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# Genes – Cells – Interpretations

## What Hermeneutics Can Add to Genetics and to Bioethics

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### Prologue

I began to write this text when I had to wait a few hours for a flight connection at London Heathrow. I sat down with a coffee and my laptop at a small table, a bit away from the crowds. The topic I was thinking about was how we can make sense of what we know about the genes in our bodies. We know about genes and DNA, about genetic risks associated with mutations we happen to carry, and about the genome functioning within us. All this is something of us, something that belongs to our embodiment, makes it possible for us to live. I listened and looked around.

Complexity is within me, and outside as well. The acoustic space around me was filled by a constant rush from an enormous air ventilation system in the airport hall, an occasional squeak of a not too well lubricated escalator going down to the arrivals level, the chat of some fellow travelers nearby, and a strong, slowly speaking female voice over the loudspeakers giving instructions to two individuals to 'go immediately to gate 14'. Signs everywhere with written instructions for passengers to go here or there, invitations to buy this or that, screens announcing the next flight departures and the corresponding gate numbers. Here, you just need to know where you want to go, to have the right ticket ready, and this immense machine of air transport will interact with you and take you there, I thought. The planes outside seemed like external extensions of the airport machine, little spin-off machines, which fly away and distribute people to places far off around the globe. That complexity outside was clearly a human-made construct, easy to read, *made* to be easy to read. Instructions all around. But our bodies? Do the genes make them readable for us too, testable and foreseeable? Genomes as our bodies' instruction books? That was the question I wanted to think about.

Nobody would doubt that in an airport, the texts we see all around us are texts indeed. The act of gathering information from screens and panels (or from a hastily spoken 'Hi'ere, how're you?' at an immigration officer's desk) is essentially a complex

act of understanding, and sometimes, if it is not entirely clear what it means, even interpreting. There is a meaning in all these signs. They really *are* signs, not just things that look like signs. Signs are fascinating constellations. Language is not an object. Language speaks. The information that is understood by passengers making their way through the airport is essentially lingual in its form. Its origin is a human mind, therefore those hearing or reading the messages know that what they hear and see are indeed messages: complex signs that can be understood as meaningful. Somebody wants to say something to you there. But who wants to say something to you through the genome? Is the genetic information information in and 'for' the organism? But in what sense of 'for'?

And what about all those people that I saw sitting, chatting and walking around there in Terminal 5? I know that they are not human-made, and I know that they know it too. My body was not 'built' by my parents and the genome was not 'written' by them. I am glad, otherwise I would perhaps blame them for all the mistakes and limitations within it. It was rather the nature of their bodies that created my body. Our bodies are self-organizing, living organisms and essentially products of nature. How should we comprehend what we explain when we explain their functioning? Biology tells us how cells and bodies function. But then we need to explain to ourselves and to others what it means *for us*. It is only the psychological meaning of an experience that constitutes a 'phenomenon' [1].

We know that scientists who are gathering information about the structure and functioning of human bodies are supposed to avoid all subjective bias. They should measure and observe. The ideal of scientific knowledge is objectivity, provided by impartial measurement and reproducible experiments. But is this division of the world of knowledge into a realm of human information (that can be understood, misunderstood, that sometimes must be interpreted) and a realm of natural information (that can be gathered by measurements and in experiments) not too simple? Interpretation certainly happens also in biology, most active biologists would admit that. Biological theory is not an enumerative process of copying and pasting information from measurements together and adding them up into theories. Such theories would never make sense. To build theories that do make sense and have explanative power is not just an enumerative but a creative act. You need to see a pattern, a picture in all these data. The scientist's task is much more challenging (and rewarding) than just scooping up data and pasting them together: it is putting pieces together in a puzzle without knowing in advance what image the puzzle will have. Sometimes there are several possible combinations leading to different pictures, different 'puzzles' with the same pieces. Theories of the natural sciences sometimes seem to be 'underdetermined' by experimental facts, as Quine [2] has claimed. Applied to genetics: is there an alternative picture of the genome besides the image of the instruction book?

The least we must admit is that the life sciences produce descriptions which, in a certain way, interpret nature. The language of biology is no translation from another

language; it describes. And this act of describing is essentially an act of making sense of what relates us to ourselves and to others in a certain way. Biological descriptions interpret the biosphere. They interpret the processes going on in our bodies. And they express their interpretation in a way that is meant to be as objective, as comprehensive, and as accurate as possible, in the form of an understandable language. The life sciences open a space of lingual meanings that are expressed in language, meanings that are 'about' the nature and the functioning of the body with its cells, membranes, proteins and chromosomes. This step of description is therefore, in a very fundamental sense, also a step of understanding. Aristotle, in his treatise *De interpretatione*, spoke of *hermeneia* as the act that is performed *on things* by language [3, p 105]. If this makes sense, hermeneutics, usually thought to be relevant only for the humanities and social sciences, would have relevance also for the natural sciences.

Again these people sitting about around me: what do they know about their bodies, about their genes? Do they have a picture in their mind of how the genes work in their bodies? If they have taken images from the media, their image will probably be an image of DNA as text, or instruction book, or blueprint. The genes would then contain instructions for the body on how to develop, how to stay alive, how to grow, and how to age. This is the message that is abundant in the media. It is the basic picture the media draw of the meaning of the molecular genetic evidence. Scientists themselves helped to create this picture. It corresponded to their expectations of molecular biology, at least in the 20th century [4, 5]. But today the scientific literature, when we listen to researchers, contains a different view and also the media start to take it up [6–8]. The old paradigm of the genome containing the genetic program has come into disrepute and a new idea is emerging. – Now in more detail:

## Hermeneutics

The way in which the results of molecular biology are connected with meaningful images and stories, and how it is socialized, politicized and technologically exploited is deeply cultural. Therefore, molecular biology, even if it is a natural science, can fruitfully be looked at from a hermeneutic point of view. The task of hermeneutics, when we follow one of the most important theorists of hermeneutics, Hans-Georg Gadamer, is not merely to develop a procedure to understand difficult texts, but to discover and explore the very conditions under which human understanding takes place [9, Part 2, II.1.c]. When we apply this to molecular biology, this means that the task of (genetic) hermeneutics is to discover and explore the conditions under which the meanings of genes, genomes, genetic texts and genetic factors in human life and societies can be understood.

I want to explore some aspects of this hermeneutic process that manifest themselves in the practical, cultural sides of genetics, mainly those that are connected to the fact that genetics is a heavily *lingual* undertaking. Taking the phenomenon of

language seriously in such complex inter-textual relationships (genetic information vs. information about genes), we can more clearly see how cultural understandings of biology and biological theory work together. And we can also deduce what ethical implications different understandings may have.

## Political Texts

One of the key moments when genetics became visibly politicized and a political text of genetics was written, was the announcement that a 'working draft' of the human genome sequence was finished. This took place on June 26, 2000; the key figures were President Bill Clinton and Prime Minister Tony Blair. At a media conference in the White House, they announced it as an 'historic achievement' of science. The politicians' task was to find a comprehensible explanation as to *why* it was so important to humankind to know the boring details about the order of the T, A, G, and Cs in their DNA.

According to the White House press communiqué issued one day before, the key point in the subsequent announcement by Clinton and Blair would be:

> 'that the international Human Genome Project and Celera Genomics Corporation have both completed an initial sequencing of the human genome – the genetic blueprint for human beings' [10].

People who did not know about genetics and the biological significance of DNA did possibly know what a 'blueprint' is supposed to be: a detailed plan, more precisely a paper-based reproduction of a construction plan as it is commonly used in architecture or engineering.[1] The image of the blueprint seemed to fit with DNA because it is also a result of a copying process that occurs in every cell division.

However, the message contained in the lightheartedly spoken phrase the 'genetic blueprint for human beings' was complex and contained several elements. We can perhaps better identify them when we tentatively translate 'blueprint' into the term 'construction plan'. I see at least six elements in this statement:

(i) There is a construction plan that contains the details about how we are made;

(ii) Development and life are essentially a constructive process based on a plan;

(iii) The DNA sequence is or represents the construction plan for building the organism, i.e. for its development and life;

(iv) By sequencing the human genome we learn the details of the construction plan for human beings;

(v) Now we know how human beings are constructed, and

(vi) Two countries that are scientific leaders, the US and the UK, have achieved this.

[1] The 'blue' stems from the photochemical reaction leading to Prussian blue that is used in the cyanotype process which was developed by photographer and astronomer Sir John Herschel in 1842. For a century, blueprint was the only available low-cost process for copying drawings [11].

Bill Clinton, in his oral speech, was even more outspoken:

> 'Today's announcement represents more than just an effort making triumph of science and reason. After all, when Galileo discovered he could use the tools of mathematics and mechanics to understand the motion of celestial bodies, he felt, in the words of one imminent researcher, that "he had learned the language in which God created the universe". Today we are learning the language in which God created life' [12].

This breakthrough must be immense, comparable to Galileo's mathematical astronomy and the birth of modern cosmology (that was not anti-religious). The laws of nature were thought of as language that God used in His (perhaps still ongoing) act of creation. With his reference to God and to creation, Clinton *theologized* or *sacralized* the genome. Genome sequences do not just look like language, they *are* language, even the most important language one can imagine: the language in which God created us as living creatures.

It is interesting to see how the old biblical image of the 'book of life' has been transformed by this explanative step. Originally it had a moral meaning. In *Exodus* (32: 32f) it was said that *HaShem* had a book that contains the names of those who are righteous and worthy of life. Those who are blotted out of this book will die. In the context of genomics, the book of life and its language is re-read as God's language, the instructions He uses in His work of creation. The moral meaning, which said that the book of life noted who is worthy and should live, drops away. A new moral meaning is established instead of the old. Now, it is a hopeful source of benefit for human life, of good to be done, particularly of medical innovations and cures for some of the most devastating diseases.

National interests certainly played their roles. Behind the Human Genome Project was an international partnership led by the US and the UK. For this purpose it was useful that it was something so powerful that could be announced: nothing less powerful than the language in which humans were made. It is human life's innermost secret, previously known only and exclusively to the One who created us. Now it would be available and accessible for human use. But it is not just the power that this genetic knowledge provides to those who control it that makes this performance by Clinton and Blair a political text, it is also the structure of this knowledge itself that proves to be power-related. From a Foucauldian perspective it cannot be overlooked that there is a correspondence between the genome as the controller, genetic information that is our 'makeup', the language in which we are created and the power of those who have control over genomic information or who control the experts who provide the necessary genetic know how.

## Metaphysical Texts

When the metaphor of the 'program' first appeared in the published literature of molecular biology in the early 1960s, very little was known on a molecular basis about how different genes actually work in development. The genetic program was a story

in a nutshell that explained comprehensively in advance how genes could organize development and make life possible. If the genome contains only information (a sequence of four different nucleotides), an explanation was needed of how organisms can be made of information, i.e. how the 1-dimensional sequence of components of the DNA polymer can be transformed into a 3- or 4-dimensional reality of an organism. The program was the key idea.

The notion of the 'gene' originated much earlier, but in another context. It was the problem of inheritance not development that first led biology to talk about genes. Johannsen's famous definition in 1909 [13] aimed at the factors – whatever their precise nature may be – that can be passed on by egg and sperm and determine the traits and characteristics of the next generation of organisms. The gene was an answer to what we can dub the 'bottleneck-problem' of biology [14]. This problem is located within the gap between the generations. How can the form and structure of a species in one generation be rebuilt from the two tiny germ cells that are passed onto the next generation? Oocyte and sperm fuse and build together one single cell, the zygote, which must be capable of developing into the whole new organism. What component of the oocyte can be responsible for this? A major discovery was that it is not the membranes, not cytoplasm, not the proteins, but nucleic acid, essentially the nucleic acid contained in the chromosomes. Chemically it is DNA, a double-stranded, enormously long molecule shaped as a double helix. Rosalind Franklin, James Watson and Francis Crick discovered its chemical structure in 1953. The implication was, however, that a sequence of only four different building blocks, the nucleotides, must be the key responsible element in heredity. How can that be possible? How can a sequence, or the information contained in the sequence, guide development? The bottleneck-problem was tightened from a cellular level to a molecular one.

Information is essentially a pattern of differences that can be reliably translated into another pattern and therefore can be said to determine the second pattern. However, genetic information was not thought to be semantic in the sense of carrying an intention to represent this second pattern. It is neither the previous generation that encodes an intention within its genetic information, nor any spirit in nature, nor God. This is very important to keep in mind. The notion of genetic information was not thought to be intentionalist but purely mechanical.

Before developmental geneticists in the 1980s and subsequently could investigate more and more of the actual mechanisms of developmental processes, and elucidate the precise roles that different genes and gene products play, two of the most productive molecular biologists of the earlier time, François Jacob and Jacques Monod, in a historic paper of 1961, used the term 'program' to explain how the imagined development was possible. The paper was about their discovery of gene regulation in bacteria, the *Lactose operon*. In the concluding section they observe:

> 'The discovery of regulator and operator genes, and of repressive regulation of the activity of structural genes, reveals that the genome contains not only a series of blue-prints, but a co-ordinated program of protein-synthesis and the means of controlling its execution' [15, p 354].

Protein synthesis was the essential process for the development and life of the organism. As we will see later, the crucial part of this quote is the statement that 'the genome contains' the program. DNA contains a program for development, and therefore the cells can execute this program if they are properly equipped. The genome, according to Jacob and Monod [15, p 221], even contained the means of controlling its execution [4, 5]. The DNA molecule was thought of as a central organizer of all essential steps in the life of the organisms. The *Lactose operon* provided an example of how this could work: genes are regulated by regulator molecules that are again synthesized from other genes. The genome is a self-regulatory system controlling the development and behavior of the cell.

In the same year, 1961, another biologist who was more preoccupied with evolution and inheritance than biochemistry, Ernst Mayr [16], published a somewhat similar idea also using the program metaphor. But for him, the metaphor served other needs. His problem was teleology, i.e. the question of how it can be thought possible within a strictly Darwinian framework that allowed for no reference to vital forces, that organisms are such miraculously well-functioning constructions and show goal directed behavior. The assumptions of Modern Synthesis Darwinism combined the molecular evidence of DNA-copying and the 'central dogma' of molecular genetics (information flow goes from nuclear DNA to protein, not back from proteins into DNA) with the Darwinian mechanism of random variation and the survival of the fittest. This excluded the possibility of inheriting phenotypically acquired functions from the previous generation. Everything had to be in the genes. The solution that Mayr saw was given by the idea of a 'genetic program'. If the previous generation passes a program to the next, containing all the information that the system needs to reconstruct itself and to behave, then we do not need any more assumptions to explain an apparent goal-directedness in development and behavior. Programs evolve by chance and selection. Teleology, the obscure old doctrine of nature following certain aims, could be replaced by a cybernetic model of goal-directed, negative feedback systems, or 'teleonomy' [4, pp 196, 221; 16] The processes *seem* to be goal-directed, but this is only their appearance to us. Actually, development is programmed by DNA information, and it is the program that is passed onto the next generation, perhaps including mutations that may give advantages or disadvantages to the organism and to its chances for reproduction.

This was an argument against vitalism. Vitalism was a basically metaphysical doctrine arguing on the level of ontology. It claimed that living processes contain a nonphysical force or principle that make them what they are, which can never be explained by the physical sciences. Therefore, in Mayr's text, the assumption of the genetic program was also a metaphysical argument, working on the level of ontology. It explained how is it possible that living beings come into existence, and their way of existing in the world. In terms of theory building, the idea of the genetic program replaced intentionality in nature and the vitalist non-physical forces. It was therefore *negative* metaphysics that Mayr was arguing for. With the physically plausible

assumption of a genetic program it was no longer necessary to believe in nonphysical forces and intentions to explain the apparent functional organization and goal-directed behavior of organisms. Jacob and Monod [15] were comparatively more constructive in their approach. They saw how such a genetic program could be conceptualized: as a sequence of regulatory steps whereby genes are regulated by the products of other genes.

But was this discursive move to the programs-containing genome just a step towards dropping unnecessary metaphysical ballast and therefore in itself ontologically or metaphysically 'innocent' or neutral? I do not think so. In order to see this, we need to advance another 45 years in the history of biology and look at the ideas of contemporary systems biology. Kunihiko Kaneko, a Japanese biologist and influential theorist of complex molecular systems, summarizes the current approach to explaining the emergence of relatively stable and regular developmental pathways of organisms in a very simple way as follows:

> 'Thus the situation is one of mutual influence, not unidirectional causation. Hence, although the genes can be thought of as in some sense controlling such processes, in fact it is not true that an understanding of the genes alone is sufficient for their complete description. For example, even if we were somehow able to obtain the DNA of a dinosaur, unless we also knew the initial conditions of the cellular composition that allow their proper expression of genes, we would not be able to create a Jurassic Park. The conclusion we reach from these considerations is that … we should be studying models of interactive dynamics. Then, we should inquire whether, within such dynamics, the asymmetric relation between two molecules is generated so that one plays a more controlling role and therefore can be regarded as the bearer of genetic information' [17, p 20].

If we compare this idea that Kaneko is outlining, referring to vast experimental evidence and to mathematical models, with the image inherent in the 'genetic program', several important differences become obvious. The relation between different molecules and processes in the cell are seen as mutual influence, instead of a unidirectional causality contained in sequences of linear *if-then* events. Parts interact in many ways, loops of causal influence going forward and backward, branching in many directions and making the system as a whole relatively open or relatively closed. The division of roles within such a system is not a precondition, but must itself be explained as a result of the interactive dynamics of the system. Therefore, the apparent specialization of DNA as the bearer of genetic information, and the many very important roles singular genes can play in the development of the organism, are products of the interrelation of the parts of the system and their dynamics. This is the second striking difference to the genetic program approach. There, it was thought that a causal program is a precursor of development in the shape of the sequential composition of the DNA polymer. Thirdly, a regularity of developmental events that could be described as something like a program is to be located on the level of those interactive dynamics, not on the level of one component of the system. In terms of the distinction between genotype and phenotype, the assumption of systems biology is that the program (if anybody still wants to talk of programs) is a *phenotypic* regularity. What

behaves regularly in foreseeable and reproducible sequences of events is the whole organism within an environment, not one isolated molecule.[2]

Molecular genetics, particularly in the context of developmental biology and genomics, has contributed to this enlargement of the picture. A wide variety of mechanisms that enable the cell to use DNA sequences in different ways have been discovered. The active RNA molecules (still suggestively called 'messenger' RNA) are compiled in much more complicated ways, and most of the RNA molecules (MicroRNAs) are no templates for proteins at all. DNA sequences that code for proteins (containing the genes in a classical sense) and some proteins are multifunctional. Which effects will be realized depends on a multitude of other factors, and sometimes on spatial information as well, i.e. on the place within the cell or a multicellular network. Some genes overlap, some genes can be spliced in multiple ways, depending on the situation, and the resulting RNA variants will lead to different proteins that are all related to the same DNA stretch. Sometimes the cell uses fractions of one and sometimes fractions of the other of the two single DNA strands as a template for producing a functional RNA. There are also switches to alternative reading frames, i.e. the shifting of the three-letter code by one, resulting in different sequence information. There is sometimes even post-transcriptional editing of mRNA, i.e. the introduction of changes in the sequence of an mRNA molecule after its composition, which also leads to a different amino acid sequence of the protein being built from it [14, 19–22]. Genes are multifunctional [23], and therefore they can no longer be considered as independent factors in a chain of events. But this is precisely what the idea of the 'genetic program' suggested.

Taking these and other phenomena into account, Eva Neumann-Held [24] has reconsidered the very concept of the gene from a systems perspective. If we still want to call what explains the biosynthesis of a particular type of protein in a cell a 'gene', we can no longer say that one stretch of DNA is responsible. It is rather a range of factors, interacting with DNA and with each other, and processes sometimes transgressing the boundaries of the cells and the body, that are actually contributing. This set of contributing factors includes DNA, but also much else. Neumann-Held bases her reflection on a groundbreaking book by Susan Oyama from 1985 that has the title 'The Ontogeny of Information' [25] and has inspired many authors to new formulations under the umbrella term of a 'developmental systems approach' [26, 27]. The key idea was a new attempt to theorize development. Previously, we thought development was basically a result of two different information resources, one internal and genetic, the other external, i.e. social, environmental, or cultural. The divide between these two information resources has materialized in the 'nature or nurture' debate in developmental psychology. One school emphasized the genetic contributions (sociobiology, evolutionary psychology, etc.), the other more the social and cultural factors. Oyama's point was that development is better seen as an interaction of both, but not

[2] Elsewhere [18], I have argued that a phenotypic 'program' cannot consistently be said to be a program, because the term program is based on the distinction between prescription and realization.

in the sense of an interaction between two independent types of factors. There can be no genetic factors *without* the environment, and there can be no environmental factors *without* an organism and its internal resources. Both are mutually related, so that we should avoid making a distinction between those two classes of contributing factors. From this, Oyama came to a different understanding of genetic information as developmental information. Developmental information itself has a developmental history. With reference to Gregory Bateson's [28] famous definition of information as 'difference that makes a difference', she explains:Genetic information 'neither preexists its operations nor arises from random disorder. … Information is a difference that makes a difference, and what it "does" or what it means is thus dependent on what is already in place and what alternatives are being distinguished' [25, p 3].

Genetic information, in the sense of developmental information, is itself 'developmentally contingent in ways that are orderly but not preordained, and if its meaning is dependent on its actual functioning, then many of our ways of thinking about the phenomena of life must be altered' [25]. Following this line of thought, biology's basic picture is being transformed.[3]

The program view assumed that the development of the complex organism we see in the biosphere depends on the existence of genetic information, which can be copied and reproduced from a template. It said that the generations do not transmit a small prototype or the adult structure to the next generation, and no supernatural intentions or forces are necessary for a comprehensive explanation of the development of a new generation. What is transmitted is a list of instructions for making that structure [29, p 2]). The systems view by contrast sees that in fact it is the entire cell that is reproduced, not only some lists of instructions. The cells reproduce not because the genome contains instructions for building it, but

> 'because any inheritance involves passing on DNA and all the cellular and extracellular structures, processes, and materials necessary for its exploitation' [25, p 77].

Information can therefore be seen in at least two different ways: either as something inherent in a pattern that is transmitted or as something that is itself a product of interactive dynamics. Accordingly, two different ontologies of living phenomena are put forward.

But they are not equivalent offers, from which we could choose one arbitrarily. There are today serious reasons for preferring the systemic approach. The most compelling of these comes from science itself.

If information for development is a product of interactive dynamics, it does not exist *before* the development of the system actually takes place. Developmental information continually emerges from the interactive dynamics of the cellular (or multicellular) system and – we need to allow this conclusion as well – continually fades away afterwards. In this sense, genetic information is contingent and ephemeral. DNA is an inert and relatively constant molecule, a source of stability for the system and highly

[3] See our collection [31].

important in many ways, but DNA is *not* the carrier of developmental information. We can say that the organism is essentially a self-informing system. The whole system develops and behaves regularly and predictably in many ways, but the regularity is not a result of a preexisting program.

This theoretical rereading of the molecular evidence in terms of systems cannot take away any of the empirical evidence that we have about the causal involvement of DNA sequences or mutations in the development of certain characteristics like diseases. The systems view, as I understand it, is not an argument against genomics, medical genetics or against DNA-related research in any way. The argument does not work on the level of experiments or empirical work, but on the level of the interpretation of the empirical evidence, which can be seen as plausible or implausible.

### Who Is the Author of the Genetic Text?

The impact of the systems approach and of reinterpreting genetic information reaches beyond criticizing the genetic program metaphor. It contains also a critique of other metaphors that are used to explain the meaning of genomic information in terms of *signs* contained in DNA sequences: the book of life, the instruction book, the architecture plan, the blueprint, the text, and related ones, in other words all metaphors that work with a difference between signifier and signified and introduce a semantic relation between DNA as a 'sign for' and the meaning of this sign. Sign metaphors do not work within a systems approach because they presuppose that information for development preexists.

The assumption of preexisting meaning in organisms would also be difficult to defend from a hermeneutic point of view. Signs or compositions of signs (texts) that we use in language are not just prints on paper that can be copied or transformed by certain rules. Because they belong to language, texts are expressions of personal life. In contrast to spoken language, they are permanently fixed expressions of personal life. Language, as Gadamer puts it, is the universal medium of understanding, i.e. a medium in which the acts of understanding itself can occur [9, p 392]. If we have a text, we must assume a writer who transformed meaning into written signs, and there is a reader who transforms written signs back into meaning. Who and where is the writer of the genetic 'text'? The genome is the product of evolution; nobody has 'written' it. Therefore, the text as a metaphor for explaining DNA must always be essentially flawed. It would be a non-written text, part of non-meant language. To seriously claim such a thing implies a conceptual confusion.

Metaphorically speaking, not biologically of course, we could say that in the framework of the systems approach that assumes that genetic information does not preexist development but is itself an emergent product of interactive dynamics, the *body* acts as something like 'the author' of the genetic information. I have myself used this way of speaking [14]. If genetic information as developmental information is composed from step to step as a result of the interactive dynamics in the cells, it is actually the

body that brings about this information. This use of the metaphor of the body as author is nonetheless lopsided because the 'bringing about' of the text is certainly no intentional act. It is no act of speaking, but rather mindless, even if our body is not an object but an animated body, this sensible, living body we ourselves are. If we use this metaphor we must see its limits as well.

This holds true for all metaphors. We should not naturalize the metaphors. Often metaphors can be of great help in making sense of a natural phenomenon in a context where sense is not obvious.[4] The metaphor tells a little story, it is a narrative in a nutshell, or, as Paul Ricoeur [31] has said (with reference to Beardsley), a miniature poem. Metaphors graft meaning from one discourse to another and sometimes also modify their meaning when they arrive within the new discursive context. Sabine Maasen and Peter Weingart [32] speak of metaphors as messengers of meaning. The 'author' is such a metaphor of the body in relation to developmental genetic information: a messenger bringing meaning from the discourse about texts into the discourse about embodiment.

To regard the descriptive text as a text is not so far away from what the humanities (as the sciences of the texts) see as a text. Also regarding a historical text, the meaning that we understand is not necessarily the same meaning put into the text by the writer. The act of reading is interpretation. There is a convincing argument by Hans Georg Gadamer that the act of interpretation involves the reader in her or his proper cultural and social context as well. There is no interpretation without the active contribution of the interpreter, who has questions in mind, brings them to the case, questions which might differ considerably from those of the writer or other readers. A text brings something up, raises a subject; but it can only do this because of the *interpreters' participation* [9, p 391]. The situation of the biologist who constructs a text in her or his attempt to understand is therefore not so different from that of the historian or the reader of historical literature who interprets a text as a testimony that has been written under different circumstances. But mind that this way of speaking about texts in genetics treats the *interpretation* of DNA as a text, not the sequence of DNA.

To see description as interpretation can perhaps also help to liberate our minds from old images and doctrines. We can *play* with metaphors more easily when we are aware of what they do, with which questions they resonate, and what they do not do. Living in highly technologized worlds where most things are constructed according to plans and instructions are abundant, it is no surprise that biologists started from the question how the organism is constructed according to instructions or a plan. Today we obviously need new metaphors for the genome-cell relationship that make better sense but are still easy to grasp. Many things are possible.

We could, for example, see the genome like a library. A library is – in contrast to a book – not an organized text, not a message with a stable content. The meaning that

[4] Another line of critique against the genetic program view would be that it naturalizes its metaphor. The assumption is that programs are not just our 'way of understanding' but that genes 'really are' programs, i.e. that they 'work as' programs.

readers take out of a library depends on which books they are picking, which books they are leaving behind, what proportion of the books they check out they are reading, in which order they are reading them, what they read, hear or see from elsewhere, and on what they make of the texts they are using. The library metaphor is, however, also lopsided, because libraries still contain books that were written by authors, whereas the genome is not a written text at all. But when we put the emphasis on the side of the reading act, the comparison is more accurate. The cell 'reads' its genome like readers read when they are selectively and creatively using a library.

Or we can compare the mechanisms of how words gain meaning in spoken or written language. There is a similar phenomenon that we know well in language to that of the multifunctionality of genes or proteins. Words have multiple meanings; they are polysemous. *Polysemy* means the capacity for a sign to have various meanings. How can we understand each other with words if the words can mean different things? The answer is that one word can say different things, but which meaning is in the foreground depends on the context in which it is used.

When we now look back on the history of the genetic program we see that it was an attractive preconception about the meaning of the genome drawing on the language of computers, whose attractiveness can be explained in the historical and cultural context in the second half of the 20th century. It was essentially an anticipated story of how the genes work, invented before experimental knowledge in developmental genetics was available. Lily Kay has written the 'history of the genetic code' in a book with the ambiguous title 'Who Wrote the Book of Life?' [4].

The book of life was meant to be a book written by nature. But it turns out that it is rather written by humans, scientists in particular, but not just by them. We have seen politicians play their role as well. This writing, it emerges, happens not on the level of the genes but on the level of the explanations that have been promulgated and were selected because they seemed to be more meaningful than others.

When scientists today explain genetics to the general public there is a risk that they use the same old preconceptions over and over again, just because they feel or anticipate that this is what the public 'out there' will understand. They might be right that it is the program view and the family of sign metaphors that they do know 'out there'. But this is nothing other than what, a few years earlier, the public was told by scientists to believe. I believe that the storyteller (in the best sense of the word: the scientist truly explaining genetics to the general public) has a responsibility to be not just rhetorical but authentic.

## We Do Our Genes

It is easy to see that genome interpretations do have ethical implications. Space allows me only to mention some. Consider pre-symptomatic genetic tests. Within the framework of program genomics, a mutation in a cancer-related gene is understood as information

that the body carries and that instructs the cells to make tumors, or, in the case of mutated tumor suppressor genes, as a 'fault' in the information that tells the body how to suppress tumor cells that might emerge. In the framework of systems genomics it looks different. The same mutation in a cancer-related gene is an indicator for an elevated likelihood that the body under certain circumstances can get cancer, or an indicator that the body's capacities to prevent cancer are weakened. Within this interpretation, the mutation does not indicate 'information for making cancer' or a 'fault in the information on how to suppress cancer'. There is no information 'for cancer' in the body right now. The patient does not walk away with the idea that 'I have a fault in me', but knows about a risky, even dangerous condition and hopefully about possible precautions to take.[5] The practical measures that are recommendable will not be different, but the relationship of the patient to his or her body will be different. This has implications for the language used in genetic counseling, and also for the ideas of what 'good counseling' means.

Or consider embryo ethics. One argument that plays a crucial role in the politics and ethics of embryo research (stem cells, cloning, etc.) is potentiality [33]. Many bioethicists who defend this argument base it on the genome. The embryo, after fusion of the egg and sperm, carries the full genome for the individual. Alfonso Gómez-Lobo [34] writes:

> 'The potentiality to become a male or female human adult is due to the biological program contained in the genome'.

And therefore, he argues, it is not the gametes that are entitled to moral and legal protection but the embryo and the fetus, right from its beginning. Or read Otfried Höffe who argues in a similar way:

> 'Was Kritiker als "blossen Zellhaufen" abtun wollen, trägt von Anfang an, als befruchtete Eizelle mit doppeltem Chromosomensatz, das volle genetische Programm für die Entwicklung eines Menschen in sich. Das Programm liegt tatsächlich rundum vor, in seiner notwendigen und zureichenden Gestalt' [35, p 137].[6]

In the framework of systems, obviously, this argument does not work. To recognize this not necessarily changes our ethical attitudes of care and parental responsibility, which we owe to embryos. It will not make them freely accessible for research, because there are other grounds for responsibility as well. But nevertheless, it will change the reasons why philosophers can defend a responsible legal framework for embryo research. And other positions might be less dogmatic and allow more freedom for individual ethical judgment.[7]

[5] Thanks to Lorraine Cowley, herself a genetic counselor, now social researcher in genetics, who brought to my attention that the usual language in genetic counseling sessions in Britain includes 'genetic fault' for mutations and 'instruction book' for the genome.

[6] 'What critics want to dispatch as 'just a heap of cells' in fact carries the whole genetic program for the development of a human being, from its very beginning as a fertilized egg cell. The program is integrally present, in its necessary and sufficient form'.

[7] Implications for morally interpreting the role of the embryo donor in stem cell research are pointed out by Scully and Rehmann-Sutter [36].

Bioethics, I want to conclude, needs a contextual hermeneutics of the body, of genes, of cellular systems, and of nature, which is methodically and topically not separate from the hermeneutics of traditions, art, discourses and morality. This bioethics that society needs cannot be a shallow kind of 'applied ethics' where a certain moral dogma is taken for granted and 'applied' to a practical dilemma. Society needs a bioethics that is part of broad practical philosophy and works closely with the social sciences and humanities. Philosophy needs to go into the world and to work in interdisciplinary collaborations with social and cultural studies. It also needs to learn from people out there in the situations, who live those new kinds of dilemmas, who feel where and how moral questions arise. In the practical circumstances surrounding biotechnologies or biomedicine, the deepest questions about what is 'good', what is our desire for 'a good and fulfilled life with others and for the others' in a social and natural environment arise. Questions about what are 'just institutions', and what is 'ethical governance' in bio-societies arise. Bioethics therefore also needs a strong theoretical component reflecting independently the needs of society with regard to the conceptual tools and methods used. In this respect, biosciences are a fruitful soil on which ethics can grow.

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