16-102-R "Epigenetic Metaphors: Encodings and Decodings"

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Abstract
Looking at the new, emergent and often disputed science of epigenetics, we aim to examine the challenges faced by scientists when they communicate such research to the public using metaphors and social representations that aspire to make a difference in relation to the "old" genetics. This article charts the encodings and decodings of metaphors in the context of epigenetics, first through interviews conducted with epigenetics scientists, and second through focus groups, conducted in 2017-18. Findings show that while scientists and lay people agreed on a few dominant metaphors as being the most or least helpful, there was also a diversity of interpretations. We conclude by discussing these metaphors and their interpretations in the context of a shift from pre-deterministic genomic metaphors to more active, dynamic and control-seeking epigenetic metaphors, and its relevance to science communication and scientific boundary-maintenance.

Keywords: epigenetics; gene–environment interaction; metaphors; media**Introduction**
The new science of epigenetics is an unsettled and contested area, full of controversies, hypes and skepticism, both within and beyond the scientific community (Pickersgill et al. 2013; Morange 2006). There is a huge gap between public opinion (usually fueled by media sensationalism) and critical expert views. By looking at a new science in its emergent and disputed stage, exposing the usually latent scientific boundary-making (Gieryn 1983; Tolwinski 2013), we aim to examine the challenges faced by scientists when they communicate such research to the public using metaphors and social representations.
"The New Mysteries of Our Inheritance," a popular science film released by ARTE in 2015, introduces epigenetics in the following manner: "Our hands, our eyes, our face, our all body is an aggregate of billions of cells. At the heart of each of them is nestled the DNA, the one that we received from our parents and that we'll transfer to our children. What is exactly passed from one generation to the other, from one cell to the other? We know that DNA is transmitted but not only DNA. Identical twins have the same DNA, the same genome, and nonetheless have physical differences. How is that possible? The genome has been considered like a book and indeed book's editions can be very different from each other. Scientist have assumed for a long time that DNA ruled our biologic destiny. Nowadays they're discovering a new world: We're becoming more and more aware that DNA doesn't explain everything. All around the world, biologists are investigating this new mystery." (http://www.arte.tv/guide/fr/052761-000-A/les-nouveaux-secrets-de-notre-heredite).
This popular introduction illustrates the challenges of communicating a new science by reframing old scientific metaphors (the DNA as "a book," the "book of life") to address new scientific paradigms ("book's editions can be very different from each other"). Metaphors are among the most powerful tools for producing new knowledge, and strongly influence how we conceive of the world around us (Lakoff and Johnson 1980). Metaphors highlight iconic and familiar aspects that help us to come to terms with the less familiar (Wagner et al. 1995). The metaphors we use in the context of epigenetics, in comparison to the "old" genetics, are arguably connected to a broader shift in social representation – from the previous grand, pre-determined genomic metaphors of the “book of life” type, to more active, modest and dynamic metaphors that convey hopes of improved control (Stelmach & Nerlich 2015). The sociological critique of the hype surrounding the mapping of the human genome – "led astray by genetic maps" (Lippman 1992) – now arguably finds support in the new biological paradigm of epigenetics. However, we still know very little about how the new science of epigenetics is metaphorically encoded (by scientists) as well as decoded (by lay people).

Epigenetics, broadly defined, denotes heritable changes in gene expression that do not involve changes in the DNA sequence. Epigenetic events can be influenced by several factors including age, the environment/lifestyle, and disease. Epigenetic modifications play critical roles in normal cell differentiation, as well as in diseases such as cancer. Epigenetic changes are initiated and sustained by at least three types of molecular mechanisms, including DNA methylation, histone modifications and gene regulation non-coding RNAs (Egger 2004; Feil and Fraga 2012). Epigenetics has been referred to as one of the "next revolutions" in science (Meloni and Testa 2014). This study aims to empirically examine the challenges faced by scientists when they communicate epigenetics research to the public using metaphors and mental models, and the metaphors and mental models deployed by the public to interpret these communications.

Epigenetics started (and continues to deal) with animal models such as the queen bee, yellow (agouti) mice (in which coat color variation is correlated with nutritional and environmental influences on the fetal epigenome, Dolinoy 2008), and inheritable stress syndromes in rodents (Szyf 2014). A major part of epigenetic research deals with cell differentiation and developmental pathways, also in the context of disease, especially cancer (e.g., "Epigénétique et cancers: l'espoir au-delà des genes," http://curie.fr/sites/default/files/jic103.pdf). Epigenetic research that is of special relevance to the social sciences can be subsumed under two inter-related categories, both remaining highly controversial: (i) 'epidemiological epigenetics' refers to epigenetic markers in the general population which correlate with the effects of stress, diet, lifestyle etc., on physiological and behavioral changes. A study in Scotland (McGuinness et al. 2012) suggested a social gradient influence in global DNA methylation of white blood cells among adults (the headline in *The Scotsman* newspaper read '*Babies born into poverty are damaged forever before birth*', McLaughlin 2012). Studies in the U.S. linked PTSD to methylation states affecting genes that contribute to immune system function (Uddin et al. 2010; Smith et al. 2011). Another U.S. study examined the developmental origins of social disparities in cardiovascular health (Kuzawa & Sweet 2008). (ii) The second area focuses on particular social and historical circumstances that suggest how early-life factors can be transferred to adult life and to offspring via epigenetic mechanisms of transgenerational inheritance. Examples include the study of long-term effects of the Nazi blockade of Holland in 1944 (Dutch Hunger Winter) which is today linked to second-generation effects (Painter et al. 2008). Another example is a study of higher rates of post-traumatic stress amongst Israeli soldiers who are the offspring of Holocaust survivors and potential epigenetic programming of their stress hormone system (Yehuda & Bierer 2009).

We know very little about the public perception of these studies. Indeed, what scientists and science journalists may regard as innovative, some people may see as lacking actual benefits or representing abuse of animals in labs, while others may emphasize already-familiar elements in their interpretation, such as that social stratification influences (now also epigenetically) life prospects and reproduces health inequalities, or ideas about maternal blame and women's responsibility for child health (Mansfield 2012).

Encoding the Science of Epigenetics: From Book and Blueprint to Cooking and Playing

Substantively and metaphorically, epigenetics inevitably builds on genetics. We can therefore expect that the "grand" metaphors/narratives of popular genetics, such as the book, blueprint and map of life, as well as the code and software of life (Nelkin & Lindee 1995), will continue to serve as reference points that epigenetic metaphors build on. Intriguingly, while the grand metaphors of genetics expressed the hope that DNA holds the keys to the secretes of human life and health, the more reserved and necessarily additive metaphors of epigenetics are probably connected to the realization that DNA is "not the whole story" (Stelmach & Nerlich 2015; Nerlich and Hellsten 2004). For example, the focus has shifted in the book metaphors of DNA to more dynamic aspects of reading/writing such as punctuation and highlighting (Hellsten and Nerlich 2011; Calvanese, Lara, and Fraga 2012; Boyle 2011).

Epigenetics has also spawned a new set of metaphors linking genes and environment. One of these is genetic memory, storing traces of past experiences which may influence future generations. Music metaphors are also prominent in descriptions of epigenetics, where "the

pianist corresponds to the epigenetic processes that 'play' the otherwise static linear information represented in DNA" (Klinghoffer 2012). Similarly, scientists have used technological metaphors of epigenetic tags as the "dimmer switch" or "the marker" (Stelmach and Nerlich 2015).

As a bridge between the DNA and its surroundings, epigenetics should be considered not just in relation to its basis (the DNA) but also as a connective platform. Although still in its infancy, the scientific as well as metaphorical significance of epigenetics for the social sciences lies in its potential to reconnect sociology and biology in new and exciting ways, both substantially and epistemologically. Although molecular epigenetic research is highly biochemical, it is of substantive interest to sociologists because epidemiologic and environmental epigenetic research might be able to track mechanisms by which social forces—from pollution to nutrition to mothering to traumatic experience—become molecularly embodied, affecting gene expression and inducing durable changes in behavior and health (Landecker and Panofsky 2013; Meloni 2014a; Jablonka and Raz 2009). From the perspective of the sociology of science, epigenetics can also be considered as a novel "post-genomic" phase that helps to us understand the historiography of genetics and the politicization of human heredity (Meloni 2016; Lock 2015). From the perspective of social theory, epigenetics has been regarded as a framework for rethinking the relationship between the biological and the social world and the *nature/culture* dichotomy (Rose 2013; Goodman, Heath and Lindee 2003; Meloni 2014c).

A growing debate over the (mis)representation of genetic knowledge in the media and among the public has emphasized the need to counter genetic determinism and reductionism (Condit 2007, 1999; Condit et al. 2004). Indeed, knowledge of epigenetics – propelled by a recent flock of popular books (Carey 2011; Francis 2011; Woodward & Gills 2012) – has an important role to play in countering genetic determinism and reductionism. In the recent British television series, *Brave New World,* hosted by physicist Stephen Hawking, the veteran presenter of TV nature and science programs, David Attenborough, says: '*I think the most significant discovery in the last decade or so has been the recognition that genetics is not just a matter of chromosomes*'. However, the scientific knowledge of most lay people may prove problematic for understanding epigenetics. Furthermore, as popular science education focuses on Mendelian genetics, it might bias and obstruct lay people's interpretations of epigenetic concepts.

A preliminary point of departure for such exploration is the recognition of the critical role of language in mediating information. As a framework for this analysis we employ Hall's (1973) model. It includes three major decoding methods: dominant, negotiated, and oppositional. In Hall's original articulation, a **dominant position** is one where the TV/film consumer takes the actual meaning directly, decodes it exactly the way it was encoded, and reproduces the intended meaning. Within the context of our study, a dominant decoding would be one that reflects (at least partly) the scientific conceptualizations of epigenetics. A **negotiated position** is one where the decoder acknowledges the dominant message, but simultaneously resists and modifies it in a way which reflects her/his own experiences, interests and beliefs. Negotiated decoding evidently encompasses a wide spectrum, in need of more nuanced sub-categories that go beyond Hall's original articulation. This is precisely the goal of this empirical study. For example, a negotiated position could reach a different conclusion (than the dominant one) or reach the same conclusion, but for substantially different reasons. Finally, in the **oppositional position** the decoder resists and rejects the dominant message and its premises, which in our case would be the scientific conceptualization of epigenetics with its underlying cultural outlook and ethical values. For examples employing Hall's model for analyzing audience decoding of films communicating messages about genetics, see Raz et al. (2016) and Raz (2003).

Methodology

The present results are based on two sources of data. First, interviews conducted by the first author with four epigenetics scientists (three of them appearing in the ARTE film), asking about the major metaphors they typically use to teach epigenetics and how these reflect their

understanding of the current state of epigenetics. Second, six focus groups (FGs) discussions involving 46 participants, conducted in 2017-18 in Paris, France. Focus groups were chosen since they both offer a method for analyzing what participants bring to the group and how group discussion potentially changes personal opinions, thus constituting "thinking societies in miniature" (Jovchelovitch 2001: 2; Bloor et al. 2001). The areas of conflict and consensus that develop in FGs can therefore teach us about social processes that underpin public reception (Marková et al. 2007). We conducted, between 2017-2018, 3 FGs with a total of 29 biology/genetics/medicine students and 3 focus groups with a total of 17 humanities (philosophy, architecture, informatics, high school generalists) students (see table 1). Each FG was internally homogeneous in terms of age and educational orientation. Following the publication of a recruitment ad in academic and social networks, potential participants were contacted by the second and third co-authors and invited to participate. All participants volunteered and gave their informed consent to take part in the study. Each FG met once, and the discussions lasted 60–90 minutes.

Each FG meeting began with showing the film about epigenetics made by ARTE in collaboration with the third co-author, "*Les nouveaux secrets de notre hérédité*" (2015; Réalisation: Laurence Serfaty), available in French and English. A semi-structured interview guide was used in all groups, encompassing questions concerning relevant background variables such as age, education, gender, country of origin, and religiosity; knowledge of epigenetics; and preferences and views regarding epigenetics metaphors (see appendix 1). The knowledge questions were developed based on topics shown in the ARTE film on epigenetics which we used as a trigger for the discussion and validated with an epigeneticist. Knowledge score was computed by adding the number of correct replies out of all the questions. The epigenetics metaphors were based on those highlighted in the film. They matched, in general, the list of epigenetics metaphors found in the popular scientific media (Stelmach & Nerlich 2015), including the metaphors of the software/code, the biochemical landscape/map, the book, genetic memory, the pianist on the genome's keyboard, punctuation, and the architect's blueprint (see also Ouzounis and Maziere 2006; FrameWorks Institute 2010). Participants were asked to grade each metaphor as helpful or misleading on a scale of 1-10. To select the most helpful/misleading metaphors, we counted the frequencies of metaphors with a score of more than 9 in each category within each group. In the discussion that followed, participants were asked to reflect on how they perceive the most helpful/misleading metaphorical models, including suggesting new metaphors.

- Insert table 1 around here

Table 1. Focus groups included in the study

Group #	Participants	Number and gender	Age range (years)	Educational background	Date
FG 1	genetics students	7 (M=3, F=4)	22-30	MA genetics, biology, medicine	6/11/2017
FG 2	biology and medicine students	12 (M=3, F=9)	23-30	MA biology, medicine	6/11/2017
FG 3	biology and medicine students	10 (M=3, F=7)	20-28	MA biology, medicine	6/11/2017
FG 4	humanities students	5 (M=4, F=1)	27-36	MA-PhD humanities	21/11/2017
FG 5	humanities students	4 (F=4)	19-21	BA humanities	22/1/2018
FG 6	high school generalists students	8 (M=1, F=7)	17-18	high school	14/2/2018

Group discussions were audio recorded and transcribed. Discussions were held in French or English; for the purposes of this paper, all quoted examples have been translated into English. To ensure anonymity, all participants have been given codes. The transcripts were analyzed thematically to uncover discursive themes and categories of themes recurring within and across groups (Denzin and Lincoln 1994). The quotations given illustrate the range of responses regarding the emerging themes. Due to the small number of respondents in this exploratory study we used descriptive statistics for the knowledge scores and the metaphor preferences.

Epigenetics: Encodings by Scientists

Helpful Metaphors: The Musical Score and the Cookbook

Music metaphors, such as "the pianist on the genome's keyboard" and "the symphony in your cells" were amongst the most helpful for understanding and communicating epigenetic, according to the epigeneticists. One scientist explained that he uses "violinist" rather than pianist, because

> in orchestras the violinists have to decide how they will play their sequence: the musical phrase can start from one extremity of the bow, or it can start from the other end – pushing or pulling the bow. It impacts the color of the music. In the orchestra the violinists have to have the same movements. So in the rehearsal the violinists agree where to start. There is a little conventional mark that the violinist will write on the score. It's called bow notation. [Interview A]

This image brings together two dynamic metaphors: music playing and notation. The positive value of the music metaphor, for all the interviewees, was that it brought together three components in a manner that people could relate to: the written message (DNA), the interpreter or decoder (epigenetics), and the environment. We can have the same musical sheet but when you change the interpretation or the environment the music is different. As one of the interviewees stressed, the environment has a tremendous impact – is the music played in Carnegie Hall or a metro station? That was seen as a good part of the metaphor because epigenetics is influenced also by the environment. Moreover, as bow notation is written with a pencil and can be erased and re-written, it could be compared to methylation – the epigenetic notation. Epigenetics is the way the musician interprets the score, the music which is written in the genome. Musicians can decide to skip some parts of the music just like epigenetics does with genes.

Interviewees also acknowledged several limits of the music metaphor. First, playing music does not produce an object – contrary to the cook that produces a physical object (a metaphor we will explicate later). Second, the problem of personification – who is the player/pianist/violinist? Here the scientists entered another, more philosophical, level of interpretation, with open questions such as "is there a composer to the genomic score?". Third, superficiality: Environmental modulation of epigenetic states does not just turn the music (genes) on and off or make it louder – it is much more complicated than that.

Another metaphor which most scientists agreed was helpful was the recipe – if the genome is the book of life, epigenetics is the cook. Different cooks will prepare the recipe differently. Once again, the emphasis was on the three components: the message, the decoder or cook, and the kitchen – the environment and the ingredients. As one scientist put it, "Nobody says that the recipe has produced a tart, so nobody should say DNA has produced a protein." Moreover, the two metaphors could be combined:

> You can underline the recipe but also the history of the cook, the way s/he works, and epigenetic is not simply marking things – this is the easiest part, but the whole constitution of the cell and the hormones are part of the epigenetic system […] the decoding is not simply marking things in the text but all the experience of the organism. You can have proteins which are bare or not and which change the way you read the DNA. A repressor would repress a gene – the classical example of a repressor that enhances production… If you stopped producing this protein, then you start activating the gene. [Interview B]

Misleading Metaphors: Map, Signature, Memory and Blueprint

The metaphors of the map, the blueprint and the code/software were regarded by the epigenetics scientists as largely misleading. This was evidently also connected to the fact that these metaphors were originally coined to explain the DNA before epigenetics came into the picture. They were therefore regarded as too restrictive and outdated, as the following quotes from different epigeneticists illustrate:

> The map has a very restrictive definition, only the nucleus, does not include hormones, the proteins. [Interview A]
>
> The signature effect… something is needed – it is like the environment itself puts the signature, what about the mechanism, where is the epigenetics. [interview B]
>
> Genetic memory – that is confusing. The methylation does not belong to the gene. The gene does not remember the environment except for selection. It's something else [interview A].
>
> The blueprint is very problematic. Code is very bad; the epigenetic code is terrible. Why? It gives the idea that we would be predictive, decipher, based on the code." [Interview D]
>
> Biologists use the concept of translation not as a metaphor. When biologists talk about post-translation this is not metaphor. […] Architectural blueprints, that is a concept that scientists really stopped using, they also abandoned the word "program" – too orderly and linear. [Interview B]

Scientific insights could still be communicated by explaining why the metaphor of memory was misleading, as the following quote by an epigeneticist shows:

> We use genomic imprinting but in a very specific way, to denote a very precise mechanism during development. The genome can retain daily interaction, there is memory, epigenetic scars, traumatic events leaving traces… Cellular memory, that would be extra-nuclear, cytoplasmic epigenetics. That is unclear. Marks like methylation, that's the imprinting mechanism, as a biomarker of memory. It's nice because of the idea you have a past. Random and limited like personal memory. That's quite nice. I quite like it, but you have to spend time to explain it. The idea is a trap... crossing too many metaphors, Freud would say memories of childhood, is that inscribed genetically? that's seductive but also misleading. Memory is linked to the brain, that links epigenetics to neuro, that's misleading. Memory is also taken by immunologists – infection and epigenetic memory, very seductive but not yet convincing. Postnatal trauma – that's a memory issue, an example would be stress due to hunger… it's not clear how far we should take it. Useful and problematic at the same time. [Interview B]

New Metaphors: Landscape Punctuation

The epigenetic "landscape" was originally a metaphor coined by Conrad Waddington (1905–1975), a biologist who is given credit for coining the term "epigenetics". The (modern) epigeneticists we interviewed confronted the landscape metaphor with ambivalence. It was on the one hand something of the past, but on the other hand an important signal in need of updating. In Waddington's classical conceptualization, the "landscape" denoted organismal-induced cellular differentiation: even though cells share an identical genotype, organismal development generates a diversity of cell types with disparate, yet stable, profiles of gene expression. Thus, cellular differentiation may be considered an epigenetic phenomenon. At various points in this dynamic visual metaphor, the cell (represented by a ball) can take specific permitted trajectories, leading to different outcomes or "cell fates" that are largely governed by changes in what Waddington described as the "epigenetic landscape" rather than alterations in genetic inheritance (Waddington, 1957; Figure 1).

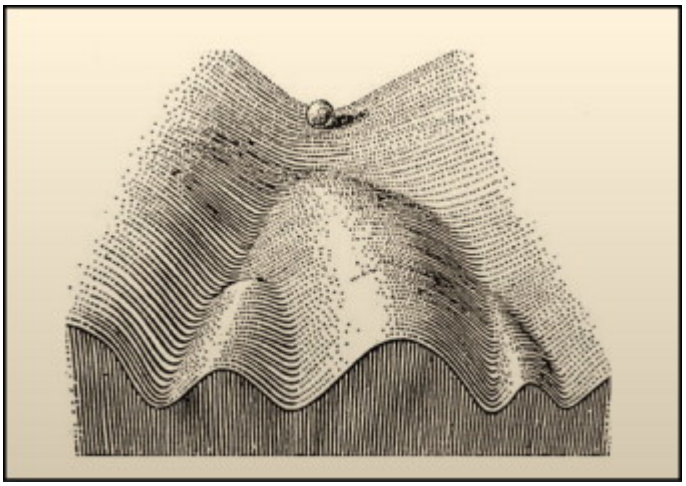

Figure 1. Waddington's Classical Epigenetic Landscape

The following quotes illustrates the epigeneticists' acknowledgement of the importance of the landscape metaphor while at the same time searching how to move beyond it:

> It's Waddington's image but it needs to be developed. [interview A]
>
> Some metaphors are useful at the beginning and then get lost like the epigenetic code and landscape. [interview B]
>
> [the landscape] It's useful because it's visual but even Waddington wasn't clear about it. He left it as a visual legacy. Everyone uses it in a completely different way. [Interview C]

For some epigeneticists, the landscape metaphor was the basis for new metaphorizing:

> [the landscape] that's quite a useful image, but I think about DNA as black and white and two dimensional. The epigenome gives it a third dimension. It's packaging the DNA into a 3-D shape, packaging and bundling the DNA. That provides a template where the interacting proteins can come and interact...
>
> [the epigenome] It's a sculpture, it sculpts DNA into a shape. A landscape is a shape, the genomic landscape in which this particular gene finds itself. Some of this landscape can have more liquid or hydrophobic regions… Chemical properties of the molecular packaging, voltage, density, that can influence the function of the DNA. The epigenome is that landscape punctuation where the DNA is the scaffolding of the sculpture. [interview C]

In one recent scientific review of epigenetics the landscape metaphor was playfully transformed into a pinball machine (Goldberg et al. 2007).

Decodings by Lay People

As could be expected, the knowledge score of the genetics/medicine students (range: 7.14 - 8.5, M=7.88) was a little higher than that of the humanities/generalist students (range: 8.4 - 5.4, M=7.35). Table 2 summarizes the most helpful/misleading metaphors according to frequency, within and across FGs in the two categories. While participants had diverse choices and the distribution of frequencies was never (as could be expected) equal across groups, selecting the 3 most helpful/misleading metaphors according to the combined frequencies across groups reflects patterns that are representative. It was intriguing to find certain metaphors coming up repeatedly as helpful/misleading in the different groups of the same category. We did not find correlations between knowledge and perception of metaphors.

Insert table 2 around here

	Genetics/medicine FGs			**Total across FGs**
	FG 1 (7)	**FG 2 (12)**	**FG 3 (10)**	
3 Most helpful metaphors (frequency	Punctuation(4) Memory (4) Pianist (2)	Landscape (4) Memory (4) Book (3)	Pianist (7) Punctuation (3) Recipe (3)	Pianist (9) Memory (8) Punctuation (7)

)				
3 Most misleading metaphors (frequency)	Software (4) Book (2) Blueprint (2)	Blueprint (5) Software (4) Map (3)	Software (4) Blueprint (3) Map (3)	Software (12) Blueprint (10) Map (6)
	Humanist/generalist FGs			
	FG 4 (4)	**FG 5 (4)**	**FG 6 (8)**	
3 Most helpful metaphors (frequency)	Landscape (2) Recipe (2) Software (2)	Software (3) Landscape (2)	Pianist (7) Punctuation (3) Recipe (3)	Pianist (7) Software (5) Landscape (4)
3 Most misleading metaphors (frequency)	Map (2) Memory (1) Blueprint (1)	Blueprint (2) Map (1) Recipe (1)	Book (2) Software (2) Blueprint (1)	Blueprint (5) Map (3) Software (2)

Table 2. the three most helpful/misleading metaphors according to frequency, within and across FGs in the two categories.

A few general observations about the decoding process in the focus groups are worth noting first. In the FGs of the genetics/medicine students, the most helpful metaphors were the pianist, memory and punctuation, while the most misleading metaphors were blueprint, software and map. In the FGs of the humanities/generalist students, the most helpful metaphors were the pianist, software and landscape, while the most misleading metaphors were blueprint, map and (also) software. *The pianist* was the most helpful metaphor across all groups, in line with the preferred music metaphor of epigeneticists. In addition, software, blueprint and map were the most misleading metaphors across all groups, in line with the same metaphors rejected by epigeneticists. However, memory and software – two metaphors rejected by the epigeneticists – were selected as most helpful by the genetics/medicine and humanist/generalist students.

In general, almost all participants had clearly defined preferences for helpful and misleading metaphors, and most participants said they did not change their mind based on the discussion. The finding that preference for metaphors was highly individual and stable received further support from the observation that participants chose only metaphors that they felt were directly relevant to them personally – for example, several said 'I don't play music so I don't relate to the pianist metaphor'; or 'I know nothing about architecture so I don't understand this blueprint metaphor.' This furthermore reflected a gender bias, with female participants often rejecting the informatic metaphors as "not talking to me because I understand nothing about informatics," and instead relating more positively to the playing/cooking metaphor as "more convincing". In what follows we describe three major axes of argumentation that emanated from many of the group discussions concerning the selection of and against certain metaphors: the problem of agency, static/dynamic, and accurate/helpful.

Accurate/helpful

many participants across the groups echoed the scientists' encoding when selecting the most helpful metaphor as the one that was the most accurate:

> For me the most helpful metaphor is the pianist on the genome's keyboard. Compared to the other metaphors, it really describes the situation accurately, of a general dictionary of the DNA and its different interpretations by the cell system thanks to its epigenetic marks. [Group 3]

For a minority of the genetics students, "accuracy" was the same as "usefulness":

> The epigenetic landscape is the most representative paradigm used by scientists to examine the different forms cells can acquire and how epigenetic modification are implicated on that process. It is the clearest example and I can reproduce it to other to introduce epigenetics. [Group 2]

In many of the groups there was discussion of how accurate the metaphor really was, and whether the metaphor needed to be technically accurate or precise vs. helpful or insightful. In another group this discussion led to an agreement that sometimes metaphors can be helpful even though they involve a deviation from what they refer to and must be explicated through an actual example to finally go back to the meaning.

> Annotation is misleading because annotation changes the meaning of the sentence while epigenetics doesn't change the meaning of the gene, it just amplifies or turns it off.
>
> I mean the protein is always there. The same. The protein is not annotated.
>
> I chose the accent or punctuation because it's really concrete. We use it every day so it makes sense and I can picture it in my head. [Group 2]

Others argued that when a metaphor is too accurate it becomes less helpful as a metaphor:

> P1: Genetic memory, I wouldn't really call it a metaphor, because that's what actually happens. It's too accurate to serve as a good metaphor.
>
> P2: The pianist is a good metaphor but it doesn't mean it's a true metaphor.
>
> P1: Is it really that different, two pianists that play the same musical piece?
>
> P3: But isn't it the point of the metaphor to make it simple so people…
>
> P2: What would be a true metaphor?
>
> P4: The landscape is better. Yeah you can explain more things. When you take this metaphor, it means that it depends on the path like with DNA you can have other things. But with landscape you don't say what are these things. You don't know. But you don't lie about it.
>
> P2: Yes it is true that it is a good metaphor but it doesn't provide… the best metaphor is able to describe the general aspect. The punctuation I think does it best. In epigenetics there are different combinations of modifications. You don't easily get this idea with punctuation. In epigenetics you have Histone methylation, DNA methylation and so on… [Group 2]

Genetics students who discussed the accuracy of the metaphor vs. its practical value pointed out that even though they were already familiar with Waddington and the landscape metaphor, it was not selected by the majority as very helpful.

Static/dynamic

An important element in the accuracy of the metaphor, according to many participants, was its dynamic connotation. Discussion revealed that the overall conception of the organismal DNA was static (unchanged) as compared to the dynamic epigenome. Hence, music and cookbook worked better than landscape for most of the respondents:

> I think we all globally agreed that the pianist was the most helpful metaphor because it is dynamic and epigenetics is something that is changing. [Group 3]
>
> The architect is definitely wrong for me – it's very static. [Group4]
>
> The architects' blueprint for me was the least helpful – epigenetic modifications are more dynamic than that. [Group 2]
>
> The highlighting is really something fixed. But with epigenetics, when a gene is activated or deactivated this is reversible. [Group 2]

The following exchange from group 4 articulates the metaphorical dynamism of the recipe in an original way:

> P1: I prefer the recipe metaphor is that it stresses such a bare, I mean quotidian, we cook not because we want to express ourselves but because we need to, right? So. P2: That's because you're not French
>
> [group laughing]
>
> P1: True that. One reason I guess why I like the cookbook is that it kind of merges the book and the highlighting of the text, but I actually also think of recipes, you know,

> before there were cookbooks, recipes were oral, the way recipes would get transmitted it's an oral transmission, and so it both remains the same and it changes over time. But very often not because someone comes and… you know, you work with the ingredients that are there, right, and so maybe the ingredients change, or the quality of the ingredients, or the abundance of them… and so by necessity external circumstance change the way we cook, the kind of food that we end up producing. So there's the environment and there's the actor but you don't overstate the actor's role. [Group 4]

Other, minority views articulated the idiosyncrasy of what it means to be dynamic:

> The recipe is something static. It is just written. The metaphor doesn't mention something dynamic. Whereas in the landscape metaphor you see the ball that's falling, right? And it seems to me it's one of the only metaphors that take the process of… [Group 2]
>
> I like the accent and punctuation metaphor because accents and punctuation can change the meaning of the sentence but also the rest of the story! (Group 5)
>
> If our genome is in the cards we get, epigenome is the way the player is playing, the hand you have is not that important, more important is how you play your cards. [Group 1]

The following minority view (from a genetics student) that considered the genome as dynamic (in an evolutionary and phylogenetic perspective rather than in the organism) highlighted and contrasted the common view shared by the rest of the respondents:

> It seems to me that the genome also shows dynamism in evolution so it's not just hardware… software/hardware interaction is more a master/slave relationship that seems dubious in a genetics setting where genome and epigenome interact together very tightly with interdependence. [Group 1]

The problem of agency

Several of the metaphors that were preferred due to their perceived accuracy nevertheless raised the question of intentional agency, e.g., music needs a musician, cookbook needs a cook, blueprint needs an architect – this seemed to be problematic and some favored agent-less metaphors**:**

> P1: I think that the recipe, I found it the most useful one, because it provides all of the, as far as I can understand from the movie, all the aspects of epigenetics, with the environment, with the static and non-static elements inside the interpretation, and the impact of the cook in preparation, the outcome of the recipe, so…
>
> P2: Who's the cook?
>
> P1: The cook is the environment in this case. I believe.
>
> P2: So, I agree with you, I like the metaphor of the pianist and the recipe, but there is a problem of the being behind, the musician and the cook, and I think it is better to try and explain this without reference to someone who is, who would be interpreting…
>
> P1: So what is your preferred metaphor?
>
> P3: So I think the landscape. It explains the different mechanisms without someone interpreting anything.
>
> P1: So, on the one hand you don't want to introduce so much the notion of an intentional agent concept, but on the other hand what epigenetics actually does is to say that decisions actually make a difference in life, right? So it does introduce the intentional agent a little bit, right? We don't want to overstate it. But the landscape metaphor for me was too static. [Group 4]

Discussion and Conclusion

Epigenetics is a new science in search of new metaphors. Our analysis was propelled by the impetus to find out how scientists and lay people confront and negotiate this liminality – how an "old" set of metaphors such as code, blueprint and book makes way for novel metaphors that still have no clear target. With a relatively small number of respondents, our findings cannot be generalized. Nevertheless, this exploratory study provides us with several intriguing

signals regarding the framing of the epigenetic message, that can serve as the basis for future research.

We found evidence for a dominant position: The pianist was the most helpful metaphor across all groups, in line with the preferred music metaphor of epigeneticists. In addition, software, blueprint and map were regarded as the most misleading metaphors across all groups, in line with the same metaphors rejected by epigeneticists. In this context, the film (where the pianist/music metaphor features prominently) arguably influenced participants, who borrowed the metaphors articulated by the scientists, decoding it in a very similar way to that in which they were encoded, and reproducing the intended meaning. Such dominant decoding reflected, as we saw in the FGs discussions, similar criteria held by the scientists and their audience for selecting for and against metaphors. These common criteria were: accuracy, including an emphasis on dynamism (in contrast to the relatively static/unchanging genome) and usefulness in communicating the message. However, there were also findings that presented a negotiated position: for example, the metaphor of cooking, although supported by the scientists and portraying the criteria of dynamism and accuracy, did not (unlike music playing) come up as one of the three most useful metaphors among participants. In addition, memory and software – two metaphors rejected by the epigeneticists – were selected as most helpful by the genetics/medicine and humanist/generalist students. Other more creative examples of negotiation were reflected in new metaphors participants offered. We did not find any argumentation or metaphorizing going against the premises and messages of epigenetics in a manner that represents an oppositional position.

Studies of science communication have emphasized the importance of the communicator's segmenting target groups and taking their interpretative frames into account (Brossard and Lewenstein 2009). The present study shows that with an effective priming (e.g., the film), different audiences present quite similar knowledge and decoding of useful and misleading metaphors, while also sustaining a diversity of interpretations. In terms of science communication, our findings show that "framing the massage" may be just as important as providing the facts. The narrow emphasis of the traditional "deficit approach" on filling out knowledge gaps through facts should be complemented by an emphasis on the metaphorical framing of such knowledge and its embeddedness in broader, popular narratives that are often built on easy-to-understand contrasts (Bubela et al. 2009). In a similar manner to Stelmach & Nerlich (2015) who examined images of epigenetics in UK newspapers, we also found a shift amongst both scientists and lay people from the previous grand and pre-deterministic genomic metaphors of the "book of life" type, to more active, dynamic and control-seeking metaphors. Rather than the metaphors of the switch and the mark/tag that Stelmach & Nerlich (2015) report on from UK newspapers, however, the preferred metaphor across all our groups was the pianist. Not only does this metaphor highlights the dynamic nature of epigenetics over the more static perspective of the genome as a book, map or blueprint, it also apparently foregrounds hopes of control over and regulation of human physical and social health. The public appeal of the new set of metaphors (and indeed of epigenetics as a new science) seems to stem from the potential promise to have power over our genes, the power to modify their activity, turning them on and off, and "hoping we can pray our way out of faulty genes" (epigenetics Professor Edith Heard in an interview to *The Guardian*[1]).

Our findings show that the agreement on the pianist metaphor is the "tip of the iceberg" underpinned by a much broader diversity of views and images, amongst scientists as well as lay people. The diversity in opinions amongst epigeneticists has already been demonstrated in relation to the boundaries and politics of the field of epigenetics in general, whose practitioners were classified into three groups based on the claims they make about the impact

[1] Edith Heard: 'We can't undo what our parents have given us in terms of our genes' By Catherine de Lange, The Guardian Sun 23 Jun 2013. https://www.theguardian.com/science/2013/jun/23/rational-heroes-edith-heard-epigenetics. Last accessed 6/4/2018

and future of their field: champions, those who take the middle ground, and skeptics (Tolwinski 2013). Our findings complement the variance in discourse about epigenetics and future research could investigate the inter-correlation between how scientists see the future of their field, and which metaphors they prefer. The metaphorical diversity we found also suggests a far more complex and contested trajectory for the field, one that may or may not support anti-deterministic views.

Finally, our analysis shows the importance of metaphors for a sociology of science communication that is embedded in social representation. As Stelmach & Nerlich (2015: 215) summarize,

> An array of metaphors, exploiting a number of familiar source domains, are emerging to talk about epigenetics, but they have no common "target," making it difficult to communicate about this new field and its social, ethical and political implications. This plasticity of the field itself has to be acknowledged before building up promises and hopes around epigenetic plasticity.

This exploratory study illustrates the major foci of plasticity regarding the framing of the epigenetic message that can serve as a basis for future research.

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Appendix 1. The focus group questionnaire guide

Examples of Epigenetics		
Which of the following study topics is an actual example of the science of epigenetics: (Y/N)	**Y**	**N**
1. the connection between the increase in plastics in our environment and rising obesity rate		
2. why one twin may develop breast cancer but not the other twin		
3. the connection between eating and development (for example the queen bee)		
4. the connection between food deprivation in pregnancy and diabetes		
5. the connection between animal experimentation and abuse of animals		
6. how eye color is inherited		
7. how social class may affect life prospects		
8. the newborn baby of a body builder is likely to have more muscles than the newborn baby of someone who is not		
9. curing Down's syndrome		
10. the connection between academic studies and level of income		

For each of the following metaphors designed to explain the science of epigenetics, which is helpful or misleading in your view? Write down a grade between 1 and 10 (1 – not at all, 10 – totally). If the metaphor is not relevant, write N/A.

Metaphors of epigenetics	**Helpful**	**Misleading**
The pianist on the genome's keyboard (how interpreting the **musical score** can change the music)		
A nuclear **map** of chemical switches		
Genetic **Memory**: If something from the outside, like nutrition or stress, can affect the inside of our bodies, genes can remember it. Such genetic memories alter how genes run our bodies' internal workings		
If the genome is the **Book of Life**, the epigenome is how a specific cell type marks it up with **highlighters**		
The Epigenetic **landscape**		
The recipe – if the genome is a cookbook, epigenetics is the annotated recipe, different cooks will prepare the recipe differently		
An architect's blueprint that contains the instructions for constructing a building		
The computer software necessary to function together with the genetic hardware		
The accents or punctuation that change the meaning of the words or the sentence		

- For the metaphor you graded as most helpful, please explain why it is the most helpful, for you, in comparison to the others.
- For the metaphor you graded as the most misleading (or least helpful), please explain why it was the most misleading, for you, in comparison to the others.
- Can you suggest another metaphor that caught your attention in the film, or more broadly in the media, and you think is helpful for understanding epigenetics?

Following the discussion

How did the discussion influence your views and arguments about the most helpful and the most misleading metaphors?

Would you like to share any additional comments about the film or the focus group discussion? Thank you!