levels of organization (254-255). In my usage, sexing and gendering each refer to situating an entity within this multidimensional sex/gender space. Hegemonic sex/gendering typically locates an entity to a vector in the space with most or all sex/gender components aligning with normative definitions of “male” or “female.” To avoid sexing/gendering an entity, then, is to allow that entity to occupy ambiguous position(s) within sex/gender or to permit the entity to articulate its sex/gender for itself. Since sex and gender are co-constitutive and operate together on all sites of the body, they and their effects should be considered simultaneously.

For simplicity, I will refer to “sex” when highlighting how an entity’s body or physical makeup has been/is being classified. I will refer to “gender” when an entity’s psychosocial roles and behaviors come to the forefront. Note that the body, psyche, society, and culture are all biocultural; “sex” is no more or less biological than is “gender.” Importantly, for Fausto-Sterling, sex begins before birth, and gender is layered on top of a sexed newborn at the point of birth. As will become evident, I do not share this view; sex and gender operate simultaneously at all times and places, including human development before and during conception.
Isolation and Classification

Over the course of my summer internship, I isolated oocytes from nearly 100 mice. Each time, I used scissors, tweezers, needles, and pipettes to access the reproductive organs and discard the entirety of the remaining mouse carcass. Then, I tore apart the ovaries to harvest only the direct precursors to gametes, ignoring all the other structures necessary for their formation and maintenance. I physically reduced these mice to their reproductive structures, ignoring and then throwing away any reminder of the animal in its entirety. I assert that reducing a creature to its reproductive capacity – surgically or otherwise – is violent for the manner in which it excommunicates reproductive cells and tissues from their biological milieu, leaving them unintelligible as belonging to an organism and thus, wholly susceptible to interpretation by human scientists.

Reproduction is a peculiar locus: it is a capacity that links humans to every kind of living thing that has ever inhabited the Earth, and even to some things that are not themselves living but manage to make more of themselves through interactions with living things. This is a space of close overlap among all branches of the natural world – overlap that has left it vulnerable to influential theorization by human thinkers. When European botanists of the 17th century first discovered sexual reproduction in plants, they were driven to sex particular structures “male” and “female” “without knowing well the reason.” Seizing the opportunity to liken plant reproduction to the human variety with which they were more familiar, they drew together the reproductive organs of flowers and humans through forced analogy:

“The blade (or stamen) does not unaptly resemble a small penis, with the sheath upon it, as its praeputium. And the several thecae, are like so many little testicles. And the globulets and other small particles upon the blade or penis are as the vegetable sperme.
Which as soon as the penis is erected, falls down upon the seed-case or womb, and so touches it with a prolific virtue” (Schiebinger 19-20).

Discovering plant sexuality prompted botanists to reconsider stamens from “superfluous” and “idle” to “essential” and “most noble” (Schiebinger 21). Reimagining plants as sexually reproductive creatures required reconstituting their anatomy in both sexed and gendered terms: not only was the stamen considered a penis, it was an “essential” and “most noble” masculine penis.

Upon recognizing a hint of commonality in reproductive strategies between humans and plants – ignoring the great diversity of sexual and asexual modes by which plants reproduce – botanists imported their entire sex/gender system to the study of plant life.

The ubiquity of reproduction as a point of recognition across diverse life forms proved seductive to naturalists aiming to classify an ever-growing diversity of plants discovered around the world. Carl Linnaeus’ taxonomic system, still in use today, was built upon his understanding of male and female sexual structures in flowers: he prioritized the number, proportion, and position of stamens (sexed male) to define a plant’s class, and then used the number, proportion, and position of pistils (sexed female) to define orders within those classes (Shiebinger 15). All subsequent phylogeny was based upon this initial reduction to reproductive function and with it, the import of Western sex and gender norms to describe the natural world.

The violent effects of such reduction to reproductive function are especially apparent in the case of primatology, a discipline in which non-human primates are studied in order to gain insights about human biology, psychology, and culture. As with plants, reproduction was a clear point of commonality between humans and non-human primates; the very first U.S. physiology laboratory housing nonhuman primates focused on reproductive physiology, and specifically “especially the primate menstrual cycle” (Haraway 22). Other early primate studies prioritized the study of “sexual
intercourse,” considering “obligatory reproductive heterosexuality” a “basic principle of life.” This “research provided norms” “to guide [human] social life” (Haraway 71).

In some cases, primatologists “chose to study males because that meant fewer independent variables coming from the whole reproductive economy of females [since] the behavior of females changes according to their reproductive state.” This led to female primate physiology and behavior being understudied as compared to males (Haraway 177). Sex/gendered representations of behavior were placed upon non-human primates, which subsequently obscured data acquisition with the potential to refute hegemonic sex/gendered expectations. When physical anthropologists of the 1950s and 1960s observed greatly diminished sexual dimorphism in the hominin lineage – to which humans belong – they theorized “transfer of male group defense and internal dominance arrangements from the biological to the cultural tool.” Rather than localize sex/gendered difference in the body, they built it into the “logic of culture” reliant on “reproductive social relations” (Haraway 215).

Sex/Gendered Gametes, Sex/Gendered Bodies

Reproduction as a subject of study straddles the dialectic of model organism research. The rationale for biomedical research using model organisms is fully dependent on a paradox. Any claim to knowledge about human biology that comes from studies of non-humans is predicated upon the non-human being enough like the human that close comparisons are useful and informative. But research on non-humans requires violence against the bodies of non-humans, violence that can only be rationalized by claiming that the non-human is somehow deeply unlike the human.

Reproduction’s universality reinforces connections between humans and all other organisms, blurring species boundaries. This emphasized connection leaves it particularly vulnerable to human researchers explicitly and implicitly imposing their own sexed and gendered hierarchal worldviews.
onto the research subjects from which they aim to learn about human society and human biology. This, in turn, reinforces the social underpinnings of compulsory heterosexuality, transphobia, and rigid sex classification, as they appear to be supported by supposedly objective biomedical research. Simultaneously, reproduction’s profound importance to the continuation of all species serves as justification for the destruction of animals defined and constructed as non-human by the very process of tearing them apart in order to access their reproductive organs, tissues, and cells.

Conceiving of any organism principally for its reproductive functions leaves it susceptible to the violence of sexing and gendering as well as the constant threat of material bodily destruction for the purposes of human reproductive biology research. In humans, at least, we can begin to imagine how reduction to reproductive function might feel through accounts of childbirth. In The Woman in the Body, Emily Martin recounts women’s intense feelings of “fragmentation” upon giving birth, noting that a c-section made them feel even more “out of control.” “In the case of a cesarean section, the numbness” from epidural or spinal anesthesia – which may also be present during vaginal birth – “is intensified by a drape placed across the woman’s chest so that she cannot see her bottom half.” The result is the feeling of being “detached” from the body. Unlike vaginal births, c-sections involve surgeons talking amongst themselves, focused entirely on extracting the baby from the uterus safely while the mother watches, awake and aware. Her health and safety are temporarily dismissed for the good of her progeny. Women who have endured c-sections describe being “forcibly violated,” expressing feelings of complete helplessness accompanied by physical violence and likening their experience to “crucifixion,” “assault,” “evisceration,” and “rape” (Martin 1987, 82-84).

In the case of the mice I sacrificed to harvest their ovaries, I dismissed their health and safety entirely, destroying their bodies and selves irrevocably simply in order to learn about their reproductive function in a dish. In comparing murine and human reproductive functions, I forcibly
used the mouse to bolster oppressive hegemonic regimes of compulsory heterosexual reproduction and sex/gendered visions of human and animal bodies. The specific violence committed in cellular and molecular approaches to reproductive biology convincingly essentializes heterosexuality, gender, and sex. This is a quirk of multicellularity. Embryonic development in multicellular organisms typically proceeds from a zygote, a single cell that divides over and over to yield, in the case of humans, tens of trillions of cells, many with specialized roles giving rise to complex organismal functions. The zygote, of course, comes from the joining of two gametes upon fertilization. Thus, sex/gendering gametes sets a powerful precedent for subsequent sex/gendering of the resultant body ultimately derived from their fusion. In The Egg and the Sperm, Martin clearly articulates the ways that reproductive scientists have sexed and gendered gametes’ roles in the process of fertilization, rendering sperm as “heroic” male actors and eggs as “passive” female bodies or “damsels in distress” awaiting “saving” from the “wasteful” process of menstruation by the sperm. Biologists have created a narrative that “a fertilized egg…is the result of deliberate ‘human’ action at the cellular level.” This implies a “microscopic ‘culture’” consisting of a cellular “bride (or femme fatale)” and cellular “groom” making a cellular “baby” (Martin 1991, 485-491).

Narrativizing, sexing, and gendering gametes displaces personhood from human beings and places it instead on their haploid sex cells. Martin has made clear how granting an oocyte the feminine qualities of a mother may divert necessary attention away from the actual mother carrying a developing embryo or fetus and discredit her agency and human rights. Likewise, imbuing sperm and egg alike with gendered and sexed characteristics always already sexes and genders the body that generated those gametes and the person who inhabits that body. Any person existing outside the confines of “man” or “woman” is rendered illegible – if your body makes strong, heroic, penetrating sperm, you too must be strong and heroic, and additionally must have a penis with which you engage in penetrative sex, presumably with the intention of impregnating someone whose body
contains passive, receptive, nurturing eggs. In turn, if your body contains those passive, receptive, nurturing eggs, you too must be a passive caretaker with a nurturing womb who desires penetration of a receptive vagina. This is an erasure of those whose gender lies outside “man” or “woman” or whose sex lies beyond “male” or “female.” The reproductive capacity of non-binary, agender, genderqueer, gender-fluid, transgender, and intersex people is thus erased. Whatever kind(s) of gametes a person contributes to a reproductive effort function as a proxy for that person’s sex, gender, and sexuality, extending Gayle Rubin’s sex/gender system and Judith Butler’s heterosexual matrix to the cellular and molecular levels of human reproduction. Sexing and gendering gametes outside of the human bodies from which they are derived defines their reproductive capacity independently from the bodies from which they came yet essentializes their reproductive utility in a manner tied to researchers’ \textit{a priori} normative expectations of sex, gender, and sexuality.

\textbf{Pornotroping Disembodied Reproductive Flesh}

At a glance, this brief overview of the feminist science and technology studies scholarship pertaining to sex/gendering reproductive cells and tissues seems at odds with the process of un-gendering and un-sexing I described at the beginning of the chapter. After the un-sexing, un-gendering process of isolation, oocytes included in experiments typically retained the unsexed, ungendered terminology of “cells” or “sample” for the remainder of experimentation and data analysis without a return to the female sex/gender imbued early in the isolation procedure. This lasted only until the beginning of each and every lab presentation I observed over the course of the summer – including my own. Upon interpreting and presenting data acquired from oocytes that had

\footnote{Here, I have articulated how \textit{Western} reproductive biology laboratory practices of sex/gendering gametes reinforces compulsory heterosexuality and cisnormative binary sex/gender classification. It is important to note that this does not imply that sexing or gendering gametes in accordance with any other system of sex, gender, or sexuality is more benign. I am critiquing the processes of sexing and gendering, not the specific sexes, genders, or sexualities forced upon eggs and sperm.}
been un-sex/gendered at the time, scientists swiftly reverted to sex/gendered descriptions and narratives. Every researcher tied the importance of their discoveries to possible advances in women’s/female reproductive health. This was even true of those scientists who had never before mentioned women’s healthcare as a motivating force for their work in the day-to-day. Usually from the presentation’s very first slide, the un-gendering, un-sexing process of oocyte isolation was immediately undone. Similarly, every paper from the Smith Lab begins its introduction with a reminder of the centrality of women’s reproductive health to the discoveries outlined in the manuscript. Conclusions were always articulated in terms of potential implications for women and their reproductive capacity. In this manner, any window for reinterpretation of an oocyte’s position within – or outside of – an established societal sex-gender matrix was swiftly closed. The oocytes were re-sexed and re-gendered alongside the data they helped produce. Of course, oocyte research is relevant to cisgender women’s reproductive health – I have no intention of arguing to the contrary. Instead, I seek to highlight the space available within reproductive biology research to rethink sexed and gendered representations of human reproductive processes to make room for alternate portrayals and applications of knowledge.

The dynamism of the un-sexing and un-gendering I observed during the process of experimentation coupled with the abruptness of the re-sexing and re-gendering upon presenting the work made it clear that separating oocytes from their original biological context within the mouse facilitated researchers’ enforcement of compulsory heterosexuality, cisgender identification, and intersex erasure. This separation from interconnected tissues and broader biological contexts is shared between Linnaeus’ approach to botanical classification, the construction of a romance narrative between egg and sperm in fertilization, and my own observations of the mechanisms by which mouse reproductive biology data was repurposed to support hegemonic scripts of human female reproductive aging (Chapter 1). It is precisely the disembodied disconnection of reproductive
structures and functions in each of these cases that enables their deployment consistent with human scientists’ cis-heterosexist conceptions of human reproductive capacity.

How might we account for researchers’ un- and re-sex/gendering practices? Black feminist theorists provide a useful framework within which to conceptualize sexing and gendering as dynamic and active processes that are highly mutable and context dependent. Sylvia Wynter asserts that white Western European colonialism was “the first time in history” that bodily difference between humans “was no longer primarily encoded in the male/female gender division” but rather in the “cultural-physiognomic variations” between the colonizers and the colonized. For the enslaved – physically confined and separated from their social context – “sex-gender attributes are no longer the primary index of ‘deferent’ difference” (Wynter 1990, 358-359). Hortense Spillers engages in the un-gendering effects of captivity in greater detail; she describes how the “externally imposed meanings and uses” of captivity reduce “the captive body” to an “irresistible, destructive sexuality,” a “thing, becoming being for the captor,” “a physical and biological expression of ‘otherness’,” and “a potential for pornotroping” (Spillers 1987, 67). Gender is erased for the Black subject under enslavement: the captive body is excommunicated from the social framework that animates gendered constructions into legible bodily boundaries. Without such a gendered framework, the body is unintelligible, leaving only flesh, which can be violated and utilized at the will of the captors. Captivity – and subsequent excommunication from society – transform the Black subject into less differentiated, un-gendered flesh. The un-gendered Black enfleshed subject is pornotroped into a sexualized state that is always susceptible to sexual violence.

Mouse oocytes undergo a similar transformation through the process of isolation. Oocytes begin as sex/gendered entities in keeping with the sex/gender of the mouse body to which they belong. They retain this sex/gendered state for exactly as long as they can be recognized as belonging to the mouse’s body: within an ovary or even merely still attached to the cumulus cells
that surround them. As the scientist tears the oocyte away from its biocultural context, the oocyte’s sex/gender loses meaning. The oocyte becomes a cell, a sample, “a thing,” antithetical to the embodied, socially legible state of the researchers or the living mice from which it came.

Excommunicated from the biological complexities around it, the oocyte is simplified and made malleable enough to fit within researchers’ hegemonic reproductive scripts. The oocyte in captivity is not sexually violated in a manner akin to that of the Black subject but is likewise subject to insults to its own integrity – insemination, injection, laser light microscopy. The abruptness of scientists’ re-gendering when communicating their science emerges because their oocytes in captivity have become no longer precisely oocyte, no longer precisely biological, no longer understood as part of an organism with reproductive functions. The oocyte is disembodied flesh forced to fit into a narrativized explanation of reproductive biology.

Toward Enmeshment

I have formatted the title of this chapter to reflect the importance of a central paradox that shakes the ideological foundation of any sexing or gendering of gametes, as noted in Martin’s analysis in *The Egg and the Sperm* or as articulated in my own description of un- and re-sex/gendering over the course of an oocyte experiment. At the level of chromosomal sex – just one part of the complex sex-determination mechanisms at work in human biology – “female” is defined as having two X chromosomes, while “male” is defined as having one X and one Y chromosome. Oocytes are typically XX, but any egg cell successfully generated from an oocyte will be haploid, meaning it will not contain two sex chromosomes at all, but rather a single X chromosome, often noted in biology as XO – hence why I’ve emphasized the X and O in the title. Similarly, primary spermatocytes, precursors to sperm, are typically XY, but any mature sperm cell will be haploid, with either XO or OY sex chromosomes. Therefore, gamete karyotypes (chromosome arrangements) align with neither
hegemonic “male” nor “female” karyotypes. Ironically, it is reproductive scientists who are simultaneously most devoted to rigorously characterizing the biology of gametes while crafting erroneously sexed and gendered narratives about this biology. Recognizing gametes’ haploid sex cell karyotypes renders the latter pursuit unintelligible. Egg cells are not female; sperm cells are not male. This truth makes clear that sexing and gendering gametes has been a project of loose association based upon perceptions informed by hegemonic sexed and gendered methods of analyzing reproductive biology. There is no biological prerogative for sexing or gendering gametes.

Moreover, the sheer flexibility of male and female as categories applied broadly to organisms with a broad range of intra-species phenotypic variation calls into question the utility of sex/gender for categorizing whole organisms well as gametes. Chromosomal sex definitions are remarkably capacious: in the animal kingdom, “males” can be XY, ZZ, XO (containing just one sex chromosome) or entirely haploid (containing only one copy of the genome rather than two). In *C. elegans* nematode worms – the model organism with which I have worked most closely throughout my time in college, XO individuals are males, but XX individuals are not permitted to inhabit the category of “female,” instead termed “hermaphrodites” for their capacity to produce both eggs and sperm and self-fertilize to generate parthenogenic offspring. I explore the ties between gametogenic capacity and sex/gendering organisms in far greater detail in Chapter 3. Individuals of many plant and fish species can change sex based on genetic cues throughout their lifetimes. Still other species rely on temperature differences during embryonic development to differentiate between sexes. Clearly, “male” and “female” as categories reveal very little about the individuals of any species, and articulate next to nothing about the biology of a given organism. When the complex social elements of organismal societies are taken into account, the meanings of these loose, capacious sex/gender categories become even less clear. “Male” and “female” as sex/gender designations lack explanatory power – this is reason enough to question the practice of sex/gendering bodies as currently
constituted. Rather than continue to operate within a system of classification that fails to provide meaningful information about the subjects within its domain, reproductive scientists must abandon the framework of sex/gender to describe reproductive processes.

In The Social Construction of What, Ian Hacking describes the activities of natural scientists in terms of a model of “resistance and accommodation.” “Research scientists have theoretical models, speculative conjectures,” and “views…about how [their experimental] apparatus works and what [they] can do with it.” As some hypotheses are refuted, the natural world “resists” scientists’ conjectures – any scientist who wishes to continue doing science must “accommodate themselves to that resistance.” But there are multiple ways to accommodate to such resistance in pursuit of “robust fit” between “theory, phenomenology, schematic model, apparatus,” and experimental outcomes: “one can revise either the major theory under investigation or the auxiliary hypotheses about the apparatus” (Hacking 71). For centuries, reproductive biologists have revised auxiliary hypotheses to contort experimental results in reproductive biology into convoluted boxes that align well with hegemonic descriptions of human sex, gender, and sexuality.

In order to attain a more robust fit between the theories used to describe reproductive processes and the way that these processes materially unfold, reproductive scientists must abandon frameworks that inadequately describe and unnecessarily characterize gametogenesis and fertilization. I suggest that we revise the major theory under investigation rather than continue to tweak auxiliary hypotheses. This begins by recognizing that reproductive biology did not have to proceed by imposing Western norms of sex, gender, and sexuality on gametes and the gonads and bodies that produce them. I propose a radical reimagining of what gametes are, who and what they come from, and what roles they occupy in fertilization and development. This reimagining must contend with a tension that I have outlined over the course of this chapter. Sex/gendering reproductive cells and tissues confines them to specific roles and normative scripts that fail to
accommodate the immense reproductive variation between and within cells, tissues, bodies, and species. Yet, while un-gendering and un-sexing individuals and their reproductive functions opens new possibilities for how they can exist outside of hegemonic gender and sex categories. However, un-gendering and un-sexing also render such entities socially illegible – sex/gender is part of subjectivity that gives entities their meaning and belonging. Analyzing reproductive tissues outside their biocultural contexts leaves them susceptible to cisheterosexist narrativization by scientists. Thus, any efforts to queer oocytes in bioscientific research should constitute and interpolate them within their biocultural milieu. Doing so may reveal and acknowledge the full complexity and astounding plasticity of human and animal cells, tissues, and bodies that transgress sex, gender, and sexuality to redefine human reproduction.
Queering Gametogenesis, (Re)producing Inequity?

Amid the COVID-19 pandemic in the spring of 2020, the American Society for Reproductive Medicine (ASRM) issued guidelines for how best to continue managing patients undergoing fertility treatments in the hopes of conceiving children or preserving their fertility for later in life. The ASRM urged care providers to immediately suspend any new treatment cycles for ovulation induction, intrauterine insemination, oocyte retrievals or frozen embryo transfers as part of in vitro fertilization (IVF), or non-urgent egg or sperm cryopreservation. While the few patients deemed to require “urgent stimulation and cryopreservation” were permitted to continue their treatment cycles, all elective surgeries, non-urgent diagnostic procedures, and the majority of embryo transfers were suspended as of March 17, 2020 (ASRM 2020). With great uncertainty regarding the timetable for the end of worldwide social distancing practices to control the spread of the SARS-CoV-2 novel coronavirus, thousands of patients and their fertility specialists fear that the ASRM’s recommendations could derail their last chances to conceive healthy offspring. Some women’s fears have hinged upon the widespread myth that they may “fall off the cliff of fertility” – though no such “cliff” exists (Wallace and Telsey 2010) – without any means to access the reproductive care that they “consider essential” (Pfeiffer 2020).

IVF and related assisted reproductive technologies have been revolutionary for their capacity to join egg and sperm outside the body. However, the COVID-19 crisis has highlighted some of the shortcomings of existing approaches and raised recurrent questions anew. What constitutes an “urgent” or “essential” need for fertility medicine services, and for whom are such services recognized as “urgent” or “essential?” This chapter interrogates an emerging frontier of assisted reproduction: in vitro gametogenesis (IVG). I highlight its distinctions from existing technologies and outline common ethical concerns regarding its implementation in humans. I explore the ways in which IVG transgresses bodily and cultural norms of sex, gender, and sexuality, opening novel trans-
sex/gender, queer and trans-species questions and futurities. Finally, I examine its potential to reinforce existing biopolitical currents of racialization that dictate which bodies are permitted and encouraged to reproduce.

*Is there anything new here?*

In evaluating IVG’s capacity to change the landscape of human reproductive opportunity, it is imperative to distinguish its biological mechanism from that existing assisted reproductive technologies, namely IVF. IVF begins with ovarian hormonal induction to achieve super-ovulation. In a typical human ovulation cycle, only one oocyte will be released from the ovary per ovulation. Since IVF requires harvesting multiple oocytes in case only a subset produce viable embryos, the fertility specialist induces multiple oocytes to mature within one ovulation cycle by administering drugs that mimic gonadotropin-releasing hormone (GnRH) alongside supplemental estrogen through at-home injections for 8-11 days. This stimulates the pituitary gland, a regulator of endocrine function throughout the body, to release large quantities of follicle-stimulating hormone (FSH) and luteinizing hormone (LH). The high FSH and LH levels enable multiple ovarian follicles to mature simultaneously. The fertility specialist then monitors the ovary with vaginal ultrasound to track the development of the follicles and follow the increase in estrogen and progesterone by follicular cells. When follicles are ready, the patient injects a shot of human chorionic gonadotropin (hCG), a hormone that stimulates the final steps of oocyte maturation. 35 hours following hCG administration, the physician inserts a probe into the vagina and, guided by ultrasound, extends a long needle through the vaginal wall to access the ovary, piercing each mature follicle and applying suction to capture the oocyte and its surrounding fluid. Next, the harvested oocytes complete their maturation in a dish and are combined with sperm to form embryos. The embryos are permitted to develop until the 8-cell stage – sometimes genotyped to assess for any genetic “abnormalities” – and
then implanted into the uterus with a probe inserted through the vagina. This method can be used to ameliorate infertility issues including inadequate or unreliable ovulation or difficulties with implantation (inserting multiple embryos increases the likelihood that one will implant). IVF can also address reduced sperm count or sperm motility, especially when coupled with intracytoplasmic sperm injection, which places the sperm directly into the mature oocyte; typically, intrauterine insemination will be attempted first if only the sperm exhibit reduced fertilization potential. This IVF protocol can be combined with sperm or oocyte freezing to use gametes obtained previously. Alternatively, the embryos produced using IVF can be frozen at the 8-cell stage and implanted at another time. (Harper et al. 2018).

Notably, however, IVF requires that the patients providing sperm and egg alike each have functional gonads with the capacity to yield gametes in the first place. For multiple vulnerable patient populations, this is not the case. Pre-pubescent cancer patients who have yet to undergo hormonal changes facilitating gametogenesis (egg or sperm formation) before undergoing radiation or chemotherapy have no way to freeze their gametes because they cannot produce them. Pre-pubertal ovarian or testicular tissue preservation are still experimental procedures, with no live births reported from frozen testicular tissue and only a handful reported from frozen pre-pubertal ovarian tissue (Gassei and Orwig 2016). Individuals of any age who have already undergone chemotherapy or radiation for cancer treatment or have sustained gonadal injuries without any prior fertility preservation are similarly left without options. People who have had their gonads removed – either through involuntary sterilization, cancer treatment, or gender-affirming surgeries – similarly cannot produce their own gametes and thus cannot benefit from IVF procedures. Intersex and sex-diverse individuals experience a wide range in fertility potential owing to variations in sex chromosome karyotypes, reproductive organ morphology, and hormonal exposures across multiple stages of development (Rowlands and Amy 2018). The effects of cross-sex hormone therapy or puberty
suppression on gametogenesis remain poorly understood, and the reversibility of any such effects is similarly unknown. This means that individuals who decide to undergo cross-sex hormone therapy are often forced to choose between their future fertility and their bodily transition (Almendrala 2018; Nahata et al. 2019).

*in vitro* gametogenesis (IVG) holds the potential to enable or restore fertility in individuals who lack the capacity to produce their own gametes, providing new hope for those who cannot benefit from IVF. In the most common approach to IVG, scientists obtain a small skin sample from the animal from which they hope to generate sperm or egg. That skin sample contains fibroblasts, a common cell type that produces connective tissue in the skin. The fibroblasts are then de-differentiated: they are exposed to compounds (Yamanaka factors) that spur them to gradually lose their fate as fibroblasts through a sequence of successive cell divisions, changing the way that their genes are expressed until they become induced pluripotent stem cells (iPSCs). These iPSCs harbor the capacity to give rise to every cell in the human body — including sperm and egg cells (Takahashi and Yamanaka 2006). Next, the iPSCs undergo a process of directed differentiation: they are exposed to compounds and cellular environments that stimulate them to develop into primordial germ cell-like cells (PGCLCs), cells committed to the germline lineage, which gives rise to the gametes, but without most of the features that will allow them to undergo meiosis and produce mature eggs or sperm (Hayashi et al. 2018). Next, the PGCLCs are combined with somatic (non-germline) cells from ovaries or testes, either by transplanting them into intact gonads (Sosa et al. 2018), combining them with gonadal cells harvested from adult or fetal animals, or by combining them with somatic gonad cells generated from iPSCs alongside the PGCLCs. The combination of PGCLCs and somatic ovarian, testicular, or multipotential gonadal cells is typically termed a reconstituted organoid – its function is to provide the appropriate cellular environment to promote the PGCLCs to continue differentiating into mature germ cells that will enter meiosis to produce haploid gametes.
(Hendriks et al. 2015). This approach has already yielded healthy births in mice and is very close to producing human sperm and eggs (Ibtisham et al. 2017). To date, the most successful approach to human oocyte IVG utilized xenogeneic (containing tissues or cells belonging to individuals of different species) reconstituted ovarian organoids consisting of human iPSC derived PGCLCs and mouse ovarian tissue, yielding human oogonia well on their way toward producing functional human oocytes (Yamashiro et al. 2018).

For all its revolutionary potential, research progress in IVG has not been free of controversy. However, many concerns from bioethicists to date have not been specific to the case of in vitro gametogenesis, but rather shared with those emerging from other stem cell technologies proposed for biomedical use. These critiques focus on the safety risks of incomplete erasure of genomic imprinting during the de-differentiation process. Maternal and paternal copies of the genome maintain characteristic epigenetic marks in somatic cells; if not removed completely they could impair an IVG-derived gamete from producing a developmentally healthy embryo after fertilization with a similar imprinting pattern (Falls et al. 1999). Recent IVG implementations in animal studies have produced iPSCs with no evidence of residual imprinting and oogonia with epigenetic profiles that precisely mirror those of their in vivo counterparts (Ibtisham et al. 2017; Yamashiro et al. 2018). Moreover, there has been recent progress in identifying genomic regions where imprinting occurs and reversing these epigenetic marks to facilitate the creation of “bimaterna”l and “bipaternal” mouse offspring – though IVG pulls apart the meanings of “father” and “sperm provider” (Li et al. 2018). Additional bioethical dilemmas regarding safety risks common to other stem cell research and regenerative medicine applications or assisted reproductive technologies are beyond the scope of this chapter and have been addressed elsewhere (Hyun 2010; Kosteria et al. 2017). Critiques that privilege “natural” bodily products, such as eggs or sperm, from those produced “artificially” in IVG or question the capacity of same-sex couples or transgender people to produce and raise offspring,
biologically or otherwise, have similarly been addressed. These perspectives have been adequately contested by acknowledging that biological reproduction is a privilege to which most heterosexual couples can expect access enabled either through their biology or through bioscientific intervention. Insofar as such bioscientific intervention is allocated to individuals hoping to produce biologically related offspring, homosexual couples, transgender and intersex individuals, and others should also expect access (Testa and Harris 2005; Baylis 2013). This becomes somewhat more complex when considering single-parent and “multiplex” parenting configurations and will be addressed later in the chapter. This chapter identifies and probes unique possibilities and limitations that emerge from in vitro gametogenesis research and future clinical practice.

The biocultural influences of IVG extend beyond repartitioning the landscape of human fertility and infertility. IVG perturbs the boundaries between human somatic (body) and germline tissues, provides new possibilities for genetic kinship within various couple and non-couple relationships, and introduces novel interspecies intimacies within the interlocking realms of science and reproduction. IVG queers the oocyte, the sperm, the body, and the human.

How Does IVG Queer?

Shulamith Firestone’s groundbreaking 1970 book The Dialectic of Sex regarded the biological sexual dichotomy between male and female as foundational for social inequity, including patriarchy, classism, racism, and even the destruction of the environment. Working from within a cisgender lens, she identified women’s “vulnerability” during pregnancy and the extended duration of human infancy as permissive of men’s domination. Under the guise of protection, men are encouraged to dominate the public and economic spheres and control women and children within the home. For Firestone, the cultural significance of genital differences attached to sex distinction gives rise to the “biological family,” an institution that isolates each couple and their offspring and relegates women
to an inferior sex-class in which they must forego economic and sexual freedoms to bear and rear children. Firestone did not view “the ‘natural’” as “necessarily a ‘human’ value” (Firestone 1970, 10). Her imagined solution to reproductive inequity was an extracorporeal womb that would free women’s bodies from their duties within the biological family. Without the burden of pregnancy, women would be freed from their duty to perpetuate humanity. Thus, gestation outside the body would technologically abolish sex-class and thereby end sexual repression, facilitating a proliferation of diverse sexual and “childbreeding” arrangements (Firestone 1970).

Despite recent research breakthroughs in artificial womb technology to sustain lamb fetuses born “at the border of viability” (Usuda 2019), extracorporeal wombs remain far from clinical application. However, in vitro gametogenesis holds the capacity to abolish sex-class in a manner altogether different from Firestone’s imagined solution: by eliminating biological linkages between sex/gender (chromosomal, hormonal, genital, cultural, and otherwise) and gametogenic capacity. Skin fibroblasts with XY karyotypes have been used to successfully generate both sperm and egg cells in mice as well as humans. In fact, in the absence of the cellular environment of the testis, XY PGCLCs default to generate oocytes rather than sperm (Yamashiro et al. 2018). In mice with sex chromosome trisomies XYY and XXY, generating iPSCs for IVG eliminates the vast majority of the triploid sex chromosomes, yielding XY iPSCs that can produce fertile sperm and oocytes (Hirota et al. 2018). XX cells present the additional challenge that they lack a Y chromosome, which is known to facilitate differentiation of spermatocytes, but researchers have nevertheless managed to produce mouse and human sperm and oocytes alike from XX iPSCs (Hendriks et al. 2015).

IVG introduces a powerful rupture in the sex-gender system – for the first time, it uncouples sex/gendered bodies from sex/gendered gametes. This rupture reaches across male, female, and sex/gender-diverse bodies, revealing the multipotentiality of all human tissues to give rise to all the materials necessary for generating new human lives. Practically speaking, it means that individuals
sexed male may soon be able to generate their own oocytes as well as sperm no matter the spermatogenic capacity of their testes, individuals sexed female might produce their own sperm as well as oocytes no matter the size of their ovarian oocyte reserve, and gender- and sex-diverse individuals would be able to generate whatever gametes are most affirming to their identities and best complement the gametes that their partner(s) hope to contribute to a reproductive effort.

First and foremost, IVG obfuscates the boundary between somatic and germline cellular lineages. A great deal of scholarship has been devoted to characterizing precisely how these cell types differ and maintain their identities throughout an animal’s lifetime through both physical segregation and differences in regulation of the genome and epigenome. The soma has been contextualized as entirely preoccupied with sustaining an animal’s growth, development, and maintenance during the life course. The germline, on the other hand, is theorized as the exclusive realm of information transfer across generations, positioned explicitly for the purpose of generating the next generation’s soma and transmitting its own genomic contents to the next generation’s germline (Gleason et al. 2018; Kenney and Müller 2017). IVG queers this distinction: whereas previously the germline was known to generate a new soma and regenerate a new germline, the soma has never before been recognized as capable of undergoing the reciprocal transformation into germline.

The interconversion of soma and germline problematizes distinctions between capital production and workforce reproduction. In the global capitalist economy, different forms of work are highly classed, gendered, and racialized. Poor women of color remain largely bound to “unskilled” domestic work organized around reproduction while wealthy white men are freed from such labor, able to occupy jobs that principally engage the mind rather than the body. This distribution of labor has been maintained and codified as “natural” since chattel slavery, leaning on racist biological determinist reasoning that female bodies of color are suited for such labor, and thus
need not be fairly compensated (Crawford 2018, 37-38). This distinction and differential valuation of the productive and the reproductive is recapitulated within the body: the soma is the realm of the productive while the germline is the realm of the reproductive. Patterns of valuation in the physical body are flipped. Bodily reproductive capacity is viewed as precious and fleeting, thus rendered valuable above safety and comfort within the soma. Individuals hoping to induce oocyte superovulation for harvesting and use in IVF inject their bodies with high doses of hormones that can cause a wide range of mental and physical side effects all in the name of maximizing the utility of their germlines. In the case of those taking such hormones to donate oocytes for monetary compensation, hyper-valuation of the germline over the soma is even more explicit (Waldby and Cooper 2008). Moreover, trans men will sometimes delay starting testosterone treatment to inject estrogen and gonadotropin-releasing hormones instead to harvest and freeze oocytes for fertility preservation; this process often worsens somatic gender dysphoria in the name of preserving germline reproductive potential. By queering the somatic/germline distinction, IVG technology challenges differential valuation of productive and reproductive labor as well as somatic and germline health.

IVG ruptures the soma/germline boundary physically as well as ideologically; it contests the 170-year history of locating reproductive potential entirely within the gonads (Borell 1976, 310). Together, iPSC generation and IVG transform each and every cell into multiplicity and reproductive potential (skin fibroblasts are typically used simply as a matter of easy access, but iPSCs for IVG could be theoretically produced from any type of somatic cell). Crucially, in the context of IVG, working to separate a gamete from its organismal milieu – as I did so often during oocyte harvests on a daily basis in the Smith Lab – becomes an unintelligible practice. As I and my colleagues denied mouse oocytes the physical contacts that made them legible as part of an organism, we stripped them of their broader biocultural meaning in order to pornotrope them within our own
sex/gendered and racialized knowledges of reproductive science. In theorizing gametes as separable and distinct from the soma around them, we used them to produce simplified facts that failed to take into account the full complexity of their original bodily context (Chapter 2). Furthermore, we used harvested oocytes as deindividuated markers of a mouse’s proximity to temporal reproductive norms, and thus a metric to characterize the animal’s “reproductive health” and subsequent economic utility as a breeding organism (Chapter 1). In each of these interpretations from the laboratory, researchers used isolated oocytes to stand in for organisms as whole entities, which enabled simplifying, reductionist views of their biology, their value, and their structural positioning. Moreover, it seemed that researchers recognized the oocyte as the mouse’s only source of potential multiplicity for its capacity to give rise to progeny. This let the oocyte exemplify the organism’s features. Within the paradigm of IVG, somatic tissue can no longer be dismissed or distinguished completely from reproductive tissue; an organism’s reproductive potential must be considered in a manner that takes into account the full complexity of its materiality (Franklin 2006). IVG brings the body closer to a “body without organs,” a plateau that does not allow itself “to be interrupted by any external termination.” Much of biomedical science has sought to impose “forms, functions, bonds, dominant and hierarchized organizations, organized transcendences” (Deleuze and Guattari 1987, 158-159). IVG contests the stratified body, insisting instead upon a body filled with multipotentiality that can never be fully determined by dividing up its insides.

Using somatic tissue to generate pluripotent stem cells and produce fertile gametes intervenes in the normative temporality of the aging body. Whereas previously the human soma could only decay with time, de-differentiation reverses the clock, rejuvenating the genome and removing genetic and epigenetic changes accrued over time, leaving it poised to give rise to new life. This enables the feminist reproductive liberation my colleagues in the Smith Lab envisioned: a world in which people of any sex could choose to have biological children at any point in their lives,
leaving them free to explore career opportunities without considering slowly diminishing reproductive capacity. Notably, though far more has been made of age-related declines in oocyte quality, hormone production, testicular health, and spermatogenic capacity also change throughout aging; genetic and epigenetic changes in spermatozoa confer a high prevalence of genetic mutations, childhood cancers, and neuropsychiatric disorders in offspring (Gunes et al. 2016), so IVG would provide a freedom from temporal limitations in those whose bodies produce sperm by default as well. Furthermore, IVG would lessen the reproductive ramifications of enduring a “slow death” owing to subject positioning as non-normative. Black and Brown people in the United States face reduced fertility as compared to white populations due to elevated exposures to a wide variety of environmental contaminants (Chiang, Mahalingam, and Flaws 2017); IVG in these individuals could harness somatic cells to help compensate for detrimental effects on the germline. Trans individuals choosing to undergo hormonal or surgical transition would have comparable reproductive opportunities before and after undergoing these bodily changes, reducing the influence of “queer time” on the life course overall.

IVG enables new configurations for genetic parenthood that contest norms of generational temporality and genetic relatedness. Certainly, it would allow same-sex couples to produce offspring with 50% genetic relatedness to each partner. Far more provocatively, however, it would also allow the possibility of “solo reproduction,” in which a single individual would produce both sperm and egg to yield offspring. These sperm and egg could both be derived from IVG or could consist of one gonadal gamete and one IVG-derived gamete. Such a reproductive scheme is far from unprecedented in the natural world: numerous plants, nematodes, scorpions, bees, fish, amphibians, reptiles, and occasionally birds will generate offspring by parthenogenesis. Parthenogenesis can proceed by apomixis, in which a diploid oocyte develops directly into an embryo that is a perfect clone of its parent, or by automixis, in which two haploid oocytes, each of which has already
undergone meiosis, fuse to generate an embryo that is genetically distinct from its parent due to genetic recombination during meiosis. Human solo reproduction facilitated by IVG would constitute a form of automixis, as both sperm and egg produced from the single parent would undergo meiosis to reshuffle the parent’s two copies of the genome before combining the gametes. The resultant embryo would not be a clone of its parent but would rather share on average 50% of its DNA – this is the same genetic relatedness between parents and children reproduced in couples (Notini, Gyngell, and Savulescu 2019). Solo-reproduction empowered by IVG technology calls the human body’s boundaries into question – is a body truly individual, or multiple? Can a single body span generations?

Multiplex parenting also arises from IVG to queer human generational temporality. The concept of more than two individuals giving rise to a single child is decidedly not new: beliefs in partible paternity are widespread among indigenous societies in lowland South America. Partible paternity is the concept that multiple men can contribute their semen by inseminating the same woman to form a fetus. The resultant infant will have multiple co-fathers, all of which share claims to genetic relatedness. This arrangement solicits paternal investment and social support from multiple men while minimizing the risk of infanticide (Walker, Flinn, and Hill 2010). *In vitro* gametogenesis enables biological partible parenthood. If more than two individuals hope to reproduce together, regardless of their sexes, they could each generate gametes through IVG which would then be fertilized to form biparental first-generation embryos. Gametes could then be generated from each of these first-generation embryos, recombining the parental genomes used to form the first-generation embryos and yielding recombined second-generation gametes. These gametes could be combined to form a second-generation embryo with 25% genetic relatedness to each of its four parents – or rather, grandparents? 8 individuals could similarly each have 12.5% relatedness to their shared child, which is simultaneously their great-grandchild. This scheme
demonstrates that IVG has potential to perturb normative expectations of children’s genetic relatedness to their parents, expanding the possibilities for human sociality (Palacios-González, Harris, and Testa 2014). Solo reproduction and multiplex parenting each perturb Firestone’s biological family, queering the roles that individuals can occupy as they participate in child-rearing. In a future that embraces IVG as a standard assisted reproductive technology, non-normative kinship structures, including queer “chosen” families, might thus be more accepted.

There is still more to learn about the queering capacity of IVG by moving the focus from bodies and families of the future to reproductive biology laboratories of the present. In 2018, Chika Yamashiro and others in the Saitou Lab at the Center of iPS Cell Research and Application at Kyoto University in Japan generated the most mature human oogonia reported to date – an oogonium is a diploid cell that differentiates from a PGC (primordial germ cell) and ultimately establishes the ovarian primordial follicle during ovarian development. Human PGCLCs (primordial germ cell-like cells) are generated routinely in similar stem cell laboratories across the globe but pushing them beyond this point has been a great challenge. Yamashiro, Saitou, and collaborators were ultimately able to surpass this stumbling block by harnessing inter-species assemblages of human iPSC derived PGCLCs with mouse embryonic ovarian somatic cells, which they termed xenogeneic reconstituted ovaries (xrOvaries). The oogonia they generated over the course of four months of development within these xrOvaries underwent successful epigenetic reprogramming, erased their parental copy-specific genomic imprints, and acquired a physiological state immediately prior to meiotic recombination – the initiation of successful oogenesis. These xrOvaries are a characteristic expression of “transubstantiation that other animals make possible.” Just as the foundations of mammalian reproductive biology – and all subsequent advances in the reproductive sciences – have depended upon inter-species comparative physiology (Chapter 1; Franklin 2007), IVG research has been built upon a long legacy of mouse work. But Yamashiro’s study reveals the importance of a
stunning new relationship across species boundaries: transforming the human soma into a mature germline may require direct contact and enmeshment among human and animal cells and tissues. Harnessing the multipotentiality of human tissues, at least for now, seems to require excavating the boundaries of human and animal to generate a porous, “boundaryless being” in which metamorphosis is possible (Chen 2012, 152). It is well known that developing mammalian germ cells depend on the trafficking of small RNAs from the support cells around them to aid in protecting the germline and regulating gene expression (Roovers et al. 2015). Yamashiro and co-authors did not comment on the presence or absence of such small RNAs within their xrOvary-generated oogonia, but it is clear that their success in developing these oogonia have hinged upon genetic and biochemical manipulation by cells of a different species altogether. The trans-sex/gender and trans-generational resonances of IVG – at least as presently constituted – rely on an intimate trans-species entanglement. For Hayward, transformed subjectivity is facilitated by a cut that tears the body through itself, reacquainting cells and tissues that otherwise might not have met to stimulate regeneration and recovery (Hayward 2008). In the laboratory, human and animal bodies are co-constitutive – they are “invoked” through their encounters with otherness (Hayward 2010). xrOvaries are made from cells cut out of organisms from different species and forced in close contact with one another. They constitute species as they blur its boundary, generating a germline heralded as distinctly human from an organ-without-species, a xenogeneic organ-without-body.

Ultimately, in vitro gametogenesis cannot yet fulfill Shulamith Firestone’s dream of liberating human reproduction from its dependence on uterine gestation. But IVG begins to abolish sex-class – a social division created by presumed and enforced roles in childbreeding – by weakening the ties between individual sexed bodies and their possible contributions to reproduction.
(Re)Enforcing Racialization?

Earlier in this chapter, I asserted that IVG destabilizes the commodification of reproductive tissues by queering the boundary between the somatic and the germline. IVG may indeed eliminate the need for oocyte donation, and with it paid oocyte donation, except perhaps for those individuals who privilege the “natural” aspect of gonadal-derived donor oocytes over genetic relatedness to their offspring (Carter-Walshaw 2019). However, IVG also exacerbates the global trade in human reproductive and embryonic tissues for regenerative medicine applications. Waldby and Cooper argue that female reproductive biology has become a “generative site” – a machine – for producing oocytes and placental tissue used to generate embryonic and trophoblast stem cell lines as well as fertility treatments (Waldby and Cooper 2008). Once produced and harvested, donated oocytes enter a global economy contoured by racialized and classed power structures, in which eggs from white and light-skinned donors accrue greater value from darker-skinned donors and donors of color (Chapter 1; Waldby 2019).

Because IVG renders all donated human tissue as potentially reproductive – and thus potentially useful for generating stem cell lines for regenerative medicine research applications – the reproductive biology machine is extended to all sex/gendered bodies. Every human becomes a site for excavating soma that can be transfigured into stem cells and from there, into germline. Though IVG may displace the labor burden of donated reproductive tissue from bodies sexed female onto all human bodies – since it enables all human bodies to give rise to oocytes – it does not intervene in the racialized differential economic valuation of human tissues. These tissues remain inextricably tied to the racialized subjectivities of their donors despite bearing no physiognomic evidence of their origins. When considering whether to adopt another couple’s embryo rather than generate their own, prospective IVF patients may be deterred because they consider oocytes and embryos as belonging to their “drug addict,” “criminal,” “Indian,” or “Black” genetic parents (Roberts 2007,
Human somatic tissues that give rise to gametes or embryos are unlikely to fundamentally disrupt hegemonic patterns of racialized subjectivity transmitted through genetic relatedness – the very fodder for eugenic racism.

IVG facilitates novel forms of genetic kinship and normative generational temporality such as same-sex shared parenthood, single parenthood, and multiplex parenting. Establishing family structures other than the patriarchal, patronymic cisgender heterosexual Western nuclear family may help destigmatize alternate notions of family, including adoption, collective parenting, and chosen families. Black family structures have also been systemically excluded from kinship norms. Insofar as sex/gendered reproductive scripts in a patrifocal familial order are calibrated to whiteness, the “Black family” – either as identified under enslavement amid or in its wake under emancipation – is precluded from replicating the white referent (Spillers 1987, 74). Similarly, Black gendered sexuality and sociality as expressed in relationships are always “done wrong” (Ziyad 2017). Abolishing sex-class eliminates one axis upon which to distinguish racialized subjectivities as anti-Human (Wynter 2006). IVG may thus contest racialization within the sites of reproduction and kinship by proliferating alternatives that destabilize hegemonic norms.

Importantly, however, IVG does little to decentralize genetic heredity as a fundamental aspect of reproduction, family-building, and human lineages. IVG as an assisted reproductive technology is only revolutionary for its capacity to enable biological relatedness to offspring for populations that have previously been denied such access: same-sex parents, asexual individuals, transgender individuals during and after medical or surgical transition, individuals hoping to reproduce solo, and groups of more than two people hoping to share parenthood amongst themselves. In privileging blood relationships, IVG sustains the logics of pure breeding in human and animal populations that have previously facilitated the economization of specific animal strains for meat production and biomedical research, reproductive manipulation in humans including...
forced and incentivized sterilization and birth control administration and selective application of assisted reproductive technologies, and of course, genocide (Chapter 1). Research in *in vitro* gametogenesis has further emphasized genetic background as an important feature of reproductive function; scientists have recently distinguished between mouse strains in assessing which are better suited to *in vitro* gametogenesis from frozen testicular tissue (Portela *et al.* 2019). Alongside preimplantation genetic diagnosis and embryo selection, IVG may provide the technological capacity to incubate eugenics and act upon eugenic thinking like never before. Earlier, I outlined how IVG could enable multiplex parenting by combining the gametes of four or more individuals into intermediate embryos and then deriving recombined gametes from those embryos. Proceeding through multiple generations in the lab and requiring only embryonic stem cells to generate gametes would shorten generation times from months and years to days and weeks. This substantially accelerates and facilitates selective breeding. Rapid genome sequencing of each new embryo generation could allow scientists to selectively combine desired genotypes iteratively until the required genetic background has been achieved (Sparrow 2014). This kind of protocol could help produce therapeutic stem cell lines with particular characteristics. Alternatively, it could create a world in which individuals with desired genotypes could be bred rapidly in reproductive biology laboratories to fit within scientists’ conceptions of an optimal genetic makeup and its associated phenotypes. Especially when combined with CRISPR-Cas9 genome editing technology, this would enable a fast track for generating “superior” organisms.

**On Fantasies and Futures**

Returning to the Smith Lab, it is valuable to consider how my colleagues in the laboratory might have interpreted my interest in IVG as the next frontier for reproductive medicine, had I broached the subject. As I outlined in the introduction, the majority of my colleagues couched the
importance of their work either in its technical ingenuity or its potential for bringing forth a feminist revolution in which working women could delay reproduction until family-building fit within the constraints of their careers. As biologists, I can imagine that those colleagues interested in feminist revolution would recognize IVG both as a mechanism for disrupting reproductive chrono-normativity and as a fascinating subject of scientific study. The others, those more excited by the microscopy than by the oocytes themselves, might be more inclined to do the same with IVG, valuing its complexity as a stem cell technology without substantial investment in its reproductive implications.

I posit that my queer identity and investment in the wellbeing of queer people has made me particularly excited about IVG’s potential for enabling my own fantasy of greater reproductive opportunity for queer folks. I acknowledge that those with different political priorities may be less enticed by its revolutionary potential in abolishing sex-class. I hope that the arguments I have presented in this chapter and throughout this thesis may compel greater consideration of this novel reproductive paradigm and its entanglements with racialization and sex/gendering of human gametes.

It is not a coincidence that many of the future clinical applications of IVG I articulated earlier in this chapter recapitulate existing ideas about heredity and reproduction currently held by human societies. Reproductive futures – like technoscientifically generated gametes – will always be seen “through the lens of our own, pre-fabricated, culturally inherited, ubiquitous, constitutive, real and inescapable frames of reference” (Franklin 2006). IVG and other assisted reproductive technologies that are not yet emergent will come into existence through the filter of scientists’ attachments to sexing, gendering, and racializing the bodies, cells, and tissues of their human and animal research subjects. More equitable futures require an openness to novel biocultural configurations of reproductive tissues in relation to human subjectivity. Considering the full
complexity, multiplicity, and interconnectedness of tissues, bodies, and species promotes critical examination of existing power structures – among researchers and research subjects alike – at the levels of laboratory, body, and cell.
Bibliography


