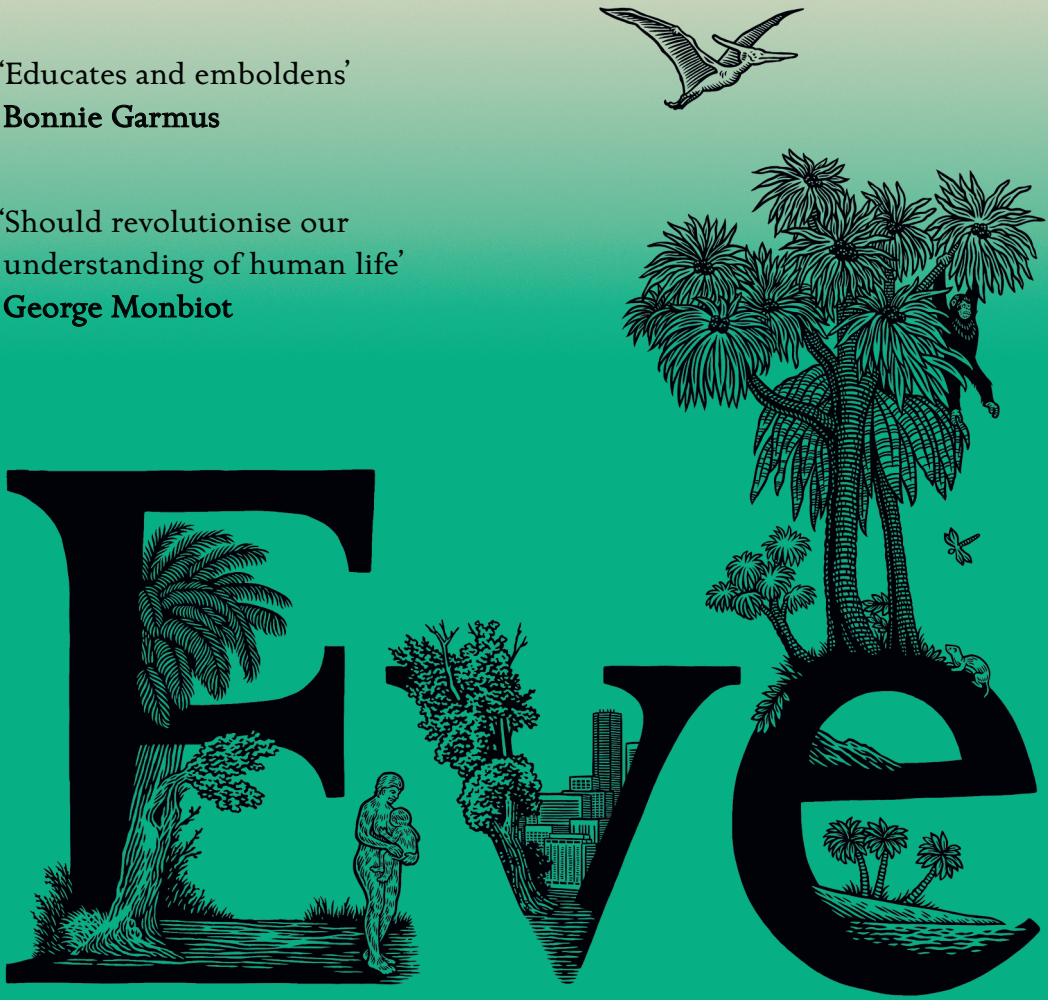
How The Female Body Drove 200 Million Years Of Human Evolution

Cat Bohannon

'Funny and very important'
Chris van Tulleken

'Educates and emboldens'
Bonnie Garmus

'Should revolutionise our understanding of human life'
George Monbiot



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For my children, Leela and Pravin—
nothing has changed my understanding of time
like the small, beautiful breaths you take, every day.

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INTRODUCTION

We did this. Conceived
of each other, conceived each other in a darkness
which I remember as drenched in light.
I want to call this, life.

—ADRIENNE RICH,
"ORIGINS AND HISTORY OF CONSCIOUSNESS"

Elizabeth Shaw has a problem. The director Ridley Scott has impregnated her with a large, vicious alien squid. Aboard the spaceship *Prometheus*, she has to find a way to abort her uninvited guest without bleeding to death. Shambling to a futuristic surgery pod, she asks the computer for a C-section. "Error," it says, "this medpod is calibrated for male patients only."

"Shit," said a woman behind me, "who does that?"

What follows is a gruesome scene involving lasers, staples, and writhing tentacles. As I sat in a darkened theater in New York in 2012 watching this prequel to *Alien*, I couldn't help but think, *Yes, who does that? Who sends a multitrillion-dollar expedition into space and forgets to make sure the equipment works on women?*

Actually, modern medicine often does precisely that. One-size-fits-all doses of antidepressants are given to men and women, despite evidence that they may affect the sexes differently. Prescriptions for pain medications, too, are considered sex neutral, despite consistent proof that some may be less effective for women. Women are more likely to die of heart attacks, even though they're *less* likely to have them—symptoms differ between

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the sexes, so women and their doctors alike fail to catch them in time. Anesthetics in surgery, treatments for Alzheimer's, even public education curricula suffer from the ill-conceived notion that women's bodies are just bodies in general—soft and fleshy, and missing a couple of significant nether bits, but otherwise, just the same as men's.

And of course, nearly *all* of the studies that produced these findings include only cisgender subjects—in the world of scientific research, there's been very little attention to what happens in the bodies of people assigned one or another sex at birth who then go on to identify differently. In part, that's because there's a massive difference between biological *sex*—something wound deep into the warp and weft of our physical development, from in-cell organelles all the way up to whole-body features, and built over billions of years of evolutionary history—and humanity's *gender identity*, which is a fluid thing and brain based and at most a few hundred thousand years old.*

But it's not just that. The fact of the matter is that until very recently the study of the biologically female body has lagged far behind the study of the male body. It's not simply that physicians and scientists don't bother to seek out sex-specific data; it's that until all too recently *the data didn't exist.* From 1996 to 2006, more than 79 percent of the animal studies published in the scientific journal *Pain* included *only* male subjects. Before the 1990s, the stats were more disproportionate. And this is hardly unusual—dozens of prominent scientific journals report the same. The reason for this blind spot concerning female bodies, whether we're talking about basic biology or the nuances of medicine, isn't just

* I know some people still struggle with this idea, but most of the scientific community agrees that biological sex is fundamentally separate from human gender identity. The belief that the sex-typical features of a person's body inevitably assign them a gender identity and behavior to match is sometimes called "biologism" or, more broadly, "gender essentialism" (Witt, 1995). The thing about gender essentialism is that it is a natural extension of sexism. Societies that form deep cultural beliefs about what one or another gender "should be" also tend to believe that a person is one of two genders from birth depending on how their body looks. Those societies then strongly reinforce those beliefs through various rules for each gender, ranging from the sort of fine, irritating cognitive grit of social exclusion to incredibly violent punishment of "rule breakers" and everything in between.

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sexism. It's an intellectual problem that *became* a societal problem: for a long time, we've been thinking about what sexed bodies are, and how we should go about studying them, in entirely the wrong way.

In the biological sciences, there's still such a thing as the "male norm."* The male body, from mouse to human, is what gets studied in the lab. Unless we're specifically researching ovaries, uteri, estrogens, or breasts, the girls aren't there. Think about the last time you heard about a scientific study—some article about a new window into obesity, or pain tolerance, or memory, or aging. More than likely that study didn't include any female subjects. That's as true for mice as it is for dogs, pigs, monkeys, and, all too often, humans. By the time a clinical trial for a new medication starts testing on human subjects, it might not have been tested on female animals at all. So, when we think about Elizabeth Shaw screaming her sci-fi head off at the misogynistic medpod, we shouldn't just feel terror and pity and disbelief. We should feel recognition.

Why is this still happening? Aren't the sciences supposed to be objective? Gender neutral? Bound by the empirical method?

When I first found out about the male norm, I was flabbergasted—not because I'm a woman, but because at the time I was a PhD candidate at Columbia University studying the evolution of narrative and cognition—brains and stories, to put it simply, and their 300,000-year history. I'd taught and conducted research at a number of the top-tier institutes of learning and science in the modern world. As such, I thought I had a pretty good overview of the state of women in the academy. While I'd seen some sketchy stuff, I'd personally never experienced sexism in the lab. The idea that much of biological sciences still rested on the "male norm" was the furthest thing from my mind. Though I am a feminist, mine was more a feminism in practice: simply *being* a woman doing quantitative research was, to me, the revolutionary act. And honestly, the biologists and neuroscientists and psychologists and biophysicists *I* knew, from the people I collaborated with to the people I drank with, were some of the most cosmopolitan,

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* In the scientific literature, this is also called "male bias."

liberal, clearheaded, intelligent, and frankly *good* people I'd ever met. If I'd been one to gamble, I'd never have thought of them as the sort who'd perpetuate some systemic injustice, much less one that undermines their science.

But it's not entirely their fault. Many researchers default to male subjects for practical reasons: it's difficult to control for the effects of female fertility cycles, particularly in mammals. A complex soup of hormones floods their bodies at regular intervals, whereas males' sex hormones seem more stable. A good scientific experiment aims to be *simple*, designed with as few confounding factors as possible. As a postdoc in a Nobel laureate's lab once told me, using males "just makes it easier to do clean science." The variables, in other words, are easier to control, thereby making the data more interpretable with less work, and the results more meaningful. This is especially true for the complex systems involved in behavioral research, but can even be a problem with basic things like metabolism. Taking the time to control for the female reproductive cycle is considered difficult and expensive; the ovary itself is thought of as a "confounding factor." So, unless a scientist is *specifically* asking a question about females, the female sex is left out of the equation. The experiments run faster, the papers come out sooner, and the researcher is more likely to get grant funding and tenure.

But making such decisions to "simplify" is also prompted by (and perpetuates) a much older understanding of what sexed bodies are. It's not that topflight scientists still think female bodies were made when God pulled a rib from Adam's side, but the assumption that being sexed is simply a matter of sex organs—that somehow being female is just a minor tweak on a Platonic form—is a bit like that old Bible story. And that story is a lie. As we've increasingly learned, female bodies aren't just male bodies with "extra stuff" (fat, breasts, uteri). Nor are testicles and ovaries hot swappable. Being sexed permeates every major feature of our mammalian bodies and the lives we live inside them, for mouse and human alike. When scientists study only the male norm, we're getting less than half of a complicated picture; all too often, we don't know what we're missing by ignoring sex differences, because we're not asking the question.

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After being struck by the stubborn reality of the male norm, I did what researchers like to do: I dug into the databases to see how big a problem it was. And, well, it's huge. It's so huge that many papers don't even mention that they used only male subjects. I often had to email the authors directly and ask.

Okay, maybe it's just mice, I thought. Maybe this is only a problem with animal studies.

Sadly, that's not the case. Thanks to regulations established in the 1970s, clinical trials in the United States, for one, are actually "strongly advised" not to use female subjects who "could be of childbearing age." The use of pregnant subjects is all but verboten. While on the face of it, that may seem perfectly sensible—no one wants to mess with our kids—it also means we've been continuing to steer the ship in a fog. The National Institutes of Health managed to update some of these regulations in 1994, but loopholes are regularly exploited: as of 2000, one in five NIH clinical drug trials still wasn't using any female subjects, and of the studies that did, nearly two-thirds didn't bother analyzing their data for sex differences. Even if everyone actually followed the new rules, given that it usually takes more than ten years for drugs to move from clinical trial to market, 2004 was the first year any new drug approved for sale would have been tested on significant numbers of women. Drugs that were released before the new regulations took effect are in no way obliged to go back and redo their clinical trials.*

And so, the majority of subjects in clinical trials continue to be men, just as the vast majority of animal studies use male subjects. Meanwhile, women are *more* likely to be prescribed pain medica-

* Similar problems appear in legal guidelines in much of the industrialized world including Canada, the U.K., and France. The good intention to *protect* pregnant women and their potential children dropped much of the female sex out of medical research for a very long time. Recent legislation in a number of countries has boosted the numbers—for instance, now NIH-funded studies in the United States have to justify *why* they're not including women in a clinical trial if they fail to—but there remain enough loopholes in the system to drive all the elephants in a three-ring circus through (Geller et al., 2018; Rechlin et al., 2021). Some journals have taken up the charge—*Endocrinology*, for instance, now demands the methods sections of papers be explicit about animals' sex (Blaustein, 2012). But most peer-reviewed scientific journals haven't made such rules.

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tions and psychotropic drugs than men—drugs that haven't been tested on nearly enough female bodies. Since dosage is usually based on body weight and age, if there aren't specific recommendations for women coming from the research, doctors have to rely on anecdotal knowledge* to figure out whether a prescription needs to be "jimmied" for a female patient.

This is particularly problematic for painkillers. While recent research has demonstrated that women require higher doses of painkillers in order to feel the same level of pain relief as men, that knowledge isn't currently built into dosage guidelines. And why would it be? Official guidelines are generally based on the results of a drug's clinical trials. For many painkillers on the market today—for example, OxyContin, released in 1996—clinical trials didn't rigorously test for sex differences, because they weren't required to do so. In many cases, they were legally encouraged *not* to do so, because the trials occurred before the NIH rules changed. OxyContin has since gone on to become one of the most abused painkillers in the world, one commonly prescribed to women suffering from endometriosis and uterine-related pain. Pregnant women addicted to such drugs are warned not to go off them too quickly because the stress of withdrawal might abort the fetus. (These women are typically put on methadone.) Others begin their addiction during pregnancy, sometimes after well-meaning doctors prescribe painkillers to relieve their pain, unaware that the patients are pregnant (or about to be). One study released in 2012 shows that the number of infants born addicted to opiates had tripled in only ten years, in part due to mothers

* Sometimes regulating agencies catch up, but it takes a while. For example, in 2013 the U.S. Food and Drug Administration finally issued guidance instructing doctors to prescribe lower (essentially, half) doses of zolpidem (for example, Ambien) because women seem to clear the drug from their bloodstream more slowly than men (U.S. FDA, 2013). At that point, zolpidem had been approved for medical use for twenty-one years. The original approval letter indicated that dosage should be "individualized," but made no comment about sex differences in dosage, stating "the recommended dose for adults is 10 mg immediately before bedtime" (U.S. FDA, 1992). They did offer that "elderly, debilitated patients, and patients with hepatic insufficiency" should receive "an initial 5 mg dose" (ibid.). Perhaps women should be considered hepatically insufficient, then?

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becoming addicted to drugs like OxyContin. That number is still on the rise.

According to a recent report from the American Academy of Pediatrics, many mothers didn't realize these drugs could harm their infants. They simply felt pain, asked their doctors for help, and the doctors gave them a prescription. But unlike the doctors' male patients, these women probably took more of the drug, and more often, because they weren't feeling the relief they'd expected, or the relief they felt wore off too soon: *That worked for a little while*, *crap*, *better take more*, *ugh*, *didn't work as well this time*, *better take more* . . . Most clinical studies show that across multiple drug types, women metabolize drugs more quickly than men.* This finding is usually shrugged off when it comes time for medical guidance, though. And unfortunately, addiction to pain medication becomes more likely the greater and more consistent one's dosage. In other words, women who take OxyContin are more likely to do precisely the sort of thing that will make their bodies addicted to it: front-loading pills to the point that their bodies "norm" a certain level of drug in their system. If drugs like OxyContin had been properly tested on women during clinical trials, doctors would have better guidelines for dealing with these patients' pain, and fewer newborns would begin their lives as drug addicts.

It's important to remember that "drugs" aren't just the pills we stash in our medicine cabinets. Ask yourself this: Is it really acceptable that we only bothered to test sex differences for *general anesthesia* in 1999? Turns out women wake up faster than men, regardless of their age, weight, or the dosage they've been given.

* While a lot of attention is given to the fact that women's bodies tend to be smaller, the reason we metabolize drugs differently may actually have as much to do with our livers. One recent study comparing biopsies of male and female liver tissue showed thirteen hundred genes whose mRNA expression was significantly influenced by sex; of these, 75 percent showed higher expression in females (Renaud et al., 2011). It's not, in other words, just a matter of how much drug distributes through how much body mass, but how the cells in a sex-typical liver go about their day. And "day" matters here, too: livers, like the rest of the body, have a circadian rhythm, and female mammals are especially sensitive to our long-evolved relationship to the sun (Lu et al., 2013). More on daylight and why it matters in the "Perception" chapter.

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(I don't know about you, but I'm not fond of the idea of waking up during surgery.) And that study didn't even set out to discover sex differences. The researchers simply wanted to test a new EEG monitor during anesthesia. The study used patients who were already scheduled for surgery, and four different research hospitals were involved, so, unusually, there were loads of subjects—both women and men. The EEG monitor did prove useful, in the end, but that turned out to be far less interesting than the results in women. It seems only then did the scientists go back and analyze their data for sex differences. In other words, they didn't really ask the question. They realized, after the fact, that they should have asked the question.

Not asking the question is dangerous. I'm all for simple experiment design, but who in their right minds would call that "clean science"?

At the same time that I was learning how dire the problem of the male norm is, I started finding new research into the female body that wasn't getting nearly enough attention. Scientists don't often read outside their specialties, but my field of research required I read regularly in at least three different disciplines (cognitive psychology, evolutionary theories of cognition, and computational linguistics), and I had to stay abreast of the latest literary scholarship, too. But even for me, it was pretty unusual to start digging around in anesthesia journals, in metabolism studies, in paleoanthropology. But I was driven to keep asking the question, What about women? What changes when you ask, "What's different about the female body? What might we be missing?"

For example, why are women fatter than men (to put it bluntly)? As a twenty-first-century American woman, I'd spent altogether too much time thinking about my fat, but I hadn't the faintest clue that my adipose tissue is actually an *organ*, much less that it evolved from the same ancient organ as my liver and most of my immune system.

Let me give you an on-the-ground example. In 2011, *The New York Times* published an article about liposuction. It seems that

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women who have liposuction on their hips and thighs do grow back some of their fat, but they grow it back in different places. Basically, your thighs may stay thinner, but your upper arms will soon be fatter than they were before. It was a cute article. A bit of fluff, really. But unlike the majority of plastic surgeons, I'd guess, I'd just been reading the latest research on the evolution of adipose tissue—specifically female adipose tissue.

As it turns out, women's fat isn't the same as men's. Each fat deposit on our body is a little bit different,* but women's hip, buttock, and upper thigh fat, or "gluteofemoral" fat, is chockfull of unusual lipids: long-chain polyunsaturated fatty acids, or LC-PUFAs. (Think omega-3. Think fish oil.) Our livers are bad at making these kinds of fats from scratch, so we need to get most of them from our diet. And bodies that can become pregnant need them so they can make baby brains and retinas.

Most of the time, female gluteofemoral fat resists being metabolized. As many women know, these areas are the first places we gain weight and the last places we lose it.† But in the last trimester of pregnancy—when the fetus ramps up its brain development and its own fat stores—the mother's body starts retrieving and dumping these special lipids by the boatload into the baby's body. This specialized hoovering of the mother's gluteofemoral fat stores continues throughout the first year of breast-feeding—the most *important* time, as it happens, for infant brain and eye development. Some evolutionary biologists now believe that women evolved to have fatty hips precisely because they're specialized to provide the building blocks for human babies' big brains. Since we can't get enough of those LC-PUFAs from our daily diet, women

* For example, the fat deposits around your heart behave differently than the ones under your chin, and their structure is a bit different, too.

† As such, these are also popular sites for women to get liposuction. Tummy tucks rank a close second. The so-called Brazilian butt lift combines the two and makes it worse, typically by sucking fat out of women's stomach deposits and reinjecting that same fat into their buttocks. That's particularly risky because women's buttocks are especially full of blood vessels, which is precisely where you don't want to inject a bunch of lipids, risking a fatty embolism, wherein fat breaks into the bloodstream, migrates to somewhere really vital like the heart or lungs or brain, and causes a blockage.

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start storing them from childhood forward. Other primates don't seem to have this pattern.

Meanwhile, we found out just a few years ago—again, someone *finally* asked the question—that a human girl's hip fat may be one of the best predictors for when she'll get her first period. Not her skeletal growth, not her height, not even her day-to-day diet, but how much gluteofemoral fat she has. That's how important this fat is for reproduction. Our ovaries won't even kick in until we've stored up enough of this fat to form a decent baseline. When we lose too much weight, our periods stop. We also learned—again, this is recent research—that while taking supplements can up a breast-feeding woman's LC-PUFAs, the vast majority of what the baby's getting is coming from her body's fat stores—particularly her big fat butt.* Most women's bodies begin preparing for pregnancy in childhood, not because it's a woman's destiny to be a mother, but because human pregnancy sucks, and our bodies have evolved ways to help us survive it.

But every year, nearly 190,000 women undergo liposuction in the United States alone. As reported in various medical journals since 2013, there seems to be something about the violent disruption of women's tissue during liposuction that prevents fat from recovering at the surgery site.† I suspect that the new fat that

* This was discovered by giving breast-feeding women a specially marked supplement that could be tracked via isotope. By sampling the mother's breast milk, researchers were able to trace which of the fatty acids in the milk came from the supplements and which must have come from elsewhere. Other studies have established that variations in pregnant women's diets can modify some, but not all, of the LC-PUFAs in the mother's bloodstream and the newborn baby's cord blood, which is often used as a measure for what the mother is transmitting to the child via the placenta in late pregnancy, and it also seems to matter what type is given (Brenna et al., 2009).

† Maybe it's the stabbing: in the most common sort of liposuction, the target area is typically flooded with a solution that helps loosen the adipose tissue, then repeatedly punctured with a hollow needle called a cannula that sucks out a mix of the fluid and local cells and supportive tissue. For the record, most people are happy with the result, and in a properly licensed clinic it can be essentially safe. The issue here isn't whether *any* liposuction should occur; it's whether we should be treating subcutaneous adipose tissue as fundamentally nonessential, and its surgical removal as having no effect, particularly in women of reproductive age. More

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accumulates on women's underarms post-liposuction is not the same kind of fat that was sucked from their thighs and buttocks. So I have to ask: With a violently disrupted store of LC-PUFAs, which may or may not be able to do quite what it did before, what happens if that body becomes pregnant?

I should not be the first person to ask this question. At some point during the many decades we've been "cosmetically" sucking out women's body fat as if it were as simple as getting a haircut, someone should have asked this question. Someone should have already run the study. No one has, much as I did try to get something going after I read that *Times* article.

But back then, I was a grad student in a department that didn't have the right sorts of freezers for storing the breast milk I intended to analyze—milk I'd meant to gather from a bunch of women in Manhattan who'd had liposuction years earlier and were now breast-feeding their children.* So I sent some emails to scientists at other labs. Everyone agreed that someone should do the study. Eventually someone will. Meanwhile, women keep undergoing liposuction, and no one has the foggiest clue if it matters which long-evolved depot of fat they destroy. As with huge swaths of modern medical science, female patients and their doctors are basically crossing their fingers.

Will everything be fine? Maybe. The maternal body is surprisingly resilient: battered on all sides, evolved to be so battered, and somehow, improbably, still alive. Human breast milk, as I've since come to learn, is also remarkably adaptive. All mammalian milk is. Making babies the way we do is a messy, dangerous business. It sucks, in fact.† But hey, it's *always sucked*, so the system has some fail-safes.

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deeply, what's at stake is whether the ways we think about what might "affect" the female body take into account the deep history of mammalian evolution—that what we are is made of how we got here.

* There are rather important rules about how one handles human tissue in the sciences. Also, my little freezer in an apartment on the Upper West Side didn't exactly have consistent temperature control. And I had roommates.

† It's possible the best illustration of the verb "to suck" would be a diagram of the female human reproductive system. More on that in the "Womb" chapter.

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. . .

While the majority of scientists still effectively ignore the female body, there's a quiet revolution in the science of womanhood brewing. In the last fifteen years, researchers in all sorts of fields have been discovering fascinating things about what it means to be a woman—to have evolved in the ways we have, with the body features we have—and how that could change the way we understand ourselves and our species as a whole. But the majority of scientists don't know about this revolution. And if scientists don't know about it—because they're not reading outside their field, and their field is still permeated by the male norm—how is anyone else going to piece it together?

You know that feeling when you realize that something needs to be done, and you're not sure you're the right person to do it, but damn it, *somebody should*? That was me in a crowded movie theater watching Ridley Scott exorcise his latest "mommy issue" in the form of a sexist medpod.* The lady in the row behind me felt it. I felt it. And I bet every other woman in that room felt it, too. For my part, it was like a kind of vertigo. I'd had the same feeling when I read the *Times* article about liposuction, the one that made casual fun of women for their newly fat arms. I was pretty sure neither the writer, nor the authors of the research paper the writer was reporting on, nor the women who had undergone the procedure knew that our adipose tissue and our livers and our immune systems all came from the same primordial organ, called the "fat body." That's probably why all three share so many properties: tissue regeneration, hormonal signaling, deep responsiveness to shifts in local environments. The ancient fat body is the reason you don't need to transplant an entire liver into a patient who needs one: a little lobe and you're good to go—the whole thing will regrow in situ. Adipose tissue famously regenerates, too. But unlike the liver, the separate fat depots in our bodies seem to be geared for different jobs, each intricately linked to the digestive, endocrine, and reproductive systems. This is why people who do research on adipose tissue have started call-

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* For the record, I'm a huge fan of his work.

ing it an organ system: that's not a bit of fat under your chin but a small, barely visible part of your *fat organ*. Our subcutaneous fat does different things from the deep fatty deposits around our hearts and other vital organs. The fat on a woman's butt might be more important for her possible offspring than the fat under her arms.

We don't know when that started, exactly—most mammals have special fatty deposits near their ovaries and hindquarters—but we do have a rough guess as to when our ancient ancestors split off from fruit flies, which, by the way, still have the ancient "fat body": 600 million years ago. Thinking about that timescale for too long will give you vertigo, too, but at least it's a more *useful* sort. It gives you a reason as to why it's hard to "get rid" of one's fat: if adipose tissue is a body-wide organ system that has regenerative properties that go back 600 million years, maybe lopping off a piece of it in one spot naturally triggers a self-protective response that effectively "regrows" it elsewhere. And like anything that terribly old, there are bound to be younger, newer features laid on top: specialized regions, for instance, that don't grow back. Functionality that gets lost.

Bodies are basically units of time. What we call an individual "body" is a way of bounding a series of cascading events that follow self-replicating patterns until finally entropy sets in and enough goes wrong that the forces that keep you from flying apart at the seams finally let go. Species, in a way, are also units of time. But what's unusual about the body, when you start to think about it this way, is that your basic digestive system is radically old. Your brain is not. Your bladder is a workhorse, doing essentially the same job it's been doing for hundreds of millions of years—keeping the waste products of your many millions of cells' ongoing metabolism from poisoning you to death. It's not your bladder's fault that the mammalian uterus evolved to squat on top of it like Quasimodo. That only happened about forty million years ago. Actually, if we're talking about the gravity problem, that was only four million years ago. Before then, our ancestors had the good sense not to walk on two legs, smooshing all our long-evolved organs on top of one another in our trunks (not to mention generally screwing up the spine).

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In 2012, when I got home from that movie theater, I realized we needed a kind of user's manual for the female mammal. A no-nonsense, hard-hitting, seriously researched (but readable) account of *what we are*. How female bodies evolved, how they work, what it really means to biologically be a woman. Something that would get the attention of both women in general and scientists. Something that would tear down the male norm and put better science in its place. Something that would rewrite the story of womanhood. Because that's exactly what we're doing in the lab now when we study sex differences. We're building a new story. A better story. A truer story.

This book is that story.* *Eve* traces the evolution of women's bodies, from tits to toes, and how that evolution shapes our lives today. By piecing this evolution together and connecting it to recent discoveries, I hope to provide the latest answers to women's most basic questions about their bodies. As it turns out, those basic questions are producing some truly exciting science: Why do we menstruate? Why do women live longer? Why are we more likely to get Alzheimer's? Why do girls score better at every academic subject than boys until puberty, when suddenly our scores drop through the floor? Is there really such a thing as the "Female Brain"? And why, seriously why, do we have to sweat through our sheets every night when we hit menopause?

To answer those sorts of questions, we have to make one very simple assumption: we *are* these bodies. Whether we are in pain or joyful, abled or disabled, in sickness or in health until death do we disassemble, our bodies and the brains they contain are quite simply what we are. We are this flesh, these bones, this brief concordance of matter. From the way we grow our nails to the way we think, everything we call human is fundamentally shaped by how our bodies evolved. And because, as a species, we are sexed, there are critical things we should be thinking about when we talk about what it means to be *Homo sapiens*. We have to put the

* Or at least the best I was able to do, from one little desk with access to a massive library and a small army of thankfully patient scientists and scholars willing to walk me through all the things I didn't initially understand.

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female body in the picture. If we don't, it's not just feminism that's compromised. Modern medicine, neurobiology, paleoanthropology, even evolutionary biology all take a hit when we ignore the fact that half of us have breasts.

So it's time we talk about breasts. Breasts, and blood, and fat, and vaginas, and wombs—all of it. How they came to be and how we live with them now, no matter how weird or hilarious the truth is. In this book, I aim to trace what we're finally coming to understand about the evolution of women's bodies and how that deep history shapes our lives. And there's no better time for it: in laboratories and clinics across the world, scientists are now coming up with better theories, better evidence, better questions about the evolution of women. The last twenty years has seen a revolution in the science of womanhood. We're finally rewriting the story of what we are and how we came to be, chapter by chapter.

HOW TO THINK ABOUT 200 MILLION YEARS

So how exactly does someone go about writing the story of nearly every woman, everywhere, ever?

As long as you're willing to get a little dizzy, it's fairly straightforward. This is how the evolutionary history of women breaks down: Roughly 3.7 billion years ago, on the thin crust of our lonely little planet wobbling around its yellow star, there were isolated microbes. Between 1 and 2 billion years ago, eukaryotes appeared—single-celled organisms with a nucleus. (Think amoebas.) Then, through a scrambling up of many branching trunks on our evolutionary tree, the subphylum Vertebrata appears. The earliest fossil records of vertebrates—that is, animals with spines—date to 500 million years ago. Vertebrates still represent only about 1 percent of all living species.* Thus, the majority of what you and I call evolution—what we're debating about endlessly in litigation and fitful bursts on op-ed pages and conflict-

* Twenty-two percent of the world's species are egg-laying beetles. Seriously. In the history of life on Earth, beetles do really, really well.

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ing textbooks in far-flung communities, this thing that has caused so much trouble—represents only 13 percent of the time there's been any life on Earth at all.

Once you start thinking about deep time, you quickly realize that human bodies are new because *all* bodies are pretty new. It really wasn't that long ago that we had thumbs on our feet instead of big toes. So to realize that how women's bodies evolved must shape how we experience our lives today isn't a stretch—it's a fact. Each of our bodies' features has its own evolutionary story, and we're still in the thick of it. Evolution works by building cheap upgrades on existing systems. Once one body feature is in place, that newly changed body interacts with its environment, and those interactions influence the rise of other features. Those new features lead to more changes, which often loop back and change the first feature: milk leads to nipples, and the caretaking habits involved in being a nursing mother help enable the development of the placental uterus. The placental uterus then influences our metabolism and the needs of our offspring, so breast milk starts to change. Breast milk changes, and eventually birth canals turn into petri dishes for the bacteria that help newborns digest sugary milk. In essence, the kid is coated on the way out with handy bugs that coevolved with our breast milk.

You see, evolution is a little like P. T. Anderson's film *Magnolia*, or Paul Haggis's *Crash*, or Iñárritu's *Babel*. You can't really follow it unless you're willing to pay attention to more than one major character. It's a complicated narrative, with a lot of whimsy and accident and things that seem to be unimportant at first but turn out to be vital. It's not a bildungsroman. But unlike oversimplified stories of our origins, it's true. Unraveling how each of our features really came to be gives us a better picture of what women are: one half of a very young, complex, and fascinating species.

That's the real problem with origin stories like the one in Genesis: our bodies aren't one thing. There's no *one* mother of us all. Each system in our body is effectively a different age, not only because the cellular turnover rate *differs* between cell type and location (your skin cells are far younger than most of your brain cells, for instance), but also because the things we think of as distinct to our species evolved at different times and in different

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places. We don't have one mother; we have *many*. And to each Eve, her particular Eden: We have the breasts we do because mammals evolved to make milk. We have the wombs we do because we evolved to "hatch" our eggs inside our own bodies. We have the faces we do, and our human sensory perception along with it, because primates evolved to live in trees. Our bipedal legs, our tool use, our fatty brains and chatty mouths and menopausal grandmothers—all of these traits that make us "human" came about at different times in our evolutionary past. In truth, we have *billions* of Edens, but just a handful of places and times that made our bodies the way they are. These particular Edens are often where we speciated: when our bodies evolved in ways that made us too different from others to be able to breed with them anymore. And if you want to understand women's bodies, it's largely these Eves and their Edens you need to think about.

And so each chapter in this book will follow one of our defining features all the way back to its origins—its Eve, or sometimes Eves, and their Edens, from the damp swamps of the late Triassic to the grassy knolls of the Pleistocene. I will also examine current debate around how the evolution of those features shapes women's lives today, considering the current science around each thread of the story.

Though I'll have to move back and forth in time to encompass all this, each trait will appear in the book in roughly the same order it *first* appeared in our evolutionary lineage. As such, each chapter builds on the last, moving forward in time and consequence, just as our bodies built later models of themselves on previous incarnations. Without those furry milk patches of our Eve of milk, we might never have evolved the fatty breast. Without the use of tools necessary for gynecology, we might never have evolved the sorts of societies that could support the *childhoods* that built our massive human brains. Without large, complex social groups that could support the elderly, enabled in part by gynecology, we might never have evolved to have menopause. Each evolutionary accident builds on prior accidents; each new feature depends on the circumstances that make it useful enough to outweigh its cost.

Once I established this as the order of my "manual," the way I went about choosing each feature for my chapters was fairly sim-

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ple: I looked to our taxonomic address, the organizing principle that biologists use to determine what an organism is. Taxonomy outlines our relationship to the rest of life on the planet according to the features we share with others. Women, like all human beings, are *Homo sapiens.* Because we are mammals, we make milk. Because we are placentals, we have a uterus that gives birth to live young. Because we are primates, we have big eyes with color vision and ears that can hear a wide range of sound. Because we are hominins, we are bipedal and now have giant brains. And so on and so forth, climbing the evolutionary tree. As I examined each feature of our history, I then asked myself whether it had a particular story for *women:* Are there ways this trait affects us especially? Is there new research that's challenging our assumptions about this trait, and thereby, about all of humanity?

The most common way evolutionary biologists think about how traits work is by thinking about the last common ancestor of a trait we share with other species. Therefore, I located—or tried to locate—an Eve for each trait. For bipedalism, *Ardipithecus*—we just found her in 2009. For milk, a weird little weasel-beast that lived under the feet of dinosaurs![*] By looking for an Eve, I often discovered surprising new research in paleontology and microbiology that challenged yet more assumptions about women's bodies.

Along with all of this, I invite you to think of yourself: to think about where your body comes from, how the evolution of biological sex shapes it—whether you identify as a man, a woman, or another gender—and how those stories are embedded in humanity's everyday life. In her essay for Annie Leibovitz's book *Women*, Susan Sontag wrote that "any large-scale picturing of women belongs to the ongoing story of how women are presented, and how they are invited to think of themselves." As such, it raises

* Because the deep and dark earth likes to keep her secrets well hidden, not everything has a known or obvious Eve: either we haven't found those fossils yet, the trait doesn't lend itself well to the fossil record, or we simply haven't fully discovered how to interpret the fossils we already have. But in every case, if I don't have a name for a beastie who directly falls in line, I look for an *exemplar* species or genus: a creature whose body and time and place we know a decent amount about, and whose history can teach us something about what our *true* Eves might have been like.

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"the question of women—there is no equivalent 'question of men.' Men, unlike women, are not a work in progress." In scientific terms, Sontag is wrong: there is no stopping point for evolution. All of our species continues to evolve. But in the way she meant it—in the sense that looking at women begs a "question of women" while looking at men begs no question—she's absolutely right.

Why talk about the evolution of women, if it hadn't been neglected? Why focus this camera on the female form, unless it were still, amazingly, uncommon to do so? There is no more fundamental "picturing" of women than asking a reader to think about all women, everywhere, ever. And I am. I really am asking us each to look at women's bodies and think hard about how they shape what it means to be human.

THE EVES

"Morgie"—*Morganucodon*. 205 million years ago. Eve of mammalian milk. Initially found in Wales, but since found as far as China—this was a widely spread, highly successful creature. She was a bit like a cross between a weasel and a mouse. She's not assumed to be our direct ancestor, but an "exemplar" genus; our true lactating Eve was probably a lot like her.

"Donna"—*Protungulatum donnae*. 67–63 million years ago. Eve of placental mammals (not marsupials, not monotremes—but creatures with the sort of womb that humans have). Seems to appear right around the asteroid apocalypse that wiped out all the non-avian dinosaurs, but her line may stretch back into the Cretaceous. This Eve is highly specific and named, determined by extensive comparative fossil and genetic analysis. She's basically a weasel-squirrel.

"Purgi"—*Purgatorius*. 66–63 million years ago. An ancestor of primates and, by extension, our treetop-born primate sensory

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array. She is the Eve of primate perception: the reason women sense the world the way we do. Her fossils were found in the Fort Union Formation of Hell Creek, deep in the badlands of northeast Montana. So close to Donna she was basically contemporary. A monkey-weasel-squirrel.

"Ardi"—*Ardipithecus ramidus.* 4.4 million years ago. The first known bipedal hominin. There is an excellent fossil, only recently recognized. She is a big jump, both in time and in evolution, from the squirrely Eves that came before her.

"Habilis"—*Homo habilis.* 2.8–1.5 million years ago. She is the Eve of simple tools and associated intelligent sociality. A prolific tool user, Habilis coexisted in Africa with *Homo erectus* for half a million years. Her fossils were found at Olduvai Gorge in Tanzania.

"Erectus"—*Homo erectus.* 1.89 million–110,000 years ago. Erectus was a better tool user, was highly migratory, and had a big braincase. She is the Eve of more complex tools and more complex intelligent sociality. We'll look to her for one of the origins of our more humanlike brain (and perhaps at least some of the childhood that builds it).

"Sapiens"—*Homo sapiens.* Roughly 300,000 years ago to the present.* Eve of human language, human menopause, and modern human love and sexism.

* The precise start of our species remains highly contentious. Very few assume that the earliest hominins had true human language, modern-type menopause, or modern-type social rules around sex and gender; however, nor do many assume these traits predate our species. As with all things in the world of paleoanthropology, having more fossils from humanity's deep past would be phenomenally helpful.

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OTHER PLAYERS

"Lucy"—*Australopithecus afarensis.* 3.85–2.95 million years ago. Many australopithecines are associated with tools, and the general assumption is that most if not all were early tool users of one stripe or another. Given that today's chimps are known to use tools, it would be odd to assume that ancient ancestors like Lucy didn't at least do the same, if not even more intelligently. *Australopithecus* are both among the best-known hominins (more than three hundred individual fossils have been found so far) and the longest lived of all the hominin species—in other words, theirs was a body plan and lifestyle that worked well for a very long time. Found in Ethiopia and Tanzania. Lived in trees and on the ground, fully bipedal.

"Africanus"—*Australopithecus africanus.* 3.3–2.1 million years ago. Her fossils were found in southern Africa, and it's unknown if Africanus is a descendant of Lucy's species. She had a bigger braincase than Lucy, and smaller teeth, but otherwise she was still pretty apelike, though bipedal.

"Heidelbergensis"—*Homo heidelbergensis.* 790,000–200,000 years ago, though she may stretch back to 1.3 million years. Probable ancestor of Neanderthals, Denisovans, and *Homo sapiens* (or she at least has a common ancestor with these), according to genetic research, with divergence around 350,000 to 400,000 years ago. The European branch led to Neanderthals. The African branch (*Homo rhodesiensis*) led to *Homo sapiens.* Heidelbergensis carried on, meanwhile, and died off just before *Homo sapiens* was officially on the scene. This was the first species to build simple shelters of wood and rock. She had definite control of fire and hunted with wooden spears—the first known hunter of large game (as opposed to scavenger). She lived in colder places and showed evidence of adapting for those problems. As the name implies, her fossils were first found in Germany, and later in Israel and France as well.

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"Neanderthals"—*Homo neanderthalensis.* 400,000–40,000 years ago. Neanderthals coexisted with *Homo sapiens* as they spread through Europe, and the two interbred.* Anthropologists have found tons of fossils and living environments; this was a successful species. Former assumptions of Neanderthals have now been overturned: they are known to have had a complex culture, including burials, clothing, fire, and tool and jewelry making, and might even have been capable of language. Their braincases were shaped differently but don't seem to be *smaller* than *Homo sapiens*'—in fact, sometimes they were larger (which may correspond to their larger, robust bodies). They seem to have developed more quickly than we did, however; their childhoods were shorter.

"Denisovans"—Presumed to be *Homo denisova* or *Homo sapiens denisova*, though not yet formally described. 500,000–15,000 years ago. This Eve is known only from three teeth, a pinkie bone, and a lower jaw found in a cave in Siberia and through comparative DNA sequencing. Denisovans are known to have lived at least 120,000 years ago, with the longer time stretch inferred by sediment analysis and DNA research. Thought to be a small population, Denisovans lived in Siberia and eastern Asia, including at high altitudes in what is now Tibet, potentially passing down a gene that continues to help populations in these regions succeed at that altitude. DNA research establishes that many modern humans—particularly Melanesians and Indigenous Australians—share up to 5 percent of their DNA with these ancestors, implying that like the Neanderthals, ancient humans probably interbred with them. All this interbreeding, in fact, makes the "species" boundaries between these later hominin groups rather blurry.

* I, for one, have loads of Neanderthal in my genome, as do most people descended from recently European folk.

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CHAPTER 1

MILK

No sooner had the notion of the Flood subsided,
Than a hare paused amid the clover and trembling bellflowers and said its prayer to the rainbow through the spider's web.

. . . . . .

Blood flowed in Bluebeard's house—in the slaughterhouses—in the circuses, where God's seal made the windows blanch. Blood and milk flowed together.

—ARTHUR RIMBAUD, "AFTER THE FLOOD"

Got Milk?

—ADVERTISING CAMPAIGN FOR
THE CALIFORNIA MILK PROCESSOR BOARD, 1993

There in the soft grass, in the wet crush of evening, she was waiting: furred body shirred with drops of rain, no bigger than a human thumb.

We call her Morgie. Little hunter. One of the first Eves.

She waited at the mouth of her burrow because the sky was still pale—streaky threads of photons refracting through clouds, the deepening blue beyond. She waited because her cells told her to, all the little clocks in her clockwork, and her eyes, and her whiskers twitching in the air, and the temperature of the dirt under her footpads. She waited because there were monsters in the world, and they waited for her, too.

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When the night was good and dark, Morgie risked it, skit-

tering along the ground, searching for her prey—insects, some nearly as big as she was. She heard them before she saw them: the high-pitched hum of their wings, the wheezy tapping of their legs. Quick as that, her skinny muzzle snapped. She loved the sweet crunch of its chitinous body, loved the little dribble of fluid down her chin. She licked it off and resumed the hunt. Never safe to stop. Jaws everywhere. Claws and teeth. The thing that looked like a tree could be a leg; the wind in the ferns could be hot breath. So, she ran, and hunted, and ran, and hid, the wet air heavy as a fist. She flitted over the feet of dinosaurs like a grasshopper hopping an elephant's toe. She felt their low bellows not as a sound so much as an earthquake.

This was life every night for *Morganucodon:* she who lived under giants.

When she was tired, she returned to her waiting place, fleeing the gray dawn. She crawled down her tunnel like a lizard, belly dragging over the familiar earth, paws pulling her forward into the close dark of home. The burrow was warm with the soft, radiating heat of her pups, all piled together. Their breath stank of old milk. Scraps of their leathery eggs mildewed gently in the dirt, along with urine and shit and dried spit, the smells mingling in the damp hole she'd dug for her family. A place safe from the monsters that thundered above. Safe enough.

Exhausted, she settled in. Her pups woke, blind and chirping, and swam across one another toward her belly, where beads of milk sweated out of her skin. Each pup jockeyed for the best spot. They slurped her wet fur, faces soon coated in milk. She stretched out on her side, whiskers finding the one closest to her head. Lazily she rolled him over on his back, nuzzling his unrolled ears, his thin eyelids, still closed. She dragged her raspy tongue down his belly to help him defecate, which he couldn't yet do on his own.

The milk and the crap and the egg scraps in that dark little burrow—these are the origins of breasts. Morgie is the real Madonna. Creatures like her nursed their young in a dangerous world, not only to feed them, but also to keep them safe.

To put it in the simplest terms, women have breasts because we make milk. Like all mammals, we nurse our young with a cloy-

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ingly sweet, watery goo that we secrete from specialized glands in our torso. Why human breasts are high on our chests, rather than near our pelvis, why we have only two of them instead of six or eight, and why they're surrounded, to varying degree, by fatty tissue that some people find sexually appealing are all questions we'll get to. But at the heart of things, human beings have breasts because we make milk.

And as far as the latest scientific research can determine, we make milk because we used to lay eggs and, weirdly, because we have a long-standing love affair with millions of bacteria. Both can be traced back to Morgie.

WHICH CAME FIRST, THE CHICKEN OR THE EGG . . .

Jurassic beasts tramped above Morgie's burrow every day. Meat eaters as big as lorries ran around like ostriches on steroids. Some, in fact, looked like ostriches on steroids. Loch Ness–style plesiosaurs lived in the seas. With all the big niches in the ecosystem taken, most of our early Eves evolved underfoot, which is hardly the place you wanted to be 200 million years ago. Even the earth was dangerous: the supercontinent, Pangaea, was starting to break up. Tectonic shifts tore Morgie's world apart. Water rushed in to fill the widening gaps, birthing new oceans with the hiss of lava hitting water.

Still, Morgie was an incredibly successful species. Her fossils have been found everywhere from South Wales to South China. Where there could be a Morgie, it seems, there was. She was adaptable. Resourceful. And she had a lot of kids. The geneticist J. B. S. Haldane* liked to say that God had an inordinate fondness for beetles, for he made so many of them; eating them was a successful strategy for insectivores like Morgie. For God so loved the beetles, and the furry, warm, heart-fluttering Eves who ate them.

* If you've ever heard of a "clone," that was Haldane. He was also the first person to compose a scientific paper in a forward trench—specifically in France during World War I. One of his co-authors, sadly, was killed in battle, so Haldane apologetically submitted for publication early, given the man's inability to collaborate further (Subramanian, 2020).

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But it wasn't just the surfeit of beetles that made Morgie so successful. Unlike the Eves who came before her, Morgie nursed her young.

Once they are born, newborn animals face four essential dangers: desiccation, predation, starvation, and disease. They can die of thirst. Something can eat them. They can starve to death. And if they manage to dodge all of those, they can still die from bacteria or parasites overwhelming their immune systems. Every mother in the animal world has evolved strategies to try to protect her offspring, but Morgie managed to combat all four by dousing her kids in stuff made of her own body.

When we talk about breast milk, we usually describe it as a baby's first food. The last thing you want to do is underfeed a baby, because a newborn needs fuel to build new fat and blood and bone and tissue. As a result, we usually assume newborns cry for milk because they're hungry, but that is and isn't true. The most important thing infants need after they are born is water.

All living creatures, mammal or not, are mostly made of water. While the adult human body is 65 percent water, newborns are 75 percent. Most animals are essentially lumpy donuts filled with ocean. If you wanted to describe life on Earth in the simplest terms, you could say we're energetic bags of highly regulated water.

We use that water to transport molecules between cells, between organs, to splice molecules and build new ones, to fold proteins, to cushion our various lumps, to move nutrients and waste in the right directions. Our very DNA maintains its shape surrounded by carefully ordered molecules of water. An adult human can go without food for up to a month, but without water we die in three to four days. Any biologist will tell you that the story of life is really the story of water. Our earthly cells evolved in shallow oceans, and they never got over it.

So newborn Earth animals need water as soon as possible. Fish drink constantly from the second they hatch. On land, slaking a newborn's thirst is trickier. Some newborn reptiles are small enough that they can drink water droplets and absorb mist

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through their skin. Some seek out puddles and streams. Others, like newborn sea turtles, head straight for large bodies of water. But mammals seek the ocean in their mother's abdomen; human breast milk is almost 90 percent water.

Over time, ancient land mammals like Morgie evolved to slake their hatchlings' thirst with milk. There are a number of advantages to this adaptation. For example, the newborns don't have to move: the water comes to them. Pups of burrowing animals can stay in the safety of a small burrow a lot longer than creatures that need to get to water. Also, milk isn't just water but a balance of water and minerals and other useful stuff. Too much straight water all at once can be dangerous to very young mammals, and even grown human beings. There is such a thing as water poisoning, which causes all sorts of nasty side effects: Brain swelling. Delirium. Eventually, death. Our babies shouldn't even be given water until they're six months old. If they're thirsty, they should just drink more milk or formula.*

There were other advantages in replacing water with mother's milk. Water is an ideal medium for transmitting disease. That's why you're supposed to cover your mouth when you sneeze: tiny droplets of saliva and mucus hurl away from your mouth and nose at more than thirty-five miles an hour, each drop full of viruses and bacteria. That's why people started wearing masks in public in 2020: most airborne diseases actually "fly" from host to host in tiny droplets of fluid that have aerosolized. Either you breathe in a tiny droplet or a droplet lands on something you touch that makes its way to your face, where the moistness of your mouth, nose, and eye surfaces helps it replicate. Larger bodies of water are almost always host to millions upon millions of bacteria, some of which can be dangerous pathogens. Thus, controlling exposure to water and finding ways to ensure that drinking water is clean are two of the better strategies for maintaining the health of any animal.

Think of Morgie's body as the Jurassic world's best water filter. Tiny, fragile newborns are especially susceptible to patho-

* Very ill babies who can't keep milk or formula down are sometimes given a special mix of electrolytes, minerals, and water, like Pedialyte, to keep them hydrated until they're able to digest the good stuff again.

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gens, in part because of their small size and in part because their newly independent immune systems are still developing. Morgie's milk might have contained whatever pathogens she happened to be carrying, but it wouldn't have introduced anything new to her pups. Her immune system could fight the good fight, until her pups were old enough to fight for themselves.

Scientists think milk evolved to solve both the desiccation and the immunological problem in one go. But how it started—how the very first droplets of milk actually formed—that's where the story takes an unexpected turn.

Like all the early mammaliaforms, Morgie laid eggs. And like many reptiles' today, hers were soft and leathery. When you crack a chicken's egg into a pan, you're actually tapping through a structure evolved by dinosaurs: a hard shell that prevents the liquid inside the egg from evaporating.* The eggs of most reptiles and insects, including the haphazard lineage that led to early mammals, were soft. There are a number of advantages to that strategy. For example, hard eggshells are primarily made of calcium. Like anything a body tries to build when making babies, all that calcium has to come from somewhere. Morgie was about the size of a modern field mouse. If she had tried to lay a chicken-style egg, it would have leached the calcium out of her little bones and teeth.† Even now, animals that make hard-shelled eggs are known to seek out calcium-rich diets before reproducing. (Chickens in industrial egg-laying farms often suffer from osteoporosis, their fragile leg bones breaking under the weight of their own bodies.)

But small leathery eggs, like Morgie's, can dry out before the

* Chickens are, after all, scientifically classified as "avian dinosaurs"—the direct descendants of Jurassic monsters. Hard-shelled eggs seem to have evolved three separate times in the dinosaur family tree (Norell et al., 2020).

† Modern human women are likewise advised to eat a calcium-rich diet when pregnant; it takes extra to build all those little bones. Pregnant women's bones and teeth are known to leach their own stores into the bloodstream; this can have serious effects for teenage mothers, whose own bones are still growing. If the diet doesn't provide enough for both mom and baby, she may be likelier to face dental work and osteoporosis down the road.

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pups are ready to hatch. So Morgie didn't just need to keep her clutch warm; she needed to keep it wet.

There are a few different ways to do this. Modern sea turtles, for example, find a nice patch of damp sand, above the tide line, and bury their soft eggs in a shallow pit, coating each one in a thick, clear mucus they secrete during the birthing process. If you're a more attentive sort of mother, you might still use the mucus trick, but you'll also hang around and periodically lick the eggs or secrete some more goo onto them. That's what the duck-billed platypus does. One of the last living mammals that still lays eggs, the platypus first digs a wet den, then lines it with soggy vegetable matter. Crawling into the center of that damp pit, she lays her clutch directly on her body and folds her tail over them. She waits there, curled around her eggs, until they hatch. Platypus eggs also have an extra mucoid layer that persists until birth and is especially dense in antimicrobial material.

Morgie needed to keep her eggs moist, but she also needed to keep them from becoming festering breeding grounds for water-borne bacteria and fungus. Most scientists assume her egg mucus contained a host of antifungal and antibacterial material as the sea turtle and platypus mothers' mucus still does.

When today's leather-egged offspring are ready to hatch, they use a specially evolved tool (usually a sharp "egg tooth" that later falls out) to puncture the shell. Then they also lick up some of the egg-coating goo. Their first meal, in fact, is from the wet side of the eggshell. In all likelihood, this was the first mother's milk: an egg-moistening mucus that Morgie's grandmother secreted out of specialized glands near her pelvis. When her pups hatched, some of them licked up a bit of this extra stuff, which gave these offspring a serious evolutionary boost. By the time Morgie came along, these glands had evolved to secrete a goo containing more water, sugars, and lipids. Eventually they became "mammary patches" with specialized bits of fur over them that helped channel the gunk into the pups' eager mouths. Even today, newborn duck-billed platypuses lick milk from sweaty milk patches on their mother's stomach; she doesn't have nipples.

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. . .

Early mammalian milk was probably a lot like modern women's colostrum: a thick, yellowish, sticky-sweet ichor, super dense in immunological material and protein. For the first few days after a woman gives birth, her milk is incredibly special—a hot shot of immune system for her newborn baby. New mothers can find colostrum alarming, since it looks a bit like pus, but within a few days it converts to the bluish-white stuff we're used to calling breast milk. Most mammals have this pattern: first colostrum, and later a thinner, mature milk that is richer in fat. Each of those fat globules is surrounded by a membrane that contains xanthine oxidoreductase—an enzyme that helps kill a ton of unwanted, dangerous microbes.

But colostrum is especially dense with immunoglobulins: antibodies tagged to respond to pathogens that the mother's body knows to be dangerous. In fact, before we discovered penicillin, cow colostrum was commonly used as an antibiotic.*

Despite its obvious benefits, human women throughout history have mistakenly believed colostrum to be rotten milk, or what they called beestings. Some even avoided giving it to their babies. In the fifteenth century, Bartholomäus Metlinger wrote the first European textbook for pediatrics. Despite the German's own lack of breasts, he didn't hesitate to mansplain women's milk and what to do with it:

> The first 14 days it is better that another woman suckle the child as the milk of the mother of the child is not as healthy, and during this time the mother should have her breast sucked by a young wolf.

I can't imagine where he thought each new mother would find a young wolf. But any recommendation that babies not be given colostrum as a matter of practice was, and is, dead wrong. A mammal's lactation pattern—from thick, yellow, protein-heavy colostrum to thin, white, fat-heavy milk—is specially geared toward a newborn's development. Timing is everything here. The four dangers—desiccation, predation, starvation, and disease—are dif-

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* It's also used to make a particularly sweet Indian cheese.

ferently dangerous according to a timetable. In a burrow, desiccation is the first danger, both for the eggs and for the newly hatched. Starvation comes quite a bit later, since a body can always eat a bit of itself to survive.* Predation is also a later problem, especially if the baby doesn't need to leave its underground bassinet for a while. But disease is a big deal right off the bat. Colostrum doesn't just boost the kid's immune system by injecting antibodies; it's also a reliable laxative, which is also crucial to building a baby's immune system.

On top of the thick yellow stuff coming out of her nipples, a new human mother might also be startled by what's coming out of her little darling's behind. Meconium, a baby's first poop—actually first few poops—is thick, tarry, and alarmingly green-black. It doesn't smell like much, thankfully, because it's mostly broken-down blood, protein, and fluid the fetus ingested inside the womb. But it's important that the stuff comes out fairly soon, and the laxative properties of colostrum help hurry that along—so well, in fact, that the intestines of a newborn drinking colostrum are wiped relatively clean. Which is precisely what needs to happen.

Before babies start to digest the food that will give them energy, they need to line their intestines with bacteria to help them break that food down. Mammals coevolved with their gut bacteria, because it takes a village.

Friendly bacteria—present in the mother's milk, in her vagina, and on her skin—rapidly colonize a newborn's intestines. Think of a new neighborhood: whatever group moves in first has a big influence on how the place evolves. Because of the relative lack of competition, those early bacterial colonies thrive, reproducing themselves all along the intestinal walls. Initial colonies in newborns' guts also have ways of communicating with cells in the tissue of the intestine. Toll-like receptors learn, like a neighborhood watch, which types of bacteria should be catered to and which

* This is part of why human newborns usually lose weight in the first weeks after they're born: they gobble up their own fat reserves until their mother's milk converts from colostrum to mature milk and they're able to take in—and digest—a proper meal.

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are dangerous. The earliest occupants have a profound influence over these receptors. That's one reason why preemie babies in the NICU are usually given donated breast milk and concentrated colostrum if the hospital can get it: their immune systems can be dangerously compromised without it.

Colostrum doesn't just clear the path for the early bacterial settlers. It also contains bacterial growth factors that help those colonies gain a foothold. A growing neighborhood might need a combination of public services and small-business loans, but for intestinal bacteria it's a hot dose of 60-sialyllactose. That's an oligosaccharide, one of the special milk sugars our breasts make for our babies. The early bacterial colonizers of newborn intestines—that is, *Bifidobacterium*, *Clostridium*, and *E. coli* (the good kind)—really like this stuff. It's their nectar of the gods. It helps them not only grow and reproduce but develop complicated biofilms: connected colonies of bacteria that, instead of just loosely floating around, adhere to the intestinal wall. Once they've set up shop, these bacteria help the newborn digest the milk their mothers are feeding them. What's more, we've recently discovered that oligosaccharides themselves can help deter dangerous pathogens from adhering to intestinal walls. Unable to find a comfortable, noncompetitive spot, the unwelcome invaders drift through and eventually get pooped out.

And that's one of the most surprising discoveries about breast milk. Just in the last decade or so, scientists have come to realize that maybe its nutritional value isn't the biggest deal off the top. Milk is really about infrastructure. It's city planning. Some combination of a police force, waste management, and civil engineers.

There's one last point to make against the idea that mammals' milk evolved mostly for nutrition. It turns out a significant portion of our milk isn't even digestible.

Modern human milk is mostly water. Among the things that are not water—proteins, enzymes, lipids, sugars, bacteria, hormones, maternal immuno-cells, and minerals—one stands out. The 6′-sialyllactose that colostrum delivers to newborn baby guts is not the only oligosaccharide in breast milk. In fact, the

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third-largest solid component of milk comprises oligosaccharides. These complex, milk-specific sugars aren't even *digestible* by the human body. We don't use them. They're not for us. They're for our bacteria.

Oligosaccharides are prebiotics: material that promotes the growth and generally ensures the well-being of friendly bacteria in the intestines. Prebiotics also promote certain kinds of activities among these bacteria: for example, the sort of activity that annihilates unfriendly bacteria. Commensal digestive bacteria have a complex and irreplaceable role in your digestive and immune systems, the features of which we're only starting to understand. But without prebiotics, they're up shit creek without a paddle. (Prebiotics are not the probiotics you've likely heard of—bacteria like *L. acidophilus* that the human body naturally contains. Eating fistfuls of probiotics on their own is a little like planting your garden without fertilizer, or maybe even without soil. You need prebiotics to make the whole system work.)

These special milk sugars are the target of an entirely new industry in the United States: that of lab-processed, powdered, and/or concentrated human breast milk, drawn from women who are sometimes paid handsomely for their donations. Nonprofit milk banks don't pay the mothers who donate their breast milk, because they see themselves as providing a service for patients who need such breast milk for medical reasons. These for-profit companies, on the other hand, dehydrate milk they've *purchased* from human mothers and then sell the product to hospitals, hoping to profit from providing the extra hit of oligosaccharides preemies need to start their young lives. At a cost of up to $10,000 for a few short weeks, daily doses of concentrated human breast milk product can help these little patients gain weight and develop a mature immune system more quickly.*

Other biotech companies are trying to create human-type

* The ethical questions surrounding how these women are paid are a bit less straightforward. For instance, one company—Medolac—was roundly criticized by an advocate group for African American women in Detroit, because it was believed that the company was specifically targeting poor women for donation (Swanson, 2016). If those women felt pressured to donate more milk than they really had as "extra," it could cause their own babies to suffer.

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oligosaccharides on their own, eliminating the need for women's breast milk. It's unclear whether it will be more financially viable to create the sugars de novo or source them from paid donors or whether there'd even be a market for these sugars outside human infants. Scientists are feverishly trying to figure out whether they might be part of a medical treatment for patients with Crohn's disease, IBS, diabetes, or obesity, for instance. But we simply don't know if the adult microbiome would benefit from the same sorts of prebiotics that infant intestinal colonies do. Technically, the bacteria are the same bugs. But how they interact with infant intestinal walls, and how those walls help "teach" the infant's immune system in a critical window of development, is at the cutting edge of current knowledge. We know that mammals' milk coevolved with mammalian guts. We know our bacteria matter to our well-being. But precisely how and why and when? Ask again in twenty years.

Still, humans are not known for behaving rationally when it comes to our own bodies. Some bodybuilders, for example, currently buy human breast milk on the black market, erroneously believing it will help them build muscle—even though human breast milk has far less protein than cow's milk and protein is what muscle tissue is primarily made of. If getting swole were the goal, it'd be far cheaper and more effective to buy and drink a quart of cow's milk.

Two hundred million years before there was ever such a thing as pseudoscience, much less a supplements aisle, Morgie squatted in her little burrow, half-drugged with the smell of her sleeping young, a rush of pleasant feelings flooding her brain. And deep in the warm dark of her intestines, her bacterial colonies did what they always do: ferment sugars, help her body absorb minerals, and co-regulate her immune system. And maybe that's the thing. If milk's original purpose wasn't feeding our young, but solving the water and immune problems, and then evolved those nutritional properties after the fact—a wonderful door prize, if you like—then it's safe to say that the story of milk isn't just about us. It's about what "us" should mean.

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After all, giving birth isn't just when *you* reproduce. It's also a key moment for the bacteria in and on your body: the construction of an entirely new environment that's especially suited for their survival. The ways your bacteria aid in the process might even fall under the umbrella of what biologists call "niche construction." In the simplest terms, niche construction is the way in which organisms change an environment to better suit their children and grandchildren. A beaver, for example, creates a dam that widens and deepens the watercourse it blocks into a pool, changing that ecosystem to better suit the beaver and its offspring. Different sorts of fish thrive in these deeper waters, and different sorts of riverine birds—even different strata of microorganisms: deeper waters, dammed by the beaver, are a very different ecosystem from a beaver-less creek. And so, some scientists argue, the beaver's children inherit both their parents' genetic material and a changed environment.* There's an intimate two-way relationship between the evolution of our genes and the inherited, changed environments that the expression of those genes produce.

So how are our digestive systems and gut bacteria like beavers and their dams? Put it this way: the main road through our organismal city runs from mouth to anus. What's inside your digestive tract is, technically, outside you, though bacteria are so interwoven with our intestines' function it's hard to say where the intestines stop and the bacteria begin. Destroying all the bacteria in a person's intestines can be life threatening. Hospital patients on industrial-grade antibiotics are famously prone to *C. difficile* infections, which are very hard to get rid of. Until recently, these patients would have no choice but to suffer repeated bouts of exhausting diarrhea, and even risk dying. The best cure for it, as we've only learned in the last ten years, involves pumping a brown slurry of a healthy person's poop into the patient's intestines. Some

* Some even say the dam should count as an "extended phenotype," given that specific behavioral outcomes produced by the beaver's genotype are the things that build the dam and, critically, the success of those genes' propagation depends on the dam (Dawkins, 1982/1999). Thus, much as one's body traits are the "phenotype" of one's genotype, the beaver's dam is an extra-organismal extension of that phenotype. It's important to know where to bound these arguments, of course; not everything an organism produces should count as an extended phenotype.

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feel better in a couple of days. Many are cured entirely within a week.*

Here's the thing: a beaver's river doesn't usually up and die eighty or so years after the dam is built. Human intestines do. So, if our gut bacteria are in the business of passing on their genes, they're going to evolve in ways that help their descendants colonize the intestines of their hosts' babies. In mammals, milk is one of the key ways that happens. Our milk changes depending on our environment and the sorts of things we eat, which makes sense, given that breast milk is one of the first ways we protect our children, and it needs to be responsive to both local resources and local dangers. You can see that responsiveness in individual species, too; chimps, for example, have markedly different breast milk in the wild than they do in zoos (as do human women with differing diets). But what remains consistent in human milk, no matter where we are and what we're eating, is the extraordinary number of oligosaccharides we stuff in there. In fact, human milk has the most, and most diverse, oligosaccharides of all our primate cousins', probably because unlike other apes modern humans have had to deal with cities and high-speed travel.

Cities are bacterial cesspools. Humans are not just social primates; we're *super* social. By living in such close quarters, day and night, human bodies regularly encounter an onslaught of foreign bacteria. Pathogens can easily jump from host to host, moving through a large population like wildfire. What's more, because we've invented technologies that manage to haul our bodies (and their bacteria) across land and sea so quickly, each population at each new port of call has to confront whatever bacterial guests we happen to bring with us. Some scientists think our milk sugars are so different from other primates' because they evolved to help our gut bacteria handle our crazy human lifestyle. They may even provide clues to specific infections our ancestors had in the past: not only do our special milk sugars feed friendly bacteria, but they

* Do not do this at home. Right now, the FDA approves FMT (fecal material transplant) for *C. diff* infections only. It's in clinical trials for all sorts of other things, from obesity and IBS to lupus and rheumatoid arthritis. No one knows if any of those treatments will pan out. Meanwhile, the best advice still stands: don't put things up your butt unless you really, really know what you're doing.

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can also trick unwanted pathogens to bind to them instead of to an infant's intestines, and then send them into the diaper.

Our guts are, in essence, as social as our brains—or at least as influenced by our disease-prone social nature, and that history has pressured our milk to change, too. Forget about the Paleo diet: modern *Homo sapiens* have already adapted to urbanization and the bacterial challenges that come with it.

MILK IS PERSONAL

When domesticated cats cozy up to their owners/roommates/Known Food Providers, they'll often push their forepaws against the owner's body—left paw, right paw, left paw, right paw. When kittens nurse, they do this same motion: kneading their mother's belly on either side of the nipple, helping push out the milk into their waiting mouths. Animal behaviorists think this action is something older cats do when they're content and bonding, that the body motion is just so ingrained in them from birth that, even sans nipple, their paws go to work as a part of a familial pleasure circuit. They'll do it when they feel good. They'll do it when they want to feel good. They'll do it when they feel bonded to another being. And maybe they'll do it when they're bored.

Human babies don't nurse from a string of teats the way cats do. Maybe that's why our infants don't display this push-push pattern. What babies do have is the ability to suckle. And they are able to do that because women have nipples.

Except the platypus and the echidna, all mammals living today have teats: raised, porous, nubbly patches of skin under which highly evolved milk glands get to work when mothers need to nurse their children. At some point before marsupials and placentals arrived—somewhere between Morgie's 200 million years and marsupials' 100 million years—the Eve of nipples was born. On her holy chest were not just a few sweating patches of fur but thickened bumps of skin that helped her kid latch on.

The modern human nipple is a thicker nub of skin on a woman's chest surrounded by a flattish patch of darker skin called the areola. The average nipple has fifteen to twenty small holes that

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are connected via tubes to the milk glands in the breast. When a female mammal becomes pregnant, the tissue around the nipple becomes engorged with blood and new tissue as the milk glands gear up for production. The skin becomes darker and redder. Veins swell. New capillary branches feed the growing tissue. For many mammals, this is when their nipples first become apparent to an outside observer, as the teats swell past the fur of the female's underbelly, following two long lines from armpit to groin. For humans, whose nipples are generally not covered by hair, others will spot the change in shape and size.

From a waste-management point of view, it's obvious why nipples evolved. Though Morgie's sweaty milk patches probably did have "mammary hairs" that helped guide the milk into her pup's mouths, that system had a lot of slop. Inevitably milk would be wasted. Since it takes a lot of energy to make it, having a more specialized access port to the milk glands seems like an easy product of evolution. Controlling for slop wasn't the only waste-management feature of the nipple. While the mammalian body does produce a bit of milk of its own accord—pregnant women "leaking" at various inopportune moments during business meetings or on the subway or in a particularly emotional argument with one's partner—it's nothing compared with what it does in response to suckling.

For nippled mammals, the majority of milk is a "co-produced biological product." That means that while it's the mother's body that produces it, the infant's mouth is the thing that triggers the mother's body to do so. What's more, the infant has a significant role in the type of milk that the mother's body makes. There are a few different mechanisms involved, but the most important are these two: the let-down reflex and the vacuum.

Contrary to popular belief, a nursing mother's breasts are not full of milk. They're swollen, sure, sometimes to the point that they resemble fleshy water balloons, but they're full of blood, fat, and glandular tissue. There's no bladder in a breast that holds a sloshing cup of milk that empties as the baby nurses and then gradually fills up again, ready for next time. Even a dairy cow's udder isn't the bag of milk you might think it to be; like us, a cow's udder is a visible mound of mammary tissue, along with a few nip-

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ples.* The ductwork of a nursing human breast can hold, at most, a couple of tablespoons of milk at a time. It's the act of suckling that normally triggers a breast's "let-down reflex"—a cascade of signals that tell the milk glands to kick up production and dump fresh milk out the front door.

It's a lot like what your mouth does when it comes to saliva. Chewing your way through a typical meal produces about half a cup of spit. But you don't have half a cup of spit in your mouth at all times, ready to go. Your salivary glands get the signal to start amping up saliva production when you smell something tasty, and most especially when you start chewing.

When an infant begins to suckle, the nerves in the breasts send signals to a mammalian mother's brain. In response, the brain tells the pituitary gland to produce a lot more of two specific molecules: the protein prolactin and the peptide oxytocin. Prolactin stimulates milk production. And oxytocin helps squeeze the milk out of the glands into the waiting ducts, which are then emptied by suction from the baby's working mouth.

These two molecules have roots tied to the evolution of milk itself. Some of those roots go even further back than Morgie. Prolactin has been around since fish evolved. In fish, it seems to be mostly tied to regulating salt balance. Moving up the evolutionary chain, prolactin has a number of functions in the immune system. Nowadays, it's also tied to sexual satisfaction: no matter your gender, the more prolactin you have in your body after sex, the more satisfied and relaxed you feel. This may be because prolactin counteracts dopamine, which your body produces in buckets when you're sexually aroused. Likewise, if you have too much prolactin in your system, you're more likely to suffer from impotence.†

* And like us, dairy cows tend to produce the most milk overnight and first thing in the morning; most mammals' milk production is tied to a diurnal cycle of hormones. That's why a farmer's first task of the day is milking the cow: a cow with swollen udders is going to be especially cranky if you don't tend to her fast, along with more in danger of developing a mammary infection and/or losing her milk supply. (I got mastitis twice. Hideously painful. I've never had more sympathy for cows than when I had to nurse my children.)

† This is true of both male and female bodies. Many lactating folk find their sex drives, and general sexual satisfaction, plummet while breast-feeding. There are many reasons for this, but not all are "psychological." Prolactin is one obvious

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Oxytocin also evolved to serve multiple purposes. This little peptide has garnered tons of attention lately because of its association with emotional bonding. Some of the science around oxytocin is good, and some of it is so tainted with stereotypes of femininity that we might as well dress it up in a frilly pink tutu: "Oxytocin makes you love your baby." "Oxytocin makes you love your man." "Monogamous men make more oxytocin than men who're going to cheat on you." While oxytocin does seem to be associated with a number of psychological states in various mammals, and higher levels of oxytocin are associated with more pro-social behaviors, there are simply too many other factors that produce these things to treat oxytocin as a solo player. Also, while human beings behave more altruistically toward members of their own group after a dose of oxytocin, they also act more defensively and aggressively against people they perceive as being *out* of their group—so it's hardly the angel of our better nature. And no one really knows what oxytocin is doing in the brain: Does it make us interpret others' social signals differently? Does it just make us pay more attention to faces? Does it simply make us feel warmer toward known things (like people we know) than toward unknown things (people we don't know)? In the end, the only thing we're *dead* sure oxytocin does is make certain kinds of tissues contract.

When you have an orgasm, oxytocin tells the muscles in your pelvis and lower abdomen to rhythmically contract. This is true for both men and women. For men, these contractions help shoot sperm out of the urethra—and also happen to pulse the muscles in the buttocks and anus, making them more likely to fart. For the woman in mid-orgasm, muscles in the uterus and vagina will pulse, and the anus and the buttocks and upper thighs will often come along for the ride. Sometimes those uterine contractions are so powerful they don't entirely stop after the event is over, and she'll experience rather painful aftershocks, like menstrual cramps (which, by the by, also involve the oxytocin pathway, helping the uterus rhythmically and sometimes painfully contract in order to

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factor. Estrogen and progesterone play a role, too. Vaginal tissue tends to suffer a bit in the breast-feeding woman, typically becoming more dry and fragile. That can make postpartum sex painful, even after birth injuries have had time to heal.

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slough off its old lining). When a woman goes into labor, oxytocin is a major player. It's so important for childbirth, in fact, that it's listed by the WHO as one of the world's "essential medicines."

Similarly, when a baby suckles and the pituitary gland up-regulates oxytocin, a nursing mother might also experience a deep sense of contentment and social bonding with her baby. Post-orgasm men and women tend to feel that, too, to varying degrees. We don't know when, exactly, oxytocin's "contraction" function became tied to the mammalian brain's "social bonding" and "feel good" signals, but now they tend to be coupled.

When a human baby suckles, it wraps its mouth around the mother's entire areola, the flesh of its lips splayed out in a kind of lamprey-like O. In response to being touched, the nipple contracts into a fleshy forward-jutting pyramid. When the kid properly latches on, the base of the pyramid rests on top of the baby's toothless lower gum, its tip extending all the way to the back of its mouth. And then the cheeks contract, sucking all the air out of the mouth, creating a vacuum around the nipple that helps pull the milk, freed by oxytocin, into the baby's throat. The tongue and muscles of the lower jaw roll front to back, massaging the nipple from base to tip, squeezing all that vacuum-hoovered milk out of it. Some of the milk can splash up into the lower sinuses and bubble out the baby's tiny nose, but most of it goes down the esophagus, swallowed in between gulps of air. The mechanics of the whole thing are quite the production.

Suckling is not something a newborn mammal always knows how to do. Though the "rooting" instinct seems universal in mammals—the way that a baby will start nudging its head around, looking for a nipple, when it comes near a large, warm, soft surface—latching on is quite a bit harder. Some babies wrap their lips just around the tip of the nipple's pyramid and can't form a good vacuum. Some get the vacuum part down, but don't move their tongue and jaw the way they're supposed to. Some appear to become so frustrated by it all they don't even bother, leading both the baby and the mother, exhausted, to cry.

And cry she might, poor Morgie's daughter, for her nipples may dry out and crack and bleed, sucked and gummed raw by a child who can't figure out how to feed. (My firstborn damaged my

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nipples so badly in the first twenty-four hours that they bloomed with black-purple bruises, alarming even the battle-hardened nurses assigned to my care.*) Latching can be such a problem, in fact, that a crop of "lactation consultants" have sprouted in hospitals to help new mothers teach their babies how to do this odd, recently evolved thing with their mouths. Most figure out how to do it. Eventually. But in evolutionary terms, the breast knows how to milk better than the mouth knows how to suck.

Luckily, the nipple evolved one useful compensatory measure to help withstand the learning process. Some nipple holes connect not to milk glands but to Montgomery's glands, which produce a greasy substance that coats the nipple and helps prevent the skin from being totally destroyed by insistent gumming. When a woman is pregnant, the Montgomery's glands swell and make the nipple look a bit "bumpy." For some of us, those little bumps are visible all the time. Like milk glands themselves, the Montgomery's glands probably evolved out of primitive sebaceous glands that naturally proliferate in the skin. But instead of producing the usual skin oils, the Montgomery's glands came to pump an industrial-grade lubricant that could withstand the kind of chafing a nursing baby inflicts.

It's the vacuum, though, that really changed the breast game—being able to seal a kind of docking station between the mother's body and her offspring's. Once that evolved, milk stopped being something the mother's body made on its own and started being something the mother's and baby's bodies make together. As the rhythmic rolling of the baby's tongue and jaw move the focus of the vacuum back and forth, a kind of *tide* forms between the breast and the mouth. In that rolling wave, the milk flows up over the top while, on the bottom, the baby's spit is being sucked back into the mother's nipple, in a kind of evolutionarily purposeful backwash. Lactation scientists call this the "upsuck." And that's where things get really interesting.

* He didn't have a tongue tie, for what it's worth. He just decided to chomp instead of suckle. It took weeks to recover. Meanwhile, I formed an intimate relationship with a breast pump, and he developed an intimate relationship with silicone nipples. This is fantastically common for new mothers.

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The nipple itself is packed full of nerves to help detect that vacuum, which starts the chain reaction of oxytocin for the let-down reflex. That's why, for example, modern women can use a breast pump. Just about any vacuum will do to trigger milk production. But what breast pumps obviously can't do is inject salivary backwash into the nipple. Lining the mother's milk ducts, from the nipple all the way to the glands, are an army of immunoagents. And depending on what happens to be in baby's spit that day, the mother's breasts will change the particular composition of her milk.

If a baby is fighting an infection, for example, various signals of that infection, from actual infectious agents like viruses and bacteria to more subtle indicators like the stress hormone cortisol, will be present in the baby's spit. When that spit gets sucked up into the mother's breast, the tissue reacts and her immune system will produce agents to fight the pathogen. Her milk will carry them into the baby's mouth, providing extra soldiers to combat the infection and help the baby's own immune system learn what it needs to fight. In response to raised cortisol, the milk glands and surrounding tissue will also bump up the dosage of immunoagents in the daily brew, and it may also send down the line a number of signals to soothe the child. Some of those signals are hormonal—stuff to directly counteract the inflammatory properties of cortisol. Some of them are nutritional, with added knock-on effects to change the baby's mood. For example, milk produced by a breast that's nursing a child who's stressed tends to have differing ratios of sugars and fats, providing extra energy to help the baby's body fight off any potential invasion. It can also work as an analgesic, damping the baby's pain response and helping it rest; after all, quite a lot of healing happens when we're calm and asleep. These sorts of responsive features seem to be true across Mammalia, the particular magic potion varying from species to species—different bodies need different sorts of breast-borne chicken noodle soup—but the overall principle holds true.

The resulting effect is so powerful that when many babies grow up, their brains still associate milk-related signals with healing and comfort. Eating fat-dense and/or high-carb foods, especially if they taste sweet—the sort that many humans tend to seek

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when feeling stressed or lonely—produces an analgesic effect in a number of different mammals. For rat and human alike, "comfort food" can dampen the body's pain response, a kind of grown-up breast substitute.*

The evolution of mammalian nipples provided a new, vacuum-sealed transmission point between mother and child. It was a way for them both to make milk together and to communicate with each other. Communication, in fact, is such a deep feature of mammalian nursing that it's not just a matter of the nipples; the ways and occasions in which mothers nurse their babies are also shaped by the things we want to "say" to each other. Mother felids tend to rumble and pant; apes hoot and lip smack. The majority of human women favor cradling their infants and nursing them from our left breast, which also happens to line our baby up with the side of our face that is more expressive. No, really—and other primates do this, too. Among humans, the muscles on the left side of the face are slightly more adept at social signaling, and 60 to 90 percent of women preferentially cradle infants toward the left of the body's midline, with the baby's head more exposed to the left side of her face. This preference is strongest in the infant's first three months of life, precisely the period when new mothers are nursing more often throughout the day. This is true across many human cultures and historical periods.

Meanwhile, the right hemisphere of the adult brain is largely responsible for interpreting human social-emotional cues, and it receives those signals dominantly through the left eye. So the mother's left eye carefully watches the infant's face, interpreting

* Unfortunately, eating sugary foods also tends to produce a sugar crash shortly thereafter, which can feel considerably less comforting. Emotional "pain" maps in the brain in strikingly similar ways to physical pain, and aspirin, ibuprofen, and even Tylenol can work pretty well on that, too. According to a few recent studies, taking a common over-the-counter painkiller *before* you encounter negative events can greatly influence how emotionally pained you'll feel (Mischkowski, Crocker, and Way, 2016). It may not help as much after the fact, unfortunately—a good deal of the pain of remembering has to do with your emotional state at the time of encoding—so if you happen to know that you're about to break up with your boyfriend, take a couple of ibuprofen or Tylenol. It takes about thirty minutes to kick in. Unfortunately, it may also reduce your empathy for your partner's pain, so do with that what you will (ibid.).

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the baby's emotional state, while the infant gazes intently up at the most expressive side of the mother's face, learning how to read her emotions and respond—something that human beings spend huge portions of their childhoods learning how to do.

MILK IS SOCIAL

When Morgie came back from hunting each dawn, she was stressed. Of course she was: she lived in a stressful world. But if her environment had been more dangerous than usual that night, or if she was hungrier than normal, her body would have produced a higher dose of cortisol. And when she rolled onto her side to nurse her pups, her milk would have contained similarly higher levels.

Milk with a lot of cortisol tends (at least in rats and mice and certain kinds of monkeys) to produce baby personalities that are less risk seeking, and those traits seem to persist through the individual's lifetime. These individuals explore their environment less. They're less social with other members of their own species. They react more skittishly to unknown stimuli. They like to play it safe. Babies with low-cortisol milk, on the other hand, explore more. They're more social. They spend more time playing with their den mates. And when they grow up, their personalities tend to have similar features. While many things go into building an individual's personality, at least among species we're able to study in the lab, what's in the milk they drink is, all on its own, a strongly predictive factor.*

But before we blame our stressed-out mothers for all our social anxieties, let's think about the evolutionary reasons for this pattern. Being social takes a lot of energy. If the milk you're

* Whether that's also true for deeply social beings like humans is unclear, and presumably genetics also come into play. But if personality is something that's built by a suite of influences over one's lifetime, and milk is already known to be an influencer in other model mammals, it would be foolish to discount it in humanity. Rather, milk—particularly its obvious signaling components, like cortisol—is one of many pathways of formative communication between the mother's and the infant's bodies.

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drinking—which as a baby is *all* you're drinking—has fewer sugars in it, or if you're able to nurse less often than you'd like, you have less energy to spare. You're going to want to conserve the energy you have for growing your young body into something that can survive to adulthood. Spending that energy on a bunch of roughhousing and time- and energy-intensive socializing is unwise. If you live in a very dangerous world, a fact you're "learning" through your mother's cortisol levels and other milk content, it's probably good to be a bit fearful.

Higher-cortisol milk also tends to be protein heavy, which in principle helps an infant build a lot of muscle, good for running like hell toward safety. Sugar-heavy milk, in contrast, is great for building adipose tissue, creating a comforting energy buffer, and for fueling a growing brain. Brains are, after all, supercomputers that run on sugar. Being social takes a lot of brainpower—a lot of sugar energy. Even now, many *Homo sapiens* who have convinced themselves that a low-carb diet is a good idea feel sort of sluggish as a result, with brains in a fog.*

Still, it's not true that the best scenario is milk with *no* cortisol. A low and consistent amount of cortisol in a mother's milk helps her offspring later in life. If you lace a mother rat's drinking water with low levels of cortisol, her offspring will perform better on maze tests, have better spatial recognition, and generally be less stressed out when faced with challenges than young rats whose mothers didn't drink water dosed with cortisol.

There haven't been many studies that directly test the relationship of a human mother's cortisol levels while nursing and her baby's temperament; also, many children's temperaments change over time (they do get past the terrible twos). But one study did

* A number of papers have debated the benefits and detriments of the so-called ketogenic diet on the brain. I have no intention of giving diet advice, but at least when it comes to the typical diet of our closest cousins—chimps and bonobos—it's clear they don't live on a quivering meat pile. As opportunistic omnivores, they do quite well on a range of diets, but each of those diets has a lot of fruit and vegetable matter, with a smattering of meat and bugs and nuts and what have you as it comes along. The human gut has evolved significantly since the Eve of chimps and hominins, but it'd be wrong to assume that our ancestors were eating a diet significantly different from that of other opportunistic, omnivorous apes.

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find that when a breast-feeding mother's cortisol levels were raised above a certain threshold, she would be more likely to rate her child as "fearful" or timid. But women with higher cortisol levels who were bottle-feeding their babies didn't describe them as fearful. Some degree of change in the breast milk seemed to be producing behavioral change in the infant.

So, do we want our babies to drink "stress milk" or don't we? The answer seems to be that we want milk with *just* enough cortisol and other materials, in the right balance, at the right time. Think back to the rats: A little cortisol makes rat pups learn *better* than the pups who didn't ingest any extra cortisol. Overdose them with cortisol and they freak out. That makes sense. Researchers think that to a certain degree mildly challenging environments inoculate children against the upcoming stresses of adulthood. So maybe it's better to have a mother's milk "demonstrate" a moderately dynamic and challenging environment. But if a woman is stressed out all the time, with cortisol levels through the roof, her kids might likewise be more fearful, hesitating to explore new territory and learn new things. In other words, our bodies teach our children about the world, not just by actively showing them their environment, but also by what we put in their mouths. Caretaking mothers have long evolved to take advantage of every pathway available to prepare their offspring for their looming independence. Because we're mammals, the nipple is one of our first lines of communication.

Mothers' bodies tailor milk's contents for the needs of their offspring through a complex communication system between mouth and breast. Babies' personalities are shaped by its particular makeup, are soothed by its fats and sugars and hormones, their guts purged and recolonized by friendly bacteria. Milk is something we *do* as much as something we make. It has evolved to be social.

To be fair, milk doesn't do the whole job. For example, mothers in many cultures use their spit to wipe away a bit of schmutz from the kid's cheek; it's so common, in fact, that this may be a basic human behavior. Continual exposure to the mother's more robust immune system, whether through spit or milk or breath or skin contact, should, in principle, help the child's own immune

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system develop and learn how to respond to its environment. This is also true of exposure to a father's spit, and a big brother's spit, and the spit of any other adult who has physical contact with the child. It's just that babies actively ingest breast milk on a regular basis, so it's safe to assume that the mother's body is in greatest molecular "communication" with her offspring.* Human infants drink about three cups of breast milk a day in their first year of life. That's clearly a greater opportunity for biochemical signaling than nearly any other pathway.†

And what of men's nipples, then? They clearly aren't doing the heavy lifting here, so why do they still have them?

We tend to think of men's nipples as "vestigial," but that's not quite right. First, "vestigial" is a term that implies an evolutionary leftover that no longer serves any purpose. But the body hates to waste. We have very few vestigial traits. Even the appendix, long thought to be vestigial, is now believed to have an important function in maintaining the health of the large intestine's microbiome. A grown man's nipple can, under the right circumstances, deliver milk. It's not nearly as good at it as the adult female nipple, but it can do it. Seriously. Men can—inefficiently, and with difficulty—nurse a baby.

There's a group of people who live in Congo who call themselves the Aka. In this tribe, gender roles are remarkably fluid. Men and women both hunt. Men and women both care for children. Given the demands of the day, a woman may cook and watch her child while the father hunts. If net hunting is done, rather than spears, they may well do it together, baby in tow. On another day, the woman will hunt and the man will watch the child. Aka men are either holding or within arm's reach of their children more

* On average worldwide, mothers also spend more time in physical contact with the child. But given that *Homo sapiens* are among the only species that regularly adopt the offspring of unrelated parents, these lines of physical signaling between children's bodies and their caretakers shouldn't be thought of as something that *only* happens in genetically linked mother-child relationships.

† Dad, you're great, but I think we're both pretty happy about the fact that I've never ingested a pint of your body fluid. It's okay. We communicate in other ways.

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than 47 percent of their time. Pregnancy doesn't seem to change this ratio, either; one Aka woman was known for hunting well into the eighth month of her pregnancy. And after she gave birth, the father still traded responsibilities day to day, not only the general child care, but suckling the child at his breast.

Presumably most of the Aka men do not lactate; the anthropological study didn't mention seeing it, though it's historically known to have happened in many other cisgender men. But even if some do, it's true they don't produce as much milk as women do. The point is that suckling a baby is seen not as an emasculating thing in their culture but just as a feature of the day. As the vast majority of parents know, if your infant is fussy, one surefire trick is popping a nipple in its mouth. When they don't offer their own, American women generally offer a pacifier. Aka men use the one they have built in.

But if you want to know how hardwired milk production is among *Homo sapiens*, you need only look at trans women: people born with XY sex chromosome patterns, but who identify as women. Trans women who want to breast-feed their children generally follow the same medical treatments given to XX people* who have either adopted or used a surrogate to have children. The most common protocol involves taking high-dose hormone pills to trick their bodies into thinking they're pregnant for roughly six months. After that time, they change their pill regimen in order to mimic the sorts of changes bodies experience after giving birth.† They don't produce as much milk, and not all are able to produce any, but many can.

* I use "XX people" here not to avoid the cis terminology, but rather because there are some genderqueer people with two X chromosomes who don't identify as trans and likewise desire to breast-feed a child that their bodies didn't give birth to. They, too, regardless of their genetic background, would need to follow this hormonal protocol. When I refer to "post-birth women" elsewhere in the book, I do so because while some trans men do choose to give birth, the majority of people who give birth are cisgender women and, more important, the studies that undergird the claims I'm making about these mothers have been conducted overwhelmingly on cisgender woman subjects.

† They'll also take a drug called domperidone, which interferes with dopamine receptors and, among other effects, helps stimulate the production of prolactin (Wamboldt, 2021).

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