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The Dual Matrix of Life: On Genetic Science, Art and the Truth Games of the "Third Culture"

"… at certain moments in history and in a specific culture, there is a kind of echo between artists and scientists, expressing itself in the orientation of their thoughts and the images used by them."

François Jacob[1]

I. INTRODUCTION: SCIENCE AND ART

1.

Science looks, as it were, through the "front window" of its instruments and is spellbound by what it sees lying ahead as its *object*. Its molecular gaze, supported by an industrial complex of technologies of perception, is directed ahead, cutting through surfaces and revealing life itself as an "objective matrix," producing and regulating the inherent dynamism of living things[2] that have been brought into position as specimens *prior* to the instant of observation. Art on the contrary draws attention to the life of the viewer, operating as the "subjective matrix" of the scientific gaze. It looks, as it were, through the "rear window," behind the subject of the viewer, and senses the processes of production of subjectivity parallel to scientific activity, not only in the manner of dispositives like those of the prison or sexuality, as described by Michel Foucault, but also in the sense of the Graeco-Roman *technologies of the self* that Foucault discussed in his last works as manifestations of the art of living.[3] The question that I would like to formulate in the following essay—but, for reasons which I hope will become obvious in the course of my reflections, without answering it—is, whether there is an emergent common ground between the two perspectives associated with the dual matrix of life, the perspective of a *science of the living* and the perspective of an *art of living*.

It is in such a vein that Georges Canguilhem reflects on a dichotomy of perspectives at the end of his appraisal of François Jacob's history of biology.[4] In Jacob's view, notes Canguilhem in his concluding remarks, it is no longer the mystery of life that is sought after in today's laboratories, but the logic of living systems. However, outside the laboratories the living continue to believe that they live a life, not all of them being aware that life itself has lost its life and mystery in the laboratory.[5] "Outside the laboratory, love, birth and death continue to present to the living, these children of order and chance, the timeless figures of these questions,[6] which the science of the living today no longer poses to life."[7]

II. THE TWO CULTURES

2.
I would like to begin my discussion by remembering C. P. Snow, the physicist-novelist, who became famous in 1959—six years after Francis Crick and James Watson discovered the structure of the DNA molecule—after a lecture he held at Cambridge University under the title "The Two Cultures."[8] Although the lecture text is well known, I would like to restate some of its basic observations before proceeding to use it as a kind of springboard for my own reflections. Snow discerns a rift in modern knowledge, which runs so deep that one cannot but speak of *two cultures*. On the one hand there is the culture of the natural scientists and engineers. On the other hand, there are the writers and men of letters, the so-called "literary intellectuals."

Snow himself had written a number of novels. During the day he lived and worked as a scientist. His evenings were, however, spent with his writer friends. Such a liminal mode of existence between science as the day-side and literature as the night-side of modern knowledge seemed to qualify him as a mediator between the two cultures.

3.
Snow's diagnosis of the modern condition connects the incompatibility of the two cultures to two diametrically opposing evaluations of modernity. Scientists are friends of industrialisation. But they are not very well read. When asked about their favourite books, the utmost they can claim is to have read Dickens, who represents to them the farthest possible limit of modernity and comprehensibility.[9] Nonetheless they have their political allegiances and religious beliefs just as any intellectual, even though there is, understandably, a certain social and statistical spread of their beliefs and attitudes. Despite this spread, scientists can be seen as constituting a distinct community or *culture*, because of their common mode of response to life, based, as Snow puts it, on the fact that they have "the future in their bones."[10] For in their daily work and their technical discussions, conducted doubtlessly on a high conceptual plane, they push forward the project of modernity regulated by the ideal of a progressive mechanization of life and the dual goal of democracy and general welfare for all. Writers and intellectuals on the other hand are "natural luddites."[11] With their scepticism towards industrialization and their impotence in the face of technological progress they tend to resist the future, just as George Orwell does in *1984*.[12] And if asked about the second law of thermodynamics—as when a scientist is asked, "Have you read Shakespeare?"—a majority of the literary intellectuals would be incapable of giving an answer. For they are committed to the past, and wield the arrogance of their literary education as a shield against modernity.

III. THE SCIENCE WARS

4.
Snow's remarks triggered off the so called "Two Cultures Debate," which continued unabated until recently,[13] attained from time to time a polemical pitch typified by a hair raising ignorance of the "other side." The first example is of course Snow's own depiction of the "literary intellectual." which is not only replete with stereotypes, but also quite oblivious of the complexities of a philosophically and historically informed critique of modernity and industrialisation. A second example is the immediate response to the lecture text by Frank R. Leavis,[14] a prominent literary critic of the day, who characterized Snow's "panoptical pseudo-cogencies" as expressive of his "intellectual nullity"[15] and criticised him for not having read Mathew Arnold. The Snow-Leavis polemics continued for several years till it finally lost momentum, to flame up once again in the nineties of the last century in the mode of what has since then come to be known as the "science wars"[16] between the postmodernists

on the one hand, with their critique of science and its oblivion of its own socio-historical moorings, and the proponents of an ideological scientism on the other, most prominently the mathematician Norman Levitt and the biologist Paul Gross,[17] who began their polemics with a statement on the "muddleheadedness" of the postmodernists.[18] The controversy attained its peak with the so called "Sokal Affair," when the mathematician and physicist, Alan Sokal, published a high sounding but nonsensical article on "quantum gravity"[19] for a special issue of the postmodernist journal *Social Text* devoted explicitly to the "science wars." The uncritical acceptance and publication of the article delivered Sokal a proof of the charlatanry and ignorance of postmodern critique.[20]

5.

What was remarkable in the context of the science wars, was the high-handed indifference of the protagonists of scientism towards the epistemological crux of the postmodernist critique. It seemed enough to demean the opponent, arguments were not necessary to refute the claim that scientific discourse is essentially enmeshed in networks of material and political factors.[21] Another example of such polemics is the fundamentalist scientism of Richard Dawkins, expressed in his "Postmodernism Disrobed" (1998)[22] or in the televised series "The Genius of Charles Darwin"[23]—not to speak of John Brockman, who in the mid-nineties of the last century marshalled a veritable army of the stars of scientism—including Stephen J. Gould, Daniel Dennett, Francisco Varela, W. Daniel Hillis and of course also Richard Dawkins—to present a "Third Culture,"[24] which is by no means—as one might expect—a culture dominated by a hybridised knowledge of some sorts between the natural sciences, the human sciences, literature and the arts, but instead a scientific posture turned normative and triumphant upon having allegedly beaten back the humanities in the course of what could be depicted as a particularly raw version of an *epistemic Darwinism*.

6.

As a final example, with which I would like to shift my focus to the rift between science (including the humanities) and *art*, I would like to mention one of the more recent publications of Edward O. Wilson,[25] in which he essentially depicts literature as a system of gossip that resists history and caters in the same mode in different cultures and ages to our evolutionary drive towards anthropomorphisms: those human, all too human aspects of life that generate such powerful emotions in us, when they are articulated by art as the tragi-comic pitfalls we keep stumbling into.[26]

Such a depiction is neither one of those shallow and inconsequential compliments made by a scientist to the arts, nor can it—despite Wilson's authority as a scientist and as a widely acclaimed writer—be regarded as a mere gloss of easy-going banalities, masking what is in reality a more complex experience of art. In ignoring some of the major modernist experiments in art and literature—as exemplified by the works of Mallarmé, Joyce, Duchamp among many others—that go well beyond the ken of our daily anthropomorphisms and express what Foucault would later codify as the Death of Man,[27] Wilson's statement merely reveals a deepening of the rift that Snow tried to articulate.

7.

I would however prefer to go past such oddities of contemporary discourse and focus on an epistemological tradition, which acknowledges that scientific ideas, no more than other kinds of ideas, are historically contingent and rooted in *dispositives* like the "experimental system," a term coined by the German molecular biologist and historian of science, Hans-Jörg Reinberger, signifying a hybrid constellation of materialities like the experimental apparatus and immaterialities like the discourses circulating in the scientific community or the theories regulating the experimental process.[28]

Through such an approach, I hope *firstly* to delineate the *discursive* processes that brought about historically the rift between the two cultures in the first place and *secondly* to reflect on what I perceive as the rudimentary contours of an emerging "third culture," in which the truth games of science—

genetic science in the context of this essay—and the truth games of art—art-projects responding to the achievements of molecular biology and genetic engineering—approach each other, generating what might be seen as the beginnings of a new type of hybridised knowledge. Truth, in the sense of the epistemological tradition just mentioned, is not merely something that lies somewhere, waiting to be uncovered by the scientific process, but something that is *produced* in a regulated manner in the course of an epistemic activity. A "truth game"—in Michel Foucault's understanding of the term—is an "entire set of rules for the production of truth."[29]

IV. JURIDICAL TRUTH GAMES (MICHEL FOUCAULT)

8.

Years before his histories of sexuality and the prison, Foucault presented a history of truth games in a small set of lectures held in May 1973 in Rio de Janeiro.[30] The lectures begin with a description of rituals for the ascertainment of legal truth in early medieval Europe, watched over and regulated by the community as a whole and tuned to decide the guilt or innocence of an individual alleged to have perpetrated an injustice on another individual. Such juridical procedures habitually spilled over, as Foucault demonstrates, and constituted technologies of truth production in other spheres like those of science and scholarship.

The prime technique of ascertaining juridical truth in early medieval Europe consisted in the ritual of *trial by combat*, in which the accuser and the accused entered a duel witnessed by the community. The innocence of the accused followed from the eventuality of his victory, which would indicate divine intervention in his favour. The essential criterion was founded on the bias of *force*, connecting truth with the quantities of force available to each of the conflicting parties. The ritual of combat found its parallel in the academic tradition of the *disputatio*, based on a technique that Foucault calls the *épreuve*, which decided on the truth of a thesis on the basis of the accumulated force of the authorities that could be cited in its favour.

9.

In due course, the *épreuve* was challenged by a different technique of truth production called the *ênquete*, which consisted in the systematic interrogation of witnesses. The *ênquete* triggered off a crisis of *disputatio*, since an author could either be an *authority* to be cited or a *witness* to be interrogated, but not both at the same time. Ultimately, *disputational* knowledge, based on *force* —the force of authority, physical strength, combative style, etc.—, was succeeded by an *inquisitional* knowledge based on testimonies extracted through interrogation. The new type of knowledge was administrative in nature and associated with what Foucault would later term *governmental power*, which began to dominate in West European societies shortly after the death of Machiavelli in 1527. In the late eighteenth century, a new type of power/knowledge constellation emerged, based on procedures of *discipline*, adapting individual behaviour to norms and streamlining knowledge—as Foucault had demonstrated seven years earlier in his archaeology of the human sciences[31]—through its focus on objects like *language* in comparative philology, *labour* in political economy and *life* in the new science of biology. In Kantian epistemology, contemporaneous to the constitution of the prison as a disciplinary institution, the production of truth is regulated by *categories*, taken as the immutable and ahistorical conditions of the possibility of knowledge. In the empirical sphere of scientific knowledge, the categories function as fundamental concepts corresponding to the timeless *objects* of scientific enquiry and constituting the sciences as disciplines.

V. THE HISTORICAL EPISTEMOLOGY OF SCIENCE

10.

From a contemporary perspective, however, categories—and, correspondingly, the *objects* of scientific research—are neither immutable nor ahistorical. Many decades of research in the history of science—not only Foucault's archaeology of knowledge or the pioneering work of historians of science like Gaston Bachelard[32] or Georges Canguilhem,[33] but also the work of scientists turned historians like Ludwig Fleck,[34] François Jacob,[35] Hans-Jörg Rheinberger[36]— have demonstrated that categories and objects can in fact be characterised as 'artefacts' generated by chance constellations of material and immaterial elements functioning as dispositives. They are "essentially" contingent, can be challenged by other, conflicting categories (and objects) and can break down within short spans of epistemic crises. Often the word remains the same, but the content transforms drastically. This is how for example the categories of *death* and *disease* transformed towards the end of the eighteenth century as the dispositive of the clinic was constituted. The words were retained, but the content was transformed.[37] Another example for a historical analysis of scientific categories is Ludwik Fleck's short history of the concept of syphilis, which ploughs through entire discursive arenas from the Renaissance till the nineteenth century to reveal the archaeological strata of transformation and constitution in the historical depths of a contemporary scientific category.[38] The distinctive trait of such an epistemology is its technique of incorporating the history of thought as an instrument at the service of epistemological reflection. Fleck expresses this connection in the following manner: "Biology teaches me to examine genetically anything that is subjected to development. Who would study anatomy today without taking recourse to embryology? Exactly in this sense, all epistemology undertaken without historical and comparative analyses would remain an empty play of words, an Epistemologia imaginabilis."[39]

However, the instants of innovation and epistemic crises in the history of science are not only manifested as great tectonic shifts beneath the ground of normal scientific knowledge: as collective unconscious processes that can only be revealed to the gaze of a future historian. They can also come to view in moments of questioning, reworking and constructing categories or objects by an individual thinker. To illustrate such a moment, I would like to turn to a small series of lectures held by Erwin Schrödinger in Dublin before the end of the Second World War.

VI. "WHAT IS LIFE?" (ERWIN SCHRÖDINGER)

11.

The lectures were delivered in February 1943 at Trinity College in Dublin under the title *What is Life?* First published in 1944,[40] they were to become a powerful stimulant for the process that ultimately led to the microbiological revolution of the 50s of the twentieth century, influencing not only ideas and concepts, but also the lives of individual scientists. Thus James Watson writes about Francis Crick, with whom he discovered the DNA structure and later shared the Nobel Prize: "A major factor in his leaving physics and developing an interest in biology had been the reading in 1946 of *What is Life?* by the noted theoretical physicist Erwin Schrödinger. This book very elegantly propounded the belief that genes were the key components of living cells and that, to understand what life is, we must know how genes act."[41] Crick in fact "wrote to Schrödinger on August 12, 1953 after the discovery of the double helix, sending reprints and telling Schrödinger that both he and Watson had been influenced by *What is Life?*"[42]

12.
Throughout the lectures, Schrödinger tries to come to terms with the discontinuity between the object of biology, which he takes to be *life*, and the objects that normally concern physics. He senses that jumping from the object of one science to that of another, while presupposing something like an *a priori* unity of nature, requires a transformation of existing categories.
It is in this vein that he introduces the category of an *aperiodic crystal* as a tool for specifying the distinction between living organisms and physical structures, calling "the most essential part of a living cell–the chromosome fibre" an aperiodic crystal, while keeping in mind that physics till then had dealt only with periodic crystals.[43] Indeed, says Schrödinger, the latter might appear to the physicist as the most fascinating and complex material structures in inanimate nature, but, compared with the aperiodic structure of the chromosome, they are simply "plain and dull."[44] If a periodic crystal is comparable to a simple wall paper, in which the same pattern is repeated over and over again, the aperiodic crystal resembles a Raphael tapestry, "which shows no dull repetition, but an elaborate, coherent, meaningful design traced by the great master."[45]
13.
Thus, in order to think of life as the object of biology, Schrödinger needs first of all to extend a category of physics: that of the crystal.[46] In a next step, he formulates an elementary question tuned to the transitional zone between physics and biology: Why are atoms so small? The answer is simple: because we are so big. But why are we so big? Or rather: Why do we *have to be* so big? Before giving the answer, Schrödinger draws attention to the fact that even physicists, whose predilection for the microphysical compels them to measure space in Ångströms, happen to wear suits and that they prefer to be told "that the new suit will require six and a half yards of tweed—rather than sixty five thousand millions of Ångströms of tweed."[47] The yard, as Schrödinger informs us, goes back to the humour of an English king, who simply stretched out his arm sideways and proposed that the distance between the middle of his chest and his fingertips be taken as the standard unit of measurement within his kingdom. The physicist, in other words, is not merely an abstract gaze directed dispassionately towards the microscopic, but also a concrete body, situated in a macroscopic world, in which suits are necessary and space is best measured in yards.[48]
14.
Schrödinger's gaze thus swerves between the two matrices of life—the microscopic life spread out in front of us, and the lived and liveable life behind our gaze. He begins with the microphysical reality of atoms and molecules, goes over to the macromolecules of the chromosome fibres, which are foundational to life and consist in enormous populations of atoms, to finally reflect on the scale of the human organism. Why are we so big? Why is our brain, the material basis of our thoughts, so big? To understand that, we must imagine, what it must be to have the dimensions of microorganisms like bacteria. We would feel as if we were in a boat, tossed about on stormy seas. Due to the chaotic thermic motion of atoms and molecules, we would be constantly subjected to the impacts of the single atoms and molecules of our environment.[49] Under such conditions, we would not be capable of thinking or even feeling. For thought is an "orderly thing," which is why its material vehicle, the brain, must also have a certain degree of orderliness.[50] Order, however, is in the physical world a *statistical* phenomenon involving huge populations of atoms and molecules. The larger the population of atoms and molecules, the more accurate are the statistical laws governing their collective behaviour. In fact, all "the physical and chemical laws that are known to play an important part in the life organisms are of this statistical kind; any other kind of lawfulness and orderliness that one might think of is being perpetually disturbed and made inoperative by the unceasing heat motion of the atoms."[51] That means: we must be big, because our brains must be big. Our brains again must be big enough to accommodate a statistically relevant population of atoms in order to

be capable of incarnating an orderliness corresponding to the orderliness of thought. We must be big enough to be able to think and feel without being disturbed by the incessant impacts arising from the thermic motion of the atoms and molecules in our environment.

15.

In the course of such reflections, Schrödinger elegantly brushes past the Cartesian problem of *mind and matter* to observe an "intimate correspondence" between the orderliness of thought on the one hand, which remains otherwise unspecified in nature and composition, and the statistical orderliness of the brain on the other, as well as the sensorial system associated with it.[52]

Thirteen years later, Schrödinger would take up the issue of mind and matter once more in the context of another lecture delivered this time at Cambridge.[53] The lecture begins with the following words:

> The world is a construct of our sensations, perceptions, memories. It is convenient to regard it as existing objectively on its own. But it certainly does not become manifest by its mere existence. Its becoming manifest is conditional on very special goings-on in very special parts of this very world, namely on certain events that *happen in a brain*. That is an inordinately peculiar kind of implication, which prompts the question: What particular properties distinguish these brain processes and enable them to produce the manifestation? Can we guess which material processes have this power, which not? Or simpler: What kind of material process is directly associated with consciousness?[54]

VII. THE INTERFACE

16.

It might be interesting to consider such reflections in the light of the epistemological history of science pioneered by Gaston Bachelard almost a century ago and further developed in recent times by Hans-Jörg Rheinberger. Bachelard understood scientific research as a *phenomenotechnical* practice, implying that the objects of scientific enquiry are not to be seen as originating in the pristine purity of a nature that remains untouched by and is transcendent towards all that is human, but rather as *historical* phenomena that are systematically generated by the ensemble of discursive and technological elements that go to constitute an *experimental system*. In a phenomenotechnical context, Schrödinger's reflection on the brain entails the suggestion that the human brain is no less an element of the dispositives of scientific research as the instruments of science crafted by human industry. We would then need to go a step further in the hybridisation of the *experimental system*,[55] by determining it as a dispositive composed of elements that are not only material and immaterial, but also biological and technical.

However that might be, even in the earlier text *What is Life?*, Schrödinger does not hesitate to draw attention to the mystery of the *interface* between the dual matrices of life: the immaterial and orderly dynamism of thought on the one hand and the statistical materiality of the brain on the other, "even though we are ignorant of the true nature of this close parallelism. Indeed, ...it lies outside the range of natural science and very probably of human understanding altogether."[56]

17.

The "outside" Schrödinger alludes to can easily be taken in the metaphysical sense of a reality outside the ken of human understanding and accessible only to an absolute knowledge. However, in view of the problem at hand it seems more fruitful to associate Schrödinger's "outside" with the boundary between two incompatible perspectives of knowledge: the perspective of the observable life of an object and that of the liveable life of a subject.[57] The parallelism of the two lives obviously lies "outside the range of natural science."

Whenever we focus on such an *interface* and the "parallelism" associated with it, two distinct possibilities of knowledge and the perspectivism common to both come to view. In fact, even within the boundaries demarcated by the dichotomy of the "two lives" and the corresponding opposition between artistic and scientific knowledge, one discerns the possibility of different kinds of *scientific* knowledge, supported and enabled by different knowledge systems or *epistemes*. It is in this vein, that almost a century of epistemological histories of science— from Bachelard to Rheinberger through Fleck, Canguilhem, Foucault, Jacob—has demonstrated that scientific categories and objects are no less artefacts[58] than works of art, as expressed in the Bachelardian idea of the *phenomenotechnicality* of scientific research as well as in Rheinberger's more recent reflections on the *interface* between *technological objects* and *epistemic things*.[59]

VIII. SCIENCE, ART, LIFE (FRIEDRICH NIETZSCHE)

18.

The complex and fateful relation between life, science and art—enabled by a "history of truth" emanating from real and describable relations of power—is one of the constant focal points of Nietzschean thought. In his late "preface" ("An Attempt at Self-Criticism," 1886) to his first book, *The Birth of Tragedy* (1872), Nietzsche states that the essential task articulated by this book and destined to outlive its success was "to regard science from the perspective of the artist, but art from that of life."[60]

In the context of Nietzsche's late work, which is also the context of other similar attempts at retrospective reflections on earlier works (1886/87),[61] the observation just quoted implies a deep and many-layered connection between science and art. Both science and art generate illusions or "lies" that are instrumental to life and to the task of acquiring *mastery* over whatever comes one's way to resist the blossoming of life. Art generates images and knows that they are images. Science also generates images. But its epistemological disposition makes it forget that they are images.

In his short essay, "On Truth and Lie in an Extra-Moral Sense,"[62] an early text that remained unpublished during his lifetime, Nietzsche characterised truths as illusions, "of which people have forgotten that they are illusions."[63] Truths are *metaphors* grown weak with use: coins that have lost their mintage and reverted to metal.[64] In this sense, art and science involve different "truth games." In science, the artefactual nature of truth—the fact that truth is *produced* and not dug out by knowledge—is habitually forgotten, whereas in art the artefactual or "fictional" nature of truth is structurally impossible to ignore.

19.

The lowest common denominator of science and art is the practice of *interpretation*, but in the sense of *mastering* whatever comes our way rather than in the hermeneutic sense of extracting *meaning* from texts (Schleiermacher) or from the outer manifestations of human life (Dilthey) or from our being-in-the-world (Heidegger). Interpretation in the Nietzschean sense unfolds in both artistic and scientific endeavours as a practice of connecting with the world and mastering our experience of the world.[65] It is a technique of acquiring and retaining the upper hand on our trajectories through the labyrinth of life.

All interpretation can operate in a reflexive mode, in which we see ourselves as living and thinking beings targeted by our techniques of self-interpretation. In the ascetic practices of the ancient Greek and Romans, self-interpretation becomes a technique of mastering the self.[66]

In general, we tend to interpret ourselves as living beings in two different modes. In the scientific mode, we focus on things *in front* of us. Since the end of the eighteenth century, we have got accustomed to transforming our own lives and the lives of organisms in general into *objects* of observation and reflection. Objects are things projected *in front* of us, resisting us and our gaze, which seek to penetrate them and explore the possibilities of exploiting them technologically by placing them at our disposal. We respond to their intransigence by cutting them up and analysing them, till we attain the molecular scale in the medium of an *experimental system* based on techniques of image production.

In the artistic mode, on the other hand, we focus on things *behind* us, that reveal to us the conditions of possibility of our own lives, taken, in this perspective, as the real lives lived by us: the lives that inform and infuse our actions, including our artistic actions.

20.

At the end of the section "How the 'true world' finally became a fable" in his *Twilight of the Idols*, Nietzsche draws attention to the fact that the age of Zarathustra, which is the age contemporaneous to us, his readers, is a strange and concluding stage in a long history of truth games beginning with Plato. At this stage, we will not only have abolished the true world, but also the apparent world, so that the traditional opposition between the true world and the apparent, between the conceptual realities of science and the metaphorical realities of art, will cease to orient us. A great deluge of fictional processes—attaching to the elements of knowledge the emblems of their "constructedness" and artefactuality—will sweep through our discourses, leaving behind myriads of differences between different kinds of fiction like the scientific model and the artistic installation. The dynamic difference between the fictions will take the place of the traditional, immutable opposition between the true and the false.[67]

This implies, in tune with Michel Foucault's prediction in *Words and Things*, that we shall be witnessing a major discursive upheaval since the end of the eighteenth century, triggered off by a process that can be termed the *fictionalization of truth*. In the course of such a process, the historically constituted rift between science and art is withdrawn and the chessboard of knowledge is shaken up once more for a new game to be started. I will try to spell this out in more precise historical terms in the following section.

IX. THE FICTIONALISATION OF TRUTH (MICHEL FOUCAULT)

21.

In *Words and Things*, Foucault describes an epistemic crisis[68] contemporaneous to the Industrial and French revolutions, which led to the breakdown of an entire system of knowledge, termed by Foucault *classical knowledge*. This epistemic system functioned perfectly in the seventeenth and eighteenth centuries and was based on the idea that all knowledge essentially depends on a relation of substitution or *representation*, because perception is never immediate. Every object has to be *represented* in an idea, before it can find its way into the human imagination and mind. All ideas again have to be represented by *signs*, before they can be analysed, classified and stored.

Logical analysis introduces the *order of discourse* into chaotic masses of signs such as words and images. Classificatory techniques introduce the *order of knowledge* into chaotic masses of representations. Thus grammar classifies words, natural history classifies plants and animals, the analysis of wealth classifies values.

22.

A fundamental epistemic principle regulating this system of knowledge is the *complete and essential transparency* of the figure of representation, corresponding to the essential transparency of language, which is nothing other than a representation of representations in a temporal process, in which the elements of a representation are unfolded step by step through the words designating them. If representation ever loses its transparency, the classical order of knowledge will necessarily break down. This is exactly what happens in the second half of the eighteenth century, ushering in a new era of knowledge characterised by a critique of the Kantian type, which starts out from the self-evident *limits* of representation and unfolds a reflection on them.

As a first consequence of the loss of transparency of representation, *language* loses its transparency and acquires the depth and opacity of an *object* of the new science of comparative philology. In a parallel process *life* emerges as the object of the new science of biology and *labour* as the object of the new science of political economy. The loss of the transparency of representation leads to the constitution of *language*, *life*, and *labour* as new objects of new forms of scientific knowledge.

23.

However, when language becomes an *object* of representation instead of being a *mode* of representation as in the classical age, it is dispersed to assume four different and incompatible roles and therefore gets dispersed: (1) it is an *object* of philological inquiry; (2) due to its opacity as an object, language becomes dysfunctional as an instrument of scientific knowledge and has to be reduced through techniques of *formalisation* to prevent it from obscuring the objects of scientific knowledge; (3) due to its opacity as an object, language also becomes a chance expression of subjectivity, obscuring the clear and distinct ideas of the mind, and therefore needs to be reduced through techniques of *interpretation*.

Thus, representation—and science as a practice of representation—can only survive the loss of its transparency, if language becomes (1) the *object* of a new kind of knowledge, (2) the target of *formalisation* so as to re-enable knowledge to represent objects and (3) the target of *interpretation* so as to re-enable knowledge to represent ideas. Thus, when representation loses its transparency, three distinct scientific techniques with respect to language emerge: objectification, formalisation and interpretation.

24.

There is, however, a fourth mode of existence of language, in which language finds itself entirely dissociated from representation. In this mode, language is neither an object of representation, nor a hindrance to representation, but rather the medium of a new type of *fictional* discourse, for which Foucault uses the term *literature*. In literature, there is nothing left to be represented: neither language itself as an object of representation, nor a reality beyond language, waiting to be represented. In the *counter-discourse* of literature, representation is replaced by fiction, as language becomes productive, churning out fictions from within its own folds.

25.

Thus, the loss of transparency of representation leads to a rift between two modes of language: the language of *representation*, which is the language of science; and the language of *fiction*, which is the language of literature. Thus, in the opposition between *representation* and *fiction*, one can recognise Snow's two cultures. Foucault's archaeology of knowledge reveals itself as a genealogy of the rift between the two cultures.

However, language is not only in a state of dispersal. It is also absorbed in the process of its reconsolidation and return, manifested in the sixties of the twentieth century as an inflationary preoccupation with language in the arts as well as the sciences. The fragmentation of language, resulting from its transformation into an object of philological knowledge, is—as Foucault puts it—"the most secret and most fundamental" consequence of the break-down of classical knowledge.[69] All efforts to master this primordial epistemic event at the threshold of our post-industrial modernity must therefore assume the form of a quest for the lost unity of language, which can only be reconstituted

within a space, in which the play of language can be revealed again in its entirety. This would amount to a major transformation of contemporary knowledge, triggered off by an uncontrolled process of *fictionalisation of truth* spanning across the abyss between the arts and the sciences.
A *third culture* in this sense would be determined by a truth game, in which truth no longer stands in opposition to fiction, but is itself fictionalised. In the final two sections of this essay, I will try to provide a rudimentary sketch of the process of emergence of such a *third culture*, in which science and art approach the dividing line inherent to the dual matrix of life from opposite directions.

X. SCIENCE AT THE INTERFACE

26.
It is not uncommon for scientists to step back from time to time in order to reflect on their science or explain it to the non-scientist. Francis Crick, George Beadle, Max Delbrück formulated their philosophical standpoints or applied their didactical techniques after attaining a certain stage in their scientific careers.[70] Jacques Monod, with whom François Jacob shared the Nobel Prize in 1965, wrote a philosophical best seller five years after the prize[71], almost simultaneously with Jacob's *Logique du vivant*[72]. In his book, Monod also tries to formulate something like a logic of the living upon the background of his own research at the Pasteur Laboratories. However, he takes the standpoint of an epistemological optimist, convinced of an ultimate, transhistorical validity of his science and expressing at the end of his book the utopian hope that an ethics resting on such a science would lead to a more humane world.
Jacob speaks on the same scientific discipline as Monod. He also draws from his research years at the Institut Pasteur in Paris, where he worked for more than a decade alongside Monod. But he speaks with a different voice. *Logique du vivant* is a book written by a scientist turned historian, exercising a historical and epistemological *critique* of his own discipline. The result is a historical narrative, replete with details from what I would like to term a *nonlinear* trajectory of biological thinking, as it traverses different and distinct epistemic configurations corresponding to different segments of historical time. Instead of projecting the present into the past to produce a continuous history of biological ideas steered by a *teleology of reason* or an *epistemic Darwinism* based on a "natural selection of ideas," Jacob explores the discontinuous historical processes, in which the objects of scientific enquiry are constituted[73] by clarifying the "nature of these objects, the attitudes of scientists and their modes of observation, the obstacles resulting from their education under historically specific conditions."[74] It is the general thrust of such a history, that makes a statement like the following possible:

> Between the hand of Fernel, who conceptualised the word "physiology" and the hand of Harvey, who rendered the human blood circulation accessible to experiment, neither the form nor the efficacy of the scalpel had improved.[75]

27.
The long and arduous historical processes of constitution of objects, theories, new areas of enquiry are similar to what Jacob would later on term a *night science* with respect to the individual research process. Drawing from Bachelardian observations concerning the psychoanalysis of scientific thought, Jacob distinguishes between the two faces of science. On the one hand, we have something like a *day science*, consisting in the observations, validations, conclusions, presented to the scientific community mainly as readymade theories bearing little or no trace of their genesis, saturated with the power of certitude and the majesty of an order, which can be "admired like a

painting by Leonardo or a fugue by Bach".[76] On the other hand, there is the *night science*, replete with experiences like faltering in the dark, chronic uncertainty, doubts, fears and the occurrence of sudden and inexplicable intuitions – all typical not only of the night side of research and its quest for answers to premeditated and pre-formulated questions, but also of the artistic processes documented in museums as chronologies of works that can be seen as repeated trials responding to historically specific artistic problems.[77] Jacob observes in passing that the sciences and the arts always flourished simultaneously and at the same places in European history[78] and draws attention, after presenting a series of historical illustrations of such a statement, to the fact that the term 'biology' surfaced towards the end of the eighteenth century at different points of the institutionalised discourses on the living at the same time as the first suicide occurred in modern literature: that of Goethe's young Werther.[79]

This strange parallelism between science and art provides a backdrop to Jacob's observations on the truth games of the life sciences, as in the following:

> Like the other natural sciences, contemporary biology has had to discard numerous illusions. It no longer searches for truth; instead, it constructs its own truth. Reality then comes to view as a perennially unstable equilibrium. Concerning the study of living beings, history reveals a series of oscillations [like, P. M.] the movement of a pendulum between continuity and discontinuity, structure and function, the identity of phenomena and the diversity of beings. In the course of such oscillations, the architecture of the living emerges step by step, manifesting itself in ever deeper strata.[80]

Thus, Jacob conceptualises scientific practice not only as a complex historical process with the characteristics of a *night science*—not unlike the tortuous processes accompanying artistic production—, but also as an activity regulated by a truth, which is not searched for, but constructed. At the interface between the two matrices of life—the life subjected to scientific observation and the life lived by the practitioner of scientific observation—science and art seem to approach each other from 'opposite' directions in the element of a *fictionalised* truth. This can count as a possible manifestation of the 'unity of discourse' as envisaged by Foucault in his archaeology of knowledge.[81] It certainly explains the enthusiasm, with which Foucault assessed *La logique vivant*, shortly after its publication, as "the most remarkable history of biology ever written."[82]

28.

The interface I have repeatedly touched on in the course of this essay—as the boundary inherent to the dual matrix of life—finds its point of reflection or reduplication at the core of an *experimental system* as conceptualised by the German molecular biologist and historian of science, Hans-Jörg Rheinberger. Rheinberger calls such a point the *interface* ("Schnittstelle") at the centre of an experimental system and regards it as an essential and unbridgeable gap between the instruments of observation and the objects to be observed. One can imagine that the tangible nature of such an interface would enable a clearer and more nuanced understanding of what I have been calling the dual matrix of life, which is why I would like to turn to some of Rheinberger's categories at this point. In his *Experimentalsysteme und epistemische Dinge*,[83] Rheinberger characterises his own project as an "archaeology of molecular biology" with reference to Foucault's use of the term 'archaeology' as a historiographic technique of *rewriting* things already said (*les choses dites*) and gathering them into new constellations.[84] Starting out with the Bachelardian idea of the experimental apparatus as a unity of materialised theory and a phenomenotechnical device, he defines the *experimental system* as a "minimal functional unit of research"[85] based on a hybrid constellation connecting the objects of knowledge and the technical conditions for generating them.[86]

Thus, the experimental system includes on the one hand the objects of knowledge or *epistemic things*, as Rheinberger calls them. These are to research what a sculpture or painting is to art[87], implying that an epistemic thing is *not pre-existent* with respect to scientific observation, but rather grows and transforms with it as a hybrid entity that includes both discursive and material elements. At the focal point of an emergent scientific knowledge, an epistemic thing can position itself as a physical structure, a biological function, a chemical reaction, etc., the common trait of all such possibilities being that it is *essentially* unknown, so that—in a Derridean turn of Rheinberger's argumentation[88]—the experimental *presence* of an epistemic thing seems to be nothing other than its *absence*. For if it were present, or known, that would be the end of research.[89]
On the other hand, the experimental system includes *technological objects*, which are those instruments of observation that Bachelard depicted as incarnated theory. Pre-planned, carefully constructed and well determined, the technological objects can be applied to epistemic things as a frame is applied to a picture, enabling us to "touch" them, deal with them and limit them. Whereas the epistemic things in biological research are usually soft, moist and instable, and therefore in a constant state of flux and transformation—much like the *reality* of the living that François Jacob depicted as a "perennially unstable equilibrium"[90]—, technological objects are the hard, dry and stable elements of an experimental system, functioning to gather and *write* the "traces" of epistemic things and, ultimately, to generate their scientific representations.[91]
A history of experimental systems therefore must include on the one hand a history of instruments and their production, but on the other hand also a history of *things*, of *epistemic* things, but not in the sense of given, immutable elements of "nature," but as things that evolve in the course of their being represented by technological objects. Such a history therefore unfolds as a "biography" or "genealogy" of things, similar to the *history of things* conceptualised by the American art historian George Kubler, whom Rheinberger acknowledges as one of his inspirational sources and quotes as follows:

> The value of a convergence between a history of art and a history of science lies in the practice of gathering common instants of innovation: common processes of transformation and attrition, to which the material works of artists and scientists are subjected in the course of time.[92]

29.
In the course of his historical investigations, Rheinberger closes in on the *interfaces* between epistemic things and technological objects, which, as mentioned earlier, lie at the heart of experimental systems.[93] He unfolds a specific historiography of interfaces under the premise that different interfaces are constituted under different historical conditions to generate the *epistemic value* of an experimental system, and depicts an interface in general as the

> surface of contact between instrument and object. How are these surfaces of contact between the living and the non-living, between the organism and the instrument constituted? The investigative efficacy and value of an instrument depends on the interface, which decides, if a certain instrument and a certain object can be brought into a fruitful analytical constellation. It also serves as the common focal point for craftspeople, manufacturers and users. For it is at the interface, that the hand of the scientist takes over from the hand of the constructor. And even in the age of industrial production and research technologies, the interface often remains the privileged site for a collaboration between different crafts.[94]

Without providing further details, which would go beyond the scope of this essay, I would like to underscore the relevance of Rheinberger's conception of the interface for a reflection on the dual matrix of life, which can be generally characterised as the ontological site of human existence in the modern experimental situation. The duality of the life "driving" me from behind and the life lying objectified in front of me is reflected at the interface between the instrument conceptualised/used by me and the specimen prepared/observed by me, which is also the boundary, at which the stable and anorganic surfaces of technology hit on the moist and soft surfaces of the living:

> In biological experiments, the interface between the objects of observation and the technologies of their representation or measurement means the boundary between an organic and an inorganic entity. In a sense, the interface is the point at which life and technology collide. And since the living side is usually moist or soft and the technological side usually hard and dry, special measures need to be undertaken to ensure the compatibility of both sides. All action at the interface therefore determines the scientific, cultural and even the aesthetic or ethical ramifications of experimental systems.[95]

With such categories and distinctions, Rheinberger sets out to formulate a specific history of the interfaces of experimental systems, drawing attention to the highly artefactual character of specimens, which need to be prepared and made compatible to specific technological objects before they can take up their position at the interface. The result is a presentation of a series of historically constituted interfaces at the core of experimental systems like the *microscope*, the *kymographion* for measuring the blood pressure of injured animals, the *in vitro experiment* along with the *ultracentrifuge*, *X-ray crystallography*, *electron microscopy*, etc.[96] With the advent of genetic engineering, the interface becomes complicated, for the technological object no longer *surrounds* the organism, enabling its observation, but *penetrates* it in order to transform it:

> … genetic engineers no longer construct their instruments around the organism, but into the cell. From within the cell, their instruments get into action. They no longer analyse the organism, they recompose and reformulate it. They are constructive and synthetic.[97]

XI. ART AT THE INTERFACE

30.
As science approaches the interface (of its experimental systems), its inherent constructivism and the fictionalisation of its truth game come to view. Specimens reveal themselves as intensely prepared and intensely artificial objects that leave behind their "writing" on the representational apparatus composed of technological objects. The interface itself is no longer the traditionally expected boundary between *nature* and *culture*. Instead, it reflects the boundary between the observable disposition of the specimen and the liveable disposition of the observer.
As art responds to genetic engineering and penetrates the organism, it also approaches the interface between lived life and objectified life, but from the opposite direction, as it were. At the interface, it becomes intensely conceptualist, substitutes the studio for the laboratory and unfolds a propensity to collaborate more with science and engineering than with the traditional manual crafts. Its outcome is no longer the traditional work of art organised as a representational gathering of materials and forms as in the case of painting, sculpture, etc. Its outcome is instead the work of art as a *living thing*.
In the following, I will try to present a selection of some of the most remarkable examples of genetic art in the recent history of this art form.

31.
The discovery of the double helix in 1953 marked the beginning of a veritable career of the helical form, which spread out in the second half of the twentieth century in a kind of uncontrollable paroxysm through art and popular culture.[98] The first artist to have integrated the helical form as an iconological element into an artwork was Salvador Dali in his *Butterfly Landscape, The Great Masturbator in Surrealist Landscape with DNA* (1957-58),[99] in which the double helix figured in his view as "the only structure linking Man to God."[100] Since then, the forms of the double helix or other genomic molecules have attained an iconic circulation,[101] as for instance in Tony Cragg's *Code Noah* (1988), in which children's stuffed toy animals, cast in bronze, were welded together to create a spiral chain;[102] or Andrew Leicester's open space terracotta *G-Nome Installations* (1990/2016) atop the four corners of the molecular biology building of the Iowa State University;[103] or Roger Berry's *Portrait of a DNA Sequence* (1998) hanging in the massive four-story spiral stairway of the Life Sciences building at the University of California in Davis.[104] In the field of design, Helen Storey, a London artist, collaborated with her sister, Kate Storey, an embryologist at the University of Dundee, to create "Primitive Streak" (1997), a dress collection chronicling the first 1,000 hours of human life. Almost half of the collection reflected the different ways in which genes influence early embryonic development, using the weave of cloth and the cut of fabric to build the double helix into the design.[105]
32.
However, iconic representation is incapable of creating any substantial transformation of the artistic practice or medium. In each of the examples cited above, the new form of the double helix is simply integrated with all its symbolic trappings into a pre-existing artistic practice.
Of greater significance are probably experiments in translating molecular biological knowledge into music, like the *Sonic Gene* project, started in 2001 at the European Bioinformatics Institute in Cambridge, England, to mark the completion of the Human Genome Project. The basic idea was to convert different nucleotides in various DNA sequences into pitches, rhythms etc. and to render them audible with the help of a special software. Collaborating with a pop musician, *Sonic Gene* went a step further to spice up the DNA music by translating gene expression processes into rhythms.[106]
Another example is the *molecular music* of Susan Alexjander, a composer from Santa Cruz, who translated the different light frequencies absorbed by different nucleotides into different sonic frequencies; or the *musical molecules* of Marie Anne Clarke, a professor of biology at Texas Wesleyan University, who assigns different pitches to 20 different amino acids according to their different modes and intensities of mixing with water.
33.
Since the advent of biotechnology, artists have increasingly turned to the laboratory techniques of genetic engineering in the course of what can be summed up as a "technological turn" in artistic responses to genetics, which has, in its turn, has "backfired" as a radical transformation of artistic techniques and media.
One example of such intense interaction between art and genetic engineering is the *genetic portrait*. In 1988, Kevin Clarke requested genetic scientists working for what was then known as Applied Biosystems Inc. to create a "non-comparative, individual-specific DNA sequencing procedure"[107] on the basis of his own blood. What Clarke wanted, was a sequencing method that "revealed something specific to the individual, a sequence of part of the person's basic physical identity."[108] In response, the scientists experimented and developed the first automated sequence using PCR (Polymerase Chain Reaction), which has been in application in DNA sequencing procedures since then. They published their results in 1989, acknowledging Clarke's role in initiating the experimental process.[109] However, almost a year before the publication of the science article, Clarke had already

created his first genetic portrait with the aid of this technique, his *Self Portrait in Ixuatio* (1988), transforming thereby the traditional genre of portrait art. In a similar manner as fifteenth century Chinese painting, which combines painted metaphoric images with calligraphy, Clarke combined the DNA sequence as a kind of "hereditary calligraphy" with a photograph of a pictorial theme intimately connected with the person being portrayed and resulting from an intense exchange between the artist and his subject.[110]

What is truly striking in this story is not merely the fact that the invention of a basic DNA sequencing technique goes back to the query of an artist. It is equally significant that the dual innovation in portrait art and genetic engineering occurred almost simultaneously, as in George Kubler's speculations concerning the "common instants of innovation,"[111] or in François Jacob's observation quoted at the beginning of this essay.

About ten years later, Clarke created 26 genetic portraits for the Museum Wiesbaden (Germany), among them a portrait of James Watson, the co-discoverer of the double helix structure of the DNA molecule. Clarke superimposed Watson's DNA sequence on a photograph of bookshelves in a wave-like helical motion of shelf units.[112]

Shortly after Clarke's exhibition in Wiesbaden, the conceptualist Marc Quinn presented a quite different type of genetic portrait at the National Portrait Gallery in London under the title *A Genomic Portrait: Sir John Sulston*,[113] depicting John Sulston, who had played a major role in the international collaborations to map and sequence the human genome. Quinn's portrait comprised colonies grown from bacterial cells taken from John Sulston's sperm, containing segments of his DNA. The colonies spread out as creamy blots across a mirror-like surface that reflected the viewer's own image. Quinn defines the work as "the most realistic portrait in the Portrait Gallery," because it carries the actual genetic instructions that led to the embodiment of John Sulston, the subject of the portrait. Unlike Clarke, Quinn does not merely use genetic information for his portrait, but the actual genetic material taken from the subject's body.[114]

34.

Nonetheless, genetic portraits remain within the confines of representational art. Despite Quinn's use of a "collage" between the living—the bacterial colonies—and the non-living— the mirror-like stainless steel surface—, the artwork remains representational by virtue of its function as a portrait, as well as the manner, in which it was mounted and presented.

With the advent of *bio-art*, however, artistic response to genetic science and engineering seemed to cross a genuine threshold. For here, the work of art is no longer a representation of something that takes place elsewhere, but is in itself, and for itself, a *living thing*. One example is the work of the Australian artists Ionat Zurr and Oron Catts, who founded the project group *Tissue Culture and Art* (TC & A) in 1996 and launched a series of provocative and political projects, in which tissue-engineering techniques were used for the creation of what they called *semi-living entities*.[115] In 2003, they presented an installation titled *Disembodied Cuisine* installation at the L'Art Biotech exhibition in Nantes (France), comprising "tiny, 'deathless' steaks"[116] grown from tissues collected from a live African clawed frog, *Xenopus laevis*. The idea was to draw attention to the issue of animal slaughter for food. In 2004, TC & A presented *Victimless Leather*, using tissue techniques to grow a miniature leather jacket from immortalised cell lines, thus demonstrating the possibility of producing leather without killing animals.

Since then, big business has followed suit, with new companies like *Modern Meadow* coming up to produce industrially grown leather.[117] Since the advent of bio-art, there have in fact been several occasions, in which science and technology have taken the cue from art and transferred an artistic innovation into the utilitarian sphere of commerce, as observed by Alexandra Ginsberg:

> As Oron Catts…explains, in this disciplinary integrity and avoidance of making “useful” things lies the ability to create shock to create discourse. Yet Kac’s infamous green fluorescent *GFP Bunny* from 2000 or Tissue Culture & Art’s *Semi-Living Steak*…have over time encountered the strange frontier where provocation becomes absorbed into and even part of scientific progress. “Victimless meat” has become a stock phrase in media reports on the burgeoning industry of lab-grown burgers.[118]

A further example of bio-art is the work of the British artist-activists, Heath Bunting and Rachel Baker, who founded the *Cultural Terrorist Agency* as a funding organisation to support actions against large corporations. In 1999 they announced the release of *SuperWeed Kit* 1.0 containing natural and genetically modified weeds resistant to Monsanto’s glyphosate herbicides, offering the weeds free of cost to anybody interested. The idea was to use genetic technology to effect something like an agricultural sabotage. The strategy was intensified in 2005, when Bunting collaborated with Danish activists to use small N55 rockets to dispense *SuperWeeds* more effectively and over larger areas than with mere hand dispersal.[119]

35.

A pioneer of bio-art and one of the most radical among the bio-artists is Joe Davis. In the 1980s, Davis worked together with the Harvard geneticist Dana Boyd in projects involving interstellar radar transmissions for extraterrestrial intelligence. The limitations of radar technology led Davis to consider biological media as possible vehicles for interstellar messages due to “the ‘universal’ language of biology; convenient and economical production of astronomical numbers of individual …messages…robust media (bacterial spores and viruses) that could survive both the environmental rigors of space…and the periods of ‘geologic time’ that would be required for the ‘journey out’.”[120] In 1986, Davis and Boyd encoded a pre-Germanic character representing life and femininity into a binary image and inserted this as a 28-mer synthetic DNA molecule into *E. coli* bacteria, yielding an art work as a living medium, which was probably the first of its kind. The work, titled *Microvenus*, prepared the ground for numerous scientific experiments that explored the possibilities of introducing generic information into living organisms in the form of synthetic DNA. In the publications, Davis was cited and his contribution acknowledged. *Microvenus* is probably the earliest example of the impact made by an art project on the evolution of genetic engineering. Subsequently, Davis synthesized an entire assortment of DNA molecules in different laboratories to serve him as vehicles of generic information, calling them “artistic molecules.”[121]

Almost ten years later, Davis realised another project called *The Riddle of Life* for a Harvard exhibition. The work goes back to the early days of translating normal English language messages into the genetic code. In 1958, the molecular biologist Max Delbrück, sent a string of 229 letters corresponding to the DNA bases to his colleague George Beadle, who had gone to Stockholm to receive the Nobel Prize. The message encoded in the letters read: “Break this code or give back the Nobel Prize.” After Beadle had decoded the message, Delbrück created another coded message, this time as an installation of tooth-picks with four different colours, which read: “I am the riddle of life. Know me and you will know yourself.”[122] In 1995, Davis collaborated with a laboratory at the Free University of Berlin to synthesize a 174-mer DNA molecule—first conceived by Max Delbrück—and encoded it with the words of the message. The Harvard show included a number of installations like a helical array of broomsticks, a string of coloured toothpicks, a rack of test tubes containing light-sensitive pigments, all of them displaying Delbrück’s “riddle of life” message in a different way. Ironically enough, the bacterial installation itself could not be shown due to reasons of biosecurity.[123]

36.
Bio-art attains a rare conceptual intensity in the works of another of its pioneers, the Brazilian artist Eduardo Kac. In 1999, Kac created a work called *Genesis*, in which he translated a statement from the biblical *Book of Genesis* into DNA code, incorporated it into bacteria and exhibited this as an installation in the Gallery of the Centre for Contemporary Art in Linz (Austria). The message read: “Let Man have dominion over the fish of the sea, and over the fowl of the air, and over every living thing that moves upon the earth.” Participants in the Web could turn on ultraviolet light in the gallery, which triggered off real, biological mutations in the bacteria, changing the biblical message in the process. Genetic technology is thus used to transform a statement formulating a traditional value concerning the metaphysical superiority of humans, which in its turn can be found in the value system at the root of that same technology.[124]
Two years later, in 2001, Kac presented another installation, *The Eighth Day*, at the Arts Institute of the Arizona State University in Tempe (U. S. A.), displaying diverse transgenic fluorescent life forms and a biological robot (biobot) under a Plexiglas dome. The life forms that included plants, amoeba, fish and mice, were created through the cloning of a gene coded for the production of green fluorescent protein. The work explores the ecology of coexistence of bioluminescent creatures, which, according to Kac, are being created in laboratories worldwide and need to be ascribed to an “eighth day” after the seven days of Biblical creation.
Another example from Eduardo Kac’s prolific transgenic practice is the *Edunia* (2003-2008), a genetically produced hybrid of Kac himself and the flower Petunia, described as follows on Kac’s website:

> The Edunia expresses Kac’s DNA exclusively in the red veins of the flower. The gene Kac selected is responsible for the identification of foreign bodies. In this work, it is precisely that which identifies and rejects the Other, that the artist integrates into the Other, thus creating a new kind of self that is partially flower and partially human.[125]

37.
In its elementary tendency to produce works of art as living things, bio-art follows a contemporary trend towards the *fictionalisation* of life[126] by virtue of its fabrication, which it shares with genetic science and technology. If the Industrial Revolution in the nineteenth century manifested itself as a technology of serial production based on the cloning of projected artefacts, then the genetic production of life can be seen as a “biological turn” in the history of industrialization, enabling the serial production of living things. In this context, bio-art can be regarded as a non-utilitarian element of a dispositive that enables the *industrialised production of life*.
The question, however, that persists at the background of contemporary microbiological discourse concerns the status of human life in the wake of the microbiological revolution. In his *Genesis*, Eduardo Kac applies genetic engineering to deconstruct the biblical premise concerning the superiority of mankind in the slavatory order of Creation. Nonetheless, it is impossible to ignore the distinguishing factor, which lies in the fact that human life is the only life-form that positions itself at the interface of the dual matrix of life.
Within such a context, it comes as a surprise that jewellery art has hardly yet entered the exchange with genetic science and technology, despite its inherent anthropomorphism, expressed in the fact that it positions itself between the human body and the world at large to enhance the physical and spiritual being of the wearer. Since its archaic stages, jewellery has always shown the tendency to augment *life* with *life*, human life with the animal or plant lives surrounding it, as in the case of totemic

jewellery that consists mainly in constellations of claws and teeth arranged across the surface of the human body. In contemporary studio jewellery, this ancient tendency plays a marginal role, figuring in rare works like the road kill jewellery of Anne Loucks,[127] April Hale[128] or Lucy Jenkins;[129] or pieces by Helena Bierman, like *Death* (2004), a necklace of 1500 encapsulated dead insects, or *Hit the Road* (2008): brooches displaying the broken bodies and blood stains of insects that hit her car on a highway drive from Germany to Austria and the Czech Republic; or Eunmi Chun's brooches of compressed pigskin;[130] or Julia Deville's taxidermic works[131]—to name some of the contemporary works in this genre of jewellery art.

However, even though such works reflect on the problems of the co-existence between humans and animals in modern life, they scrape past the socio-cultural challenges posed by genetic science and fail to address its impact on human self-understanding since more than half a century.

38.

One exception is, however, the work of the Norwegian jewellery artist Reinhold Ziegler.[132] As with Joe Davis, Ziegler's initial focus was on the cosmic, as documented in his *Cosmic Debris* (2014), a series of pendants made of extra-terrestrial matter extracted mainly from stony meteorites, which evoke their cosmic origin while functioning as elements of jewellery. As I write elsewhere: "Seeing them on a wearer's body, the camera of the inner eye swings from their cosmic horizons to the anthropomorphic dimensions of their role as jewellery within the flash of an instant," revealing the "potential of jewellery as a cosmic emplacement of its human wearers."[133] In later series like *Origin* (2016), Ziegler's pieces "evoke alternately the enormity of cosmic space and the Eons of the History of Life within their anthropomorphic dimensions."[134] In other, more recent works, Ziegler presents as pendants the following: a rough piece of carbonaceous meteorite (*Organic* meteorite, 2017) containing amino acids; a Spinosaurus tooth (*From the Mesozoic King*, 2017) to be suspended at the height of the solar plexus; a fragment of a Saltosaurus egg-shell (*Wheel of Life*, 2017); the fossilized remains of a Trilobite (*From the Cambrian Explosion*, 2017), the three-lobed marine invertebrate from the great Cambrian period, when life on earth suddenly exploded and diversified.[135]

39.

The only instance known to me in contemporary jewellery art of a direct response to developments in genetic science and technology is the recent work of Johanna Zellmer, who lives and works in Dunedin (Dunedin School of Art, Dunedin, New Zealand). For many years, Zellmer has been producing works that comment on the idea of nationhood and the politics of regulation of national borders. In the course of her reflections on contemporary politics, Zellmer often uses the technique of cutting up coins, which she depicts as a "cutting up of National Socialism."[136] One of her most prominent works, titled *Forged* (2015), involves the passport as a document of personal data of citizens, along with coins and their emblematic trappings, representing wealth and state power. In this project, Zellmer emptied out old passports of their data content to replace these by documentations of personal interviews with the passport holders. At a later stage, the passport numbers were perforated into flattened out emblems of coins, which were then attached to the plastic tubing of hearing aids and thus transformed into earrings. With the incidence of light, the perforated passport number, symbolising the data skimmed off the surface of the individual wearer and transferred into the archival entrails of the State, was projected like a neon ad onto the neck and thus symbolically returned to the surface of the wearer.

Zellmer's latest work, *ACCess mATTers: Trio* (2017),[137] are devoted to the advances in the technology of genome counting, which includes the possibility of sequencing *all* individual members of entire populations. Such technologies not only enable a radical improvement of state-controlled public health, but also the less pleasant practices of tracing ancestry/ethnicity and of identifying individuals, with major implications for the inclusion or exclusion of migrants in capitalist societies. It is thus obvious that the technology of genome counting has the potential for significantly augmenting the data power of the state.

In the context of *ACCess mATTers: Trio*, Zellmer hammered and flattened out Euro Zone coins to the scale and approximate shape of ID access cards and embossed variations of the aphorism *Money divides—Gifts connect* on their surface in DNA code. The flattened out, quasi-rectangular pieces of commemorative Sterling silver, which look like hybrids of credit cards and military dog tags, are slipped into ID card holders. For the verso of the metal card, also to be slipped into the cardholder, Zellmer uses discarded flow cells donated to her by her scientific collaborator, Aaron Jeffs of the Genomics Facility of the University of Otago (New Zealand). Flow cells are single-use items of precision engineering made from glass and plastic, essential to DNA sequencing machines. Digital images of the flow cell surface are converted to human-readable sequence data files, and the flow cell is discarded.

In the finished stage of *ACCess mATTers: Trio*, one can see on the reverse side of the access ID cards a flow cell showing a pair of eyes, cut out from the photographs in donated old passports. The card along in the holder is attached to a red lanyard ribbon with the emblem of the European Union.

To sum up the essentials: Zellmer's access ID card is made of silver coins of the Euro Zone and bears the DNA-coded aphoristic shorthand of a critique of capitalism. The flattened coin lies back to back within the same ID card holder with a flow cell that has been instrumental for the genetic sequencing of an individual and is now discarded. The flow cell is provided with the image of a pair of eyes.

Thus, the access ID card can in a sense be worn like a chip of a hybrid discourse. On the one hand there are the coins and the flow cells: material elements of capitalist societies and contemporary identity discourses. However, these elements are *firstly* transformed into the ironic form of an access card: ironic in the context of contemporary societies, where not much is accessible to the majorities which rarely comes to the fore except at election time. *Secondly*, they are embossed with an aphorism in the DNA code and a pair of eyes as symbolic elements of an alternative, critical discourse that is superimposed on the original materials and forms, evoking the necessity of critique and incarnating the impossibility of ignoring critique.

Thus, Zellmer's pieces seem to mark a rudimentary stage of a jewellery form capable of articulating genetic technology and its impact on modern living. It can only be hoped that jewellery art, which is unique among the arts due to its inherent association with the human body, finds its entry into the kind of critical discourse that has been practiced by bio-art since almost four decades. For if in painting and sculpture a thought process incorporated into the work is absorbed by the eyes, in jewellery art, the reflection embodied by a piece is in a sense absorbed by the entire body through the act of wearing it.

1. François Jacob, *La souris, la mouche et l'homme* (Paris: Éditions Odile Jacob, 1997) 174. All citations from German and French, in which the source of translation is not specified, I have rendered into English.
2. This is what François Jacob depicts as the "logic of the living," See François Jacob, *La logique du vivant. Une histoire de l'hérédité* (Paris: Gallimard, 1971); English version, François Jacob, The Logic of Living Systems. A History of Heredity (London: Allen Lane, 1973). In the title of the American publication—The Logic of Life —, the term "life" is reified, contrary to Jacob's essential insight.
3. See Michel Foucault, "Technologies of the Self" in Luther Martin, Huck Gutman, Patrick Hutton (eds.), Technologies of the Self. *A Seminar with Michel Foucault* (Amherst: The University of Massachussetts Press, 1988). See also Foucault's last two books: Michel Foucault, *The Use of Pleasure*. Volume 2 of *The History of Sexuality* (New York: Vintage Books, 1985) and *The Care of the Self*. Volume 3 of *The History of Sexuality* (New York: Pantheon Books, 1986).
4. Jacob: 1971.
5. See George Canguilhem, "Logique du vivant et histoire de la biologie" in Sciences 71:1971, 25.
6. This refers to questions formulated three pages earlier: "… most readers would search for the ancient question in Jacob's work: What is life?, or in the Kantian form: What can I know? What may I hope? or in Gauguin's manner: Where do we come from? Who are we? Where are we going to?" *Ibid*., 22.
7. Ibid., 25.
8. Charles Snow, *The Two Cultures and the Scientific Revolution: The Rede Lecture 1959* (Cambridge: Cambridge University Press, 1959). Snow's Rede Lecture was based on an article published by him three years earlier.
9. Snow:1959, 12.
10. *Ibid*. 10.
11. *Ibid*. 21.
12. "Compare George Orwell's 1984, which is the strongest possible wish that the future should not exist, with J. D. Bernal's *World Without War*." Ibid., 49: Note 6.
13. See for instance the special issue of *Technology in Society* on the two-cultures-debate in contemporary bioethical discourse. Joseph J. Fins and Inmaculada de Melo-Martín (eds), "Perspectives on C.P. Snow's *The Two Cultures*, Fifty Years later," *Technology in Society*, 32:1, January 2010, 1-64.
14. Frank R. Leavis, T*wo Cultures? The Significance of C. P. Snow: With an Essay on Sir Charles Snow's Rede Lecture by Michael Yudkin* (London: Chatto & Windus, 1962).
15. *Ibid*. 30.
16. See the introduction to Andrew Ross (ed.), *Science Wars* (Durham etc.: Duke University Press, 1996).
17. Norman Levitt and Paul Gross, *Higher Superstition: The Academic Left and its Quarrels with Science* (Baltimore etc.: Johns Hopkins University Press, 1994).
18. *Ibid*., 1.
19. Alan Sokal, "Transgressing the Boundaries: Toward a Transformative Hermeneutics of Quantum Gravity" in *Social Text*, 14:1996, 217-52.
20. See Alan Sokal, "A Physicist's Experiments with Cultural Studies," *Lingua Franca*, May/June, 1996.
21. This is the thrust of Derrida's statement in *Le Monde*, in which he compares Sokal's "censorial" project to a hunt with "badly trained" horsemen having occasional trouble in identifying the prey. Jacques Derrida, "Sokal et Bricmont ne sont pas sérieux" in *Le Monde*, 20 November 1997; English version, Jacques Derrida, "Sokal and Bricmont Aren't Serious" in *Paper Machine* (Stanford, California: Stanford Univ. Press, 2005) 70-2. It is not surprising that Foucault was excluded from Sokal and Bricmont's blacklist of "postmodernists," although he had published profusely on biology and medicine. See Michel Foucault, *Naissance de la clinique. Une archéologie du regard medical* (Paris: Presses Univ. de France, 1963); *Les Mots et les choses. Une archéologie des sciences humaines* (Paris: Gallimard, 1966) (henceforth: MC); and numerous articles compiled in *Dits et écrits*. 1954-1988 (Paris: Gallimard, 1966) 4 volumes, 1994 (henceforth: DE). The obvious reason is that Foucault's work cannot be caricatured without intense prior study: not only due to the complexity of his approach, but also the wide spectrum of topics and styles in his oeuvre.
22. In Richard Dawkins, *A Devil's Chaplain: Reflections on Hope, Lies, Science, and Love* (Boston: Houghton Mifflin 2003) 48-53
23. First shown in August 2008 by British Television Channel 4. Written and presented by Richard Dawkins. Produced by Russel Barnes and Dan Hillmann.
24. See John Brockman, *The Third Culture* (New York: Touchstone, 1995).
25. Edward Wilson, *The Meaning of Human Existence* (New York: Liveright, 2014).
26. See the chapter "The New Enlightenment" in *ibid*.
27. See Foucault:1966, MC.
28. See Hans-Jörg Rheinberger, *Experiment. Differenz. Schrift. Zur Geschichte epistemischer Dinge* (Marburg an der Lahn: Basilisken-Presse, 1992) [henceforth: EDS]. I will return to Rheinberger and his ground breaking work towards the end of this essay.
29. Michel Foucault, "L'éthique du souci de soi comme pratique de la liberté" in Foucault:1966, DE, IV:356, 725.
30. These lectures were first published in 1974 in Portuguese and much later, posthumously, in French. See Michel Foucault, *La verité et les formes juridiques* (Paris: Gallimard, 1994).
31. Foucault terms these objects *empiricities* in view of their epistemological depth and opacity. See Chapter 8 in Foucault:1966:MC.

32. See Gaston Bachelard, *La rationalisme appliqué* (Paris: Presses Universitaires de France, 1949); *Essai sur la connaissance approchée* (Paris: Vrin, 1987); La *formationde l'esprit scientifique. Contributions à une psychanalise de la connaisance* (Paris: Vrin, 1996).
33. See Georges Canguilhem, *Idéologie et rationalité dans l'histoire des sciences de la vie. Nouvelles études d'histoire et de philosophie des sciences* (Paris: Vrin, 1981); *La connaisance de la vie* (Paris: Vrin, 2009); *On the Normal and the Pathological* (Dordrecht etc.: Reidel, 1978).
34. Ludwik Fleck (1896–1961) was a Polish immunologist and microbiologist, who turned early in his career to the problems of an epistemological history of science. See Ludwik Fleck, *Entstehung und Entwicklung einer wissenschaftlichen Tatsache. Einführung in die Lehre vom Denkstil und Denkkollektiv* (Basel: Benno Schabe & Co., 1935) (henceforth: EWT]; English translation: *Genesis and Development of a Scientific Fact* (Chicago: University of Chicago Press, 1979).
35. François Jacob (1920–2013), a prominent molecular biologist who received the Nobel Prize for medicine with Jacques Monod and André Lwoff in 1965 for his work on the transference of genetic information and the process of gene expression in bacteria and viruses, published, in 1970, his "archaeological" history of the life sciences (Jacob, LV). The book was acclaimed by Foucault as "the most remarkable history of biology ever written." Michel Foucault, "Croître et multiplier (sur François Jacob)" (1980), no. 81, Foucault:1966, DE II, 99.
36. See Rheinberger:1992, EDS; *Experimentalsysteme und epistemische Dinge. Eine Geschichte der Proteinsynthese im Reagenzglas*, stw 1806 (Frankfurt/M.: Suhrkamp Taschenbuch Wissenschaft, 2006); *Epistemologie des Konkreten. Studien zur Geschichte der modernen Biologie*, stw 1771 (Frankfurt/M.: Suhrkamp Taschenbuch Wissenschaft, 2006).
37. See Michel Foucault, *Naissance de la clinique. Une archéologie du regard médical* (Paris: Presses Univ. de France, 1963).
38. See Fleck:1935, EWT, "Wie der heutige Syphilisbegriff entstand," Chapter 1, 7–27.
39. *Ibid*., 28.
40. Erwin Schrödinger, *What is Life? With Mind and Matter & Autobiographical Sketches* (Cambridge: Cambridge University Press, 1967) [henceforth: WL].
41. James D. Watson, *The Annotated and Illustrated Double Helix*, ed. by Alexander Gann & Jan Witkowski, (New York etc.: Simon & Schuster, 1968) 7.
42. *Ibid*. I am not suggesting that *influence* is the only or even a decisive factor in the history of knowledge. As Georges Canguilhem observes: "Convergence… is better than influence, for influence can only take place on the condition of a convergence that could do without influence." See "Die Logik des Lebenden und die Geschichte der Biologie" in Georges Canguilhem, *Wissenschaft, Technik, Leben. Beiträge zur historischen Epistemologie*, (Berlin: Merve, 2006) [henceforth: WTL], 90
43. Schrödinger:1967, WL, 5.
44. *Ibid*.
45. *Ibid*.
46. Later on in the lecture, Schrödinger will also borrow the category of *negative entropy* or *negentropy* from Ludwig Boltzmann, in order to explain how "living matter evades decay to equilibrium" [*ibid*., 69], understood as the highest possible state of entropy. This is done through eating, drinking, breathing, but not in the sense of an exchange of matter or energy between an organism and its environment, as envisioned in the German term *Stoffwechsel*. For why should one atom of nitrogen, oxygen etc. be any better than another? Why should it be necessary to exchange one calorie against another, which is just as good? Instead, an organism avoids death by *feeding on negative entropy*. It feeds on the order surrounding it and generates entropy in the process, increasing thereby the disorder in its environment. (*Ibid*., 70-71.)
47. *Ibid*., 8.
48. *Ibid*., 7-8.
49. *Ibid*., 14.
50. *Ibid*., 9.
51. *Ibid*., 10.
52. *Ibid*., 9.
53. See "Mind and Matter" in Schrödinger:1967, WL, 93-164.
54. Emphasis by P. M., *ibid*., 93.
55. See footnote 28.
56. *Ibid*., 9.
57. The idea of the perspective is of central importance not only in Nietzschean thought from its earliest beginnings till the final fragments, but also in the reflections of early twentieth century physics, as exemplified in the concept of *complementarity*, introduced and developed by Niels Bohr during the two decades between 1927 and 1949.
58. The term *artefact* can only be used in this general sense, provided (1) it is freed of all utilitarian reduction and (2) seen as emerging from the interactions between the material and immaterial elements associated with scientific activities. Thus the *truth* that emerges as an artefact and outcome of *truth games* is neither a commodity with its characteristic promise of utility to the subject of knowledge, nor an expression of the agency of the subject. It is instead to be seen as the outcome of the material and discursive forces at play in epistemic practices.
59. See the further below.
60. Friedrich Nietzsche, *Die Geburt der Tragödie, "Versuch einer Selbstkritik"* in *Sämtliche Werke. Kritische Studienausgabe*, ed. Giorgio Colli and Mazzino Montinari (Berlin, New York: dtv, de Gruyter, 1967–1977) [henceforth: KSA)]. Vol. 1, 14.

61. See "Chronik zu Nietzsches Leben" in Nietzsche:1967-77, KSA, vol. 15, 158-69.
62. "Ueber Wahrheit und Lüge im aussermoralischen Sinne" (1873) in Nietzsche:1967-77, KSA, vol. 1, 875–90.
63. *Ibid*., 880-1.
64. *Ibid*., 881.
65. Thus Nietzsche regards physics as a practice of interpreting and constructing the world, but by no means a practice of explaining it. See *Jenseits von gut und Böse*, no. 14, Nietzsche:1967-77, KSA, vol. 5, 28. In *The Gay Science*, he declares that we have to be physicists in order to be Creators. See *Die fröhliche Wissenschaft* no. 334, Nietzsche:1967-77, KSA, vol. 3, 563-561. Generally speaking, science is characterised in Nietzsche's late work as a transformation of nature into concepts for the purpose of mastering nature. See Friedrich Nietzsche, *Der Wille zur Macht. Versuch einer Umwertung aller Werte*, no. 610, Stuttgart: Kröner, 1952, 416.
66. See Foucault's late works, among others. Michel Foucault, *Histoire de la sexualité III. Le souci de soi* (Paris: Gallimard, 1984). See also Michel Foucault, "Technologies of the Self" in *Technologies of the Self. A Seminar with Michel Foucault*, ed. by Luther Martin, Huck Gutman and Patrick Hutton (Amherst: University of Massachusetts Press, 1988).
67. In this sense, the *fake news* discourse that flared up during the American elections in 2016 might in fact be merely the tip of an onto-epistemological iceberg that has been constituting itself since the end of the eighteenth century.
68. See Foucault:1966, MC, sections 8.V. ("Le langage devenu objet") and 9.I. ("Le retour du langange"), 307-18. In the following I will render the basic stages of the major transformation of discourse at the threshold of our modernity, that Foucault describes in these few pages.
69. *Ibid*., 318.
70. See George and Muriel Beadle, *The Language of Life. An Introduction to the Science of Genetics* (New York: Doubleday, 1966); Crick, Francis: *Of Molecules and Men* (New York: Prometheus Books, 1967); Max Delbrück, *Mind from Matter? An Essay on Evolutionary Epistemology* (Palo Alto: Blackwell, 1986).
71. Jacques Monod, *Le hasard et la nécéssité* (Paris: Seul, 1970).
72. See footnotes 2 and 38.
73. Jacob:1997, LV, 18-19.
74. *Ibid*., 19.
75. *Ibid*., 22.
76. See "The True and the Beautiful" in François Jacob, *Die Maus, die Fliege und der Mensch. Über die modern Genforschung* (Berlin: Berlin Verlag, 1998) 164.
77. *Ibid*., 167.
78. *Ibid*., 171.
79. *Ibid*., 172.
80. Jacob:1997, LV, 24.
81. See last section.
82. See Foucault, Michel, "Croître et multiplier (sur Jacob)" in *Le Monde*, no. 8037, 15-16 November 1970. See also Foucault:1966, DE II, 1970, no. 81, 99. One year later, in 1971, Foucault says in an interview in Brazil: "Everything that he [Jacob, P. M.] says on the history of biology in the 17th, 18th and 19th centuries, is in agreement with my statements on this topic concerning the dates and the basic principles. And yet he has not taken these things from my book [*Le mots et le choses*, P. M.], for he wrote his book before he had the opportunity to read mine." Foucault, "Entretien avec Michel Foucault" in Foucault:1966, DE II, 1971, no. 85, 162. In a similar vein, Georges Canguilhem draws attention to the similarities in style and reference between François Jacob's archaeology of biology and Michel Foucault's history of the clinic and archaelogy of the human sciences, distinguishing thereby between the categories of *convergence and influence*. Influence cannot take place without convergence, but convergence does not require influence. See Canguilhem:2006, WTL, 90. See also footnote 45.
83. See Rheinberger, *Experimentalsysteme und epistemische Dinge. Eine Geschichte der Proteinsynthese im Reagenzglas*, (Frankfurt/M.: Suhrkamp Taschenbuch Wissenschaft, 2006). Hereafter referred to as EE.
84. *Ibid*., 15-16. See footnotes 31 and 39.
85. Rheinberger:1992, EDS, 25.
86. Rheinberger:2006, EE, 8-9.
87. Rheinberger:1992, EDS, 69, footnote 10.
88. Rheinberger characterises the truth game at the heart of the experimental system by using Derrida's conception of *différance*. See for instance Rheinberger:2006, EE, 11.
89. *Ibid*., 70.
90. Jacob:1997, LV, 24. See footnote 85 above.
91. See Rheinberger:2006, EE, 29: "The technical conditions not only determine the range of possibilities of epistemic things, but also the form of their possible representation. Conversely, sufficiently stabilised epistemic things can be inserted as technical elements into an existing experimental arrangement." See also Rheinberger, *Epistemologie des Konkreten. Studien zur Geschichte der modernen Biologie*, stw 1771 (Frankfurt/M.: Suhrkamp Taschenbuch Wissenschaft, 2006), 315. Hereafter referred to as EK.
92. George Kubler, *The Shape of Time. Remarks on the History of Time* (New Haven etc.: Yale Univ. Press, 1962) 43. Quoted in Rheinberger:2006, EE 10.
93. See "Interfaces", chapter 11 in Rheinberger:2006, EK, 313-35.
94. *Ibid*., 313-14.
95. *Ibid*., 315.
96. See *ibid*., 315-35.
97. *Ibid*., 335.

98. See Suzanne Anker and Dorothy Nelkin, *The Molecular Gaze. Art in the Genetic Age* (Cold Spring Harbor, New York: Cold Spring Harbor Laboratory Press, 2004) [henceforth: MG]. See also Harmke Kamminga and Soraya de Chadarevian, *Representations of the Double Helix* (Wellcome Unit for the History of Medicine, Cambridge: Whipple Museum of History and Science, 1995), [henceforth: RDH].
99. See Anker:2004, MG, 23. See also https://artist-dali.tumblr.com/post/161082339601/butterfly-landscape-the-great-masturbator-in-a.
100. Kamminga:1995, RDH, 31.
101. Suzanne Anker and Dorothea Nelkin have termed them the "iconic molecules." See Anker:2004, MG, 28. See also Amy Harmon, "A revolution at 50; twist and shout! The double helix replicates itself in popular culture" in The New York Times, 25 February 2003, http://www.nytimes.com/2003/02/25/science/revolution-50-twist-shout-double-helix-replicates-itself-popular-culture.html. See also "The art of DNA. Back to bases" in *The Economist*, 24 April 2003 [henceforth: BB], http://www.economist.com/node/1730781.
102. See http://www.nature.com/nrg/journal/v3/n12/fig_tab/nrg950_F1.html.
103. https://www.facebook.com/media/set/?set=a.1458917397525162.1073741843.124047477678834&type=3.
104. Anker:2004 MG, 27-28.
105. 105 See the website of the Helen Storey Foundation, http://www.helenstoreyfoundation.org/pro2.htm.
106. See BB, http://www.economist.com/node/1730781.
107. See http://www.kevinclarke.com/portraits/invisible-body/.
108. See http://www.kevinclarke.com/portraits/works/.
109. L.J. McBride, etc., "Automated DNA Sequencing Methods Involving Polymerase Chain Reaction" in *The Journal of Clinical Chemistry*, Vol. 35, No. 11, 1989, see http://kevinclarke.com/pdf/works_dna.pdf .
110. See footnote 107 above.
111. See footnote 97 above.
112. See footnote 107 above.
113. http://marcquinn.com/exhibitions/solo-exhibitions/a-genomic-portrait-sir-john-sulston-by-marc-quinn.
114. Using bacteria in painting is not as new as it might appear at first sight, if one considers Alexander Fleming's figurative "germ paintings" on paper, representing things like stick figures and houses. Fleming in fact stumbled upon penicillin through his bacterial painting on discovering that fungi killed bacteria in paper artwork. See Ali Yetisen, etc., "Bioart" in *Trends in Biotechnology*, Vol. 33, Issue 12, 2015 [henceforth: BA], 724-34 http://www.cell.com/trends/biotechnology/fulltext/S0167-7799(15)00205-X.
115. See the website http://www.tca.uwa.edu.au.
116. Yetisen:2015, BA.
117. See "Leather grown using biotechnology is about to hit the catwalk. Genetic engineering is used to make leather without animals" in *The Economist*, Print Edition Science and Technology, 26 August 2017, https://www.economist.com/news/science-and-technology/21727059-genetic-engineering-used-make-leather-without-animals-leather-grown-using.
118. Ginsberg, Alexandra Daisy et al., *Synthetic Aesthetics. Investigating Synthetic Biology's Designs on Nature* (Cambridge, Mass., London: The MIT Press, 2014) 69.
119. See http://bak.spc.org/hayvend/artists/box.rand/104.html.
120. Quoted in Ingeborg Reichele, *Art in the Age of Technoscience* (Wien, New York: Springer-Verlag, 2009) 99.
121. See *ibid*.
122. See Steve Nadis, "'Genetic art' builds cryptic bridge between two cultures" in *Nature*, 378:16. November 1995, 229.
123. See *ibid*.
124. See Kac's Website, http://www.ekac.org/transgenicindex.html.
125. *Ibid*.
126. In adopting the term, I am appropriating selectively the etymology of the word *fiction*, which goes back to the Latin *fictio* and the Proto-Indo-European *dheigh*, meaning not only a ruse, a devising, a feigning, but also an invention, a fashioning, a *fabrication*. See http://www.etymonline.com/word/fiction.
127. https://www.treehugger.com/sustainable-fashion/lady-locks-roadkill-animal-jewelry.html.
128. https://makezine.com/2009/04/17/roadkill_jewelry_the_art_of_ap/.
129. http://www.ifitshipitshere.com/real-road-kill-bracelets-by-metalsmith-jeweler-and-taxidermist-lucy-jenkins/.
130. http://cargocollective.com/hegehenriksen/Eun-Mi-Chun.
131. http://www.juliadeville.com/bespoke/taxidermy/.
132. See Pravu Mazumdar, "Distant Horizons. Jewellery and Transgression in Rheinhold Ziegler's Artistic Universe," in Klimt02, 24 April 2017. https://klimt02.net/forum/articles/distant-horizons-jewellery-and-transgression-reinhold-ziegler-artistic-universe-pravu-mazumdar.
133. *Ibid*.
134. *Ibid*.
135. See *Ibid*.
136. See Johanna Zellmer, *Forged* (Cologne & New York: Darlington Publications, 2015) 22.
137. The project was realized in the context of the Arts and Genetics Exhibition of the Dunedin School of Art and the University of Otago, opened in summer 2017 in the Otago Museum in Dunedin. See https://www.eventfinda.co.nz/2017/art-and-genetics-exhibition/dunedin.