More to Genes Than That:

Designing Metaphors to Explain Epigenetics

A FrameWorks Research Report

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INTRODUCTION

The research presented in this report was undertaken by the FrameWorks Institute and sponsored by the Harvard Center on the Developing Child. What we describe here is part of a larger investigation exploring the way that Americans think about genetics and the impact of environments, specifically the ways that genes and factors external to the body (or environments) interact with each other. The name for this emerging body of scientific knowledge is *epigenetics*. In this particular report, we examine the challenges that are faced by metaphorical shorthands or "simplifying" models that attempt to communicate some of the key components of the science of epigenetics — namely what is the epigenome and how does it work? The simplifying models described in the report were also designed to counter dominant patterns of reasoning held by the public, patterns that constrain the ability of nonspecialists to think and talk about genes, environments and their roles in early child development.

Simplifying models are metaphorically-based frame cues that change the fundamental ways that people understand what issues are "about." They are, therefore, a useful ingredient in changing the ways in which people process and interpret information. For this reason, FrameWorks considers simplifying models as one of a set of communications tools that can be used in reframing scientific and social issues.[1]

Following FrameWorks' multi-disciplinary approach of Strategic Frame Analysis™, we pay attention to how Americans' understanding of genes and environments is shaped by a shared set of assumptions and understandings — what anthropologists call "cultural models."[2] These shared assumptions are what enable individuals to navigate their social worlds. However, cultural models can also play a more restrictive role, shaping available interpretations and making some messages easier to think than others.

American cultural models about genetics are informed by popular culture and educational curricula and are reinforced when individuals find personal experiences (their own or others') reflecting those discourses.[3] As a result, Americans understand the significance of topics like heredity, mutation and genetic determinism, and can talk about the personal and social implications of technologies such as diagnostic genetic screening. The notion of "genetic predispositions," particularly for disease, readily came to the lips of participants in our qualitative research, as did the attempt to predict which individual features (e.g., appearance, health, personality, demeanor) come from either genetic or environmental factors and in what percentages. At first glance, it would seem, therefore, that Americans know a substantial amount about genetics. As we reported earlier, however, the understandings that are accessible to most Americans proved problematic for understanding epigenetics.[4] Our investigations show that, paradoxically, the biggest obstacle may be that science education focused on Mendelian genetics has been *too* successful. As a result, the simplifying models that we tested faced *too much* information (albeit of the wrong kind) about the target domain, rather than too little. Put another way, the core of the genetic knowledge that individuals possess did not help them understand epigenetics but instead was an active obstacle to understanding this new but vitally important field.

The relatively new science of epigenetics investigates the complex molecular biological changes to gene expression which are triggered by sources outside the gene and the cell that contains it. In order to begin to understand the epigenome and the importance of environments and

experiences for promoting positive development in children, people must understand that genes contain instructions or messages to the cells of the body, and that these instructions are continually being delivered over an individual's lifespan. Translating this understanding appears easy enough, but our research shows that such translation is frustrated by the dominant understanding of genes as the vehicles of traits that are delivered from parents to offspring. "Genes as vehicles for traits" does not extend to the notion of "genes as cellular instructions," nor can the latter easily be inferred from the former. This is because epigenetics is the science of the intra- and inter-cellular, while lay understandings of genetics are rooted in the intergenerational. We hasten to point out that this understanding is correct but incomplete, in that it describes only part of the function of genes.

As we describe in this report, this paradox was the major factor that kept people from fully understanding all the aspects of epigenetics that the simplifying model tried to concretize. Here we present our experiences with two simplifying models which we observed in our research process to be assets in helping the general public think and talk about epigenetics and its significance for early child development.

Frequent readers of FrameWorks reports, especially those on simplifying models, should be accustomed to our unreserved recommendations for a single model. However, for epigenetics, two models emerged from the research, each of which has considerable strengths but also some weaknesses. This is not to suggest that either model is ineffective. Rather, it points to the formidability of translating this science when one part of the story about genetics has become so entrenched. Our research shows that the models discussed here are usable, beneficial communications tools. Their effectiveness should not, however, suggest that the translational work on this concept is complete. Aspects of this science exist for which additional translational tools are required. The fact that neither emerging models translate the full concept of gene-environment interaction is also not evidence of a weakness with our research methodology. In fact, it is through this research process that FrameWorks has been able to dissect the usability of these two models — and in so doing has captured some of the crucial challenges of communicating epigenetics to members of the general public.

Something else to keep in mind: Other metaphors have been proposed by scientists and science writers for the epigenome, including "instruction manual," "the pianist on the genome's keyboard," "a map of chemical switches," "a subcellular landscape of chemical signposts," or "if the genome is the book of life, the epigenome is how a specific cell type marks it up with highlighters."[5] Despite any minor similarities between these metaphors and FrameWorks' simplifying models, there remains one overwhelming difference: Only FrameWorks' metaphors have been subjected to a rigorous, multidisciplinary research process that empirically demonstrates which explanatory models are relatively more effective, and why this is. And, in fact, the research process we undertook to identify successful models provides insights into predictable deficiencies in many of these creative attempts to communicate core principles of epigenetics.

It is important to note that not even the best simplifying model can accomplish everything that needs to be done in reframing a complex social or scientific issue. Other frame elements — Values, Messengers, Tone, Causal Chains, etc. — need to be tasked with addressing other routine misdirections. For the topic of epigenetics, however, we discovered two simplifying

models that made some, but not all, aspects of the science more concrete and some, but not all, of the interactions between genes and environments "thinkable."

What is a simplifying model?

A simplifying model can be thought of as a bridge between expert and public understandings — a metaphor that presents a concept in a way that the public can readily deploy to make sense of new information. More specifically, FrameWorks defines a simplifying model as a research-driven, empirically tested metaphor that captures and distills a concept by using an explanatory framework that fits in with the public's existing patterns of assumptions and understandings (cultural models).[6] A simplifying model renders a complex problem as a simpler analogy or metaphor. By pulling out salient features of the problem and mapping them in terms of more concrete, immediate, everyday objects, events or processes, the model helps people organize information into a clear picture in their heads, thereby enhancing their understanding and potentially making them more effective interlocutors, consumers of media and, ultimately, citizens.

On the basis of this theoretical perspective, FrameWorks has built a robust, reliable sense of what an effective simplifying model looks like and how it behaves.[7] An effective simplifying model:

1) improves *understanding* of how a given phenomenon works (in this case what the epigenome is and how it works);

2) creates more *robust, detailed and coherent discussions* of the target issue;

3) is able to be *applied* to thinking about how to solve or improve a situation;

4) *inoculates* against the dominant unproductive default patterns of thinking normally applied to understand the issue;

5) is highly *communicable* — moving and spreading easily between individuals without major breakdowns in key concepts; and finally,

6) is *self-correcting*. In other words, when a breakdown in thinking does occur, people using the model can re-deploy it in its original form, where it is able, once again, to clarify key aspects of the issue.

What must a simplifying model do for epigenetics?

When FrameWorks researchers design and test simplifying models, they employ the results of earlier qualitative research, cultural models theory and an understanding of the communications challenges surrounding a particular topic. Given that epigenetics is a fairly rarified topic, a simplifying model must do a different sort of work than a model on topics such as budgets and taxes, which have been exploited by politics and reshaped by media. Put another way, the work of a simplifying model on epigenetics is largely about defining the concept and doing so in a way that prepares people to understand new information. By contrast, a simplifying model on an issue like budgets and taxes must be less definitional and, instead, supplant deep and dominant patterns of thinking that lead to misunderstandings about how budgets and taxes work and are

related. In recognition of the unique challenges posed by the issue, we conceived of the work that a simplifying model for epigenetics had to accomplish as the following:

1) The metaphor had to be understandable.

2) The simplifying model had to give people a way to understand interactions between environments and genes, and introduce the notion that genes are vulnerable to factors external to the genes themselves and to the individual's body.

3) The simplifying model had to inoculate people against dominant cultural models about genes, e.g., that genes are set in stone, that there is always a precise, set and calculable ratio of genetic vs. environmental influences, etc.

4) The simplifying model had to provoke a sensitivity toward the importance of environmental influences that might impact children's genomes and in so doing affect genetic expressions and developmental outcomes, both as children and later as adults.

5) The simplifying model had to be generative; that is, it has to build a working model to enable individuals to productively encounter other information.

6) Crucial elements of the metaphor had to be persistent in social interaction.

Following the executive summary below, we briefly discuss the methodological process by which FrameWorks researchers identified, developed and empirically tested the power of several simplifying models. We then examine the findings from this research, and conclude with specific recommendations about using two simplifying models as well as approaching expert-devised metaphors in communicating the science of epigenetics. Those who want to read specifics on research methodology are invited to read Appendix A.

EXECUTIVE SUMMARY

FrameWorks' research process produced two simplifying models, "Signature Effect" and "Genetic Memory." Both of these metaphors had significant strengths in helping people think about gene/environment interactions; the process also produced valuable insights into how to scientists should and should not communicate about epigenetics.

- The two models successfully increased peoples understanding of interactions between genes and environments; helped them talk fluently about examples; kept them from employing many unproductive default cultural models about child development and genetic/environmental determinism; and, importantly, helped them ask important questions about the topic. Features of the models as well as their titles were also highly persistent and traveled easily between individuals.

- However, neither model was absolutely successful at countering all default cultural models. This is because, paradoxically, science education, the media and the culture at large have done a very good job in communicating certain aspects of genetics to the nonspecialist public — mainly an implicit critique of Lamarkian genetics and the idea that experiences *can't change genes.* Though people understood quite solidly that genes encode traits that are passed from parents to offspring, in many ways this kept them from understanding the role genes play in

everyday biological functioning. In turn, this kept them from grasping the models for the epigenome.

- Based on the finding that people do not understand genes' role in everyday biological functioning, we flag the metaphors for the epigenome that scientists often employ that compare it to the genome, and recommend that these metaphors not be used. Simply, people's knowledge about gene function was confined to how genes determine physical traits and predispositions for disease.

- Though the "light switch" metaphor for gene/environment interactions is easy to think, we would caution against its use because when individuals talk about it, they will default to a dominant cultural model in which "will power is the ultimate determinant of outcomes and differences." This makes them quick to point out that people have the power to flip their switches — and are to blame if they don't.

- Based on our analysis of the characteristics of many models that did not perform well and the thinking they provoked, we would anticipate that an expert-favored "software/hardware" metaphor does not capture important aspects of epigenetics *as related to policy* — specifically, that environmental impacts persist over time, that environmental impacts accumulate and that early negative impacts can alter the course of development. In addition, employing this metaphor threatens to inadvertently cue a viral discourse about computers as the downfall of the younger generation, culpable for social and developmental problems ranging from ADD to obesity.

- It is possible to build basic concept of epigenetics around several core ideas: 1) that genes contain instructions that control ongoing physical processes in the cells; 2) that factors from outside of the organism can affect how those instructions are relayed and carried out; 3) that early changes have a much larger impact on growth and development; and 4) that the changes accumulate over time. In our research, people found it easy with the help of our simplifying models to think about the last three core ideas, but they will need significant help understanding the first core idea.

METHODS: HOW SIMPLIFYING MODELS ARE IDENTIFIED AND TESTED

Phase 1. Mapping the Gaps

FrameWorks' research team first conducts two types of interviews, *cultural model interviews* and *expert interviews*. Cultural model interviews are conducted with members of the general public and are designed to gather data that, through qualitative analysis, reveal the underlying patterns of assumptions — or cultural models — that members of the public apply in processing information on a given topic. Expert interviews are conducted with researchers, advocates and practitioners who possess an "expert" or technical understanding of the given phenomenon. These interviews are designed to elicit the expert understanding of the issue. Comparing the data gathered from these interviews reveals the gaps that exist between how experts and average Americans understand and approach issues.

Phase 2. Designing Simplifying Models

FrameWorks' research team then analyzes transcripts of the interviews conducted in Phase 1 to generate a list of metaphor categories that capture salient elements of the expert understanding. These elements have the potential to be easily visualized and incorporated into the public's thinking about the target issue. The result of the design process is a list of both metaphor categories (e.g., "writing," "remembering") and multiple candidate simplifying models in each category ("waterway," "to-do list").

Phase 3. Testing Simplifying Models

FrameWorks tests the candidate simplifying models in multiple research formats, beginning with on-the-street interviews, followed by experimentally controlled surveys that test the candidate models against controls on measures of issue understanding, attitude and policy support. Finally we take the most effective models into a phase of qualitative testing that mimics the game of telephone and offers social interactions through which the models are expected to hold up, both in their linguistic expression and clarifying effects.

These three research methods are described here.

Test I. On-the-Street Interviews

On-the-street interviews provide an opportunity to gather data on the effectiveness of candidate simplifying models. These interviews examine which specific elements of the models are functioning well and which are less successful at shifting perspectives. Interviews are recorded and analyzed using a combination of grounded theory, social discourse analysis and cultural models analysis, to identify the impact of the models on redirected patterns of thinking.[8]

Test II: Quantitative Experimental Research

Using the results from on-the-street interviews to winnow candidate categories and help guide the development of further iterations of the models, FrameWorks designed a large-scale quantitative survey in order to demonstrate the efficacy of certain simplifying models over others with statistical accuracy. The survey was conducted online with roughly 2,000 participants, who were drawn from a national online panel. A nationally representative sample was first created. Individual members of the online panel were then selected to "match" this sample — constructing a nationally representative experimental sample.

The survey measured the efficacy of seven different models in helping people think about gene/environment interactions and their relevance for policy solutions related to early child development. Multiple-choice questions were designed to test the understanding of the metaphor, the ability to apply the metaphor and the ability to explain the metaphor. An additional question asked people to rate the ability of the metaphor to capture important features of the epigenome.

The two models that scored the highest on these questions were Signature Effect and Chemical Memory, which were graduated to the next phase.

Test III: Persistence Trials*

Based on the results of the quantitative experiments, the two top-scoring simplifying models, Signature Effect and Chemical Memory, were brought to Persistence Trials in Phoenix, Ariz., and Boston, Mass. In this phase of research, participants are recruited on the basis of their involvement in their communities, and to assure variation in gender, race/ethnicity, education level, occupation, community involvement and self-reported political affiliation.

In the trials, an initial pair of participants is presented with the paragraph-long iteration of the simplifying model, which they discuss with the moderator, then teach to a subsequent pair after being given a few minutes alone to discuss the model and plan their presentation. Following the transfer, the second pair explains the model to a third pair. Finally, the first pair returns to hear the transmitted model from the third pair. This last step closes the chain and enables us not only to see how the model has changed over the session but to see if participants can reason why these changes occurred.

Overall, this series of model transfers gives us opportunities to see how the participants react to and use the model, how and how well the model travels and holds up as it is passed between individuals, what parts of it are "sticky," and how it appears to change participant thinking on the target issue. The design of these sessions also allows researchers to observe several types of interactions (e.g., alone with each other, alone with the moderator, with the moderator and a new pair), which provides valuable insight into how the model is articulated and its thinkability.

Three Persistence Trials were conducted on each of the two candidate simplifying models (Signature Effect and Genetic Memory) and data were gathered from a total of 36 participants (18 for each of the two candidate models). Data were recorded and transcribed. Analysis of video and transcripts facilitated a detailed look at the specific communication advantages and challenges inherent in both models tested. These data were also used to make final refinements to the iterations in order to address specific issues and maximize the models' effectiveness.

RESULTS: TWO MODELS FOR COMMUNICATING EPIGENETICS: SIGNATURE EFFECT AND GENETIC MEMORY

Employing the research process outlined above, FrameWorks' research team identified, refined and empirically tested three simplifying model categories (Writing, Remembering and Emergence) and a total of 12 iterations across those categories. Two of these simplifying models helped concretize and clarify the science of executive function.

Initial iterations of these two models are provided below. Based on data from Persistence Trials, these iterations were modified and are presented in their final form at the end of this document.

* "Persistence Trials" replaces the term "TalkBack Testing," which no longer describes our current methodology.

Signature Effect

A new topic among experts who study human genes is called the epigenome, which is like a signature on our genes. The idea is that our genes have instructions on them that tell our bodies how to work. However, the environment has to sign for the instructions first. Positive experiences, such as good nutrition, are environmental signatures which authorize instructions to be carried out. These can lead to positive development. Negative experiences, such as exposure to toxins, are environmental signatures which can't authorize the right instructions, or which sign for the wrong ones. These can lead to poor development. Because this environment's signatures on a person's genes can last a lifetime, it's crucial that the genes get positive signatures early on.

Genetic/Chemical Memory[*]

A new topic among experts who study human genes is called the epigenome, which is like a chemical memory. The idea is that our genes have instructions on them that tell our bodies how to work. However, an individual's environment can leave traces behind, chemical memories that affect how the genes' instructions are carried out. Positive experiences, such as good nutrition, leave chemical memories that enable these instructions to be carried out. These can lead to positive development. Negative experiences, such as exposure to toxins, leave chemical memories that obscure or even change the instructions. These can lead to negative development. Because a person's genes can remember these chemical memories for a lifetime, it's crucial that the genes have good chemical memories of the environment from the start.

What the models contribute to the public understanding

Below we review the development of these models through the iterative research process. We discuss the general effects of the models, summarize the empirical evidence that demonstrates their explanatory power and describe the specific strategic advantages they would confer in communications on genes, environments and early child development. Additionally, we describe some of the caveats and reservations about the models that were uncovered in the research process, which led to revisions in the models. We conclude with insights into how to apply these models to more effectively communicate about epigenetics.

[*] A note about "Genetic Memory": Earlier in the research process, the model "genetic memory" had the title "chemical memory." In the first Persistence Trial in Phoenix, people had difficulty explaining a "chemical memory," though the notion of "memory" alone led people to talk readily about how genes might have memories. For this reason, we saved the "memory" part of the metaphor but changed the name of the model to "genetic memory." This enabled people to utilize meaningful aspects of the "memory" domain without encountering "chemical memory" as an obstacle. Interestingly, the metaphor of a "gene memory" was spontaneously generated in a Persistence Trial about the Signature Effect and in another trial of "chemical memory." Also, one participant utilized this metaphor in conjunction with the metaphor of the environment "signing" the gene, without any apparent dissonance.

1. Evidence from On-the-Street Interviews.

Signature:

Results of on-the-street interviews illustrate how well the "Writing" category (from which Signature draws its clarifying and concretizing power) performed. In these interviews, FrameWorks' researchers tested an iteration of this category called "Autograph." This iteration, based on the results of these interviews, was later refined and re-iterated using a slightly different but conceptually related metaphor of "Signature."

In on-the-street testing, "Writing" successfully increased people's understanding of how genes and environments interact and the role of this interaction in shaping individual outcomes and differences. First, the metaphor led to discussions in which many informants were able to realize that *external* environments have the power to shape the *internal* workings of a person's genes. Furthermore, these informants grasped the idea that changes at the genetic level influence outcomes and shape individual differences. Informants were generally able to use the metaphor to discuss the fact that environments leave a mark on genes and that the environments in which people live affect how genes function. While this shift was not apparent in all interviews, when it did occur it was a dramatic change from the way that informants in earlier in-depth interviews viewed environments and genes as disconnected concepts and saw genes as "set in stone."[9] Furthermore, the metaphor appeared to open informants up to a wider set of environmental influences, and in this way, showed potential to deactivate another dominant assumption that emerged from the earlier interviews; namely, that parents *are* environments.

> I think a perfect example is, if you have some genes that may make you conducive to, for instance, *alcoholism*, I know there's been a lot of research surrounding that, but if you're never put in a situation where that gene may be triggered, it's probably always there, but it may not have a *catalyst* to make to autograph that gene and make it actually come to the forefront. I do believe that research has shown that, genes are autographed by certain environmental stimulus that is presented to us.
>
> Participant in On-the Street Interviews

> I think if you're exposed on a continuous basis to things that are very bad for you physically, I think that that could affect how your internal workings are going.
>
> Participant in On-the Street Interviews

Chemical Memory:

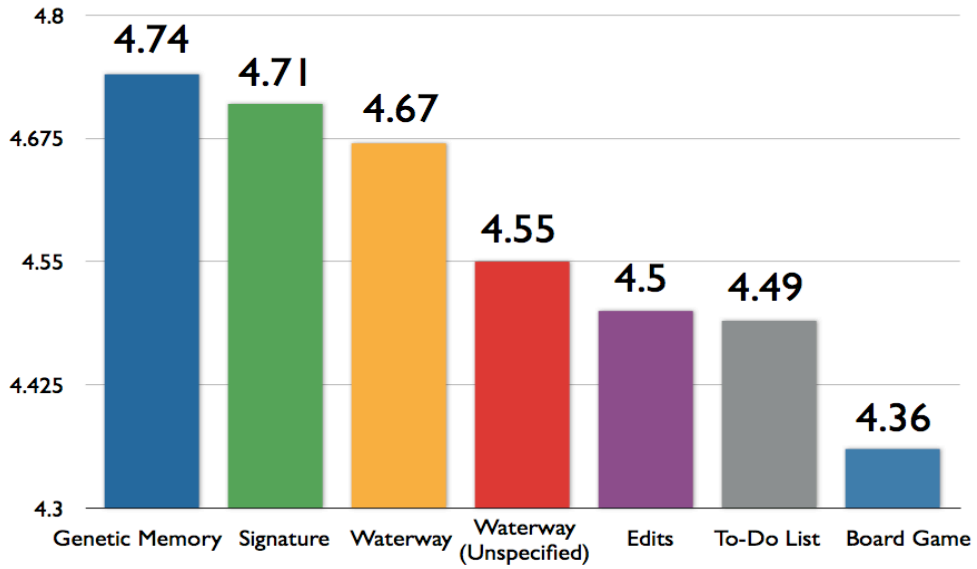
Like the "Writing" category discussed above, the chemical memory metaphor was relatively successful in conferring an understanding of and facilitating conversations about the fact that environments "get into" and affect the ways bodies work by impacting genes. Again, in the face of the dominant cultural models that Americans implicitly rely on to think about these issues, this was seen as a monumental shift and perceptual expansion.

> I would say, maybe just-just like your memories, you physically, physically are influenced by your environment, and it can change anything inside of you. It can change your brain patterns, and can change you physically.

2. Evidence from the Quantitative Experiment. The quantitative experiment provided statistical evidence for the effectiveness of Signature Effect and Genetic Memory. As part of an Overall Effectiveness measure, the experiment measured the general understandability of the metaphor (understanding), each model's efficacy in structuring understandings of what epigenetics is, why the epigenome is important (application), and the participant's assessment of the metaphor's appropriateness as a way to think about genes, environments and their interaction (aptness). These three measures were aggregated into an Overall Effectiveness score for each model, which are presented below in Figure 1.

Though all of the models performed relatively well on this measure, two simplifying models emerged as "winners" relative to these outcomes, as demonstrated in Figure 1. That is, they prompted respondents to answer most of the application and understanding questions correctly. Also, respondents rated them as having a high degree of "fit" in the aptness measure.*

Figure 1: Overall Effectiveness



* A note about statistical significance: The two models that were ultimately most successful had scores on Overall Effectiveness that were statistically significant when compared to the lowest performing model but not to others. We treat these data directionally, in combination with data from on-the-street interviews and cultural models interviews, in order to determine likely winners. On their own, the quantitative data suggest that all the models perform relatively well, but we use the small differences among them to select the models that are the most effective relative to the rest of the group.

3. Evidence from Persistence Trials. Both challenges and benefits of the two simplifying models, Signature Effect and Genetic Memory, were vividly evident in Persistence Trials.[10]

In Persistence Trials, we evaluated the performance of both simplifying models according to the five criteria listed below. The performance of the two "winning" models along these measures is summarized here, and more detail on these outcomes provided in Appendix A.

Analysis

In Persistence Trials, we evaluated the performance of simplifying models according to the following five criteria, and their performance is summarized here.

1) *The simplifying model had to give people a way to understand interactions between environments and genes, and introduce the notion that genes are vulnerable to factors external to the genes themselves and to the individual's body.*

Here, a participant inquires about what the researchers meant by "environments":

(Genetic Memory)

Cause I was gonna say the same, not on that respect, I was talking about like smoking, you know, smoking in the house, my parents smoked and stuff, you know, and maybe when I was younger and stuff, and I can't stand the — the whatever, would that be an example of what you're talking about, where it's environmental, I don't, you know, uh … is that…

Here two participants take diabetes as an example of a disease with environmental triggers: (Signature Effect)

Participant A: You know, and I think we, you know, say we took diabetes as an example.

Participant B: Sure.

Participant A: Um … obviously there's a genetic chemical link there …

Participant B: Right.

Participant A: … as to how that could be passed on.

Participant B: Uh-huh.

Participant A: Through the signature effect, through the — the change of environment through diet, through exercise …

Participant B: Right.

Participant A: … through things along those lines, that genetic makeup can be changed.

2) *The simplifying model had to inoculate people against dominant cultural models about genes, e.g., that genes are set in stone, that there is a calculable ratio of genetic vs. environmental influences, etc.*

FrameWorks' cultural models reports on gene/environment interactions indicated some of the dominant cultural models that Americans possess about genes and environment and how they interact.[11] The identified models are listed here:

- The "will power is the ultimate determinant of outcomes and differences" model
- The "parents are environments" model
- The "genes are set in stone" model
- The "percentages of influence" model

In discussions of genes and environments, each of these four models restricts the thinkability of public solutions to problems of early child development. An ideal simplifying model would control the persistence of these dominant models in the social setting of the Persistence Trial. Unfortunately, neither simplifying model candidate was predictably successful at this task, as detailed here:

Signature Effect: "Will power as ultimate determinant." This idea, when articulated, was not countered by the Signature Effect.

Signature Effect: "Parents are environments." Participants readily discussed a broad range of factors in the individual's environment that operated outside of the family. To be sure, parents and family interactions came up, but so did factors like air quality, water quality, other pollutants and toxins, and neighborhoods and other aspects of place (e.g., living on Long Island versus living elsewhere).

Signature Effect: "Genes set in stone." Participants easily grasped the notion that genes were not fixed quantities but could be vulnerable to other forces. Though the Signature Effect successfully inoculated against the fixedness of genes, the model ran into difficulties because of underlying problems in the ways that participants understood genetics. In one instance, participants talked about the only mechanism for genomic alterations that they knew: mutation. In another instance, a participant agreed that a mark could, indeed, be placed on a gene, but that this did not change genes, because "I feel like your genes are something that you pass on." To understand how epigenetic effects are dynamically mutable would require already having moved past this particular dominant cultural model.

"Percentages of influence." Participants remained apt to assign responsibility for how individuals come out to a varying mix of genetic and environmental influences, and they also discussed which sorts of outcomes were due to which set of influences. The Signature Effect was not observed constraining the appearance of this model, nor did people use the Signature Effect to argue against it.

Genetic Memory: "Will is major determinant." This model did not come up in the Genetic Memory trials, so we are unable to say if the simplifying models inoculated against it.

Genetic Memory: "Parents are environments." Participants readily discussed a broad range of factors in the individual's environment that operated outside of the family. To be sure, parents and family interactions came up, but so did factors like air quality, water quality, other pollutants and toxins, and neighborhoods and other aspects of place (e.g., living on Long Island versus living elsewhere).

Genetic Memory: "Genes set in stone." This simplifying model was moderately successful at getting people to think beyond the idea that "genes are genes are genes." We explain this according to the entailment that, like personal memories, genetic memories are continually being altered (either formed anew or lost).

Genetic Memory: "Percentages of influence." In discussions about Genetic Memory, individuals talked about percentages of influence less than in Signature Effect. The model did give one participant a new way to think about the age at which environmental influences on gene expression begin or stop, given that a person continues to accumulate memories throughout their lifetime; so, thus, should the gene's memories.

Other dominant models. In addition to models identified in the cultural models report, other operative cultural models appeared in the conversations. These are relevant because some of them hold the key to the simplifying models' success and also the challenges they faced in communicating epigenetics. For example, one recurring theme was the search for a mechanism that explained the transmission of cultural, as opposed to biological, traits. As an explanation, people seemed to prefer a genetic mechanism, and both Genetic Memory and Signature Effect became viable versions of how this occurs. See this example from a Signature Effect trial:

> Those are things that genetically I feel like are passed because it's […] the norm, it's the *consistency.* It's what is understood to be the correct thing, or the way to approach something. […] And so, the whole idea of environment affecting genes, to me, is the idea of your parents are probably subjecting you to an environment that they understood to be the correct way, and so they're passing that to you …

The genetic mechanism seems to be attractive because as far as many people understand what genes do, they are vehicles for inherited traits that transport them across generations. This led to another recurring theme: Because epigenetics are interpreted as Lamarckianism, individuals object to the content of the models. Even though neither Genetic Memory nor Signature Effect discussed intergenerational transmissions, this was read into the models by many of the participants. In the main, this was a harmless entailment. However, individuals who possessed more literacy in genetic sciences and remembered that Lamarckianism has been discounted, interpreted Genetic Memory and Signature Effect as violations of mainstream science.

4) *The simplifying model had to be generative; that is, it had to build a schema to enable individuals to productively encounter other information.*

Both models were most widely and consistently successful in their generativeness. In this context, by "generativeness" we mean three things:

1) Did individuals ask targeted questions about the topic area that suggest that they might incorporate new information about epigenetics into their understanding?

2) Did individuals create and/or use additional metaphors?

3) Over the course of the trial, did individuals add to what they had to say about the models?

Some examples of what we identified as the generativeness of the models:

> (Signature Effect)
>
> *Participant*: You're saying that contains the potential for how a person becomes, or whatever, right? You're saying that at the core of that genetic material has changed, or are you saying that just that individual as a whole person is uh … changed in some way? You know what I'm saying?
>
> (Signature Effect)
>
> *Moderator*: So I mean, can you think about the possibility that environments might impact genes?
>
> *Participant*: No, that's cool. I'm down for that if there's like, you know, research and information and stuff.
>
> (Genetic Memory)
>
> *Participant:* No, it took — I was just curious to know if it was … if these things develop in the womb depending on like what the mother does, or is it … from birth, environmentally, kids that grew up in urban settings aren't particularly inclined to have a patience for bugs and wildlife, or … [LAUGHTER]
>
> (Genetic Memory)
>
> *Participant*: Yeah, I mean, I don't know — I don't know enough about genetics. I'm not sure how I feel about this. It seems a little bit — but I do — I actually do believe that experiences can change the wiring in our brains, in brain plasticity, so I — I don't know if there's a relation to that, but that's kind of what I was thinking about, and I really do believe that *experiences can rewire the brain*, so um …
>
> (Genetic Memory)
>
> *Participant*: Well, the word "memory" becomes a little confusing there because when — when you talk about a gene having a memory, now I'm kind of like thinking of a motherboard in a computer … I remember when I first came to Boston, uh … those kind of memories that we … store in our brains … When we first started talking about "gene memory," I was assuming, okay a child is born, and it's got these genes that he got from mom and dad, and everybody in the back, and the memories that you're talking about are in those genes day 1. Now we're going in a different area here, now we talk about, oh you can add to the memories of those genes? I hadn't even considered that possibility. … I suppose if at the age of two, when he's in the early childhood development stage, um … he catches measles, then I suppose his genes would now have a gene memory of measles and

> recognize that type of sickness, and — isn't that one of those things where if you've had it you can't get it again? That's because your gene remembers having it. That the kind of gene memory we're talking about?

5) *Crucial elements of the metaphor had to be persistent in social interaction.*

Signature Effect

The title "Signature Effect" was easily repeated. Less persistent was the notion that the signature involved a "mark" on the gene, and it took significant prompting to get people to articulate what was being marked and what was doing the marking. However, when participants took to "leave a mark on the genes," they tended to repeat this easily. Other synonyms were used: stamped, imprinted.

The model itself was repeatable by people across the generations, as in this moment when an individual in Generation 1 described the model to Generation 2:

> *Participant:* So, when we first got in here they had us read a paper about half long about a concept called the Signature Effect, and it pretty much described in what I felt was vague detail about how we're born with a set of genes and how relative that is, they react to the, whatever environment you grow up in. The premise of the Signature Effect, from what I understand, is that if the environment is negative, it suppresses whatever the gene is supposed to instruct. It's … let me think, it's so confusing, um, and if the environment is positive, the, um, genes turn out positive.

One aspect of the model that challenged participants was the interpretation of what it meant to "mark" the gene, as in this statement:

> *Participant:* Yeah. If you — and even saying "left a mark on my genes" implies — a "mark" is like a change. It's like a — it's something, … but her terms were implying an actual change in the genetic structure, which I was like, you can't say that. You should say something like, "I've used the potential of my genetic material in a different fashion from the environment in which my parents were" — I don't know. There's got to be some better nuance way of saying it than "left a mark on my genes."

This is another example of a place where individuals mistook the epigenetic metaphor for Lamarckianism.

Genetic Memory

In the first two sessions of Persistence Trials, this model had the title "Chemical Memory" but was switched to "Genetic Memory" for several reasons. One was that "chemical memory" was not evocative for participants. Another was that the word "chemical" cued the possibility that epigenetics referred to drug interventions. A modification was clearly necessary. More significantly, "gene memory" or "genetic memory" came up several times spontaneously in discussion, even in sessions testing Signature Effect. This was a clear indication that model

building was easier for people if the title referred to "genetic memory." For example, see this exchange between two participants from Generation 2 discussing between themselves:

> *Participant A*: *[referring to the previous generation]:* I think that that's why … they removed the word "chemical" because it confused them and went to "gene" or "cell memory."
>
> *Participant B:* Cell memory?
>
> *Participant A:* You know, like your — the cells of your body. That's why, I think, they were using "genes and cells" memory versus "chemical", because the chemical — that's exactly, it took her a while. She thought they were going to add a chemical to the gene or something.

The notion that "genes have a memory" was very persistent and transmittable, but the notion had a number of interpretations (e.g., "gene memory" is the same thing as neural memory, the genes remember emotional experiences and are the bearer of personal experiences). Also persistent was the notion that genes "absorbed" features of the environment within them.

6) Miscellaneous effects

One notable feature of the Persistence Trials for both models was the willingness of participants to engage each other in working out aspects of the model. What was meant by gene? How would they talk about environment? Did marking the gene imply that the gene itself was changed? While these questions were not necessarily resolved, seeing the collaborative nature of these interactions was a positive sign that even unsuccessful simplifying models provide a site for fruitful discussion. For instance, here are all four participants and the moderator attempting to reason through an example of the Signature Effect:

> *Participant A*: No, because the signature is something that you would spot in everybody, that's my signature, and so the signature of pizza will be genes, A-B-C-D that pop up in you and me. Here everybody in …
>
> *Participant B*: I just …
>
> *Moderator*: So everybody has a signature, that's the commonality?
>
> *Participant A*: The trigger, the environment signature on the person.
>
> *Participant B*: Oh, environment signature.
>
> *Moderator*: Okay.
>
> *Participant A*: On the person.
>
> *Participant B*: But everybody's print — everybody's genes are different.
>
> *Participant C*: They're different, but they're the same.
>
> *Moderator*: She means the signature … Because …

Participant C: The difference, yeah, she's meaning the same thing to be the pizza.

Participant B: Okay.

Participant D: She's making the pizza the subject and the people the object of the …

Participant A: Yeah, I'm making the … [LAUGHTER]

Participant D: So I would — that's where I'd part it, and do it the other way around.

Participant B: You'd say what?

Participant D: Well, a signature is a signature because it's unique for you. You will sign it because only you have your signature, and so to me, the effect would be the different ways that we each react. It's unique for — we each react — we each react differently to pizza because, we each have a different signature like our …

Participant C: Body makeup.

Participant D: Our DNA is our signature, so to speak. Like …

Refinements

Despite their many assets, these two specific simplifying models had some weaknesses which were addressed in final revisions to the models.

- In the case of Genetic Memory, the "memory" aspect proved problematic in some cases and was construed to be any sort of traces, influences or effects. People in several cases interpreted "genetic memory" literally and confused it with neurological memory. When this occurred, the literal interpretation blocked the desired response that environments in early childhood are crucial, and led people to believe that children cannot consciously remember early experiences.[12]

Consequently, the model was revised to sharpen the metaphorical meaning of "memory" in use and to even exploit its entailments. For instance, if a person's memories make them behave in new ways, then the gene's memory might also do the same thing.

- In the Persistence Trials on the Signature Effect, people had difficulty describing what thing was marked and what was doing the marking. In a final version of the model, the relationships were stated more clearly.

- Persistence Trials also demonstrated that the word "environments" was an ambiguous term, as was "experiences." That is, "environment" was often taken to mean "ecological," while "experiences" were taken to be "personal experiences." The final version of Genetic Memory now discusses "things from outside our bodies" instead, while the final Signature Effect clarifies that "environments" are "where children live."

- To attempt to counter the understanding of genes as intergenerational vehicles of traits, the final iterations of the models were changed to stress that genes are more than that. Earlier versions also stated that "genes have instructions on them."

Outstanding Issues

These two models also encountered other obstacles that could not be fixed by revising the text of the model. For example, one weakness of the Signature Effect was the notion that genes are "marked" or "imprinted" on became interpreted as "changing the genes." In several instances, this "changing the gene" idea was interpreted as an endorsement of Lamarckianism, and therefore not an orthodox position. In other words, for some participants the idea of epigenetics was seen as a direct affront to what they saw as a fundamental feature of genetics — that acquired characteristics *simply can not be inherited.* In addition to demonstrating a misunderstanding of the metaphor — that it proposed a change to the actual genetic structure — this interpretation is evidence of the strength and depth of the "genes are set in stone" cultural model.

Additionally, in other simplifying models research, FrameWorks has depended on models to be able to "self-correct" — that is, when a breakdown in thinking does occur, people using the model can redeploy it in its original form, where it is able to clarify key aspects of the issue. Neither simplifying model exhibited this property in a robust fashion. In one Genetic Memory trial, participants in Generation 2 who conflated genetic memory with neurological memory were corrected by participants from Generation 1, but the original misusers continued to use the uncorrected sense.

It is important to consider that these weaknesses point to a need for further research on other frame elements that, along with the models developed here, can communicate aspects of the concept of gene-environment interaction. In short, while the models discussed here were helpful in the ways described above, research showed that there are outstanding parts of the science of gene-environment interaction that remain to be effectively communicated.

CONCLUSION: APPLYING THE RESEARCH

In this final section of this report, we describe the final versions of the models, provide recommendations for explaining epigenetics and add some thoughts about the work that simplifying models do on this topic.

Signature Effect

> A new topic among experts who study human development is called the epigenome, which is like a *signature* on our genes. Our genes have instructions on them that tell our bodies how to work, and those genes interact with a growing child's environment. Here's how the interaction works. The environments that children live in and the experiences they have leave a signature on their genes. These things leave a mark on the gene that authorizes some parts of the gene to go ahead and others to hold back from giving their instructions that make our bodies work. When signatures from outside the body mark genes inside the body early in a child's life, they leave imprints for years. Therefore, it's crucial that children begin developing in positive environments early on.

Genetic Memory

> A new topic among experts who study human development is called the epigenome, which is like a memory that our genes have of the environments we live in — what we can think of as a *genetic memory*. Genes can remember the things from outside our bodies that affect how things on the inside of our bodies work. Examples might be how our bodies heal, how children's bodies develop and how our bodies deal with stress. The idea is that if something can affect the inside of our bodies, the genes can remember it. Such genetic memories alter how genes run our bodies' internal workings, just like a person's memories can affect the decisions they make and how they live their daily lives. And just like a person builds new memories, genetic memories are constantly forming and affecting how other parts inside our bodies work. The most crucial time for building good genetic memories is early in childhood, because their growing bodies and minds will live with these memories for the rest of their lives.

We conclude with two notes of caution in the application of these simplifying models in communications about early child development. First, the simplifying models were tested both for their underlying concepts and with respect to the linguistic execution of this concept. Therefore, the paragraph of text represents both an effective metaphorical *concept* and an effective linguistic *packaging* or expression of this concept. For these reasons, while a certain latitude and flexibility in use and application is to be expected, even encouraged, what has been tested is the specific concept and the language that appear in this report. We do not therefore claim to know the results or effectiveness of using alternative but related concepts or dramatically different linguistic executions of either Signature Effect or Genetic Memory. In short, scientists, practitioners and advocates should include the following basic elements in using the simplifying model:

1. **What genes do:** In addition to passing traits from parents to offspring, they contain instructions that tell our bodies how to work.

2. **What creates the genetic memory or signature:** "Things outside our bodies" (environments and experiences) create it.

3. **What the "environment" is:** Environments include access to resources, quality of experiences, social contexts.

4. **Where the genetic memory or signature goes:** It gets placed on the gene — leaving a mark on the gene.

5. **What the genetic memory or signature does:** It authorizes (or motivates) certain behaviors and characteristics, while prohibiting others.

6. **Why and when the genetic memory or signature matters:** It is particularly important when it happens early because it stays on the gene for a lifetime/long time.

Recommendations for Explaining Epigenetics

Both researchers and those communicating the concept of epigenetics should take into account the following points:

Do not explain the epigenome in terms of the genome. On the basis of our research, we can foresee the problems that epigenetic metaphors used by scientists and science writers will have when they reach the nonspecialist public. (Some examples of such metaphors are "instruction manual," "the pianist on the genome's keyboard," "a map of chemical switches," "a subcellular landscape of chemical signposts" and "if the genome is the book of life, the epigenome is how a specific cell type marks it up with highlighters"[13]). The simplifying models that FrameWorks tested were designed to capture the *interactions* between genes and *environments*; by contrast, these other metaphors attempt to capture the relationship between the genome and the epigenome. However, as we found in our research, people's knowledge about genetics was often too Mendelian to be built into an effective metaphor. Often, individuals thought that there could be multiple definitions for the gene, but when they fixed on a single definition, it was that genes determined physical traits and predispositions for disease that were inherited by offspring. While correct, this understanding inhibits explanations of epigenetics.

Another favored metaphor is that of a "light switch" (where genomic expression is the light and the environment flips it on or off). On the basis of our research, we can predict what would happen if this metaphor were deployed to explain epigenetics. People would inevitably bring up predispositions for disease, but they would rapidly default to the dominant cultural model that was termed "will power is the ultimate determinant of outcomes and differences."[14] Employing this cultural model, individuals would be quick to point out that people have the power to flip their switches and are to blame if they don't.

Do not explain the epigenome using a software/hardware metaphor. A metaphor that spontaneously popped up in one trial to explain the epigenome was that of software and hardware. Genes are hardware, composed of hard-wired circuits, while environments are software, giving instructions that run the hardware in a variety of ways but which do not change the hardware. Given the technological literacy of the current era, it is tempting to treat this as the metaphorical seeds of a viable simplifying model. Moreover, it also relates genes and environments (not, as discussed above, genomes and epigenomes). However, it does not capture important aspects of epigenetics *as related to policy* — specifically, that environmental impacts persist over time, that environmental impacts accumulate and that early negative impacts can alter the course of development. In addition, employing this metaphor threatens to inadvertently cue a viral discourse about computers as the downfall of the younger generation, culpable for social and developmental problems ranging from ADD to obesity. These varied shortcomings make recommending this metaphor difficult.

Anticipate encountering "beliefs" about genetics. In each of the Persistence Trials, participants often referred to "beliefs" about genes and environments, using the verb "believe" to describe ideas they possessed about gene/environment interaction. This suggests that genetics is a domain in which people's beliefs do not so much resist the introduction of facts, as people have grown accustomed to having beliefs and (potentially) contradictory facts living alongside each other. Communicators may expect to find religious beliefs in the realm of evolution and creation, not genetics. But some participants in Persistence Trials, for instance, possessed religious views that

precluded any role for sociobiological determinants. In their views, God sets individuals with their purpose in life which shapes how they develop and grow up. There are other explanations for the use of the word "belief." 1) People often draw on personal experiences as examples for resolving "nature versus nurture" arguments. Even though epigenetics resolves this pairing, participants often returned to this zero-sum default view of a discourse about genes and environment. 2) Individuals who are used to encountering personal experiences and religious views expressed by other people hedge their own commitments to certain ideas in order to show sensitivity to others' views. Regardless of the reason, epigenetic explainers and early childhood development framers should anticipate some intersection of belief and genetics.

Anticipate that people will know enough about "genetics" to mine it for its metaphors. People appear to find the topic of genetics to be a conceptually rich domain whose meanings were available to explain other things. One such topic that we observed in Persistence Trials was how culture gets transmitted. People found a genetic explanation for this very easy to think; one explanation is because they see genes as vehicles that transport traits across generations. It is an easy move from biological traits to cultural traits. Both Genetic Memory and Signature Effect became viable explanations of how this occurs (which disrupted the efficacy of the models). See this example from a Signature Effect trial:

> Those are things that genetically I feel like are passed because it's […] the norm, it's the *consistency*. It's what is understood to be the correct thing, or the way to approach something. […] And so, the whole idea of environment affecting genes, to me, is the idea of your parents are probably subjecting you to an environment that they understood to be the correct way, and so they're passing that to you …

Attitudes, behaviors and preferences which are culturally shaped were all debated in conversations as possibly being transported genetically. This tendency suggests that other communications and translation tools are required to work on reshaping the way that people see genes, inheritance and the outcomes affected by these processes.

Final Thoughts. FrameWorks designs and tests its simplifying models to be robust elements of the frames that will help shape public discourse by bridging the gaps between specialists and non-specialists. We routinely remind the people with whom we engage that simplifying models are only one kind of frame element, and that successful reframing of an issue can and should involve deploying more than one element. We might also remind them that the explanatory effects of the simplifying model depend not only on the model itself, and not only on individuals' understanding of the source domain (genetic memory), but sometimes on their understanding of the target domain (genetics), too.[15] Our research has shown that contemporary understandings of genetics do not yet match the fast-moving science. In a way, people have a solid basic knowledge of genetics, though at some past state of the art. However, the simplifying models discussed here can serve as precursors that can help create additional understandings around the science of gene-environment interaction. Without these models as foundations of understanding, it will be difficult to build subsequent explanations.

A basic concept of epigenetics can be built around several core ideas: that genes contain instructions that control ongoing physical processes in the cells; that factors from outside of the organism can affect how those instructions are relayed and carried out; that early changes have a much larger impact on growth and development; and that the changes accumulate over time. As

we found in the research we report here, people found it easy with the help of our simplifying models to think about the last three core ideas. Getting them to understand the first core idea is work that remains to be done.

About The FrameWorks Institute

The FrameWorks Institute is an independent nonprofit organization founded in 1999 to advance science-based communications research and practice. The Institute conducts original, multi-method research to identify the communications strategies that will advance public understanding of social problems and improve public support for remedial policies. The Institute's work also includes teaching the nonprofit sector how to apply these science-based communications strategies in their work for social change. The Institute publishes its research and recommendations, as well as toolkits and other products for the nonprofit sector, at www.frameworksinstitute.org.

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APPENDIX: THE METHODOLOGICAL APPROACH TO IDENTIFYING AND TESTING SIMPLIFYING MODELS

I. PHASE 1: MAPPING THE GAPS

In the first phase of this simplifying models research process, FrameWorks employed an interview method called cultural models interviewing. Using a detailed interview guide, interviewers asked questions aimed at getting at how average Americans understand and approach the issue of genes and environments in the context of early child development.

More generally, cultural models interviews reveal the cognitive "terrain" on a given issue by focusing on the implicit patterns of assumptions — or cultural models — which individuals employ to process incoming information on an issue. These patterns are the "mental bins" into which people try to fit incoming information and represent both potentially productive and damaging ways of making sense of information. To uncover the gaps in understanding on genes and environments, we conducted cultural interviews as well as interviews with experts, who are asked about their understanding of the current state of genetic science as well as any metaphors they typically use to teach these concepts. FrameWorks calls this entire process "mapping the gaps."

II. PHASE 2: DESIGNING SIMPLIFYING MODELS

FrameWorks had two goals for the simplifying models on this issue. First, the models were designed to connect genes and environments in a way that people could apply their new understanding. Second, the models were designed to open new mental frameworks for participants so that they might accurately and readily process new information about epigenetics they might encounter.

After identifying the gaps in understanding, the second phase of the simplifying models research process aimed to generate a set of candidate simplifying models that were then empirically explored and tested in the third research phase. The result of the design process is a list of both metaphorical categories (e.g., "Emergence," "Writing," "Remembering") and multiple iterations or "executions" of each category (e.g., "Signature Effect," "To-Do List"). FrameWorks' linguist analyzes all of the transcripts from the "mapping the gaps" phase of the research process and generates a list of metaphor categories that represent existing conceptual understandings that can be recruited as well as overlap between the experts' and general public's use of metaphorical language and concepts. The linguist generates metaphor categories that capture the *process* element of the expert understanding in metaphors that, given the data gathered from members of the general public, have the potential to be easily visualized and incorporated into thinking about the issue under consideration.

FrameWorks researchers who are specialized in cultural models and cognitive theory conduct a cognitive analysis of the model categories, which examines the *expected* public response to the metaphors based on cultural models theory and existing FrameWorks research on cultural models that Americans employ in understanding how genes and environments interact. Researchers then use this analysis to review the metaphor categories, adding new possibilities and suggesting ones to be cut. At this stage, researchers also compare the candidate metaphors to the data from the initial cultural models interviews. Metaphor categories that contain elements or

aspects of models found to be damaging or distracting in the public's thinking about the topic are suggested as categories to be eliminated from the candidate list. On the other hand, simplifying model categories containing elements of more productive cultural models are highlighted as particularly promising.

During the process of designing candidate simplifying models, FrameWorks also assesses the models' abilities to be incorporated into practice by journalists and advocates/practitioners. In some cases, this practical assessment has suggested that some candidate models are too provocative or insipid to pass into the public discourse. These models are removed from the working list. The refined list is then returned to the linguist, who begins to compose iterations or executions of the categories on the list. The list of categories and iterations is sent back to FrameWorks' researchers for additional revisions.

PHASE 3: TESTING SIMPLIFYING MODELS — THREE TESTS OF MODEL EFFECTIVENESS

Test I: On-the-Street Interviews

As the initial opportunity to test candidate simplifying models, on-the-street interviews present an ideal opportunity to gather empirical data on the effectiveness of candidate simplifying models — which specific elements of the models are functioning well, and which aspects are less successful in clarifying concepts and shifting perspectives.

The metaphors are written up as "iterations," paragraph-long presentations that cue the listener/reader to two domains of meaning, one of which is typically referred to as the "source," the other of which is known as the "target." In the metaphorical statement "encyclopedias are goldmines of information," the source domain of meaning is "goldmine" and the target is "encyclopedias." In FrameWorks' terms, "encyclopedias" is the target because it is the object or process that the application of knowledge about goldmines is meant to illuminate.

In March 2009, FrameWorks tested a total of six candidate simplifying models in Boston, Mass., and Baltimore, Md. Each candidate model was presented orally, in separate interviews, to three or four informants in each of three locations for a total of seven interviews per model, comprising a total data set of 35 10-minute interviews. All informants signed written consent and release forms and interviews were video and audio recorded by a professional videographer.

The six models tested represented executions of four candidate simplifying model categories (e.g., Writing, Remembering, Emergence). Data from the interviews were used to winnow and refine categories as well as to refine the individual executions of metaphors within categories.

Subjects

A total of 18 informants were recruited on site in each of the two locations. A FrameWorks researcher approached individuals on the street or walking through a mall and asked if they would be willing to participate in a short interview as a part a research project on "issues in the news." The recruiting researcher paid particular attention to capturing variation in gender, ethnicity and age.

Data on each informant's age and party affiliation, as self-identified, were collected after the interview. Efforts were made to recruit a broad range of informants. However, the sample is not meant to be nationally representative. Although we are not concerned with the particular nuances in how individuals of different groups respond to and work with the simplifying models tested in these interviews, we recognize the importance of between-group variation and take up this interest in quantitative testing of simplifying models — where the virtues of quantitative sampling techniques can effectively and appropriately address issues of representativeness and across group variation.

The Interview

FrameWorks had the following goals in designing and conducting on-the-street interviews: (1) identify particularly promising simplifying model categories, (2) refine those categories with more mixed results and (3) eliminate highly problematic categories, in which the underlying *concept* created problems that could not be overcome by refining existing or designing new executions. FrameWorks' approach to this winnowing process is highly conservative to assure that only the most unproductive categories — those that are beyond repair — are eliminated.

However, winnowing is a necessary feature of a process that intentionally produces a large set of possible iterations, but that culminates in the one most effective simplifying model.

More specifically, interviews were designed to gather data that could be analyzed to answer the following questions:

A. Did the informants *understand* the model and its underlying metaphor?

B. Did they *apply* the model to talk about genes and environments?

C. Did the model *shift* discussions away from the dominant thought patterns that characterized the initial responses?

D. Did exposure to the model *lead to more articulate answers and robust, fully developed conversations* of issues that informants had problems discussing prior to being exposed to the model?

The interview began with a short series of open-ended questions that dealt with genes and environments and how children develop. The interviewer then discussed one of the candidate simplifying models using a memorized but conversational script. Following this exposure to the simplifying model, the researcher asked informants a second series of open-ended questions designed to gauge the effect of the simplifying model in shifting perspectives on genes and environments and in facilitating more robust conversations around these issues. Some of these questions were reformulations of the initial questions using different language so as not to appear repetitive.

The results of on-the-street interviews were used to pare the four categories into the following three:

Writing

Remembering

Emergence

Test II: Quantitative Experimental Research

After analyzing on-the-street interview data, FrameWorks subjected the refined set of simplifying models to an online quantitative experiment. The overarching goal of this experiment was to gather representative and statistically powerful data on the models' effectiveness. These data then provided an empirical basis to select one or two models that were most successful relative to a set of theoretically driven outcome measures. In the end, experimental data were used to select and refine two models that were then taken into the final stage of the empirical testing process.

In February 2010, FrameWorks conducted the survey, which measured the performance of seven candidate simplifying models and three metaphor categories in relation to a set of outcome measures. 2,600 survey participants were drawn from a national online panel and data were matched on the basis of gender, age, race, education and party identification to ensure that the sample was nationally representative.

Experimental Design

Following exposure to one of seven "treatments" — paragraph-long iterations of candidate metaphors — participants answered a series of questions designed to measure a set of theoretically based outcomes. Effects were compared both across and within categories — meaning that general categories were tested against other general categories, and specific iterations were tested against other iterations both within and across categories. Outcomes measured included: *understanding, application, extending* and *aptness.*

Treatments

Coming into the experiment, results of on-the-street interviews were used to pare the four categories into three: Writing, Remembering and Emergence. In designing the survey instrument, multiple iterations were generated by a linguist as alternative representations of the larger metaphor categories. For example, the Writing category included iterations for Signature Effect and Edits, while Remembering included Chemical Memory and To-Do List and Emergence contained Waterway and Board Game. Two versions of Waterway were included: one which linked positive and negative inputs to positive and negative outcomes, and one which did not explicitly link them.

In total, seven specific simplifying model iterations were developed and were tested in a sample of 2,000 participants. Each treatment consisted of a paragraph that described the metaphor, as in the following example:

> *edits*
>
> A new topic among experts who study human development is called the epigenome, which is like edits to a document. The idea is that our genes have instructions on them that tell our bodies how to work. But an individual's environment can edit the gene's instructions. Positive experiences are environmental edits to the instructions that preserve them. These lead to positive

> development. Negative experiences are environmental edits that confuse the instructions or make them say something else. These lead to poor development. Because the environment's edits on a person's genes can last a lifetime, it's crucial that the gene get positive edits early on.

All seven iterations were parallel in overall length, sentence length and complexity and sequence of items. They also included examples and entailments derived from the metaphor. For example, the authorizing of the gene's instructions by a signature was an entailment discussed in the Signature Effect, and the unpredictable interactions between genes and environments over time in both versions of Waterway was another entailment. On the whole, the treatments were substantial enough in length to trigger thinking in the minds of participants. Among iterations, only the name of the model (e.g., Waterway), entailments and structural features specific to that metaphor, and appropriate lexical items or phrases differed. This balance of *variation* between models and *standardization* in construction and language is designed to ensure that any differences in effect were due to differences between the models themselves, and not to some unintended confounding variable.

Data Collection

In the experiments, participants were asked to respond to a brief series of introductory questions where they rated their level of concern about a set of political issues unrelated to genes, environments and early child development. To avoid contaminating the effects, these issues were both broad and rotated each time the survey was administered. Following these questions, subjects were assigned and exposed to one of the nine treatments. Subsequently, participants were asked to answer a set of questions specific to their treatment.

Outcome Measures

After receiving the treatment paragraph, participants were asked a series of multiple choice questions to test each model's performance in relation to four outcome measures.

A. One understanding question was designed to gauge the participant's grasp of the source domain (e.g., Signature). In other words, these questions gathered data on whether the participant understood, for example, what Signature refers to and how it functions.

B. Two application questions measured whether or not participants could answer a question that extended their understanding of the metaphor. Participants were asked to map the model onto ideas about genes and environments.

C. One question measured participants' ability to understand the target domain (e.g., "The idea of the 'epigenome' suggests that …").

D. One question measured how participants reported that they would explain the concept of epigenome to a friend. As in the other questions, the correct answer followed from the model, while the choices representing incorrect answers came from dominant cultural models as uncovered in the "Mapping the Gaps" phase of research.

E. A final question measured the "aptness" of the metaphor. Participants were asked to rate how strongly the metaphor captured important aspects of the target domain.[16]

As reported above, the scores on questions A through D are charted in Figure 1.

Test III: Persistence Trials

After using quantitative data to select the most effective model(s), FrameWorks conducts Persistence Trials to answer two general research questions: (1) *can* and *do* participants transmit the model to other participants with a reasonable degree of fidelity? and (2) *how* do participants transmit the model? In other words, the method examines how well the simplifying models hold up when being "passed" between individuals, and how participants use and incorporate the models in explanation to other participants.

The Persistence Trial

A Persistence Trial begins with two participants. The researcher presents one of the candidate simplifying models and asks the two participants a series of open-ended questions designed to gauge their understanding of the simplifying models and their ability to apply the model in discussing the target domains (here, genes, environments, how they interact and their relevance for early child development). For example, the researcher asked how the participants understood the simplifying model; what they imagined the source domain (e.g., Signature Effect) referred to; and how the idea presented related genes and environments. Questions and analysis were also designed to locate any terms or ideas in the execution of the model that participants had difficulty with or explicitly recognized as problematic.

After 15 to 20 minutes of discussion between the two initial (hereafter referred to as "Generation 1") participants and the interviewer, Generation 1 was informed that they would be "teaching" the simplifying model to another group of two participants (Generation 2). Generation 1 was given five minutes to design a way of presenting the simplifying model, after which they had five minutes to present the simplifying model to Generation 2. Generation 2 then had five to 10 minutes to ask Generation 1 questions about the presentation. During this time, the interviewer allowed dialogue to unfold naturally between the two groups but periodically probed for additional information on ideas that emerged.

Generation 1 then left the room, and the interviewer asked Generation 2 an additional set of questions designed to elicit their understanding of the simplifying model and ability to apply the concept. This questioning lasted for approximately 10 minutes, at which point Generation 2 was informed that they would be "teaching" the idea to two new participants (Generation 3). Generation 2 had five minutes to plan their presentation after which Generation 3 entered the room and the two groups went through the same steps and questions as described above.

A Persistence Trial ends when Generation 1 returns to the room, where they are allowed to debrief with Generation 3 on the direction the metaphor has taken. The interviewer then reads the original paragraph-long iteration and asks questions about its transmissibility.

For the gene/environment research discussed here, FrameWorks tested two candidate simplifying models (Signature Effect and Genetic Memory) in Phoenix, Ariz., and Boston, Mass., in April 2010. Each candidate model was tested in three Persistence Trials. All informants signed written

consent and release forms prior to participating in the sessions, and interviews were video and audio recorded by professional videographers. After the sessions, recordings were transcribed.

Subjects

A total of 36 informants participated in Persistence Trials in Phoenix, Ariz., and Boston, Mass. These individuals were recruited through a professional marketing firm, using a screening process developed by and employed in past FrameWorks research. Informants were selected to represent variation along the domains of ethnicity, gender, age, educational background and political ideology (as self-reported during the screening process) for reasons mentioned above.

Analysis

In Persistence Trials, we evaluated the performance of simplifying models according to the following five criteria, and their performance is summarized here.

1) *The simplifying model had to give people a way to understand interactions between environments and genes, and introduce the notion that genes can be influenced by factors external to the genes themselves and to the individual's body.*

One of the more notable instances of application of both of the models in all of the Persistence Trials was the steady stream of examples which participants gave in order to elucidate their thinking. About half the time, participants talked about their own upbringings; in other instances, they brought up hypothetical situations. The examples, involving various types of disease and behavior, were all similar in that they were counterexamples to claims about either genetic determinism or environmental determinism.

2) *The simplifying model had to inoculate people against dominant cultural models about genes, e.g., that genes are set in stone, that there is a calculable ratio of genetic vs. environmental influences, etc.*

FrameWorks' cultural models reports on gene/environment interactions indicated some of the dominant cultural models that Americans possess about genes and environment and how they interact.[17] The identified models are listed here:

- The "will power is the ultimate determinant of outcomes and differences" model
- The "parents <u>are</u> environments" model
- The "genes are set in stone" model
- The "percentages of influence" model

In discussions of genes and environments, each of these four models inhibits people's ability to understand the science of epigenetics and be able to incorporate an understanding of this science into how they think about solutions to problems of early child development. In general, it is important to remember that dominant cultural models are only detrimental to public discourse if they shift people's attention away from desirable public solutions that solve certain types of problems. Therefore, we do not necessarily look for simplifying models to inoculate against *all* identified cultural models. After all, some dominant cultural models may help communicators

achieve their goals. This was not the case here, however, and we looked for people to use the simplifying model candidates to counter the cultural models listed above when they arose in conversation.

The models inoculated against several dominant cultural models: People did consider positively the notion that genes could be vulnerable to outside influences (this was counterposed against "genes are set in stone"), and they did not talk as readily about "percentages of influence" (i.e., how much genes vs. environments contributed to the development of the individual) as they did in cultural model interviews. However, neither simplifying model candidate was successful at inoculating against all of the dominant ways of thinking. (For details, please see Appendix A.)

3) *The simplifying model had to provoke a sensitivity toward the importance of environmental influences that might impact children's genomes and in so doing affect genetic expressions and developmental outcomes, both as children and later as adults.*

The models engaged participants' sensitivity to the environments in which children develop. When probed, participants could acknowledge that preventing negative effects as early as possible was desirable. However, some participants continued to use dominant cultural models to counter the argument that early environments matter, along the lines of "the consequences of many life experiences can be overcome by will." When participants invoked will, they were obviously working from within a dominant cultural model that should be avoided, as explained above.

4) *The simplifying model had to be generative; that is, it had to build a framework to enable individuals to productively encounter other information.*

Both models were most widely and consistently successful in their generativeness. In this context, by "generativeness," we mean three things:

1) Did individuals ask targeted questions about the topic area that suggest that they might incorporate new information about epigenetics into their understanding?

2) Did individuals create and/or use additional metaphors?

3) Over the course of the trial, did individuals add to what they had to say about the models?

This criterion was based on the expectation that the ideal epigenetics simplifying model would help people assimilate new information about gene/environment interactions that they would be likely to encounter in their everyday lives, as scientific and medical advances make the epigenome more visible.

Of the two simplifying models, Genetic Memory prompted more precise questions about the epigenome, but Signature Effect prompted more metaphorical invention by participants. For example, in one Signature Effect trial, "gene memory" came up without prompting. One explanation is that the metaphor encouraged metaphoric thinking: Even if people did not fully reason through epigenetic concepts, the model provoked them to think about what they *might* need to know in order to process it.

In the trials, Genetic Memory appeared to prompt further thinking by participants, who were able to generate other constructive entailments of the metaphor.

5) *Crucial elements of the metaphor had to be persistent in social interaction.*

What recommends Genetic Memory (or "gene memory") very highly is the fact that the concept that "the genes have memories" came up several times spontaneously in discussions, even in sessions testing Signature Effect. The notion that "genes have a memory" was very persistent and transmittable. Also persistent was the notion that genes "absorbed" features of the environment within them.

The titles of the models were easily repeated and the content of both models traveled easily from generation to generation. Both models instilled the notion of the environment leaving a "mark" on the gene. However, it took significant prompting to get people to articulate with great specificity what was being marked and what was doing the marking.

Entailments of both metaphors were persistent and were even extended by some participants (e.g., that just as human memories are continually being reformed, so are genetic memories, so that what happens to children at early ages is important).

> *Participant A*: The environment affects the genes that are passed over from generation to generation is what I understood it to be.
>
> *Moderator*: How does the environment affect the genes?
>
> *Participant A*: Somehow it reshapes them or degrades the actual chromosome. I don't have a ton of experience in the scientific area, but somehow, the air you breathe, the water you drink, the pesticides we eat, somehow does something detrimentally to genes.

6) Miscellaneous strengths.

One notable feature of these discussions was the willingness of participants to engage each other in working out aspects of the model. What was meant by gene? How would they talk about environment? Did marking the gene imply that the gene itself was changed? While these questions were not necessarily resolved, seeing the collaborative nature of these interactions was a positive sign that the simplifying models provided a site for engaged and fruitful discussion.

ENDNOTES

[1] Kendall-Taylor, N. (2010). *An empirical simplifying models research process: Theory and method*. Washington DC: FrameWorks Institute.
[2] Kendall-Taylor, N. (2009, Winter). Mapping cultural models and translating expert explanations of child development with simplifying models. *New Directions for Youth Development, 124*, 51-59.
[3] Gerbner, G., & Gross, L. (1976). Living with television: The violence profile. *Journal of Communication*, *26*(2), 172-199.
[4] Kendall-Taylor, N. & McCollum, C. (2009). *Determinism leavened by will power: The challenge of closing the gaps between the public and expert explanations of gene-environment interaction*. Washington, DC: FrameWorks Institute.
[5] Maher, B. (2009, October 15). *On methylome metaphors*. Retrieved from http://blogs.nature.com/news/thegreatbeyond/2009/10/on_methylome_metaphors.html
[6] Quinn, N. (2005). *Finding culture in talk: A collection of methods*. New York: Palgrave Macmillan. p. 3.
[7] Kendall-Taylor, N. (2010). *An empirical simplifying models research process: Theory and method*. Washington DC: FrameWorks Institute.
[8] For description of grounded theory analysis, see Glaser, B.G., & Strauss, A.L. (1967). *The discovery of grounded theory; strategies for qualitative research*. Chicago, IL: Aldine Publishing. And Strauss, A.L., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. Newbury Park, CA: Sage Publications. For description of social discourse analysis see Strauss, C. (2001). Analyzing discourse for cultural complexity. In Quinn, N. (Ed.), *Finding culture in talk*. New York, NY: Palgrave Macmillan. And Strauss, C. *Who belongs here and what do we all deserve? Americans' discourses about immigration and social welfare*. Unpublished manuscript. For description of cultural models analysis, see Quinn, N. (1987). Convergent evidence of a cultural model of American marriage. In Holland, D. & Naomi, Q. (Eds.) *Cultural models in language and thought*. Cambridge, MA: Cambridge University Press. pp. 173-194.
[9] Kendall-Taylor, N. & McCollum, C. (2009). *Determinism leavened by will power: The challenge of closing the gaps between the public and expert explanations of gene-environment interaction*. Washington, DC: FrameWorks Institute.
[10] Persistence Trials for another early child development-related model were conducted concomitantly with those for Signature Effect and Genetic Memory and cleanly produced a single recommended model for use. The results of this simplifying models inquiry can be found in the following report: Kendall-Taylor, N., Erard, M., Simon, A. & Davey, L. (2010). *Air traffic control for your brain: Using a simplifying model to clarify the science of executive function.* Washington, DC: FrameWorks Institute.
[11] Kendall-Taylor and McCollum, 2009.
[12] Kendall-Taylor, N. (2009). Conflicting models of mind in mind: Mapping the gaps between the expert and the public understandings of child mental health as part of Strategic Frame Analysis™. Washington, DC: FrameWorks Institute.
[13] Maher, 2009.
[14] Kendall-Taylor and McCollum, 2009.

[15] In the metaphor, "my job is a jail," "job" is the source domain, "jail" is the target.
[16] The question came from Jones, L. and Estes, Z. (2006). Roosters, robins, and alarm clocks: Aptness and conventionality in metaphor comprehension. *Journal of Memory and Language, 55*, 18-32.
[17] Kendall-Taylor and McCollum, 2009.