TimeLine Theatre Company

the HOW and the WHY

by Sarah Treem
directed by Keira Fromm

STUDY GUIDE

Prepared by
Maren Robinson, Dramaturg

This Study Guide for *The How and the Why* was prepared by Maren Robinson with content by Maren Robinson, Lara Goetsch, PJ Powers and Northwestern University's Women's Health Research Institute and edited by Lara Goetsch for TimeLine Theatre, its patrons and educational outreach.

— STUDY GUIDE —
Table of Contents

About the Playwright: Sarah Treem

Sarah Treem's *The How and the Why* premiered at the McCarter Theatre starring Mercedes Ruehl (with Emily Mann directing) and went on to productions at Interact Theatre and Trinity Repertory, among others. Her play *A Feminine Ending* premiered at Playwrights Horizons and went on to productions at South Coast Repertory and Portland Center Stage, among others. Sarah's other plays include *Empty Sky, Orphan Island, Human Voices* and *Mirror Mirror*.

She has been commissioned by Playwrights Horizons, Southcoast Repertory and Manhattan Theatre Club and developed work at the Sundance Theatre Lab, Ojai Playwrights Festival, the Screenwriters Colony, Hedgebrook and Yaddo. In addition to her theater career, Sarah wrote and produced all three seasons of the acclaimed HBO series *In Treatment*, for which she won a Writers Guild of America award and was nominated for a Humanitas award. She also was a writer/producer for the HBO series *How to Make It in America* and the Netflix series *House of Cards*, starring Kevin Spacey. She currently has a new pilot called *The Affair* in production with Showtime.

Sarah has taught playwriting at Yale University, where she earned her BA and MFA. She recently moved from Brooklyn to Los Angeles with her husband, Jay, and their son, Henry.

The Interview: Sarah Treem

During rehearsals, Artistic Director PJ Powers (PJP) conducted this interview with *The How and the Why* playwright Sarah Treem (ST). Spoiler alert: Some key plot and character details of the play are discussed.

PJP: I swear I'm not trying to be too cute with this question, but how and why did you become a writer?

ST: People ask this a lot and my answer sounds so cute, but it's the truth. I've always considered myself a writer. I've been writing for as long as I can remember. I'm an excellent mimic and when I was a kid, I would write poems in the voices of Shel Silverstein or Dr. Seuss to entertain myself. My grandmother lived in New York and when we came to visit her, she would take me to theater. She took me to *The Crucible* when I was 9. I guess she thought I could handle it.

I wrote my first play at 12. It won a young playwrights contest, which I took to signify that I had found my calling. I remember a certain sense of relief—like,

oh good, one less thing to worry about. I was a pretty serious kid. I continued writing all through high school and college and after college I went straight to Yale Drama. So, I wish I had a more interesting answer for this question, but I don't. I've always wanted to be a writer. It is very much a part of my identity. The writing has been my constant companion for my entire life.

PJP: What inspired you to write *The How And The Why*?

ST: So that's a more complicated question. Literally, the play is inspired by a book called *Woman* by Natalie Angier, a science writer for *The New York Times*. It's an exhaustive exploration of female physiology. I tore through the book in my late twenties and stumbled upon these two theories—one was the grandmother hypothesis and the other was the menses as defense hypothesis. They're both real theories in evolutionary biology. If you want to blow your mind, look up what happened to Margie Profet, who was my inspiration for the Rachel character. It's perfect proof of the old adage, truth is stranger than fiction.

One a personal level, it's a little hard for me to remember where I was at 28 when I started this play, but I think I was, like many girls I know, in an emotional vortex. That's a tough age. You've outgrown your childhood and your younger self, but there's a real period of searching that needs to happen before you can formulate an appropriate adulthood (at least, I think there should be). That searching can be really scary and painful because who knows where you're going to end up. That's where I was when I started that play.

When I write well, it's usually from some deep and existential anxiety. I think *The How and the Why* came from this question, "How the hell do I become a grown-up?"

PJP: Have you always been interested in science? Are there scientists in your family?

ST: Most of the members my family are doctors. I really love the history of science and medicine. For example, I did a whole study about the evolution of childbirth throughout history. It has changed drastically—even the concept of pain within childbirth, which we now take for granted, has evolved. In the colonial era, it was like "Eh, you'll live." By the Edwardian era, women were writing their last will and testaments before going into labor. Now it's all become hypermedicalized.

There's just so much you can extrapolate about the priorities and principles of a culture by examining its relationship to the body. And especially, women's bodies. Who controls them? Who makes the decisions over them? I

love that part of Zelda's explanation where she takes you through the historical re-evaluation of menopause, based on changing perspectives on femininity. Evolutionary biology, in particular, is storytelling. Scientists look at trends across millennia and come up theories for why things happened the way they did. And when I say "story," I don't mean myth. These stories are routed in empiricism. But they are narratives.

PJP: Do you connect more personally to the younger character of Rachel in the play, rather than to the older character of Zelda? Or is that a silly generational presumption on my part?

ST: I think when I was writing it, I was straddling both parts. I felt very connected to Rachel's outrage and very connected to Zelda's remove. Zelda's speech about work as a lifeline—that's from me, that's what I believe. And Rachel's speech about being dismissed for presenting a radical idea as a young woman—I believe that, too. And then there are parts of each character that are sort of antithetical to my personal philosophy. I love Zelda's speech on love as stress, but I don't buy it. And I have a lot more respect for the feminist generation than Rachel does. But in the end, when Rachel asks for help and Zelda answers, that was me talking to myself.

PJP: I know you've become a mother since this play premiered, and I'm curious if you now look at any parts of the play differently?

ST: Not really, actually. I didn't think it was easy for Zelda to give up her child when I was writing the play and I certainly don't now. And actually, I think I stand behind the play even more, now that I'm a mom, because I know how impossible it is to be completely committed to your passion as a parent. Your child becomes your priority. It just happens. I think Zelda was quite prescient to realize that and fear it. Zelda wanted to work, more than anything else. She knew she would be a preoccupied, resentful mother. And we are so judgmental of women who make those decisions. We're terrified of them actually. But everybody gets to make their own choices with their own lives. I love being a mother. I love my son literally more than anything in the world. And if you tried to take him from me, I would kill you. But I am not as productive now as I used to be. Not by a long shot. I am very lucky to have incredible support. And to be born into a generation that both recognizes the complex responsibilities in a professional woman's life and endeavors to assist her. Zelda didn't have any of that. So I understand the choice she made. Even though Rachel would hate me for saying that.

PJP: Since *The How And The Why* premiered in 2011, there has been the much-discussed book *Lean In: Women, Work, and the Will to Lead* by Sheryl Sandberg, as well as the provocative cover story in *The Atlantic* "Why Women

Still Can't Have It All." Do you sense anything shifting in recent years in the ongoing discussion about balancing work and career?

ST: Yes absolutely, and it's really exciting.

I devoured *Lean In* and also the Anne Marie Slaughter piece in *The Atlantic* that preceded it. I think this is a very special time for professional women. I love reading that Lena Dunham or Lorde proudly identify as feminists. Just 10 years ago, that was a bad word. I remember the pop stars of my generation (I'm 33) insisting that they were "humanists," whatever that means. Everyone was terrified to have the conversation aloud. To say, "Wait a second, this is hard for me. Hold up, I'm confused."

I really loved Anne Marie Slaughter's point that it's not about women making it all work—it's not about logistics—it's about happiness. Working mothers don't want to leave their children for 80-hour weeks. It isn't worth it. But our system is not set up to provide women an alternative. Especially when you get to the top of these fields—be it science or government or entertainment—there is no culture of respect for family time, for maternity leave, for helping women do good work and also be good moms. So everyone suffers. Women suffer because they're being asked to make impossible choices—themselves or their children—and the industries suffer because they're either losing talent or people are miserable. I'm so glad that people like Anne Marie and Sheryl have put this conflict into public dialogue because awareness creates action.

PJP: During the first few productions of *The How And The Why*, was the play generating the type of audience discussion you had hoped for, or have there been responses that surprised you?

ST: I don't think I hoped for any specific kind of response. I just hoped people would sit through a play that is basically a long conversation between two women about science. I had never seen these types of characters up on stage before. I wanted to write women who were complicated—strong and vulnerable and angry and loving—like real people.

I hate when I see these female characters on stage whose "strength" is a defense. Because they're really broken. Or frigid. Or crazy. Those are not the girls I know. I like a tough lady. So I was pleased to see that audiences have really engaged with these characters and not too many eyes have glazed over.

I was disappointed by the critical response to the first production in *The New York Times*, because Isherwood didn't engage at all with any of the ideas I was wrestling with—feminism, motherhood, gender discrimination, even biology. He wrote off Rachel's character for being angry, as if her anger

negates her legitimacy. Which is exactly the point she's trying to make in the play. Anger in young women makes people so uncomfortable. It makes me uncomfortable. That's why I write about it so much. So anyway, I wish he had understood that.

There was a gorgeous response from Jill Dolan who writes a blog called The Feminist Spectator, which in-and-of itself made writing the play worth it for me.

PJP: Much has been written and debated about the depressingly low percentage of plays produced in this country that are written by women. As a now-established yet still-young playwright, do you have advice for those who are earlier in their career, trying to get their work produced?

ST: Oh God, I have a ton. Mostly, hang in there. It's a war of attrition. But also, don't be precious about your talent. If you want to be a writer, write. Keep writing. Wherever and however you can.

I once had a conversation with Danai Guirara, whose work I am in awe of. She doesn't get produced as much as she should—not even close—because she's mostly writing about African women and her plays are grand and ambitious. But Danai has never stayed in New York, crying over her ramen, because nobody wants to do her work. She travels all over the world, she acts in independent movies, on *The Walking Dead*, she writes constantly. She once said to me, "I walk through the doors that are opening to me. I don't waste my time beating my head against the ones that are closed."

That advice changed my life. So I would pass it on to any younger playwrights and just add—keep moving. If a theater doesn't want to produce your play, fuck them, move on, find a theater that will. Only take notes from people who already like your work—those are the only notes that are useful. Keep reading. Don't put too much faith in agents. You have to hustle for yourself. Support your fellow artists. Get married. Have babies. Live your life. And again, keep writing. I love the artist Josh Ritter. I may get flack for that—he's a little sincere—but he has a line in one of his songs: "I'm singing for the love of it. Have mercy on the man who sings to be adored." And that's how I feel about choosing to be an artist. You better be doing it for the love of it. Because if you're not, may God have mercy on your soul.

PJP: You've been incredibly prolific in recent years, writing and producing for TV shows (*House of Cards, In Treatment, How to Make It in America* and *The Affair*) plus you have a film in the works. Yet you still write plays as well. How is the creative process different in the theater than in your other work?

ST: It's like coming home for me. It's the form I imprinted on. I think writing is a bit like that. It's the rare writer who can move easily from poetry to fiction to drama. Our creative brains choose one avenue of expression and form around it. So when I start a new play, I kind of relax—it's like yes, this is where I live.

But being a playwright has never paid my bills and I feel extremely fortunate to have become a part of the television industry. It really is the golden age of television. We're creating content that is disseminated and devoured immediately and we're influencing the national conversation. I was surprised to find that the different mediums really inform each other. Contrary to popular belief, writing for television has made me a better playwright. In TV you have to choose your words very carefully. Because with a camera, excess is obvious. Even little speeches in television have to be well justified or they feel ridiculous. The best scenes say the most with the fewest possible words. That rigor with language has absolutely improved my playwriting.

PJP: With so many projects on your plate, I'm curious what attracts you to the ones you decide to work on?

ST: Oh God, I didn't mean to have so many projects happening at once this year, but you don't get to choose when things go. The play that's opening at Manhattan Theatre Club in the spring, I started in 2011. And this TV show has been in the works for two years. And the movie just kind of appeared. So I'm just trying to keep my head above water at the moment.

But in general, I'm attracted to work about women, obviously, about families, motherhood, gender relationships, small towns, science, generational divide, living and dying … I think that's mostly it. I try to only work on projects that speak to some deep fear of mine. Because I know I'll finish the project in order to sedate the terror. If I'm not scared to write it, I'll get bored halfway through and abandon it.

PJP: What's next for you?

ST: My plate is so full now, I'm just thinking until next October, when the TV show will hopefully premiere and the play will have opened and the movie will be done. And then I want a break. I want to spend time with my husband and my son, somewhere nobody can reach us. I want to get pregnant again. That would be nice.

The Theories:
The Grandmother Hypothesis and Menses as Defense

The theories in the play are real although the characters in the play are fictional. In reality, there are often several people involved in the development of a theory.

The Grandmother Hypothesis holds that there was an evolutionary advantage for women who lived beyond menopause and cared for their grandchildren. Since these children were more likely to make it to adulthood and reproduce, the genes that select for long life were passed on, resulting in women living well after menopause.

Menses as Defense against pathogens introduced by sperm was proposed by Margie Profet *(see profile below).* She said that women menstruated in order to defend the uterus and the endometrial layer from infection that could be introduced by the male through pathogens accompanying sperm. Her theory was very controversial and was criticized in the same way Rachel is in the play. The "why" of menstruation is still debated.

The Scientists:
Key Figures in Female Evolutionary Biology

While the characters in *The How and the Why* are fictional, the science discussed in the play is based on real theories by real scientists.

George C. Williams was an evolutionary biologist who helped shape modern theories of natural selection. He pioneered the prevailing theory that natural selection works at the level of the gene and the individual—not for the benefit of the group or species (though there is disagreement and a significant number of scientists who favor group selection). His 1966 book *Adaptation and Natural Selection* worked to clarify this central question about whether natural selection works to favor elements as small as a gene or as large as a whole species. Richard Dawkins' 1976 book *The Selfish Gene* built upon Williams' ideas and made them available to a wider audience.

Williams' article "Pleiotropy, Natural Selection and the Evolution of Senescence" appeared in Evolution in 1957 and laid out the outline of what is now known as "the grandmother hypothesis." His original theory suggests that menopause and prolonged life after menopause might be advantageous

for humans. It does not suggest that grandmothers might contribute to the success of their grandchildren. It does introduce several major concepts, including the idea that senescence (or aging) is synchronized by natural selection, and the idea of antagonistic pleiotropy—that one gene may control multiple traits, including at least one that is beneficial to the fitness of the animal and another that is detrimental to it. In this way, a gene that caused both increased reproduction early in life and aging later in life would still be adaptive evolution.

Further development of the grandmother hypothesis and the potential advantages of human grandmothers to their offspring continues to be done by other scientists, such as Kristen Hawkes.

Kristen Hawkes is an anthropologist at the University of Utah and a Collaborative Scientist at the Yerkes National Primate Research Center. Her work focuses on the history of evolution and is driven by the hypothesis that grandmothering is a fundamental shift in the human genus that differentiates us from other great apes. She has published on the grandmother hypothesis in many scientific journals and in Grandmotherhood: The Evolutionary Significance of the Second Half of Life. She has studied in hunter-gatherer populations, including the Ache of Eastern Paraguay and the Hadza of Northern Tanzania.

> ***"The grandmother hypothesis highlights key differences in life history between people and our closest living relatives, chimpanzees, including the substantially greater longevity in humans—even though fertility ends at about the same time in both species."*** *—Kristin Hawkes*

Sarah Blaffer Hrdy is an anthropologist who uses a lot of evolutionary biology in her work. She received the W.W. Howells Prize for outstanding contributions in biological anthropology in 2000 and 2012 and is the author of *Mother Nature: A History of Mothers, Infants and Natural Selection* (written after receiving a Guggenheim Fellowship), *Mother Nature: Maternal Instincts and How They Shape the Human Species*, and *Natural Selection and Mothers and Others: The Evolutionary Origins of Mutual Understanding*.

Her work shocked people because she discussed the prevalence of infanticide and abortion across the animal kingdom. She also has theorized that female monkeys will copulate with many males to confuse parentage—so the males

will not kill offspring—and that primates are designed for alloparenting because it is so costly and time consuming to raise a young primate. She has been accused of personalizing her work and has written about how her ideas were critiqued because she is both a scholar and a woman.

> ***"I found myself torn between my work and an admittedly adorable but insatiably demanding human baby."***
> — *Sarah Hrdy in* Discover *magazine, March 2003*

Margaret "Margie" Profet is an American evolutionary biologist. The daughter of two Berkeley-trained engineers, she has degrees in political philosophy and physics and also studied mathematics.

With no formal training in evolutionary biology, Profet caused a stir in the scientific community when, in 1993, she published her findings on the evolutionary role of menstruation as a defense against pathogens introduced by sperm, and other theories about allergies and morning sickness as ways of eliminating pathogens, toxins and carcinogens from the body. Also that year, she received a MacArthur "Genius" Award, which drew attention to her theories and led to profiles in major science and news outlets.

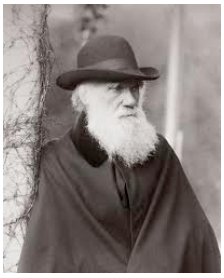
Profet told a dream researcher, professor of psychology Deirdre Barrett, that the idea for her article about menstruation came in a dream about black triangles in a red field.

Because of her lack of background in the field, Profet was ill-equipped to deal with the criticism lobbed against her ideas. In 1996, her theories were rebutted point by point by anthropologist Beverly Strass-mann in the *Quarterly Review of Biology*.In 2005, Profet disappeared from the Boston area and was missing for seven years. Friends and family were concerned and hinted she had serious psychological problems. In 2012, she was reunited with her family after having been sick and living in poverty. Profet said she had not realized her family was looking for her until a friend saw it online.

Beverly Strassmann is a professor of anthropology at the University of Michigan and the director of a 27-year study of the human biology of the Dogon of Mali. She countered Margie Profet's claims about menstruation in a1996 article in the *Quarterly Review of Biology*, "The Evolution of Endometrial Cycles and Menstruation."

Major Figures in Evolutionary Biology

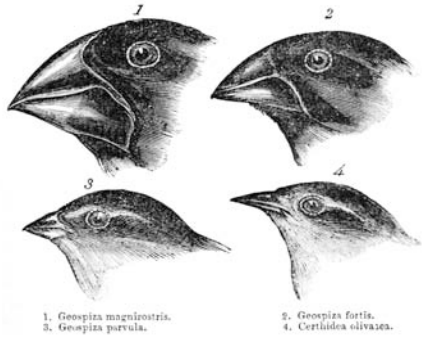
Many of the individuals below are mentioned in the play. Others, while not mentioned, are key contributors to evolutionary biology. Certainly there are many others who are not listed below.



Charles Darwin (February 12, 1809 – April 19, 1882) was a British scientist who laid the foundations for how we think about evolution.

He was born to a wealthy Shropshire family and attended Edinburgh University, planning to study medicine but switching to divinity. In 1831 he joined a five-year scientific expedition on the HMS Beagle. During the voyage Darwin read Lyell's *Principles of Geology,* which suggested fossils in rocks were millions of years old. This was at a time when most Europeans believed God created the world in seven days, as described in the Bible.

On the voyage he observed and collected many new species of animals, but his breakthrough came in observations he made in the Galapagos Islands. He noticed that each island supported finches that were closely related but varied in key ways such as beak size and shape. After he returned to England, he began to puzzle out his observations and gradually developed the theory of evolution occurring through a process of natural selection. The theory is that animals or plants that are best suited to their environment are more likely to survive and reproduce—passing on those helpful characteristics to their offspring and changing a population over time (such as the variations he observed in the size and shape of beaks in the finches, which would be called Darwin's finches).



He worked on his theory for 20 years and after discovering another naturalist, Alfred Russel Wallace, had a similar idea, the two scientists made a joint announcement in 1858 and Darwin published *On the Origin of Species by Means of Natural Selection* in 1859. The book was extremely controversial because the logical extension of his ideas was that humans were just another species (homo sapiens) and could have evolved from similar species, which was seen to undermine the authority of the church.

Almost as controversial was his theory of sexual selection, put forward in his book *The Descent of Man,* which argued that females selected mates for the

most advantageous traits to pass on to offspring. The logical extension of this idea was that human females had interest in the desirability of male traits, which was at odds with the prevailing Victorian attitudes that females were passive receptacles rather than having an interest or volition in sex.

Richard Dawkins (born March 26, 1941) was born in Nairobi and educated at Balliol College at Oxford University, where he is an emeritus fellow of New College. He is an evolutionary biologist, atheist and writer who is gifted at bringing scientific ideas into the public discourse. His books include *The Selfish Gene*, *The Extended Phenotype*, *River Out of Eden*, *The Blind Watchmaker* and *The God Delusion*. He created the Richard Dawkins Foundation for Reason and Science. He is a proponent of the gene-centered view of evolution, which posits that the gene is the principle unit of selection in evolution. He is known for a somewhat cantankerous personality and has clashed with other scientists and thinkers such as Stephen Jay Gould. He is an ardent critic of creationism.

> ***"We admit that we are like apes, but we seldom realise that we are apes."*** — Richard Dawkins

Theodosius Grygorovych Dobzhansky (January 24, 1900 – December 18, 1975) was a prominent geneticist and evolutionary biologist. He was born in Imperial Russia in the region now known as Ukraine and immigrated to the United States in 1927. His most well-know work is *Genetics and the Origin of Species*, published in 1937, which is a cornerstone of modern synthesis of evolutionary theory and lab work. He provided laboratory evidence for natural selection when there previously had been only field observation. He worked with the fruit flies Drosophilia. One key discovery was that naturally occurring mutations provided the raw material for natural selection to act upon.

Since 1981, the Theodosius Dobzhansky Prize has been awarded annually by the Society for the Study of Evolution "to recognize accomplishments and the future promise of an outstanding young evolutionary biologist. The prize was established in memory of Professor Dobzhansky by his friends and colleagues, and reflects his lifelong commitment to fostering the research careers of young scientists."

Stephen Jay Gould (September 10, 1941 – May 20, 2002) was an American evolutionary biologist, paleontologist and well-known popular science writer. He was a professor at Harvard University. With fellow scientist Niles Eldredge, he developed the

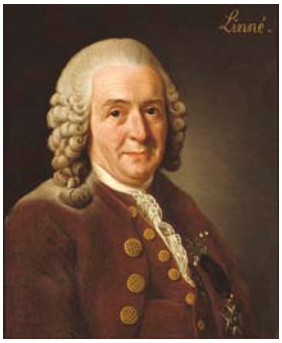
theory of punctuated equilibrium, which is that evolutionary change in the fossil record came in sudden bursts rather than as a slow and steady process. His book *Ontogeny and Phylogeny* drew attention to the relationship between how an organism develops (from egg to adulthood) and how organisms evolve. He also wrote *The Structure of Evolutionary Theory*, a book that took him decades to write and that synthesizes Darwin's ideas with his own ideas on macro-evolutionary theory. He wrote essays on popular science for *Natural History Magazine* and many books intended for a mass audience. He was a recipient of a MacArthur prize.

Jean-Baptiste Lamarck (August 1, 1744 – December 18, 1829) was a French naturalist and soldier. He was a proponent of evolution and developed a systematic theory of evolution.

He argued that the environment gives rise to changes in animals. He outlined his theories in several books: *Recherches sur l'Organisation des Corps Vivant*, *Philosophie Zoologique* and *Histroire Naturelle des Animaux sans Vertèbres.*

Lamarckism or Lamarckian Inheritance is an example of the way a theory may work its way out and in of scientific discourse. It is the idea that an organism can pass on characteristics it acquired during its lifetime to offspring, known as the "heritability of acquired characteristics" or "soft inheritance." He also believed animals were continually evolving to be more complex and more perfect. Darwin rejected aspects of Lamarck in his *On the Origin of Species* and Mendelian genetics supplanted the notion of inheritance of acquired traits.

Lamarckian evolution had generally been scientifically dismissed. However, some scientists are now interested in the way in which certain traits, such as a paternal high-fat diet in rats, could transfer to offspring a propensity for obesity that was not in specific genes.



Carl Linneaus (May 23, 1707 – January 10, 1778) was a Swedish botanist, biologist and physician. He is most well known for introducing to biology the system of binomial nomenclature using Latin (two names, the genus and species—for example, Homo Sapiens) and as the father of modern taxonomy (a system of classifying living things).

His original *Systema Natura* was 12 pages—by its 10th edition it classified 4,400 species of animals and 7,700

species of plants. It systematized the irregular and often unwieldy system of referring to specific species and allowed for clearer communication between scientists. Linneas based his groups on a hierarchy based on observable similarities, starting with Kingdoms, then Classes, then Orders, then Genera, then Species, and finally, Varieties. The organization system has changed and expanded over time, but operates in largely the same fashion as Linnaeus imagined.

Thomas Robert Malthus (February 12, 1766 – December 23, 1834) was a British scholar and cleric with interests in political economy and population. He wrote *An Essay on the Principle of Population*, in which he observed that a population will be checked by famine or disease sooner or later. This concept came to be known as a Malthusian catastrophe. His work was influential to both Darwin and Wallace.

Ernst Mayr (July 5, 1904 – February 3, 2005) was a German-born evolutionary biologist, taxonomist and scientific historian. He wrote the book *Systematics and the Origin of Species*. He helped define the modern synthesis of evolutionary theory, particularly in understanding the mechanisms of evolution from one species to another and the importance of species as a keystone of evolution. He was an ardent supporter of the Scientific Method as the correct approach to scientific research.

One of Darwin's unanswered questions in *On the Origin of Species* encompasses two of the same questions that form the title of the play: How and why do species originate? If species are distinct from one another, but evolution is a steady gradual process, then there must be some separation or gap between them. Mayr proposed that when groups become separated for a long period of time, they eventually develop different traits and can no longer interbreed. These "isolating mechanisms" help create new species and discourage populations from interbreeding.

Johann Gregor Mendel (July 22, 1822 – January 06, 1884) was an Austrian biologist and monk. He discovered the basics principles of heredity through meticulous experiments with his monastery's pea plants. Working at the same time as Darwin, his work was ignored until long after both Mendel and Darwin were dead.

Without the benefit of microscopy, Darwin knew that a lack of explanation for heredity was a hole in his theory of natural selection. Darwin hypothesized that there was some sort of blending of parent traits. Mendel disagreed with the idea of blending traits but assumed there was some method by which traits were carried by tiny particles and inherited intact by the next generation.

Mendel crossbred pea plants to see how a few specific traits would be transferred across subsequent generations, which allowed for the development of the theory of genes (Mendel never used the term "gene" himself) and dominant and recessive traits. He worked with 30,000 plants over eight generations. This proved that an adaptive mutation could be spread through a population but never be entirely wiped out. His work was rediscovered in 1900.

John Maynard Smith (January 6, 1920 – April 21, 2004) was an emeritus professor of biology at the University of Sussex. He attended Eton College, then Trinity College at Cambridge in Engineering and then Zoology at University College London. He was the founding Dean of Sussex University's School of Biological Science. He introduced mathematical models and game theory to the study of behavior and showed that an individual's success often depends on the behavior of other individuals. His 1978 book *The Evolution of Sex* pointed out that organisms that reproduce sexually produce offspring of both sexes, but those that do not reproduce sexually need only produce females. He also had a popular science series *The Theory of Evolution* with Penguin books.

Alfred Russel Wallace (January 8, 1823 – November 7, 1913) was a Welsh naturalist, explorer and biologist. He independently conceived of the theory of evolution through natural selection at the same time as Charles Darwin, and they co-presented the idea in 1858. He is often known as the "forgotten naturalist" because Darwin's works receive more attention than his, in spite of the fact that Wallace did extensive fieldwork in the Amazon and the Malay Archipelago. Also skilled at geography, he was a pioneer in biogeography, the geographical distribution of animals and other life forms. He also pioneered the theory of warning coloration in animals. His statue was recently unveiled at the Natural History Museum in London.

Wallace and Darwin differed in their views on evolution. Darwin thought that evolution worked on the level of the individual and only indirectly on the group. Wallace thought that evolution might work against the individual in favor of the overall benefit of the group. When you hear biologists refer to themselves as Darwinian, it is in part in reference to this distinction.

The Poetry: Tennyson and Edna St. Vincent Millay

It is striking the way the poetry of Edna St. Vincent Millay is woven through a play about science. We also found this poem by Alfred Lord Tennyson (1830 – 1868) particularly inspiring during the rehearsal process.

The 'How' and the 'Why'
I am any man's suitor,
If any will be my tutor:
Some say this life is pleasant,
Some think it speedeth fast:
In time there is no present,
In eternity no future,
In eternity no past.
We laugh, we cry, we are born, we die,
Who will riddle me the how and the why?
The bulrush nods unto his brother
The wheatears whisper to each other:
What is it they say? What do they there?
Why two and two make four? Why round is not square?
Why the rocks stand still, and the light clouds fly?
Why the heavy oak groans, and the white willows sigh?
Why deep is not high, and high is not deep?
Whether we wake or whether we sleep?
Whether we sleep or whether we die?
How you are you? Why I am I?
Who will riddle me the how and the why?
The world is somewhat; it goes on somehow;
But what is the meaning of then and now!
I feel there is something; but how and what?
I know there is somewhat; but what and why!
I cannot tell if that somewhat be I.
The little bird pipeth 'why! why!'
In the summerwoods when the sun falls low,
And the great bird sits on the opposite bough,
And stares in his face and shouts 'how? how?'
And the black owl scuds down the mellow twilight,
And chaunts 'how? how?' the whole of the night.
Why the life goes when the blood is spilt?
What the life is? where the soul may lie?
Why a church is with a steeple built;
And a house with a chimney-pot?
Who will riddle me the how and the what?
Who will riddle me the what and the why?

Edna St. Vincent Millay (1892 – 1950 was a Pulitzer Prize winning poet and playwright. Known for brilliance as a writer she became equally known for her feminist activism and numerous love affairs.

My candle burns at both ends;
It will not last the night;
But ah, my foes, and oh, my friends —
It gives a lovely light!"

— "First Fig," from the 1922 book
A Few Figs from Thistles

Safe among the solid rock the ugly houses stand:
Come see my shining palace built upon the sand.

— "Second Fig" from the 1922 book *A Few Figs from Thistles*

The Biology: Evolution and the Human Female

"I should say that the majority of women (happily for them) are not very much troubled with sexual feeling of any kind." — William Acton, physician and sexologist, 1857

"It must be distinctly recognized that the assertion that sexual passion commands more of the vital force of men than of women is a false assertion, based on a perverted or superficial view of the facts of human nature."
— Elizabeth Blackwell, one of the first women in the United States to obtain a medical degree, 1902

In biology, evolution refers to the cumulative changes that occur in a population over time. When naturally occurring mutations create characteristics that have a survival or reproductive advantage, these traits tend to increase in a population. Traits that are a disadvantage to survival tend to decrease. Traits that develop during a creature's lifetime and cannot be passed on to another generation are not examples of evolution.

Research on evolutionary biology in the human female did not begin until the late 19th Century. Initially, women were viewed as passive receptacles for semen from the male. In fact, even the role of the egg was not understood at first. Women exhibiting sexual behavior or desire were considered pathological.

Charles Darwin's theory of sexual selection suggested that females of any species made choices in sex partners based on their desirable traits (such as

plumage in birds)—a key component in inheritance. At a time when human species were not thought to have sexual feeling, the idea that females made choices so key to the inheritance of traits was revolutionary.

Early research revealed that human women generally ovulate mid-cycle and that estrogen regulates ovulation. Researchers looked for estrus (heat) in human females and by the 1960s mixed results led many researchers to conclude that estrus had been lost in recent human evolution. Biologist Randy Thornhill and evolutionary psychologist Steven Gangestad have argued that estrus was not lost, but has been concealed, like human ovulation.

In short, there is an evolutionary arms race between human males and females. If a male wants offspring, it is advantageous to mate with as many females as possible. However, for females it is beneficial to conceal the time of heightened fertility. Doing so means a male cannot know if he has mated with the female while she was fertile—thus he has a vested interest in staying with her, to guarantee offspring. And given the amount of time and care human children require, offspring are more successful if they benefit from the contributions of both parents. Human women's physical appearance does not change with fertility (as opposed to many primate species), creating the appearance of continuous fertility.

Scientific research is always a process of building on, revising or discarding earlier theories. Current theories suggest that human females menstruate because the body would require more energy to maintain the endometrium than to shed it on a cyclical basis. Current theories around menopause suggest it is advantageous for human females to stop ovulating because mortality risks increase with pregnancies in older females, as do problems with the egg. Ultimately, it is advantageous to invest more time in the success of existing offspring or in raising grandchildren.

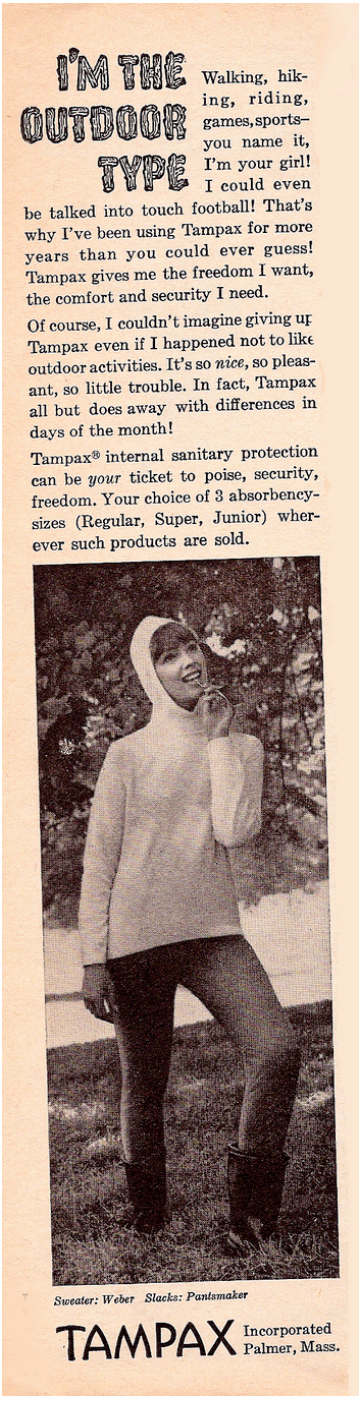
The Taboos: A Brief Cultural History of Women's Bodies

The cultural taboos surrounding menstruation have been strong around the world throughout history. In fact, "taboo" is a Polynesian word and originally referred to a place restricted from menstruating women.

The ancient Greek physician Hippocrates thought that a woman's womb was likely to wander around the

body causing illness or hysteria (the word "hysteria" is derived from the Greek word for "womb"). In AD 77 Pliny the Elder wrote his *Natural History*, in which he declared that menstrual blood could make seeds infertile, kill insects, flowers and grass, cause fruit to fall from trees, and drive dogs mad.

Historically as well as today, some tribes and religions have required women to avoid the community and sacred spaces while menstruating, perform ritual purification after menstruation, or both. Popular medical treatments for women during the Victorian era seem shocking by modern standards. Medical doctors would masturbate a "hysteric woman" until she came to a "hysterical paroxysm." Vibrators and the "water treatment" (shooting jets of water at the female genitalia) became popular methods for treating a variety of women's illnesses. In some cases, parts of the female reproductive system were surgically removed in the belief that the womb was a cause of various mental illnesses in women.



During the 1950s and '60s, health guidelines for menstruating women suggested avoiding exercise, swimming, and showers that were too hot or cold. The first time the word "period" was mentioned on television was in a 1985 Tampax commercial.

Today, women's bodies are still a source of anxiety and controversy. One question is whether women should stop menstruation altogether by continuously taking the hormones in birth control. Another concerns the heightened risk of some types of cancer from hormone replacement therapy during menopause. And in both cases, hormones may escape in urine and make their way into the water supply, where they can cause gender changes in frogs and fish.

Another concern is that medical research has been slow to recognize that differences between men and women might be important in drug research. A landmark study on the heart benefits of daily aspirin therapy did not include any women. So more work still needs to be done on a variety of issues surrounding women's health.

The Discrimination: Gender Bias in Science

In 2005, Harvard President Lawrence Summers suggested so few women held tenured jobs in the hard sciences due to "issues of intrinsic aptitude." His suggestion that biological differences between genders might be responsible for the lack of women in the sciences—as opposed to other factors such as discrimination—opened a heated debate about why there are still so few women in science.

A 2012 study from Yale University showed that American science professors view female undergraduates as less competent than their male counterparts despite comparable accomplishments and skills. The Yale study asked professors to evaluate the same one-page resume of a potential student employee, altering only the name (John or Jennifer). They were asked to score the application for competence on a scale from 1 to 7 and to offer a starting salary.

The professors gave John an average score of 4 and Jennifer a 3.3. John was offered a salary of $30,328 while Jennifer was offered $26,508. Strikingly, the bias was not related to the professor's age, sex, field or tenure.

Another study, funded by the National Science Foundation and titled "Gender Segregation in Elite Academic Science," found that in a survey of 2,500 biologists and physicists at elite institutions of higher education, a majority of both male and female scientists viewed gender discrimination as a factor in women deciding not to choose a career in science. However, male scientists tended to feel that the discrimination took place in grade school, while female scientists believed the discrimination was ongoing.

In an October 3, 2013 article in *The New York Times* entitled "Why Are There Still So Few Women in Science?," many of the women interviewed described discouragement and discrimination by advisors and colleagues while others worried how they would conduct research and teach once they had children. Even as more women enter scientific fields, discrimination and the lack of high-ranking women at universities remains an issue.

> ***"We live in a scientific age, yet we assume that knowledge of science is the prerogative of only a small number of human beings, isolated and priest like in their laboratories. This is not true. The materials of science are the materials of life itself. Science is part of the reality of living; it is the way, the how and the why for everything in our experience."*** *—Scientist Rachel Carson in a 1952 speech*

The Gap: The Gender of Science

This article courtesy of Northwestern University's Women's Health Research Institute

Science is gendered. The core of science as a systematic accumulation of knowledge gained through observation and experimentation reveals science as a uniquely human activity mediated through the lens of gender. As men have, historically, claimed a larger role in the development and perpetuation of the sciences, they have influenced the very patterns, languages, and methods used by scientists even today.

This male-dominated realm has subtly subverted both the biological and intellectual role of the female, touting the role of the male as active and female as passive. Even the textbook definition of reproduction paints females in a biologically-passive state, stating *the egg is fertilized by the sperm*, accrediting the "action" of life to be male-mandated—in other words, the docile female egg awaits stimulation from the ever-mobile sperm.

These predetermined gender biases have permeated nearly every facet of the scientific realm. The very structure of many scientific careers, which places an extreme emphasis on research accumulation during one's 20's and 30's, directly coincides with women's "biological clocks," placing *scientific professionalism* and *domesticity* in opposition. The same career dedication that paints men as ambitious connotes women as selfish.

As the 2005 Harvard President rudely reminded us, the biases that still suppress women in the sciences have questioned not only females' intellectual competencies but also women's biological responsibilities. This begs the question: *Do women have to suppress their femininity to find success in a scientific career?*

Instinct tells us *"no"*—yet, a 2012 Yale study found that male scientists are more likely to be hired over females with equal qualifications. And, nationally, women hold less than 18% of science faculty positions.

Charged to address this gender gap in academia as well as increase the level of sex-and gender-based research, Northwestern's Women's Health Research Institute came to fruition. We urge women to participate in our Illinois Women's Health Registry, which addresses the underrepresentation of women in scientific and clinical research studies and provides women the opportunity to impact women's health through participation in studies that explore sex and gender differences. It's time to celebrate, not suppress, women's contributions to the sciences and stand with men, shoulder-to-shoulder, as we set a new standard for scientific academia.

To learn more about Northwestern University's Women's Health Research Institute, visit our website at *womenshealth.northwestern.edu*.

Scientific and Medical Terminology

Abstract — When proposing an academic or scientific article for publication or to present at a conference, it is traditional to submit an abstract or summary of the article, paper or presentation.

Adrenal Glands — Part of the endocrine system; they sit on top of the kidneys. They are responsible for releasing hormones (such as cortisol) in response to stress. These hormones are also involved in the regulation of metabolism.

Alloparenting — When members of a family group (grandparents, aunts uncles) other than the mother are involved in child rearing.

Amenorrheic — The suppression of menstruation by any means other than pregnancy. For example, famine could make females in a population amenorrheic.

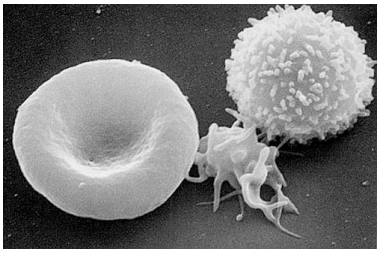
Beta Blocker — A class of drugs used to regulate beta reception in the heart muscle and in other tissues that are part of the sympathetic nervous system. Developed to treat certain cardiac and hypertension issues, they have an unsanctioned use to reduce performance anxiety among performers, musicians and public speakers.

Biology — Biology is the branch of science dealing with living things.

Bonobo Monkeys — Are a great ape and one of two species in the pan genus, the other being chimpanzees. They are found primarily in the Congo in Africa. They are one of the closest primate relatives to humans. Bonobo communities are matriarchal and they are known for their sex practices, which seem to fulfill a variety of roles outside of procreation—stress reduction, preventing conflict, and social status among them. They are an endangered species and live about 40 years in captivity.

Breast Cancer (Phase 3) — Stage or phase three breast cancer means the cancer has spread beyond the tumor to other tissues, such as the muscles and lymph nodes, but it has not spread to more distant organs. At this stage, cancer is divided into the categories operable and inoperable. Treatments at this stage may involve a mastectomy and radiation as well as hormone therapy or chemotherapy.

Carcinogenic — A substance that is shown to increase the risk of cancer.



Cells — Cells are the basic structural unit of all living creatures. A cell is the smallest unit of an organism that can replicate on its own. Cells often have different functions in an organism. Immune cells attack pathogens to protect the body from infection. Blood cells include red blood cells (erythrocytes), white blood cells (leukocytes) and platelets (thrombocytes). Red blood cells carry oxygen and carbon dioxide. White blood cells are also part of the immune system. Platelets are cell pieces involved in the flow of blood and blood coagulation. T Cells and B Cells (lymphocytes) are both types of white blood cells involved in immunity. *(Pictured above: Electron microscope image of a T cell (from left), a platelet and a red blood cell)*

Cervix — Derived from the Latin for "neck of the womb," it is the inch-long connection between the top of the vagina and the bottom of the uterus. The cervical opening allows menstrual blood to flow and a fetus to pass from the uterus; it also allows sperm into the uterus. It does thicken during pregnancy and at menopause.

Chromosome — The organized DNA, protein and RNA found in cells; it contains genes and other regulatory elements.

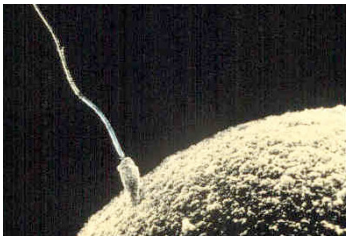
Concealed Ovulation — Human women do not have external physical changes that allow males to know when they are fertile (in some apes there are visible changes in the genitalia).

Cortisol — A hormone produced by the adrenal glands that mediates metabolism and immunosuppression; it has anti-inflammatory properties.

Covert Menstruation — The term used for animals that reabsorb the endometrium at the end of a reproductive cycle.

DNA — Deoxyribonucleic acid is the hereditary material in humans and almost all other organisms. Most DNA is located in the cell nucleus (nuclear DNA) but it can also be found in the mitochondria (mitochondrial DNA).

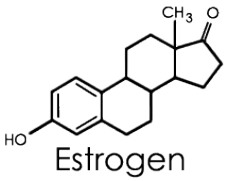
Egg (Ova) — In human females, the cell involved in reproduction. It is the largest cell in the body and contains the genetic material (23 chromosomes) that when combined with the male sperm at fertilization, rapidly begins dividing. Ova are stored in the ovaries and released in a regular cycle. In humans and other placental animals, fertilization occurs inside the female. *(Pictured at right: Human sperm and ova combining)*



Endometrium — The mucous membrane that lines the interior of the mammalian uterus.

Endocrine System — The collection of glands that produce the hormones that regulate such things as growth, metabolism, sexual development and stress response. It includes the pituitary, pineal, thyroid, thymus and adrenal glands as well as the pancreas and the ovaries or testes.

Estrogen — One of the primary female sex hormones, which helps regulate both the menstrual ad estrus cycles. Estrogen levels decline at menopause and synthetic estrogen is commonly used in Hormone Replacement Therapy. *(Pictured at right: Diagram of the molecular structure of estrogen)*



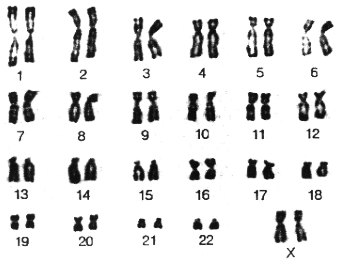
Estrus — A regularly current state of sexual excitability in which a female is most receptive to the male and capable of conceiving. In many animals this is called being in "heat." Because female humans can have sex throughout their cycle and do not have changes in appearance, there has been discussion about whether or not estrus around ovulation exists, or what form it may take for human females. In many animals this is manifested by physical and pheromonal as well as behavioral signals.

Evolution — In biology evolution refers to the cumulative changes that occur in a population over time. When naturally occurring mutations in a population create characteristics that have a survival or reproductive advantage, these traits tend to increase in a population. Traits that are a disadvantage to survival tend to decrease in the overall population. Traits that develop in a creature's lifetime and cannot be passed on to another generation are not examples of evolution.

Evolutionary Biology — The field of biology that deals with the diversity of life on earth and asks questions about why certain traits or adaptations developed in certain species and what is advantageous about those traits for the continuation of the species.

Fitness — In evolutionary biology, fitness is the ability of an organism to survive and reproduce.

Genes — A molecular unit of hereditary material that is transferred from a parent to offspring. Part of evolutionary biology is based on the belief that species have an imperative to spread their own genetic material and that the most successful genetic adaptations will assure the success and continuation of those genes in the general population. *(Pictured at right: Human female gene karyotype)*



Genetic Diversity — The variations that occur in species through sexual reproduction allow for variation in genetic material, which increases a species opportunity to change and survive over subsequent generations.

Genotype — The inherited genetic instructions of an organism—its genetic code.

Grandmother Hypothesis — The grandmother hypothesis was proposed as an explanation for why some primates (including humans) live up to one-third of their lives after their fertility has ceased during menopause. In short, the theory states that the high cost of reproduction and the longer time period required to raise young to maturity, as well as the increased risk of mutations in the eggs in older females, meant that it was no longer advantageous to be continually reproducing. It might be more advantageous for a female to focus on the care of children she already has rather than have more children, especially as the risk of death increases with age. In addition, postmenopausal women can contribute to the knowledge of the group and some scientists have argued may be involved in alloparenting—grandmothers helping to raise the offspring of their children. George C. Williams first posited this hypothesis in his 1957 paper "Pleiotropy, Natural Selection, and the Evolution of Senescence."

Hormone Replacement Therapy (HRT) — The replacement of hormones such as estrogen with synthetic versions after menopause. Because hormone levels fluctuate during and after menopause, replacing hormones can relieve symptoms such as hot flashes and vaginal dryness and may help protect against osteoporosis. However, it can also increase the risk of breast cancer, heart disease and stroke, so HRT is controversial. For some women it is part of the pathologizing of women's health issues, and they do not want HRT.

The Hadza — An ethnic group living in north-central Tanzania who are still full-time hunter-gathers. A tribe of about 1,000, their language includes clicks. They were the subject of a recent PBS documentary and have been a group popular with scientists because their means of living has not undergone the changes that it has in other populations.

Hypothesis — A hypothesis in science is the first step in the scientific method. It is an educated guess based on knowledge and observation to explain a particular phenomenon. There should be no predetermined outcome in a hypothesis and it should be testable—able to be supported or refuted through scientific experiments or observation. As a hypothesis receives sufficient data through various independent scientific studies, it becomes a theory.

Hysteria — The word is actually derived from the Greek word for "womb." In ancient Greece (as well as Egypt and Rome) it was believed that a woman's womb wandered through the body because it was seeking children, causing behavioral changes and illnesses.

Hysterectomy — The removal of the uterus, sometimes with other female sex organs, often in response to a medical issue such as cancer tumors. At certain points in medical history, parts of the womb or female genitalia were removed to treat mental illness because it was believe to cause certain mental instabilities in women.

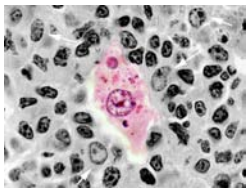
Karyotype — The number and appearance of chromosomes in the nucleus of a eukaryotic cell (an organism that has cells including a nucleus with genetic information).

Lactoferrin — A type of protein often present in human fluids such as milk, saliva, tears or menstrual fluid. It is part of the immune system and has antimicrobial properties. Lactoferrin is involved in sequestering iron to prevent it from being used by invading bacteria.

Lamaze — Developed by the French obstetrician Fernand Lamaze (1890 – 1957), it is a method of controlling pain during childbirth to facilitate delivery without medications. It involves breathing techniques.

Lymph nodes — Lymph is a clear fluid that travels through the body's capillaries to bathe cells and tissues, carrying oxygen and other nutrients and removing waste products like carbon dioxide. Lymph can build up if it is not drained away. The lymph vessels help move lymph throughout the body. The lymph nodes are rounded masses of lymphoid tissue that help filter harmful substances out of the lymph. They help filter bacteria out of the lymph by exposing them to lymphocytes and macrophages, which can engulf the

bacteria. Lymph nodes tend to cluster in areas such as the neck, groin and armpits. When a person has an infection, the lymph nodes may swell with this immune response.



Macrophage – A tissue cell of the immune system that is involved in the destruction of antigens such as bacteria and viruses. (*Pictured at right: A larger round macrophage highlighted in pink)*

Menarche — The first menstrual bleeding in female humans.

Menses — Blood, mucus and other material from the endometrial lining discharged by the female during menstruation.

Menstruation — The periodic discharge of blood and mucous tissue from the uterus or uterine lining (endometrium) and vagina in sexually reproductive humans (and some simians, bats and shrews).

Menopause — The cessation of menstruation.

Mitochondria — Part of a cell that helps convert energy from food into a form that cells can use. They also contain genetic material. Mitochondria has become an important tool in tracking genetic histories since it is present in only one copy of the 37 genes and does not recombine in reproduction. Mitochondrial DNA is inherited solely from the mother, which allows for the study of the relatedness of populations.

Natural Selection — The process by which advantageous traits in a population increase and disadvantageous traits decrease. For example, the beak of Darwin's finches on certain islands was adapted to eating a certain kind of seed. On a different island with different seeds, a thicker beak was more advantageous to eating food and became the most predominant beak.

> ***"A devil, a born devil on whose nature***
> ***Nurture can never stick, on whom my pains,***
> ***Humanely taken, all, all lost, quite lost.***
> ***And as with age his body uglier grows,***
> ***So his mind cankers. I will plague them all,***
> ***Even to roaring."***
> — *Prospero referring to Caliban,* The Tempest

Nature vs. Nurture – The modern sense of the phrase coined by the Victorian Francis Galton to refer to the ongoing efforts to understand the influence of heredity or genetics (nature) vs. the influence of environment (nurture). However, Shakespeare also used nature and nurture in *The Tempest*. Galton

was influenced by reading his cousin Charles Darwin's book *On the Origin of Species*. But the concept is not exactly Darwinian and it does set up a binary when in fact the two factors may be more complexly intertwined.

National Organization of Research Biologists — A fictional scientific professional organization, perhaps as a stand in for the Society for the Study of Evolution, which is the organization that awards the Dobzhansky Prize.

Oncology — Field of medicine that specializes in the treatment of cancer.

Ovulation — In human females, when the egg is released and available for fertilization by the sperm. It occurs about midway through the menstrual cycle when the endometrium is thickened. If a fertilized egg does not attach to the endometrium, blood will be shed during menstruation. While ovulation often occurs with menstruation, an egg is not necessarily released with every cycle.

Pathogen — Any agent that causes disease, usually a bacterium, fungus or other microorganism.

Panic Attacks — Symptoms of panic attacks include shortness of breath, the feeling of choking, a sense of impending doom, pain in the chest, nausea, dizziness, chills or heat flush. They can be treated by practicing calming skills, medication and therapy.

Placenta — An organ that develops during pregnancy and connects to the wall of the uterus. It connects to the fetus by the umbilical chord and provides oxygen and food to the fetus and removes waste products from its blood. During pregnancy the spiral arteries in the walls of the endometrium become straighter to allow greater blood flow to the placenta.

Pleiotropy — When one gene influences many seemingly unrelated traits.

Pleistocene — A geologic time period characterized by the appearance and recession of glaciation and the spread of hominids, as well as the extinction of megafauna such as mammoths, mastodons and saber-tooth tigers.

Phenotype — The collection of an organism's observable traits, they result from the expression of an individual's genes.

Phylogeny — The evolutionary development of a species or the evolutionary development of part of the organ or organism.

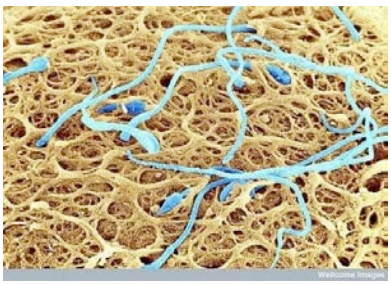
Physiology — The sub-discipline of biology, which deals with living organisms and their parts.

RNA — Ribonucleic acid is part of a group of molecules that help code, decode and regulate genes and their expression.

***Science* magazine** — A journal of original scientific research. It is affiliated with the American Association for the Advancement of Science.

Scientific Method — The scientific method is a systematic means of investigating observable phenomena used by scientists. It involves the stating of a problem, formulating a hypothesis, collecting of data and testing the hypothesis, and then reevaluating the hypothesis on the basis of those tests. Science in particular is continually revisiting hypotheses and peers in the same field may conduct research along similar lines that refutes, confirms or complicates earlier scientific studies and hypotheses.

Sexual Reproduction — Sexual reproduction allows for the contribution of half the genes of each parent to be combined in a subsequent generation. For humans this is in the combination of sperm and egg, which produces a new combination of genes. *(Pictured at right: Micrograph of human sperm on the surface of an egg)*



> ***"My conviction of the power of sexual selection remains unshaken; but it is probable, or almost certain, that several of my conclusions will hereafter be found erroneous; this can hardly fail to be the case in the first treatment of a subject. When naturalists have become familiar with the idea of sexual selection, it will, as I believe, be much more largely accepted; and it has already been fully and favourably received by several capable judges."*** — Charles Darwin, preface to the second edition of *The Descent of Man*

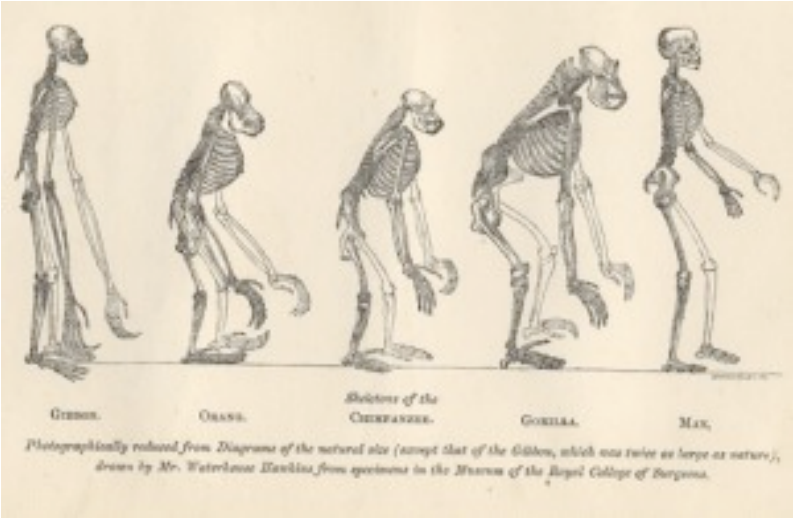
Sexual Selection — Scientist Charles Darwin first postulated a theory of sexual selection, that female choice is a key component in evolution, resulting in such male adaptations as gaudy plumage in male birds.

Senescence — The biological process of aging and the changes that occur on the molecular and cellular level in the aging body.

Scientific Theory – In science a theory is a rigorously tested statement of general principle, which accounts for observed aspects of the world. Scientific theories link facts and are supported by thousands of scientific experiments

over years and generations. They are never proven correct but stand as the explanation for observable facts until they are proven wrong by a new theory.

Sperm — Sperm is the male reproductive cell. It contains genetic material in the form of 23 chromosomes, which combine with the female ova in sexual reproduction. In humans the sperm has a flagellum, or tail, to propel the cell.



Photographically reduced from Diagrams of the natural size (except that of the Gibbon, which was twice as large as nature), drawn by Mr. Waterhouse Hawkins from specimens in the Museum of the Royal College of Surgeons.

Simian — Any of the suborder Anthropoidea of primates, which includes monkeys, apes and humans. *(Pictured above: Thomas Huxley drawing from* On the Origin of Species)

Stress Response Axis — Also known as the HPA Axis or Hypothalamic-Pituitary-Adrenal Axis, it is the complex set of interactions between these glands as part of the neuroendocrine system, which controls the body's reaction to stress as well as regulating digestion and the immune system.

Stockholm Syndrome — Named for a 1973 bank robbery in which the bank employees—after being held hostage for 131 hours—seemed to have formed an emotional bond with their captor. It is now used to describe any case in which a prisoner seems to identify with a captor and perhaps responds in ways that seem against his or her interest.

Taxonomy — A system of classification. In biology it is primarily a way of grouping living things based on characteristics from shared descent from common ancestors.

Toxicity — The degree to which a substance can damage a living organism.

Uterus — Major female reproductive organ in most mammals, including humans. It is the womb where a fetus will grow, if pregnancy has occurred and is not disrupted in some way.

Xanax — A medication used to treat anxiety disorders. It is from the family of drugs called benzodiazepines, which work by slowing down the movement of chemicals in the brain.

Yerkes Primate Research Center — A real center of scientific study at Emory University. "The Yerkes National Primate Research Center conducts essential basic science and translational research to advance scientific understanding and to improve the health and well-being of humans and nonhuman primates."

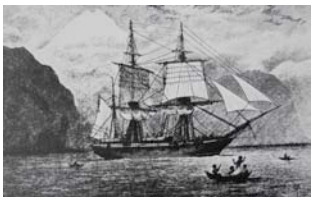
Timeline: Origins of Evolutionary Biology

610-546 BC The Greek philosopher Anaximander suggests that all life evolved from fish in the sea.

1735 Carl Linneaus publishes the first volume of *Systema Naturae*, laying the foundations for modern taxonomy.

1809 Charles Darwin is born in Shrewsbury, England.

1830 Charles Lyell publishes *Principles of Geology*. His insights about the layers of history in geological strata are influential for Charles Darwin.



1831 Charles Darwin leaves on the HMS Beagle for a five-year journey. His observations of nature during the trip will be the basis for his theories.

1857 William Acton, leading physician and Victorian sexologist, writes Functions and Disorders of the Reproductive Organs in Youth, in Adult Age and in Advanced Life, in which he writes that most women "are not very much troubled with sexual feeling of any kind."

1858 Charles Darwin and Alfred Russel Wallace co-present the theory of evolution through the means of natural selection, on which they each had been independently working.

1859 Charles Darwin publishes *On the Origin of Species by Means of Natural Selection*. The first printing sells out.

1865 The Czech monk Gregor Mendel publishes his research on an eight-year study of pea plants that looks at the inheritance of traits from one generation to another and determines the principles of dominant and recessive traits. The significance of his work will not be realized and used by other scientists for 35 years.

1871 Charles Darwin's *The Descent of Man* is published, in which he argues that females are a determining factor in sexual selection and the evolution of species.

1911 Undergraduate researcher Alfred Sturtevant realizes that he can map the location of genes and the mutations in genes in fruit flies he is studying.

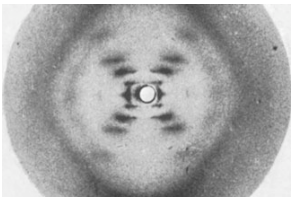
1925 A teacher in Tennessee is tried after a law makes it illegal to teach any scientific theory that denies divine creation. It becomes known as the Scopes Monkey Trial.

1942 Ernst Mayr publishes Systematics and the Origin of Species, synthesizing Darwin's evolutionary theory with Mendel's theories on inheritance. The work also proposes that if populations became isolated from each other, each could develop traits so different from the other that they could no longer interbreed and thus became separate species.

1953 James D. Watson and Francis Crick discover the structure of DNA. Scientist Rosalind Franklin will not be given credit for her contributions to the discovery of the double helix until years later.

1957 George C. Williams' article "Pleiotropy, Natural Selection and the Evolution of Senescence" appears in *Evolution*, laying the foundations of what will come to be known as "the grandmother hypothesis." He theorizes that because human infants are risky to give birth to and those risks increase with the mother's age, it is adaptively advantageous for human females to stop being reproductive and to care for the offspring they already have.

1958 Rosalind Franklin dies of ovarian cancer. Her death means she will not be able to share the Nobel Prize with Watson and Crick, as the prize is not awarded posthumously.
(Pictured at right: Franklin's Photo 51 is key in understanding the double-helix structure of DNA)



1962 Watson, Crick and Wilkins win the Nobel Prize for Physiology or Medicine for "their discoveries concerning the molecular structure of nucleic acids and its significance for information transfer in living material."

1987 Congress approves funding for the Human Genome Project, an effort to map and understand the function of all human genes.

1993 Lacking a background in evolutionary biology, Margaret "Margie" Profet publishes on menstruation as a defense against pathogens carried with male sperm. She receives a MacArthur "Genius" Prize.

1996 Beverly Strassmann counters Margie Profet's claims about menstruation in her own article in the *Quarterly Review of Biology*, "The Evolution of Endometrial Cycles and Menstruation." Most scientists feel this is the complete debunking of Profet's claims.

2003 The Human Genome Project, an effort to map all known human genes, is completed.

Euphemisms for Menstruation from Around the World

The curse
Aunt Flo
Aunt Ruby
On the rag
Little sister has come (China)
There are Communists in the Funhouse (Denmark)
The English have arrived (France)
I'm with Chico (Brazil)
Jenny has a red dress on (Australia)
The cranberry woman is coming (Germany)
The tomato soup is overcooked (Netherlands)

Method and Madness:
Scientific Method and Major Shifts

> ***"Man, being the servant and interpreter of Nature, can do and understand so much and so much only as he has observed in fact or in thought of the course of nature: beyond this he neither knows anything nor can do anything."*** — Francis Bacon, *The New Organon, Book One*

The Scientific Method has long been depicted as a flow chart.

It begins with the formulation of a problem or question and is followed by research, the formulation of a hypothesis and the testing of that hypothesis with observation and or experimentation. Next comes analysis of results and the confirmation, rejection or modification of the hypothesis. And then follows repeated testing by the scientist and other scientists.

The narrative that comes with this type of science is one of steady progress forward. In many ways that basic structure of scientific enquiry and peer review still stands, but in other ways it has come into question.

In 1962, physicist Thomas Kuhn wrote the seminal work *The Structure of Scientific Revolutions*, which brought the notion of paradigm shifts into popular culture. He argued that generations of scientist are bound by the norms and understanding of their own particular time period. Science will progress during those time periods, but when anomalies that can't be explained with current understanding mount up, new scientists come along and question the framework itself.

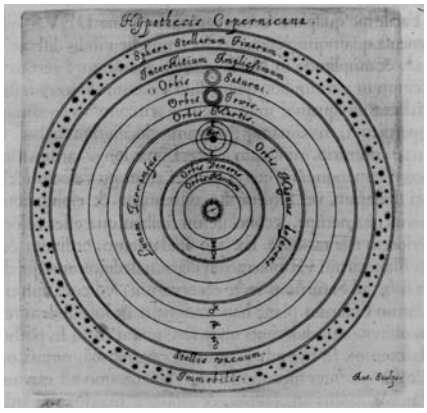
In each case of paradigm shift, the new idea did not immediately supplant the old system. Instead there was a period of controversy and research until a larger group of scientists felt that the new system better explained the observable phenomena.

Even Kuhn's paradigm model has come under criticism as being too Eurocentric, more applicable to physics than to other scientific fields.

> ***"In learning a paradigm the scientist acquires theory, method, and standards together, usually in an inextricable mixture. Therefore when paradigms change, there are usually significant shifts in the criteria determining the legitimacy both of problems and proposed solutions."*** — Thomas Kuhn, *The Structure of Scientific Revolutions: 50th Anniversary Edition*

"A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it."
— Max Planck, *Scientific Autobiography and Other Papers*

The following are examples of **major shifts** in scientific models. The change in viewpoints did not come easily but were accompanied by much debate among scientists who understood the world under the previous model. Over time the new models took hold and supplanted the old models.



Nicolaus Copernicus' model of the solar system (**the Copernican model**) placed the sun at the center with planets orbiting around it. It better explained the movement of the planets as viewed from earth. It displaced the old system by Claudius Ptolemy (the **Ptolemaic model**), which had the earth at the center. *(Pictured at right: Copernican model)*

Ancient Greeks believed in **spontaneous generation**, that life could come from nonliving matter. Louis Pasteur proposed the theory of **biogenesis**, that all life comes from other living creatures.

Antoine-Laurent Lavoisier (and his wife Marie-Ann Pierette Paulze) ushered in the chemical revolution through his **theory of chemical reactions**. In particular his understanding of the role of oxygen in combustion replaced the **phlogiston theory**, that a fire-like element called phlogiston existed in flammable materials and was released during combustion.

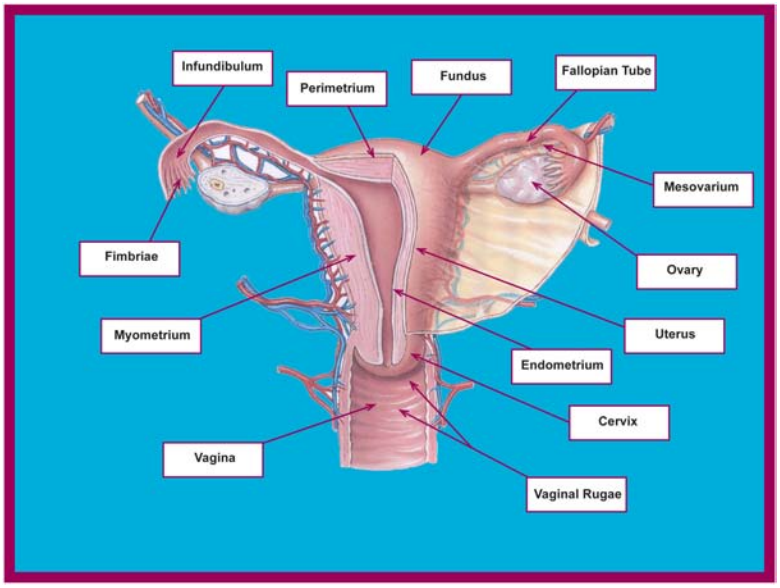
Gregor Mendel's **theory of inheritance** of traits from parents with dominant and recessive traits displaced Charles Darwin's **theory of pangenesis**, which said that gemmules of hereditary information coalesce around the gonads and become part of reproductive cells.

Charles Darwin's the **Theory of Evolution** is generally accepted among scientists, but still causes controversy among certain groups.

While the **Classical Mechanics** (laws of motion) developed by thinkers such as Isaac Newton, Johannes Kepler and Tycho Brahe still apply to macroscopic objects, Albert Einstein's General Theory of Relativity broke open our understanding of mechanics on a microscopic scale, ultimately leading to the field of **Quantum Mechanics**.

Female Reproductive System

We wanted to take away some of the discomfort and mystery associated with the female body and years of unfortunate health videos. *The How and the Why* lobby includes an invitation to label parts of the female reproductive system. Here is the answer key:



Cervix — Derived from the Latin for "neck of the womb," it is the inch-long connection between the top of the vagina and bottom of the uterus.

Endometrium — The mucous membrane that lines the interior of the uterus.

Fallopian tube
Also known as a uterine tube, one of a pair of tubes that carry an egg from the ovary to the uterus

Fimbriae — The fringe of tissue at the end of the fallopian tube over the ovaries, the ovaries are not directly connected to the fallopian tubes.

Fundus — Curved top of the uterus

Infundibulum — The funnel-like opening of the fallopian tube into the abdomen

Mesovarium — The broad ligament of the uterus that suspends the ovaries

Myometrium — The muscular layer of the wall of the uterus.

Ovaries — The ovaries store ova, or eggs, which are released in a regular cycle.

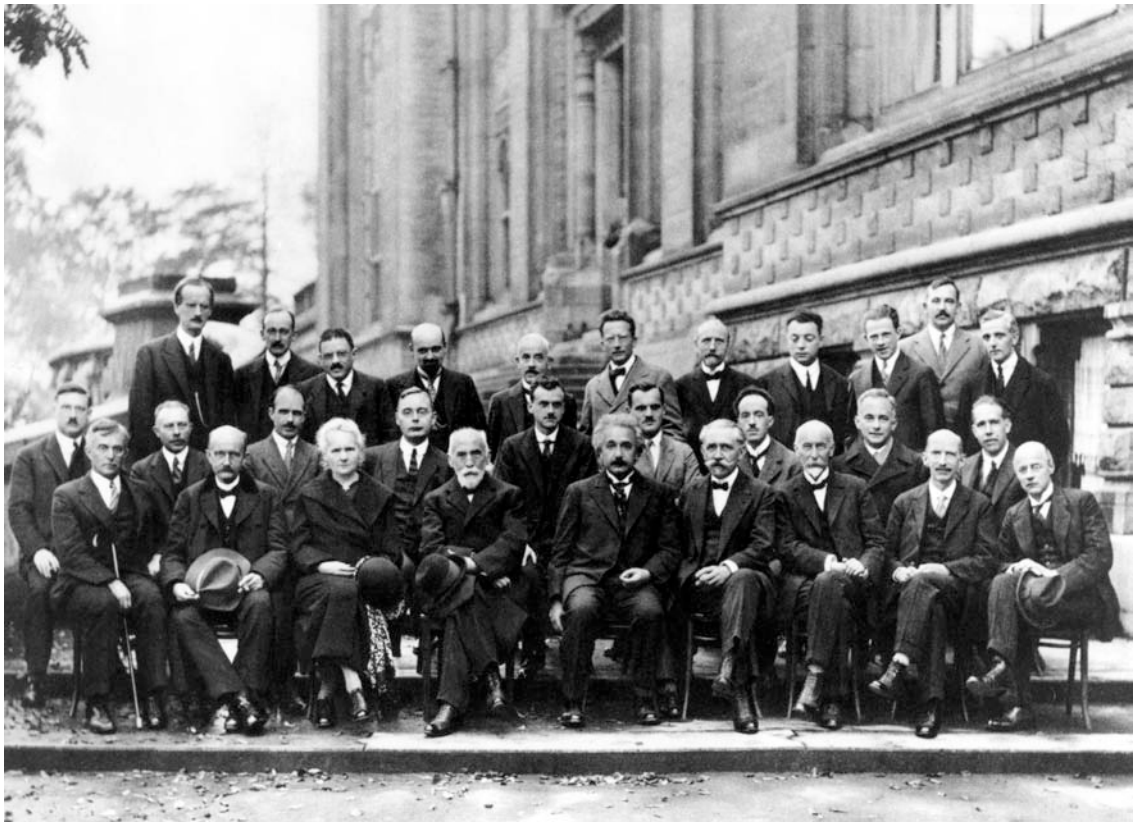
Perimetrium — The outer tissue surrounding the uterus

Uterus — Also known as the womb, it is a pear-shaped organ where a fetus will grow if an egg has been fertilized and implanted.

Vagina — The canal between the external opening and the uterus

Vaginal Rugae — Ridges on lining of the vagina which allow it to expand during childbirth

Hall of Fame: Great Women of Science



At the Solvay Conference on Physics in 1927, the only woman in attendance was Marie Curie *(pictured bottom row, third from left).* This photo of the conference is a striking illustration of how women in science have been outnumbered by men. On October 3, 2013, Eileen Pollack wrote an article for *The New York Times*—"Why Are There Still So Few Women in Science?"—to investigate what factors were keeping women from choosing and staying in careers in the science.

While women are still underrepresented in math, biology, physics, anthropology and medicine, there have long been pioneering women in these fields. The 50 women honored in our Great Women in Science Hall of Fame represent a variety of times, countries and disciplines.

There are easily another 150 other innovative and often unheralded women we could have chosen for this collection. These brief biographies are an opportunity to celebrate the variety of work that has been done and continues to be done by women in science.

Françoise Barré-Sinoussi (1947 – Present)
Virologist
French scientist Barré-Sinoussi was a co-recipient with Luc Montagnier of the 2008 Nobel Prize for Physiology or Medicine for her co-discovery of the Human Immunodeficiency Virus. She is the director of the Regulation of Retroviral Infections Unit at the Pasteur Institute in Paris, France, and has been president of the International AIDS Society since 2012.

Florence Bascom (1862 – 1945)
Geologist
She was the first woman and first geologist to be awarded a Ph.D. from Johns Hopkins University. In 1896, she became the first woman scientist hired at the United States Geological Survey (USGS). She pioneered the use of microscopes in the study of minerals and rocks and contributed to understanding the formation of the Appalachian mountain range.

Elizabeth Blackwell (1821 – 1910)
Physician
Elizabeth Blackwell was the first woman to receive an M.D. from an American medical school. She co-founded the New York Infirmary for Women and Children and was an early advocate for women's education in medicine and in other fields.

Hildegard of Bingen (1098 – 1179)
Abbess, Botanist
Hildegard of Bingen was a German Benedictine Abbess who wrote books on botany, geology philosophy, and medicine in addition to composing music and running her abbey. Interest in Hildegard was revived by 1994 and 2009 documentary films. She was named a Saint in the Catholic Church on May 10, 2012, and a Doctor of the Church on October 7, 2012.

Isabella Bird (1831 – 1904)
Explorer, Writer, Natural Historian
Bird was a 19th Century writer and naturalist. She travelled the world and supported herself by writing about the nature and people she saw in her travels. Her most famous book is *A Lady's Life in the Rocky Mountains*. She also travelled in Japan, China, Malaysia, Singapore and Vietnam. At age 60 she trained in medicine and travelled to India. She was the first woman inducted into the Royal Geographical Society.

Margaret Gray Blanton (1887 – 1973)
Speech Pathologist
Margaret Gray Blanton was a professor at many institutions, including the University of Tulane, the University of Wisconsin, the University of Iowa, and Vassar College. She was among the first in this country to publish in the field of speech pathology, was a founding member of the American Speech and Hearing Association, and contributed to developing tests on speech and literacy.

Rachel Carson (1907 – 1962)
Marine Biologist
Rachel Carson is best known for her 1962 book *Silent Spring*, which warned about the dangers of pesticides, especially DDT, in the environment. Although she was known to be an innovative and creative marine biologist, she is primarily known as a writer. After completion of her graduate studies at Johns Hopkins University, she joined the U.S. Bureau of Fisheries, writing about fishing and the sea for radio programs.

Margaret Lucas Cavendish (1623 – 1673)
Philosopher, Writer, Naturalist
Cavendish was a 17th Century British naturalist, philosopher and writer. Also the Duchess of Newcastle-upon Tyne, she published *Observations Upon Experimental Philosophy* and *Grounds of Natural Philosophy* as well as plays and an early work of science fiction, *The Blazing World*. In 1667 she was invited to

participate in a meeting of the Royal Society, but was regarded as a spectacle by many of her male peers. She was an early opponent of animal testing.

Émilie du Châtelet (1706 – 1749)
Physicist, Mathematician
Châtelet was described by her lover Voltaire as "a great man whose only fault was being a woman." She translated Newton's *Principia Mathematica* into French with her own commentary. She wrote about fire and predicted what would be known as infrared radiation. She wrote *Institutions de Physique* as a textbook for her son in which she reconciled and made connections between prevailing theories in physics. She also made contributions to the understanding of kinetic energy. She died at the age of 42, shortly after the birth of her daughter.

Margaret Chan (1947 – Present)
Doctor, Director-General World Health Organization
Born in Singapore, Chan holds a B.A. in Home Economics and an M.D. from Western Ontario University. She was the first female in Singapore to head the Department of Health, where she confronted outbreaks of avian flu and SARS. In 2006, she was appointed to her first term as Director-General of the World Health Organization. She will end her second term in 2017.

Yvonne A. Clearwater (1968 – Present)
Psychologist
Dr. Clearwater's work is as a design research psychologist, applying formal research methods, findings and theory from social sciences to the design of complex, and often highly specialized, human systems and settings. These range from challenging architectural problems to advanced informational environments and products. She leads NASA's New Media Innovation Team at the Ames Research Center, emphasizing the intersection of art, science and technology.

Jewel Plummer Cobb (1924 – Present)
Cell Biologist
Cobb's research at both the National Cancer Institute and at New York University involved comparing the effects of chemotherapy with research on normal and malignant pigment cells. She also works to promote programs that increase girls', women's and minority students' interest in scientific careers.

Irene Joliot Curie (1897 – 1956)
Chemist
Irene Joliot-Curie was the daughter of Marie Curie and Pierre Curie, earning her doctorate in 1925. She was awarded the Nobel Prize in Chemistry for 1935 in recognition of her work on the synthesis of new radioactive elements. Her research was key in the discovery of uranium fission. She died from leukemia caused by radioactive exposure.

Maria Sklodowska Curie (1867 – 1934)
Physicist and Chemist
Curie was the first woman to be awarded a Nobel Prize and remains the only woman to have won two Nobel Prizes, each in different fields. She received the first in 1903 with her doctoral advisor and husband Pierre for their research on radiation and the second in 1911 for her discovery of radium and polonium. Curie decided not to patent the radium-isolation process, allowing other scientists to continue research. She died of aplastic anemia, a consequence of exposure to massive radioactive materials.

Ingrid Daubechies (1954 – Present)
Mathematician and Physicist
Daubechies is a Dutch physicist and mathematician. She is known for her work on wavelets. She was a MacArthur Foundation Fellow and the first woman president of the International Mathematical Union. She currently teaches at Duke University.

Gertrude B. Elion (1918 – 1999)
Chemist and Pharmacologist
Elion graduated from Hunter College with honors at age 19. After rejection from 15 graduate programs because she was a women, she took a position as an unpaid lab assistant. In 1944, she was hired by Burroughs Wellcome pharmaceuticals. During her 39 years there, she developed a drug used to treat children with leukemia, as well as an anti-rejection drug for use after organ transplant surgery. She received the 1988 Nobel Prize in medicine and physiology for her "discoveries of important principles for drug treatment."

Dian Fossey (1932 – 1985)
Anthropologist and Primatologist
Fossey received her Ph.D. from Darwin College, Cambridge, writing a thesis entitled "The Behaviour of the Mountain Gorilla" in 1976. After attending a lecture by Dr. Louis Leakey (a Kenyan paleoanthropologist), Fossey became interested in the mountain gorillas of the Virunga Volcano region of Rwanda and began to study them. Her work provided the basis for our understanding of the behavior and social life of gorillas. Her struggle to protect gorillas against poachers and government officials culminated in her tragic murder.

Rosalind Franklin (1920 – 1958)
Biophysicist
Franklin went to Newnham College, Cambridge, and graduated in 1941, but was only awarded a degree titular, as women were not entitled to degrees from Cambridge at the time. She received her Ph.D. from Cambridge University in 1945. Franklin's x-ray diffraction photographs led to the understanding of the structure of deoxyribonucleic acid (DNA). Her colleague, Maurice Wilkins, without obtaining her permission, made her then-unpublished x-ray diffraction pattern of the B form of DNA available to James Watson and Francis Crick, which was crucial evidence for the helical structure of DNA.

Birute Mary Galdikas (1946 – Present)
Anthropologist
Galdikas holds bachelor's degrees in psychology and zoology, a master's degree in anthropology and a doctorate in anthropology. Similar to Jane Goodall's work with chimpanzees and Dian Fossey's study of gorillas, Galdikas has studied the orangutans of Indonesian Borneo since 1971 and is a world authority on the subject. Galdikas has campaigned tirelessly to save the orangutans from extinction and to preserve their habitat from illegal logging.

Cecilia Helena Payne-Gaposchkin (1900 – 1979)
Astronomer
She studied at Cambridge as an undergraduate but was not awarded a degree because the university didn't grant degrees to women at that time. She left England for the United States in 1923, and became the first person to earn a Ph.D. in astronomy from Radcliffe (now part of Harvard University). By studying the spectra of stars, Payne-Gaposchkin determined that hydrogen and helium were the most abundant elements in stars. She was the first woman to receive the rank of full professor at Harvard and also the first woman chairperson of a department at Harvard.

Lillian Moller Gilbreth (1878 – 1972)
Industrial Engineer
Gilbreth completed her dissertation for her Ph.D from the University of California, but did not receive the degree because she didn't complete the residency requirements. In 1915 she earned a Ph.D from Brown University in industrial psychology. Gilbreth's motion studies on production workers helped develop much of what today is called industrial engineering and human resource development.

Jane Goodall (1934 – Present)
Primatologist
Goodall, a protégé of Louis Leaky, earned a doctorate in ethology from the University of Cambridge in 1964. She is one of the world's foremost primatologists and has spent decades closely observing and studying the behavior of the Gombe chimpanzees in Tanzania. Her numerous awards and honorary degrees include the UNESCO Gold Medal and the Medal of Tanzania. In 2002, Goodall was named a United Nations "Messenger of Peace."

Sara Mae Stinchfield Hawk (1885 – 1977)
Speech Pathologist
Hawk was the first in the United States to graduate with a Ph.D. from a program with a major emphasis in speech, earning her degree from the University of Wisconsin in 1922. Her research centered on developing diagnostic taxonomies of speech disorders in order to measure various aspects of speech. She was one of the founding members of the American Speech and Hearing Association (ASHA).

Olive Clio Hazlett (1890 – 1974)
Mathematician
Hazlett received her Ph.D. in mathematics from the University of Chicago in 1915. Her graduate career focused on the areaof linear associative algebras. The development of these algebras was the result of a gradual enlargement of the concept of numbers—from integers, to rational numbers, to real numbers, to complex numbers, to quaternion, to the more general "hypercomplex numbers."

Grace Murray Hopper (1906 – 1992)
Mathematician
Hopper received her Ph.D. from Yale University in 1934. She then became a mathematics professor at Vassar College. Since her family had a strong military background, she resigned her post at Vassar in 1943 to join the U.S. Naval Reserve. By the end of World War II, Admiral Hopper had completed a manual detailing the

basic operating principles of computers. She was a leader in the field of software development concepts and contributed to the transition from primitive programming techniques to the use of sophisticated compilers.

Sarah Hrdy (1946 – Present)
Sarah Hrdy received her Ph.D in Anthropology from Harvard University in 1975. Her research has primarily focused on motherhood and natural selection. Her book *Mother Nature: A History of Mothers, Infants and Natural Selection* was a finalist for the PEN USA West 200 Literary Award for Research nonfiction.

Ida Hyde (1857 – 1945)
Physiologist
In 1896, Hyde completed a coveted Ph.D. at the University of Heidelberg, becoming the first woman to receive one for her work. She was the first woman to do research at Harvard Medical School, and her 1902 election to the all-male American Physiological Society was another first. Her most notable accomplishment was the development of a stimulating electrode small enough to insert into a cell that could simultaneously inject or remove material, which revolutionized neurophysiology.

Hypatia (circa AD 350 – AD 415)
Astronomer and Mathematician
Hypatia is one of the first documented women in math and science. She was a neoplatonic philosopher, astronomer and mathematician who taught in Alexandria. Historical sources suggest she was murdered by a Christian mob after being accused of contributing to the conflict between the Governor and the Bishop of Alexandria.

Shirley Ann Jackson (1946 – Present)
Theoretical Physicist
In 1973, Jackson was the first African American woman to receive a Ph.D. in physics, from the Massachusetts Institute of Technology (MIT). She has conducted research in subatomic particles, including studying hadrons at the Fermi National Laboratory and strongly interacting elementary particles at the European Center for Nuclear Research (CERN). She was appointed chair of the Nuclear Regulatory Commission (NRC) in 1995 and was inducted into the National Women's Hall of Fame in 1998 for her significant contributions as a distinguished scientist and advocate for science education.

Mae Carol Jemison (1956 – Present)
Chemical Engineer, Physician, Astronaut
Jemison received a B.S. degree in chemical engineering from Stanford University in 1977 and a medical degree from Cornell University Medical School in 1981. She joined NASA's astronaut training program in 1986 and on September 12, 1992 became the first African American woman to travel to space, on the space shuttle Endeavor.

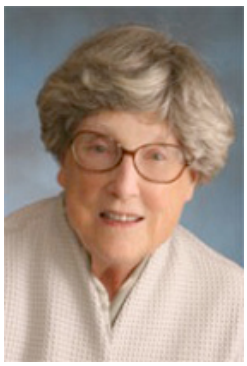
Reatha Clark King (1938 – Present)
Chemist
King received her doctoral degree in chemistry from the University of Chicago. After her graduate education, she worked with the National Bureau of Standards doing fluorine flame colorimetry research. She later became president of Metropolitan University in Minnesota. Her design for the growth of that institution included opportunities for minorities and women in higher education.

Ruth L. Kirschstein (1926 – 2009)
Physician
Kirschtein earned her medical degree in 1947 from Long Island University. She joined the National Institutes of Health in 1955 and became the first women to serve as director of the National Institute of General Medical Sciences. Her research focused on clinical pathology and the safety of polio and measles vaccines.

Inge Lehmann (1888 – 1993)
Geologist
In 1928, Lehmann became state geodesist and head of the department of seismology at the Geodetical Institute of Denmark. In 1936, Lehmann published a paper in which she theorized that the Earth's center consisted of two parts: a solid core surrounded by a liquid outer core, separated by what has come to be called the Lehmann Discontinuity. Lehmann's hypothesis was confirmed in 1970, when more sensitive seismographs detected waves deflecting off this solid core.

Rita Levi-Montalcini (1909 – Present)
Neurobiologist
Levi-Montalcini graduated from medical school with a summa cum laude degree in medicine and surgery in 1936. She focused her research on the growth of nerve fibers, discovering what scientists now call the "trophic factor" that causes nerve fibers to spread. In 1946, she continued her research at Washington University, where she was instrumental in the discovery of nerve growth factor (NGF). In 1986 she was awarded the Nobel Prize in medicine for her contributions to the field of neurobiology.

Augusta Ada Byron Lovelace (1815 – 1852)
Computer Scientist
The child of the poet Lord Byron Lovelace was privately home schooled in mathematics and science by her mother, Anne Isabella Byron. Lovelace's work laid the foundation for computer programming. The programming language "Ada" was named in her honor. In 1834 she became interested in the plans for Charles Babbage's proposed calculating machines and her article on Babbage's "analytical engine," including detailed instructions on how such a machine might be programmed, is now recognized as an early model for a computer and as a description of a computer and software.



Eleanor Emmons Maccoby (1917 – Present)
Psychologist
Maccoby earned her Ph.D. in psychology from the University of Michigan in 1950. She is a notable psychologist in the areas of developmental and social psychology. Her discoveries on the socialization of young children and the methodology of measuring social behavior in infants and preschool children have greatly influenced research in child psychology.

Barbara McClintock (1902 – 1992)
Geneticist
McClintock earned her Ph.D. in botany from Cornell University despite her mother's disapproval of spending money to send a "girl" to college. Prior to the discovery of the structure of DNA,McClintock focused on the 10 chromosomes in maize plants and the genes they carry. She became the first woman to receive the Nobel Prize in physiology or medicine "for her discovery of mobile genetic elements."

Margaret Mead (1901 – 1978)
Anthropologist
Margaret Mead received her Ph.D. in anthropology from Columbia University in 1929 and became one of the most famous anthropologists of the 20th century. She did fieldwork in Samoa, Bali and New Guinea, as well as among the Omaha Indians of Nebraska, studying human development from a cross-cultural perspective. Mead's provocative findings profoundly influenced anthropology and ideas about sex and gender.

Maria Mitchell (1818 – 1889)
Astronomer
In 1847, Mitchell used a telescope to discover a comet, for which she won her international fame and a medal from the king of Denmark. When Vassar College was founded in 1865, she joined the faculty as a professor of astronomy and director of the college observatory. She became the first woman elected to the American Academy of Arts and Sciences and founded the Association for the

Advancement of Women in 1873, chairing its Committee on Women's Work in Science until her death.

Florence Nightingale (1820 – 1910)
Nurse and public health advocate
Nightingale became known as the "Lady with the Lamp" during the Crimean War, where she served as a nurse and made nightly rounds with a lamp. After her work during the war she established a College of Nursing at St. Thomas Hospital and helped make nursing a respectable profession for women. She was also concerned about sanitation and public health. She used statistics to make the case that improved hospital sanitation would result in decreased deaths.

Emmy Noether (1882 – 1935)
Mathematician
Noether received her doctoral degree from the University of Erlangen Nuremberg in the field of mathematics. She is known today as a pioneer in the field of abstract algebra. She fled Germany in 1932 as the Nazi government dismissed Jews from university positions. Noether moved to the United States to take up a position at Bryn Mawr College in Pennsylvania.

Marie-Anne Pirette Paulze (1758 – 1836)
Chemist
Married to the French Chemist Antoine Lavoisier, Paulze worked with Lavoisier in his laboratory, translating documents from English to French. She received art training so she could more accurately diagram the apparatuses used in their experiments. Her translation of a paper on phlogiston helped convince Lavoisier that the theory was wrong and caused him to study the role of oxygen in combustion. After her husband's execution during the French Revolution, Paulze published a memoir of his work.

Beatrix Potter (1866 – 1943)
Naturalist, Mycologist
Perhaps best known for her children's books and illustrations, Beatrix Potter was also a naturalist. While she had no formal scientific training, she was a careful observer and illustrator of the natural world. She was particularly devoted to the study of fungus and illustrated more than 350 varieties of mushrooms, mosses and spores. She was also the first person to speculate that lichens are a symbiotic life form. She submitted a paper to the Linnean Society of London, but since women were not permitted to attend meetings, the paper had to be presented by George Massee of the Kew Gardens.

Judith Resnik (1949 – 1986)
Electrical Engineer and Astronaut
Resnik earned her Ph.D. in electrical engineering at the University of Maryland. Her interest in solving problems and discovering new frontiers lead her to NASA in 1978. She was one of the first six women to enter the U.S. space program and on August 30, 1984, became the second American women to travel to space, on the space shuttle Discovery. She worked with others on designing and developing the remote manipulator system. She died tragically in the explosion of the space shuttle Challenger.

Julie Robinson (1967 – Present)
Evolutionary and Conservation Biologist
Robinson earned a B.S. degree in Chemistry and a B.S. degree in Biology from Utah State University in 1989. She earned a Doctor of Philosophy in Ecology, Evolution and Conservation Biology from the University of Nevada - Reno in 1996. She is the Chief Scientist for the International Space Station Program, where she oversees hundreds of active investigations and represents scientists using the space station as a national laboratory.

Mary Fairfax Sommerville (1780 – 1872)
Astronomer, Mathematician
Sommerville published *On the Magnetic Properties of the Violet Rays of the Solar Spectrum* in 1826. In 1835, Sommerville and Caroline Herschel were the first two women elected to the Royal Astronomical Society. She translated a number of scientific works and wrote clear textbooks. She was awarded the Victoria Medal of the Royal Geographical Society in 1869.

Beatrice Tinsley (1941 – 1981)
Astronomer
Tinsley was a New Zealand astronomer and cosmologist. She received her Ph.D. in Physics at the University of Texas in Austin in 1966. Her research contributed to our understanding of how galaxies evolve over time.

Chien-Shiung Wu (1912 – 1997)
Nuclear Physicist
Wu came to the U.S. in 1936 after graduating with a B.S. degree from Nanking Central University. She received her doctorate from the University of California, Berkeley in 1940 and worked with the Manhattan Project research team to develop the atomic bomb. Her most notable accomplishment was to disprove the "law of conservation of parity."

Rosalyn Sussman Yalow (1921 – Present)
Medical Physicist
Yalow's interest in physics was piqued when she heard the noted physicist Enrico Fermi speak about the new field of nuclear physics. She earned her Ph.D. in nuclear physics and helped discover how to use radioisotopes to measure levels of tiny amounts of hormones in the human blood system. This method, called RIA, is crucial to determining conditions like hypothyroidism in infants, which can be treated upon diagnosis. Yalow received the Nobel Prize in medicine in 1977.

Discussion Questions

About the context

1. Zelda and Rachel represent two generations of women. What differences do you see in how the two women approach their personal and professional lives? How are these differences tied to the generations in which they were raised? How are the difficulties each woman faces different?

2. Menstruation and menopause still seem to be aspects of women's biology that people do not discuss publicly. Do you think that is shifting? Were there things you learned about the science of women's bodies that you did not know?

3. Women are still underrepresented in scientific fields and books like *Lean In* talk about how women balance or fail to balance personal and professional lives. Why do you think women are still underrepresented in science, business, and even on stage? Do you think that is changing?

About the play

1. Would you call either Rachel or Zelda likable? Is it important for women or for characters on stage to be likable? Would you call them relatable?

2. Both characters put forth scientific theories and theories about how they should live their lives. Did you identify with one or both of the characters? Did you find one more persuasive than the other?

3. The science in the play is based on real theories, yet many people find science makes them uncomfortable. How did the play make the science clear for a general audience?

About the production

1. Rachel and Zelda meet in two very different places in Act I and Act II. What do these locations tell us about these characters?

2. This particular set design means that the three-quarter thrust stage and floor stay the same between the acts. Does the way elements of the space stay the same connect the two characters in some way?

3. The actresses who play Zelda and Rachel look very much alike. What similarities and differences did you detect between these characters? Did they seem related? What did costumes reveal about the characters?

Resources and References

ARTICLES

Sarah Hrdy

— *The Evolution of Motherhood* on NOVA a Q&A with Sarah Hrdy
http://www.pbs.org/wgbh/nova/evolution/evolution-motherhood.html

— "The Hardy Sarah Blaffer Hrdy", *Discover Magazine*, March 2003
http://discovermagazine.com/2003/mar/feathrdy#.UpOrxJTF1Bw

— **"Raising Darwin's Consciousness: An Interview with Sarah Blaffer Hrdy on Mother Nature", *Scientific American*, March 16, 2012**
http://blogs.scientificamerican.com/primate-diaries/2012/03/16/raising-darwins-consciousness-an-interview-with-sarah-blaffer-hrdy-on-mother-nature/

Margie Profet

— Angier, Natalie. "Radical New View of Role of Menstruation," *New York Times.* September 21, 1993.
http://www.nytimes.com/1993/09/21/science/radical-new-view-of-role-of-menstruation.html

— Martin, Mike. "The Mysterious Case of the Vanishing Genius" *Psychology Today*, May 1, 2012. (profile of Margie Profet)
http://www.psychologytoday.com/articles/201204/the-mysterious-case-the-vanishing-genius

— McDermott, Terry. "Darwinian Medicine – It's A War Out There and Margie Profet, A Leading Theorist in a New Science, Things The Human Body Does Some Pretty Weird Things to Survive." *The Seattle Times.* July 31, 1994.
http://community.seattletimes.nwsource.com/archive/?date=19940731&slug=1922927

— Plummer, William. "A Curse No More," People, October 11, 1993, Vol. 40, No 15.
http://www.people.com/people/archive/article/0,,20106433,00.html

— Profet, Margie. "Menstruation as a Defense Against Pathogens Transported by Sperm", *The Quarterly Review of Biology,* September 1993.
http://www.conovers.org/ftp/Menstruation.pdf

— Strassmann, Beverley. "The Evolution of Endometrial Cycles and Menstruation." *The Quarterly Review of Biology*, 71:181–220, June 1996.
http://www.jstor.org/stable/3035646 (Response to Profet's 1993 article)

George Williams

— Williams, George. "Pleiotropy, Natural Selection, and the Evolution of Senescence," *Evolution*, Volume 11, Issue 4 (December 1957), 398-411. http://info-centre.jenage.de/assets/pdfs/library/williams_EVOLUTION_1957.pdf

Women, Work, Gender Bias and Science

— Aitkenhead, Decca. "Peter Higgs: I wouldn't be productive enough for today's academic system." The Guardian, December 6, 2013. http://www.theguardian.com/science/2013/dec/06/peter-higgs-boson-academic-system

— Chang, Kenneth "Bias Persists for Women of Science, a Study Finds, *New York Times,* September 24, 2012. http://www.nytimes.com/2012/09/25/science/bias-persists-against-women-of-science-a-study-says.html?_r=0

— Gentile, James M. "Gender Bias and the Sciences" Huffington Post Blog, November 1, 2012. http://www.huffingtonpost.com/james-m-gentile/gender-bias-and-the-sciences_b_2049771.html

— Pollack, Eileen. "Why are There Still So Few Women in Science?" *The New York Times*, October 3, 2013. http://www.nytimes.com/2013/10/06/magazine/why-are-there-still-so-few-women-in-science.html

— Slaughter, Anne-Marie. "Why Women Still Can't Have it All" *The Atlantic*, June 13, 2012. http://www.theatlantic.com/magazine/archive/2012/07/why-women-still-cant-have-it-all/309020/

— Williams, Joan C. "Women Work and the Art of Gender Judo" *The Washington Post*, Januray 24, 2014 http://www.washingtonpost.com/opinions/women-work-and-the-art-of-gender-judo/2014/01/24/29e209b2-82b2-11e3-8099-9181471f7aaf_story.html

BOOKS

— Angier, Natalie Woman*: An Intimate Geography*, Anchor Books, New York, 2000.

— Darwin, Charles. *Descent of Man,* 1871.

— Delaney, Janice. *The Curse: A Cultural History of Menstruation*. Dutton, New York, 1976.

— Houppert, Karen. *The Curse: Confronting the Last Unmentionable Taboo: Menstruation* Farrar, Strauss and Giroux, New York, 2000.

— Kuhn, Thomas S. *The Structure of Scientific Revolutions: 50th Anniversary Edition*, University of Chicago Press, Chicago, IL. 2012.

— Lee, Janet and Jennifer Sasser-Coen. *Blood stories: menarche and the politics of the female U.S. society*, Routledge, New York, 1998.

— Reed, Evelyn. *Sexism and Science*, Pathfinder, New York, 1978.

— Ridley, Matt. *The Red Queen: Sex and the Evolution of Human Nature*, Perennial, New York, 2003.

— Stein, Elissa and Susan Kim. *Flow: The Cultural History of Menstruation,* McMillan, 2010.

— Sandberg, Sheryl. *Lean In: Women, Work, and the Will to Lead*, Knopf, New York, NY, 2013.

— Thornhill, Randy and Steven Gangestad. *The Evolutionary Biology of Human Female Sexuality*. Oxford University Press. New York, 2008.

— Weideger, Paula. *Menstruation and Menopause: the physiology and psychology, the myth and the reality*. Knopf. New York, 1976.

— Weiner, Jonathan. *The Beak of the Finch: A Story of Evolution in Our Time*, Vintage, New York, NY, 1995.

FILMS

— NOVA: Neanderthals on Trial 2002 (Features the use of MtDNA)
http://www.pbs.org/wgbh/nova/neanderthals/

— NOVA: Secret of Photo 51 (on the contributions of Rosalind Franklin to the discovery of DNA)
http://www.pbs.org/wgbh/nova/photo51/

— Makers: Women Who Make America
http://www.pbs.org/makers/home/

— 1946 Disney Film "The Story of Menstruation"
http://www.youtube.com/watch?v=eLhld_PI2zg