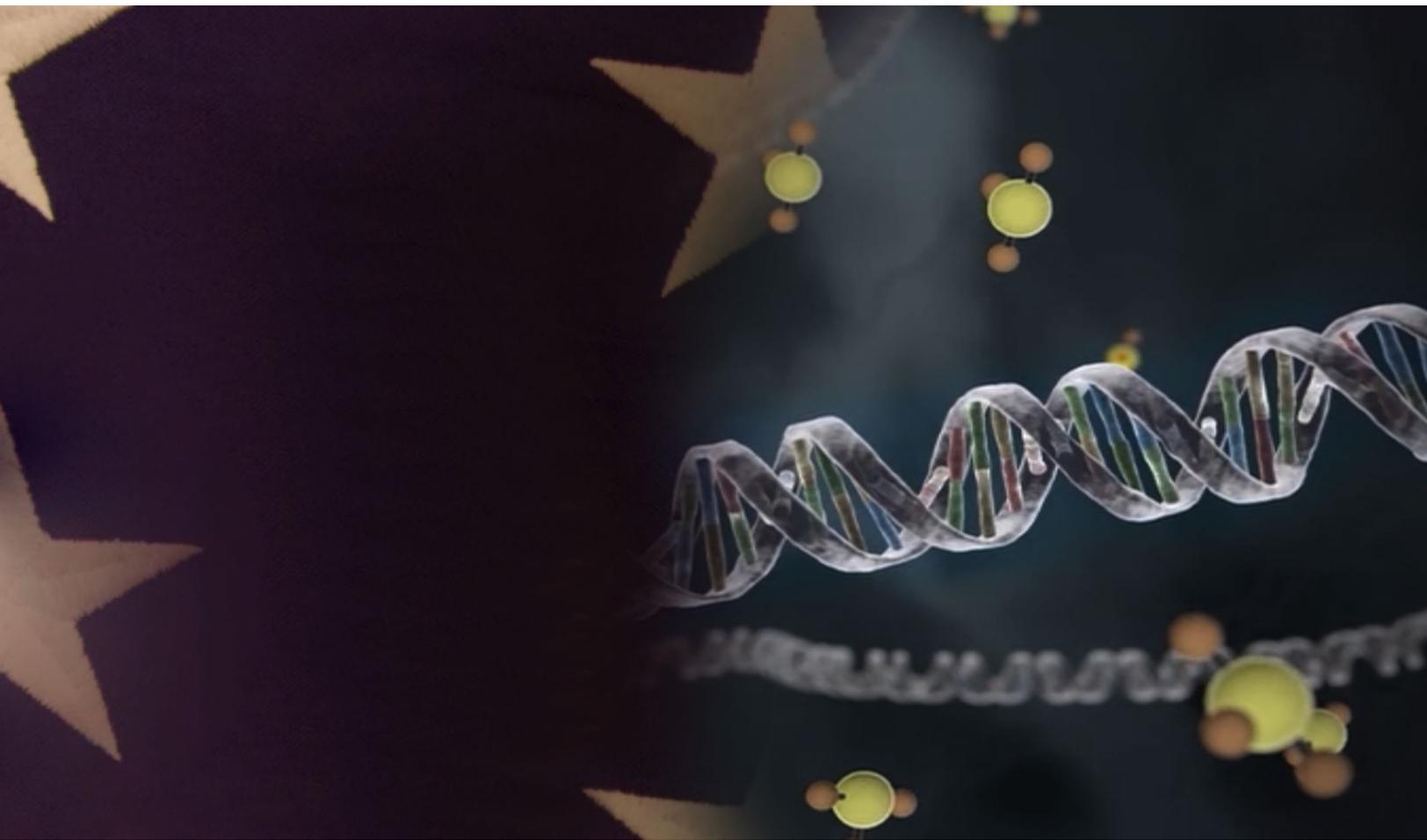


# EPISODE 5: DNA IS NOT DESTINY

HOW THE OUTSIDE GETS UNDER THE SKIN



# EPISODE 5: DNA IS NOT DESTINY

## Discussion Guide

### ***The Raising of America: Early Childhood and the Future of Our Nation***

*The Raising of America* is the acclaimed documentary series and public engagement campaign that seeks to reframe the way we look at early child health and development. It illustrates how a strong start for all our kids leads not only to better individual life course outcomes (learning, earning and physical and mental health) but also to a healthier, safer, better educated, more prosperous and equitable nation.

Learn more about each episode in the series at [raisingofamerica.org](http://raisingofamerica.org):

- Ep 1: *The Raising of America*
- Ep 2: *Once Upon a Time*
- Ep 3: *Are We Crazy About Our Kids?*
- Ep 4: *Wounded Places*
- Ep 5: *DNA Is Not Destiny*

View the hundreds of partner organizations and join the campaign ([raisingofamerica.org/become-partner](http://raisingofamerica.org/become-partner)) to change the conversation about what we can—and should—do to give all our kids a strong start.

This guide was developed by Faith Rogow, PhD, [Insighters Education Consulting](http://insighterseducationconsulting.com) with Larry Adelman and Rachel Poulain at California Newsreel. Alisha Saville produced the design with Shannon K'doah Range.

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## DNA is Not Destiny

### SYNOPSIS

**Episode 5: *DNA Is Not Destiny*** (37 minutes) is part of the documentary series *The Raising of America: Early Childhood and the Future of Our Nation*.

This episode asks:

**We know our earliest experiences influence who we become—but how deep do these changes go? How might a nurturing or toxic *social* environment actually become part of our biology? And what are the implications for our public priorities?**

*DNA Is Not Destiny* introduces viewers to the exciting new science of epigenetics, which suggest that fetal and early child environments literally become part of us. Experiences, scientists have learned, can leave chemical marks—called the epigenome—on our DNA, especially during the early years. These epigenetic marks act like a dimmer switch or volume control, switching genes on or off, making them shout or whisper. In so doing, they change the way our brains and bodies function—with enduring consequences for behaviors and mental and physical health.

The genes we're born with don't change, but the settings of the epigenome—and hence patterns of gene expression—can, especially during critical periods like gestation, the early years and the onset of puberty.

The film walks us through some of the pioneering animal and human studies that link the diets of pregnant mothers, toxic exposures, trauma, parental

neglect, poverty, and even the everyday stressors faced by middle- and low-income parents to epigenetic changes in babies. These changes in the epigenome have in turn been associated with a host of effects as children grow up: anxiety, depression, poor learning, obesity, substance abuse and even cancers. They can change the course of a child's life.

*DNA Is Not Destiny* considers the profound social and political implications of these discoveries. If social influences can alter the way our genes work, then early environments can help or hinder children's success and well-being in ways that go beyond the personal choices we make.

We can't change our genes. But we *can* change the environments which modify our epigenomes. The science is clear, says Marie Lynn Miranda, environmental researcher and provost of Rice University: improved social conditions can provide the biological foundation for healthier, more resilient and successful lives.

## WHAT IS EPIGENETICS?

Epigenetics is the study of the biological mechanisms which silence or activate genes, which in turn instruct the cells to produce proteins. Changes in the epigenome modify gene expression. They do not alter the underlying DNA sequence.

Epigenetics is a very new field. Scientists are only beginning to understand the many different ways gene expression is regulated, how those mechanisms are themselves modified by life experiences, and they debate the meanings and implications of their findings. Scientists even debate which of the many biological processes that regulate gene expression should be labeled 'epigenetic' or not.

Adding to the puzzle, most modifications of the epigenome acquired in life appear to be wiped clean during reproduction, but evidence suggests some modifications can be inherited across generations.

## THEMES

*DNA Is Not Destiny* is appropriate for audiences interested in:

Adverse childhood experiences (ACEs)	human development
biological foundation for health	maternal and child health
Bisphenol A (BPA)	mental health
brain development	nature vs. nurture debates
child development	parenting
child welfare	public health
DNA	social environments
science education	toxic stress
early childhood and family policy	trauma
environmental hazards	
epigenetics	
fetal development	
gene regulation	
genetics	
health inequities	

## FILM CHAPTERS

1. 00:00 – Prologue
2. 04:26 – Identical Mice, Which Aren't Identical
3. 06:55 – The Epigenome
4. 11:33 – The Social Environment: Under the Skin
5. 13:24 – Social Toxins and Gene Expression
6. 19:03 – Scarcity and Toxic Stress
7. 21:45 – The Wisconsin Study: Can Early Life Last a Lifetime?
8. 27:11 – The Wealth-Health Gradient
9. 29:33 – Reversability
10. 31:28 – Biology and Public Policy

## FILM PARTICIPANTS

*In order of appearance*

### **Dana Dolinoy**

Associate Professor, Environmental Health Sciences; Associate Professor, Nutritional Sciences, University of Michigan School of Public Health

Director, Dolinoy Lab - Environmental Epigenetics and Nutrition

*(Agouti gene mice studies)*

### **Marilyn Essex**

Professor of Psychiatry, University of Wisconsin-Madison School of Medicine and Public Health;

Director, Life Stress and Human Development Lab;

Co-Director and Principal Investigator, Wisconsin Study of Families and Work  
*(20-year longitudinal study of how parental stress during pregnancy and the early years can leave lasting imprints on the developmental paths of their children)*

### **Darlene Francis**

Associate Professor of Public Health and Neuroscience, University of California, Berkeley School of Public Health;

Member of Michael Meaney's research team as a graduate student

*(Effects of depriving rat mothers of normal nesting materials on her pups)*

### **Michael S. Kobor**

Professor, Department of Medical Genetics, University of British Columbia

*(Documenting "second hand stress" by correlating epigenetic methylation patterns in teens to mothers' stress levels during infancy)*

### **Michael Meaney**

James McGill Professor, Departments of Psychiatry, Neurology & Neurosurgery, McGill University;

Director, Michael Meaney Lab

*(Rat studies of impact of high and low-licking mothers on consequent behaviors of their offspring)*

### **Marie-Lynn Miranda**

Howard R. Hughes Provost, Rice University; Founder of the Children's Environmental Health Initiative

*(Inequitable impact of toxicants and place)*

# 1. Facilitating the Discussion

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A successful film screening allows participants to:

- Watch purposefully and critically
- Reflect upon what they've seen
- Consider new information and how it affirms/conflicts with preconceived ideas
- Bring viewers' attention back to their own situation and how they might tackle inequities
- Learn from others in the room

Your job as facilitator is not to lecture but to encourage participation and keep the discussion focused and flowing. Be prepared to accept reactions to the film without judgment. If people feel that you are fishing for particular opinions, they are less likely to engage.

At the same time, participants will look to you to keep the discussion from wandering. If necessary, gently guide discussants to consider how their personal experiences or concerns reflect larger systems, structures and policies.

Prior to the discussion, be sure to preview the film yourself so you won't be processing your own reactions to the issues while trying to guide the group. You can also read the transcript of the episode, available at [www.raisingofamerica.org](http://www.raisingofamerica.org).

Finally, plan in advance how you will deal with logistical issues, including strategies to ensure that everyone who wishes to speak has an opportunity to be heard.

## 2. Pre-Viewing Activities

Before screening the film, it is often helpful to prompt viewers to articulate some of their own (often unexamined) assumptions about the issues. One simple way to begin is asking: Who has heard the phrase ‘DNA is destiny’? What do you think it means? Do you believe what the phrase purports to explain? Why or why not?

After soliciting a few responses, shift your audience’s attention to the film by inviting them to brainstorm what it might imply for public attitudes towards human development (mental and physical health, learning, behaviors, etc.) if early experience and environments could change not our genes (they don’t change) but how our genes work. Remind them that the title of the film is *DNA Is Not Destiny*.



(cont. →)

### 3. *Post-Viewing Discussions*

The questions and prompts in this section are designed to help a wide range of audiences understand, analyze, explore and reflect on what they've seen, as well as on what they hear from others in the room. There is no need to use all the questions or use them in any particular order. Choose those that best meet the needs of your group.

#### A) OPENING PROMPTS

1. If a friend asked you what this film was about, what would you say?
2. Name three things from the film: one that surprised you, one that frustrated you, and one that inspired you. How did the things you named compare to the things named by other people in the room? How would you account for the similarities and differences?
3. Jot down a "tweet" describing the film's most important messages.
  - After people have had a minute or two to compose their tweet, invite volunteers to share what they wrote (and, if they wish, to send the tweet). Discuss whether there is a consensus about what the main message is or why people may have had different ideas about the main message.

(cont. →)

## B) COMPREHENSION CHECK-INS

1. Our body is made up of more than 200 types of cells—but each cell type contains exactly the same DNA. What differentiates the function of, say, a liver cell from a pancreatic cell?
2. What’s the difference between the genome and the epigenome?
3. It used to be said that genes were the blueprint or master plan of our bodies. What is wrong about that old understanding?
4. What does ‘gene expression’ mean? How can genes be turned ‘on’ or ‘off’?
5. What is “methylation” and how does it serve as one link between social conditions and developmental paths?
6. At a couple of points, the film uses the metaphor of a ‘dimmer switch’ to describe epigenetic effects. What is meant by that? What other metaphors might you use?
7. How does Dana Dolinoy explain how genetically identical mice can appear so different?



(cont. →)

8. How might the licking and grooming of rat pups in the first week of life affect their behaviors later in life?
9. What was the key finding of Marilyn Essex and the Wisconsin Studies of Work and Family?
10. What behaviors might be associated with someone whose brain has become overly primed for stress?
11. What aspects of a child's social environment might modify his or her epigenome?
12. How might 'resource scarcity' affect a parent or caregivers' ability to recognize and effectively respond to an infant or young child's often subtle cues?
13. The film asks whether the 25% of U.S. children born into poverty might be biologically primed for more difficulties in life. What did you learn from the film about the answer to that question?

## C) EPIGENETICS AND YOUR EXPERIENCE

1. The film notes that "Everything in an infant's experience can help... or hinder" healthy development. Think about some of the children you know.
  - What environments, experiences and social conditions might be on their "help" list?
  - Which would be on the "hinder" list?
  - What might your community do to better ensure that the "help" side outweighs the "hinder" side of the ledger?



(cont. →)

2. The film examines how the physical environment (place) can affect a child's development for better and for worse. It describes neighborhood amenities and assets like parks and sidewalks for walking and bike riding, as well as hazards like litter, abandoned vehicles, overgrown lots, noise and crime. Conduct an inventory of amenities and hazards in your neighborhood, the neighborhood of the young children in your care or classroom, or in a nearby neighborhood.
  - What tips the balance one way or another?
  - Why would it be in the interest of those who already live in healthy neighborhoods to ensure that all children are raised in an amenity-rich environment?



(cont. →)

3. In Michael Meany’s research, “The low-licked pups grew up to be vigilant and hypersensitive to noise or movement...on constant alert for threats, even when there was little apparent cause for alarm.” Marilyn Essex’s Wisconsin human research participants also exhibited long-term behavioral consequences from adverse early childhood experiences.
  - Have you ever encountered teens who are quick to anger, are impulsive or overly withdrawn, can’t stay on task, or exhibit other behavioral problems?
  - How was the behavior explained?
  - How did the adults respond?
  - How might responses to the behavior change if we understood that epigenetic modifications induced by one’s social and physical environment early in life can affect behaviors?
  
4. In the *Wounded Places* episode of *The Raising of America*, Dr. John Rich argues that we shouldn’t ask, “What’s wrong with you?” to children who display chronic behavioral problems but rather, “What happened to you?” What are the implications of this shift?
  
5. Investigate the disciplinary and suspension policies of schools in your neighborhood. Do the preschools and kindergartens in your community suspend young children for bad behavior? What patterns do you see?
  - How do you think suspending a four- or five-year-old with behavioral issues from preschool, kindergarten or first grade is likely to affect the future behaviors and emotional state of that child?
  - Are there any “trauma informed” schools in your community? What does that mean in practice?



## D) CONNECTING SCIENCE & POLICY

1. Marie-Lynn Miranda says “the science is clear” about improved *social* conditions providing the biological foundation for lives that are healthier and more likely to thrive. She continues, “What we need is for the policy to follow the science and get us to more protective environments for children.”
  - Can you give examples where child and family policies do NOT follow the science?
  - If the science is clear, why haven’t policies changed? What gets in the way?
  - What are possible ways to overcome or work around those obstacles?
2. Marie-Lynn Miranda suggests universal Pre-K and better schools as two examples of creating more “protective environments for our children.” What would you suggest?
3. Consider each of the research studies presented in the film (see the section “[The Scientists and Their Research](#)” for summaries). Which experiment sticks out to you and why?
  - What were your “takeaways” from each of the experiments?
  - Brainstorm how the findings from each study might translate to new initiatives and policy changes.



(cont. →)

4. Some people might advocate for parenting classes and urge mothers to eat better and spend more “quality time” with their children. What evidence in the film (or from your life) suggests that such programs, while important, would be insufficient to assure the safe, stable and nurturing environments all babies and young children need for a strong start?
  - What’s the difference between offering a parenting class and tackling the conditions which generate chronic stress in parents and caregivers? Are the two mutually exclusive?
5. Miranda says, “At some point or another we need to decide as a country that we will not tolerate one out of five children growing up in poverty.” Why do you think the U.S. as a nation hasn’t made that decision yet? (Note: In 2016 the relative poverty rate for children 0-5 in the U.S. was more than 25%; ages 0-18, about 22%).
  - What changes might lower the child poverty rate?
6. Do you concur with the film that, “The question for the United States is: How can we create environments that enrich the lives of all young children and their families, allowing them the opportunity to realize their full human potential?” Why or why not?
  - How might helping more children realize their potential benefit the nation as a whole?



## E) THE OPTIMISM OF EPIGENETICS

1. Why do you suppose the filmmaker chose the title *DNA Is Not Destiny*?
2. If more people understood that genes are not the body's set-in-stone 'master blueprint' like we used to think, what possibilities for action does that open up?
3. After finding that the negative effects of BPA exposure can be offset by good maternal nutrition, Dolinoy says that her mice studies show, "at least in this experiment, that the epigenome is quite plastic and adaptable during development." And Michael Meany's team found that enriched environments can compensate for epigenetic damage. Why is it important to know that the epigenome can be altered?
4. Miranda says, "Our obligation in this situation is to be optimistic, to say: The science is helping us to understand this better." How does the research on epigenetics serve as a source for optimism about the future of all of our nation's children?

## F) CONSIDERING THE IMPLICATIONS

1. It's long been debated whether "nature" or "nurture" was more important in shaping human outcomes. How do epigenetic findings change that debate?
2. Studies in the film indicate that the ways our brains and bodies work aren't set in stone, and that personal experiences and social conditions can modify epigenetic patterns which in turn can alter how our genes are expressed. Why is this good news?

(cont. →)

3. According to Michael Meaney, research indicates that, “when populations are freed somewhat from oppression, politically and socially, they become healthier.” Why might that be true?
  - Can you provide examples?
  - What did you learn from the film about epigenetics that might explain this pattern?
  
4. In mice and rat studies, researchers found that poor maternal nutrition during pregnancy and insufficient licking and grooming of infants can cause epigenetic changes which increase the risk of problems for the offspring later in life. Why do the researchers look at improving social conditions rather than blaming mothers?
  
5. Darlene Francis points out that, “The poorest kids in our society, not surprisingly, are the most vulnerable to just about every health outcome we can measure. These are fairly healthy young children who, with time, are going to suffer the consequences of their social class.”



- How does her observation contrast with the widespread notion that physical and emotional health outcomes are shaped either by genes or individuals making the ‘right choices’?
- Who benefits when we focus on personal decision-making at the expense of examining how larger social and economic conditions affect life chances?

(cont. →)

6. The behavioral economists Sendhil Mullainathan and Saugato Datta have written that some of the best parenting programs may have little to do with parenting at all. What do you think that means?
7. The film summarizes, “If social influences are changing the way our genes work, then the circumstances during a child’s first years can result in biological obstacles to success that are beyond just individual choices.” This suggests that health, well-being and success in life can’t be attributed to personal choice alone. What do you think?
  - Why do you think personal responsibility has such a deep-seated grip on popular belief and public policy?
  - Can you suggest any social changes that might better assure the safe, stable and nurturing conditions all babies and young children need to thrive?

## G) SUMMING UP

1. Describe one thing you learned from the film. How does your new insight affect the way you think about early childhood policy and the needs of families with young children?
2. What major questions was the filmmaker trying to answer (and how do you know)?
  - How did the filmmaker answer those questions?
  - Did you agree with the filmmaker’s answers? Why or why not?
  - Were there other questions you wanted to ask, and if so, what were they?
3. If you could arrange for policy-makers, community leaders and politicians to watch this film, what would you want their “takeaway” to be?

## 4. Moving to Action

Ending discussions by planning action steps creates energy and optimism, even when the conversation has been difficult. Powerful action ideas are most likely to come from participants themselves, so we recommend leaving time at the end of your event, meeting, or class to brainstorm.

### SUGGESTIONS FOR GETTING STARTED

1. Host a special screening of *DNA Is Not Destiny* for one or more of the organizations in your area interested in this issue: childcare center staff, teachers and parents, neighborhood associations and other community-based groups, affordable housing and racial justice advocates, service clubs, PTAs, school volunteers, social service providers, your local chapter of the American Academy of Pediatrics, health care professionals, and even stakeholders such as law enforcement and juvenile justice.



- Don't forget to include government officials and your local Chamber of Commerce or other business groups. Invite them to suggest ideas about how the business community could help address the need for affordable, high-quality child care in your city or town. Or how your city or county might make healthy housing more affordable for all residents.
- Consider screening all five episodes of *The Raising of America* as part of a local film and discussion series!

(cont. →)

## SUGGESTIONS FOR GETTING STARTED (CONT.)

2. Identify researchers or public health specialists who can speak publicly about how epigenetics is connected to the long-term well-being of your community. Help the speakers develop a press packet using information from the film and information gathered from local early childhood advocates about specific ways to better support infants, toddlers, preschoolers, and their families. Distribute the packets to local media outlets and offer opportunities for interviews.
3. Monitor the status of local, state or federal legislation related to early childhood education, family leave policy, living wages, affordable and healthy housing, or nutrition and health for young children and their parents.
  - Arrange to meet with your elected representatives and their designated education, health, labor or housing staffers and explain what you think is important and why. Share with them a copy of the film along with key talking points.
4. Investigate current advocacy initiatives, both locally and nationally. Get in touch with those that interest you and find out how you can help.
  - See the list of more than 700 *The Raising of America* partner organizations who are changing the conversation about what we can—and should—do to give all our kids a strong start. ([www.raisingofamerica.org/become-partner](http://www.raisingofamerica.org/become-partner))

## Background & Resources

### GLOSSARY OF TERMS

**Cortisol.** A hormone released as part of the stress response. It is part of a cascade of hormones and other chemicals which raises heart rate and blood pressure, releases glucose into the blood stream, and otherwise heightens arousal and alters how the body's immune system responds. When stress is chronic, a person's base cortisol levels are often higher than normal. Over time this can increase anxiety, affect working memory, impede self-regulation of emotions, interfere with reproduction, weaken the immune system and increase wear and tear on organs, raising the risk of chronic disease.

**Chronic Stress.** Whereas acute stress arises from specific events or situations which involve threat, novelty and uncertainty, chronic stress results from repeated or persistent exposures to situations which cause the release of stress hormones. Over time, this constant activation of the stress response—even at low levels—can injure the brain and body, increasing the risk for high blood pressure, diabetes and other chronic diseases and for emotional, cognitive and behavioral problems..

**DNA – Deoxyribonucleic acid.** DNA is a molecule that has two very long strands twisted together in spiral-ladder shape (called a “double helix”) and carries genetic instructions ‘read’ by the cell to assemble proteins. Each rung of the ladder consists of paired chemical groups called bases, or nucleotides, of which there are four types. The genetic information is encoded in sequences of the bases, called genes. In humans, most DNA is packaged into 23 pairs of chromosomes in the nucleus of the cells.

**DNA methylation.** The attachment of a methyl group (consisting of one carbon and three hydrogen atoms) to nucleotides in our DNA which blocks the activation of a gene. (Note: methylation is only one of several ways in which the epigenome can influence gene expression, but currently the method most studied.)

**Epigenetics.** The science of studying the epigenome; also used to refer to the collection of biochemical signals that help regulate gene expression.

## GLOSSARY OF TERMS (CONT.)

*Epigenome.* Molecules which attach to DNA and help regulate gene expression by making it easier or more difficult for the cell to turn genes on or off, activating or silencing them. Unlike genes which remain the same throughout life (save in rare circumstances), the epigenome can be modified by experience, especially during sensitive periods such as gestation, infancy and adolescence. While most modifications of the epigenome appear to be wiped clean during reproduction, evidence suggests some might be inherited.

*Gene.* A specific sequence of DNA nucleotides, or bases, which serves as the code or instructions for the synthesis of polypeptides (built from amino acids), which form part (or the whole) of proteins made by cells. Humans have 20,000 or so genes. Every single one of our cells, be they liver cells, muscle cells, neurons, etc. contain the exact same genes. But different genes are activated, or turned on, in different cell types.

*Glucocorticoid receptors (GR).* These are proteins in the cells which bind to cortisol (and related stress hormones called glucocorticoids) released by the body. The GRs in the brain's hippocampus appear to re-absorb the circulating stress hormones and thus tamp down the body's stress response. A hippocampus with fewer GRs tends to have a higher level of circulating cortisol which contributes to a prolonged or exaggerated stress response.

*Stress response.* This is the cascade of changes triggered by the release of corticosteroids and other stress hormones when the body perceives a threat and goes 'on alert.' The resulting physiological changes include increased heart and respiration rates, higher blood pressure, and more glucose released from the liver into the blood stream. This is commonly called the "fight or flight" response.

## THE SCIENTISTS AND THEIR RESEARCH

### Dana Dolinoy: The Agouti Gene

Initially working with Randy Jirtle (Duke University), Dana Dolinoy and her colleagues varied the diet fed to pregnant mother rats that were genetically identical—and found their offspring expressed very different physical characteristics (phenotypes). The mothers fed pellets rich in molecules called methyl groups (often found in fruits and vegetables) gave birth to brown and skinny pups. The offspring of mothers fed diets without the methyl groups were born yellow and obese. (A methyl group is a molecule consisting of one carbon and three hydrogen atoms).

The explanation? Dolinoy traced this difference to an epigenetic effect involving the Agouti gene, which is associated with yellow fur and obesity when ‘activated’ or switched on. When methyl groups were included in the rats’ diet, the methyl groups entered the cells’ nuclei and attached to the Agouti gene in their DNA “like barnacles to a ship,” a process called DNA methylation, which prevented the Agouti gene from switching on.

In a follow-up experiment, Dolinoy fed her pregnant mice Bisphenol A (BPA), a chemical commonly found in some plastics. For the mice fed BPA the result was less methylation, more active Agouti genes, and mice pups born obese and yellow. These mice also tended to have other health problems as they grew up.

Then Dolinoy tested the possibility of protecting the mice from the effects of BPA. She exposed pregnant mice to both BPA and a diet rich in methyl groups. The methyl diet protected the offspring from the BPA by methylating and thus silencing the Agouti gene, leading to mice pups born brown and skinny even when their mothers were yellow and obese.

(Note: DNA methylation is but one of several epigenetic mechanisms which alter patterns of gene expression. Some mechanisms have a cumulative, silencing effect on selected genes, called ‘down regulation’; others enhance, or up-regulate, gene expression. But in all cases, the DNA sequence remains the same. Dan Agin writes, “It’s not genes that rule; it’s gene expression that rules. And gene expression can be shaped by environment.”)

## THE SCIENTISTS AND THEIR RESEARCH (CONT.)

### Michael Meaney with Darlene Francis: The Effects of Maternal Grooming in Rats

Rat mothers lick and groom their pups during the first week of life. But some do it more than others. Michael Meaney and his research team at McGill University in Toronto (including Darlene Francis, then a graduate student and now associate professor of neuroscience at the University of California-Berkeley) found that the difference between high-licking / high-grooming mothers and low-licking mothers was reflected in their pups' behavior as adolescents.

The low-licked pups grew up to be more anxious, fearful and reactive to stressors than the high-licked pups; they also had more difficulty learning to navigate mazes. The experiment indicated that experiences during infancy could have enduring consequences. (To prove the behaviors were a consequence of the licking and grooming rather than genetic inheritance, Meaney's team cross-fostered the pups in another experiment not shown in *DNA Is Not Destiny*. Pups born from high-licking, high-grooming mothers were taken away at birth and raised by low-licking mothers, and vice versa. The low-licked pups still grew up to be hyper-reactive to stressors.)

### Resource Scarcity

David Sweatt of The University of Alabama-Birmingham, in an experiment illustrated by Darlene Francis in the film, wondered if resource scarcity might cause rat mothers to lick their pups less often. The team placed the mothers in an environment with poor nesting materials. The mothers became very anxious and spent much of their time frantically searching for suitable nesting materials. These mothers spent the same amount of time with their pups as mothers in rich environments, but they licked and groomed their pups less. An adverse environment impeded the mother's licking and grooming. Again, the low-licked pups grew into adolescents who were on constant alert (even when there was little apparent cause for alarm) and skittish, fearful, and hypersensitive to noise or movement. Rat pups that were licked and groomed more grew up to explore their world with greater confidence.

(cont. → )

## THE SCIENTISTS AND THEIR RESEARCH (CONT.)

What physiological changes might explain the difference? Researchers found that despite being genetically identical, the brains of the offspring were different. The low-licked rats had fewer glucocorticoid (GC) receptors in the region of their brain called the hippocampus than those which had been licked more. Those GC receptors absorb secreted cortisol, tamping down the stress response. Because the low-licked rats had fewer GC receptors, their basic cortisol levels remained high and they tended to be highly stress-reactive as they grew up.

Might the licking and grooming itself modify the rat pups' epigenome? Experiments found that methyl groups had attached to many genes in the low-licked rats. This blocked the genes which instruct for the production of glucocorticoid receptors. A purely social event early in life—licking and grooming—caused an enduring physiological change in the brain which in turn affected emotions and behaviors later in life.

Early experience had a persistent effect. And without interventions, the changes in the brains could last a lifetime.

But the researchers also discovered that if they put the low-licked rat pups in enriched environments at the time of weaning, the rats would grow up without the skittishness and anxiety common to low-licked rats. The enriched environment compensated for the early experience.

### **Marilyn Essex and Michael Kobor: The Wisconsin Study of Work and Families**

Researchers in the two decade Wisconsin Study of Work and Families, co-directed by Marilyn Essex of the University of Wisconsin, first measured the stress levels reported by 550 middle and lower middle class, mostly white parents during pregnancy and their children's first years of life in the early 1990s. They followed the families for almost 20 years in order to investigate whether parental stress experienced during gestation and the early years might have persistent effects on their children.

(cont. →)

## THE SCIENTISTS AND THEIR RESEARCH (CONT.)

They found that the higher a mother's reported adversity and stress early in her child's life, the more stress-reactive their daughters became. As they grew, even if the mother's stress levels had fallen, the children's stress hormone levels remained high, even into adolescence. The increased cortisol levels found in those teens correlated with higher risk of emotional and behavior problems. They tended to be more aggressive, impulsive, didn't get along as well with peers or teachers, and were at greater risk of substance abuse problems and even teen pregnancies.

The stress experienced by the parents got 'under the skin' of their young children. But how?

Michael Kobor, of the University of British Columbia, looked at the epigenetic profile of 109 of the children as teens and found that the DNA methylation patterns of the daughters correlated with the levels of stress reported by their mothers. The second-hand stress they experienced as infants had apparently altered their epigenetic profile, which in turn changed not their genes (they remain the same) but their gene expression later in life. In other words, the study suggested that the chronic struggles of working American families (not just those in poverty or in crisis) had a real biological effect on their children's lives. (The epigenetic patterns of sons were different than the daughters, correlating more strongly with fathers' experiences, but that story is beyond the scope of the film. [Here's their research paper](#)).

## KEY ARTICLES, WEBSITES AND VIDEOS

### Articles

Lizzie Buchen, [Neuroscience: In their nurture](#), *Nature* 467, 146-148 (2010).

Cath Ennis, [Epigenetics 101: A beginner's guide to explaining everything](#), *The Guardian*, April 25, 2014

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Virginia Hughes, Epigenetics: The sins of the father, *Nature*, March 5, 2014

Christopher Kuzawa and Elizabeth Sweet, [Epigenetics and the Embodiment of Race: Developmental Origins of US Racial Disparities in Cardiovascular Health](#), *American Journal of Human Biology*, 21(1):2-15 January 2009.

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National Scientific Council on the Developing Child, [Early Experiences Can Alter Gene Expression and Affect Long-Term Development: Working Paper No. 10](#). (2010)

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Sarah Richardson, et al, [Don't Blame the Mothers](#), *Nature* 512, 131-132 (2014).

Jannel Ross, [Epigenetics: The Controversial Science Behind Racial and Ethnic Health Disparities](#), *The Atlantic*, March 20, 2014

Darren Smith, [The Epigenetics of Being Black and Feeling Blue: Understanding African American Vulnerability to Disease](#), *The Huffington Post*, Jan. 23, 2014

Alice Walton, [How Parents Stress Can Hurt a Child From the Inside Out](#), *Forbes*, 7/25/2012 (Note: Forbes' website asks visitors either to log in or turn off their ad blocker)

### Websites

[Epigenetics](#), The Genetic Science Learning Center, University of Utah

[EPIGENIE](#) – Aggregates articles on the latest epigenetics-related research

[Gene-Environment Interaction](#), Harvard Center on the Developing Child

[International Human Genome Consortium](#) – The site for the international effort to map the epigenomes for key cellular states.

### Videos

[NOVA Epigenetics](#) – Video clips illustrating aspects of epigenetics, from NOVA ScienceNOW, July 27, 2007

[Race – The Power of an Illusion](#) – Groundbreaking documentary series exploring why 'race' doesn't live in our genes but is nonetheless very real (2003).

[Video interview with Michael Meaney-A Life in Research](#) (15:30), July 15, 2015



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