## Biotech: Life by Contagion


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### Introduction

IN 1994, the merging of biotech corporations Merck & Co. and Washington University gave birth to Genbank, which launched, for the first time, clones on the market. Since then, clones have become part of the commercial world of genetic engineering, DNA maps and, recently, pharmacogenomics.[1] In particular, the reproduction of life – from cells to embryos – without sexual mating has entered the biotech market. A new (but also ancient) mode of sex, bacterial sex (the non-copulatory transmission of genetic material) is now the motor of this commercial engineering of life, which moves beyond species barriers. Bacterial sex is the transmission of information across phyla and lineages. Bacteria (non-nucleated bounded cells) continuously modify their genetic make-up whilst infecting new cells. This sex by contagion has become fundamental to biotech's task of redesigning life.

The impact of biotech has mainly been discussed as a new frontier in the history of evolution. It could be argued that biotech's celebration of the end of organic nature reinforces the ontological belief in the gradual progression of life towards higher levels of complexity: a sort of optimizing process leading to ever increasing fitness.[2] In a sense, the manipulation of cells, genes and ultimate life appears to dwell in the Darwinian and neo-Darwinian logic of evolution: the adaptation of the fittest units of life (from organisms to genes) regulated by a supervising natural selection. The individual organism or gene selected will leave better fitted offspring than the organism or gene whose variations have not been selected. It is important to acknowledge here that this logic of evolution has not passed through the hands of Biotech's advocates without alteration.[3] Indeed, in the history of evolutionary theory there have been remarkable changes since Darwin. In

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particular, evolutionary geneticists have explained that variations are not exclusively the outcome of adaptation by natural selection. Richard Lewontin points out that in the past 60 years there has been an enormous effort in evolutionary theory to explain the emergence of variations beyond passive adaptation and the tree model of gradual change (Lewontin, 2000: 58). From the study of the acquisition of traits between totally unrelated genes to an emphasis on parallel lines of evolution and rapid changes proposed by the theory of 'punctuated equilibrium', models of evolution have undergone serious revisions (2000: 59–60). In this context, it may be also important to point out that, according to Lewontin, Darwin already proposed an alternative evolutionary model that he defines as 'variational evolution' (2000: 54). For Lewontin, Darwin's evolution was not transformational – i.e. it was not based on a homogeneous change of all the elements in a system. Natural selection was instead a sorting process among variants that produced the fit of organisms to the environment. As the survival and reproduction of different variants is directed by the conditions of the external world, so the outcome of selective pressures cannot but correspond to that world and its demands (2000: 56). However, Lewontin maintains that genetic technologies – at the basis of the Human Genome Project and cloning – rely on the 19th century's version of 'vulgar Darwinism' (2000: 56). The latter fails to understand that any cause of differential survival and reproduction entails some process of evolution, ultimately variation, and just not adaptive evolution of the organism or gene induced by an external force. Yet, as I will discuss later, the Darwinian selective model of germlife does not explain parallel dynamics of differentiation in evolution, in which selection does not eliminate but catalyzes indeterminate capacities responding to its pressures. This condition of such an immanent process of selection directly indicates a sea of microvariations: a mutual internal and external modification able to spread across lineages and phyla. In particular, as I will explain later, biotech's reengineering of life challenges a model of evolution resting on increasing genetic fitness and repressing selection. On the other hand, however, biotech's advocates also bring the logic of optimal fitness to a new extreme. As Eugene Thacker explains: '[B]iotech is specifically interested in the ways that the material components and biological organization of the body can in effect be reengineered, or redesigned' (Thacker, 2004: 10). For example, with human cloning, the selection of the fittest traits would bypass not only the reproductive functions of the father and mother, but also the function of natural selection itself. Biotech's market promises to redesign life before life, beyond all Oedipal descents, announcing a world of clones without copy: the triumph of pre-programmed identities over unexpected divergences.[4] In this case, biotech substitutes natural selection by designing the survival of the fittest from scratch.[5] It could then be argued that the evolutionary logic of biotech amounts to an old trick of naturalizing progress whilst enslaving nature to culture, biology to technology, and matter to information. From genetic engineering to artificial life, biotech revolution has indeed mainly been seen as leading to a further

disappearance of matter: the liberation of life from all biological and mortal constraints.[6]

Whilst the critical debate about biotech has concentrated on the dematerialization of life, this article suggests that biotech challenges the evolutionary models that sustain the ontology of the material and the immaterial. In particular, this article will argue against the evolutionary models of Darwinism, and to some extent neo-Darwinism, relying on a notion of inert matter.[7] The article does not dismiss models of evolution, but rather highlights non-determinist processes as a starting point to understanding the impact of biotech on life.[8] This article points out that the contemporary debate on biotech and the new biopolitics of life fails to challenge determinism in nature as it rests upon the biotic ontology of life.[9] It thus risks reiterating rather than questioning an ontology that equates nature with organic matter, and matter with already determinate forms and functions. This article questions the analogy between evolution and life, matter and the organism or units of information, biotech and complexification. It intervenes against the logic of resemblance based on the privilege of forms over processes. Life corresponds neither to pre-ordained design nor to self-replicating organization. Rather, life cannot be thought without a mutant matter.

This article suggests that biotech's re-engineering of life subtracts nature from models of evolution based on the primacy of organic unity and individuated parts, which reduces processes of variation to already determinate states. In particular, we shall see that Darwinism and neo-Darwinism are embedded in a model of evolution based on the increasing optimization of already actualized variations preserved through the functions of natural selection and sexual filiation. However, whereas Darwinism still relies on filiative reproduction as a way to preserve variation through the inheritance of the fittest traits, neo-Darwinism explains the roles of fitness through the self-replication of genes and their capacities to preserve variation beyond sexual reproduction.[10] Yet it could be argued that these models share a common ground: they both sustain a purposeful reproduction of life, the optimization of the fittest.[11] This article states that evolution cannot occur without indetermination, or unexpected change in the ecological dynamics of life. As is later discussed, in *Creative Evolution* (1983), Henri Bergson argues against Darwinism as it fails to account for the creative response of a collective individual to selective pressures. We shall than see how Bergson's evolution pushes life towards the virtual and exposes matter to aimless modifications.

Recently, molecular scientist Lynn Margulis has re-elaborated Konstantin S. Mereschovsky's (1855–1921) notion of 'symbiogenesis'.[12] Like Mereschovsky, Margulis's endosymbiotic theory or SET (Serial Endosymbiotic Theory) rejects the Darwinian theory of natural and sex selection as sources of fitness and innovation, and instead argues that the appearance of new organisms in evolution stems from prolonged symbiotic associations (Margulis, 1981). Endosymbiosis challenges the belief that

*Homo sapiens* – man, the wise – stands at the pinnacle of evolution. For endosymbiosis, the human species partakes of the vaster molecular ecology of lowest cellular bodies: bacteria.

Since the 1970s, molecular biology has brought into question Linneaus's classification of the species between plant and animal kingdoms, substituting it with a more fundamental difference in life between eukaryotes (cells with membrane-bounded nuclei composing plants, animals and humans) and prokaryotes (cells without membrane-bounded nuclei), also called monera or bacteria.[13] Bacteria, single and multicellular bodies, small in size but highly influential in our environments, were, according to Margulis, at the very inception of life nearly four billion years ago. The emergence of cells with nuclei (eukaryotes) two billion years later is explained in terms of symbiogenesis, when anaerobic bacteria were poisoned by the very oxygen some of them released into the atmosphere as waste (Margulis and Sagan, 1986b: 17). From the standpoint of bacteria, plants, animals and humans are recent organizations of life on a larger microbial phylum encompassing organic and inorganic matter.[14] Endosymbiosis, as we shall see, opens up evolution to the virtual: indeterminate mutations emerging in the gap of contagion between the host and the guest. Contagious transmission rather than filiative heredity. Molecular differentiation rather than differences of form and function. Mutual engineering rather than addition of parts. Endosymbiosis grasps the dynamics of a mutant matter without ante-posing forms to life. For endosymbiosis, life is not given but is under continual construction in the contagious making of matter.

From this standpoint we may ask: does it follow then that biotech is natural?

It may be important to state that biotech is not to be considered as the next step in the complexification of simple matter as if it would lead us to a higher order of nature. Biotech cannot be thought of in isolation from a symbiotic nature. Yet beware: symbiosis does not correspond to the boundless capacity of life to triumph over the intentions of Man. If so, we would be in danger of re-celebrating the metaphysics of the given as a transcendent imperative of life. On the contrary, symbiotic nature has to be seriously considered in its process of aimless construction and singular modifications. Aimlessness precludes the erection of a predeterminate and ultimate position over a process of mutual making (the intensive relations between bodies, milieus and selective pressures) out of which new symbionts arise. Aimlessness, however, is neither a question of relativism nor determination. Rather, it forces us to start in between: in the virtual movement of actualization, waiting for potential modifications to actualize in an unpredictable fashion whilst plunging in a process of double mutation.

It would be misleading, therefore, to consider such aimless nature as the new regime of equivalence between differences. To the contrary, a process without finality, far from eluding differences, exposes the microvariations that compose difference as a continual movement from the virtual to the actual and back again preceding and exceeding positions, states of

equilibrium, outcomes and absolute determinants.[15] Molecular life does not correspond to species and genes, sexual reproduction and passive adaptation, competition and survival of the fittest. As we shall see, for endosymbiosis, life is twinned with mutant matter, the parasiting contagion of bodies: schizogenesis rather than ontology. The problem of life at the core of the biotech market cannot be addressed without engaging with a non-determinist – or borrowing from Deleuze and Guattari, *machinic* – nature.

In the following sections, I will discuss the Darwinian, and to some extent neo-Darwinian, understanding of life based on the centrality of genetic reproduction and natural selection in evolution. I will argue against such evolutionary models by drawing on Bergson's notion of creative evolution and Margulis's theory of endosymbiosis. I will then suggest that biotech symbionts mark the re-emergence of indeterminate mutations in life.

## Evolution

It may be difficult to understand the novelty of endosymbiosis vis-à-vis biotechnology without explaining the Darwinian model of evolution first. This model introduced notions of movement, mutation and extinction in life that challenged the great chain of being, mirroring the celestial order of God on earth.[16] Each creature's position reflected a predeterminate embodiment of a universal essence, which was eternally reproduced from father to son. This classification of life according to general types, eternal and unchangeable essences, was questioned by the new focus on the relation between populations and territories, constituting a species. Darwinism suggested a notion of life based on dynamics of change, regulated not by an all-foreseeing God, but by natural selection: a blind force favouring the survival of one species over another. Species would change by preserving and transmitting variations across populations through sexual reproduction. This model of 'descent with modification' substituted the great chain of being with gradual change, explaining the metamorphosis of the species as responses to environmental pressures.[17]

Darwin's study of the relation between the individual and the environment did not seek general laws, but historical and accidental contingencies enabling variations in populations. According to Darwin, variations between species are the result of feedback relations between populations and territories regulated by selective pressures, which favour the best-adapted organisms under constrained conditions. In *The Origin of Species* (Darwin, 1993 [1809]), the action of natural selection upon organic adaptation explains evolution.[18] Herbert Spencer translated this function of adaptation with the notion of the 'survival of the fittest', according to which natural selection acts upon organisms competing in an environment of lack and scarcity – disorder – to preserve the best-adapted species. Every individual species is part of a genealogy of species that crossbreed and sexually reproduce. In particular, sexual reproduction lies beneath the genealogical tie between species. As Darwin states, '[T]he real affinities of all organic beings are due to inheritance or community of descent' (Darwin, 1993

[1809]: 634).[19] The genealogical tree maps the self-preservation of the species by adaptation and by sexually reproducing variations in a competitive environment. Unlike natural selection, sexual selection does not exterminate the ill-adapted but determines the system of inheritance of the species. Natural selection compels organisms and species to strive for stability whilst sexual mating guarantees branching philogeny (the preservation of the lineage).

Darwinism considers the internal capacity of the organism to survive in terms of adaptation and filiative inheritance. Mendel's atoms of heredity and Weismann's doctrine of the germplasm helped to formalize the organism's internal capacity to transmit best-adapted traits. Mendel's study of transmission across generations pointed out that traits were inherited in certain numerical ratios, according to the dominance and segregation of certain traits over others: each parent transmits only half of its hereditary factors (chromosomes X and Y) to each offspring, and finally, different offspring of the same parents receive different sets of hereditary factors. With Mendel, the genealogical reproduction of variation through sexual mating defines the complexification of the lineage in evolution.[20]

August Weismann more specifically hypothesized that life resides in germ cells (1882). Germinal life is bound to sexual reproduction not only because coupling ensures the transmission of life to the offspring, but also because sexual mating enables the rejuvenation of the species and ultimately of life itself. For Weismann, germinal life can only be transmitted internally from parents to offspring in total independence of environmental conditions. On the level of the cell, the separation of internal from external forces was defined as the 'Weismann's barrier'.[21] The germplasm (nucleic genes in membrane-bounded cells or eukaryotes) transmits life in total autonomy from the somaplasm (or cytoplasmic genes dwelling outside the nucleus of eukaryotes). With Weismann, the success of germinal transmission through sexual mating depends upon natural and sex selection, guaranteeing the variation and preservation of life across generations (evolution).

Nevertheless, forces of selection are unable to account for novelty in evolution as they are conceived as repressors and regulators of already actualized variations.[22] Henri Bergson argues against this notion of natural selection and explains that life's variations, far from deriving from linear transmission, are inseparable from an indeterminate potential of differentiation (Bergson, 1983). Such potential is irreducible to gradual accumulations, random mutations and blind selection insofar as these notions are embedded in the realm of possibility: already calculated outcomes. Thus, the transmission of variations across generations, even when open to random mutations selected under certain pressures, will always be re-conduced to the logic of the possible (i.e. determinations). For Bergson, on the contrary, indetermination in evolution defies the assumption that life moves from the homogenous to the heterogeneous, from simplicity to complexity. It is not a question of starting from a unit that then differentiates and complexifies.

Rather, it is a matter of laying out the heterogeneity of indeterminate differentiation moving towards determinate actualities. Novelty in evolution does not derive from actual forms of life adapting to the external stress of selection in order to preserve and ensure variations across generations. The movement of evolution can only be understood if compared to the movement of life defined by the division of a virtual multiplicity that weaves into innumerable tendencies.[23] While the law of natural selection reduces life potentials to an already realized possibility, creative evolution highlights pure potentials moving towards singular yet collective actualization.

As Bergson points out, Darwinism implies a sort of mechanism in nature, whereby natural selection preserves variations accumulating in the organism as they are simply added to one another (1983: 28–31, 169). It assigns the organism the task of passively reproducing life without participating in the movement of evolution. Hence, life remains enclosed in the mechanism of constant reproduction of already actualized forms, devoid of any real force of modification. The internal principle of transmission of life does not coincide with the passage between actualized fitted variations regulated by an external force. For Bergson, such a transmission involves heterogeneous actualizations of a virtual multiplicity: an arrest of energy-flows (*élan vital*), whose potential emerges from, yet surpasses, actualizations (1983: 104–5, 258). Thus, the transmission of life involves not a passage from actuals to actuals but the emergence of the virtual in all actualizations. Yet actualizations never resemble the potentials of life, as if they were points of arrival, a completion or exhaustion of the virtual. On the contrary, each actualization exposes emergent properties that are in asymmetrical relation with their field of emergence (virtual life or *élan vital*).[24]

Thus, an organism does not adapt to the external environment as if in an effort to strive, maintain balance and survive in a competitive manner simply by adding new traits to a given life. Rather, adaptation cannot be thought of without the emergence of unpredictable modifications, which lead to new internal responses to selective pressures. Thus, the organism responds to selective pressures by changing its field of action and inventing new internal regions, which resonate with the external environment.[25] These internal regions are not self-enclosed interiorities strictly distinguished by exteriorities. The internal power of a living organism, which expresses a power to differentiate and modify, needs to be thought of as an open envelope of the outside in which the inside is at the same time enveloped: a *metastable* or *co-causal communication*.

The action of selective pressures is not denied but confronted with a virtual action, which plunges the organism and the environment into an ecology of mutual modification.

For Bergson, germinal life is not the end result of selection acting on already actualized variations (1983: 27, 78–9). Geminal life above all entails virtual, and not possible, dynamics of evolution. Geminal life cannot be defined by closed systems insofar as these are not sufficient to explain unpredictability. On the contrary, the open-ended yet always singular

tendencies of life grasp the movement of evolution as a continuum through disassociation: duration (Bergson, 1983: 5, 9, 37, 161–2). Duration as the unquatifiable yet real passing of time defines the amodal link of the past and the future in an incomplete present. At the heart of duration lies intensive movement: a becoming of the past into a future that is unforseeable and irreversible. Each present actualization simultaneously falls back on its past and forward on its future as if it were an interzone of time subtracted from its quantitative spatialization. The past and the future are not distinguished by what no longer exists and what, on the other hand, will exist. Duration links the past with the future in an emerging present by injecting unpredictability in evolution. With Bergson's creative evolution, the time of inheritance no longer matches with the genealogical tree of transmission – gradual changes across generations. Evolution ceases to be equated with progressive development regulated by repressive selection. Rather than a succession of stages in which every future will constitute a present and every present will become a past, for Bergson, evolution proceeds by splitting tendencies of time devoid of pre-existing goals: novelties do not resemble the past and do not predetermine the future (1983: 9, 37).

## Bacterial Sex

> In the fast world of bacterial genetic switching, large organisms are cumbersome, overstuffed operators . . . People and other eukaryotes are like solids frozen in a specific genetic mold, whereas the mobile, interchanging suite of bacterial genes is akin to a liquid or gas. (Margulis and Sagan, 1986a: 89)

With Bergson's introduction of the virtual in evolution, dynamics of organization, mutation and transmission move beyond the centrality of closed systems, gradual accumulation, passive adaptation, individual species, exterminating selection and linear heredity. The elastic tension between *élan vital* and matter entails a disassociation of tendencies, a differential relation between virtual potentials and actual emergences, which bypasses the centrality of the human species in evolution based on sexual reproduction, the selected mode of transmission of life. For Bergson, the emergence of the human species, far from determining the accomplishment of a natural design, is a contingent chance linked to the indeterminate potentials of life (Bergson, 1983).

The subtraction of the human species from the pinnacle of life is at the core of Margulis's theory of endosymbiosis (1981). The microbiological distinction between eukaryotic and prokaryotic cells, or between cells with and without membrane-bounded nucleic DNA, has classically been explained in terms of a sudden mutation from a less to a more organized genetic transmission of life (Margulis, 1998: 24). Yet, according to Margulis, the emergence of nucleic cells not only has not substituted bacterial modes of transmission, but more importantly, it cannot be disentangled from the prokaryotic plane (1998: 43–4). The passage from bacteria to eukaryotic cells is not explained in terms of gradual variation but according to

prolonged symbiosis between distinct bacterial cells under certain pressures. Similarly, endosymbiosis contends that, far from eliminating the ill-fitted cell, selective pressures catalyzed the emergence of eukaryotes in a newly constituted atmosphere, which forced anaerobic bacteria to become hosts in breathing cells. In other words, eukaryotic cells – the constituent cells of all animals and plants – are not the result of random and gradual mutations: their newly constituted nucleic organization stems from the symbiotic parasitism of distinct bacterial cells – anaerobic and aerobic (Margulis, 1998: 37). This symbiosis occurred during the oxygen revolution, when oxygen, from being a waste product of hydrogen-frantic bacteria, became the very source of life for these anaerobic bacteria entering the bodies of their aerobic hosts (Margulis and Sagan, 1986b: 108–9).

For endosymbiosis, the line of descent with modification entails a vast plane of molecular relations that virtually link singular cellular bodies tending towards critical thresholds of modification under certain pressures. For example, the evolutionary response of those bacteria that became eukaryotic cells under the pressures of oxygen-polluted atmosphere highlights the symbiotic actualization of indeterminate potentials, which eventuates a new way of life through an unpredictable modification of matter. In other words, endosymbiosis defies the strict distinction between the individual and the environment, laying bare the molecular interdependence of distinct systems. From this standpoint, each cellular waste poisons the atmosphere, generating an environmental dis-equilibrium out of which a new cellular composition with a changed metabolism eventuates. From hydrogen to oxygen, the endosymbiotic explanation of life entails continual variation debunked of pre-ordained design, but also of gradual evolution and random mutations.[26]

Endosymbiosis points to the fact that we are still carrying ancient anaerobic and aerobic symbionts in our cells. This symbiotic inheritance enlivens our eukaryotic cells. Indeed, the latter are not just constituted of nucleic DNA (the so-called Master Molecule).[27] As Margulis observes, eukaryotes are composed of distinct yet parallel inheritable sets of genetic material, nucleic and non-nucleic.[28] Outside the nucleic membrane of animal cells, there are mitochondria organelles, dark membrane-bounded bodies deriving energy (adenine triphosphate: ATP) from oxygen. Mitochondria are the descendants of purple bacteria – aerobic bacteria – hijacked by anaerobic ones during the oxygen revolution (Margulis, 1998: 28–9). Indeed, mitochondria have retained many signs of their former status as independent bacteria. They have an independent genetic apparatus (DNA, messenger and transfer RNA and ribosomes) enclosed in their membranes. Mitochondrial DNA, like bacterial DNA, is not bound into chromosomes and is not covered with histone protein-like nucleic DNA (Sagan, 1992: 366–7). Most strikingly, mitochondria reproduce like bacteria, pinching and dividing in two at different times from each other and from the rest of the cell. Mitochondria, like bacteria, clone themselves. Thus, the transmission of genes through sexual reproduction does not only

concern nucleic material (i.e. chromosomes), but also a parallel, bacterial descendant set of inheritable cytoplasmic – mitochondrial – genes. The transmission of life across generations entails the duplication and reduction of chromosomal (or nucleic) DNA as well as the cloning of mitochondria from mother to offspring (Margulis and Sagan, 1986a: 69, 71, 87). For endosymbiosis, the Weismann's model of germinal life should be extended to the somatic transmission of mitochondria (Margulis and Sagan, 1995: 176).

Although the prokaryotic (or bacterial) and eukaryotic (or nucleic) worlds of cells are mapped alongside a symbiotic continuum in which one world is intertwined with the other through parasitism and contagion, there is a sea of difference between their modes of information transmission and reproduction. In eukaryotes, reproduction (i.e. the increase in the number of individuals) and sex (i.e. the transmission of genetic material) are inseparable. The eukaryotic model of transmission rests on sexual mating or reproduction – the exchange of nucleic or chromosomal material from the mother and the father – and the cloning of mitochondria in the egg's cytoplasm – i.e. through the mother (Margulis and Sagan, 1986a: 14–15, 21). For bacteria, sex is instead autonomous from reproduction. Reproduction in bacteria is asexual: they clone themselves, doubling their size, replicating their single strand of DNA, and then splitting one copy of the DNA in each of the new offspring cell. Bacteria also reproduce by budding: a small cell containing a complete set of genetic material generates itself on the parent, gradually growing to adult size until it breaks off. On the other hand, the so-called 'bacterial sex' can occur virtually at any time by a simple contact to send genes to the most immediate neighbour. Bacterial sex entails two modes of transmission: transduction, in which a fragment of the bacterium DNA can be taken up into the protein case and travel to other bacteria; and conjugation, in which DNA is transferred through a tiny tube forming between two cells as the donor passes a copy of its DNA to the recipient.[29] Whilst passing information, bacteria change their genetic make up to share, for example, immunity to drugs.[30] Indeed, all strains of bacteria can potentially share all bacterial genes. This suggests that bacteria work in packs of several kinds – networked colonies collectively responding to the environment they occupy.[31] They spread information at impressive speeds, sharing all kinds of metabolic innovations. Their life cycles are interwoven: the waste products of one kind become the food source of another. This field of microbial communication is unlocked from species, organs and generations, which are instead the determinant factors of eukaryotic cells. Not only do bacteria have no limits as to species barriers, but they also cut across phyla recombining the genetic material of distinct eukaryotic lineages.

Endosymbiosis shows that the transmission of life is not the exclusive secret of eukaryotic cells, and in particular of Weismann's nucleic germline inherited through sexual mating. The promiscuity of the microbial world is not the exception in the nucleic rule of life. On the contrary, bacterial

sex – transduction and conjugation – cuts across all levels of cellular organization, bypassing sexual reproduction and nucleic inheritance. Bacterial sex does not define simplicity as opposed to complexity, homogeneity as opposed to heterogeneity, inorganic as opposed to organic life. New symbiotic combinations are constantly tried out in the bacterial layers of matter. For bacteria, and for the parts of our cells that are most like bacteria, viral and inorganic DNA intrusions are routine. Far from confirming the neo-Darwinian model of the selfish gene and blind selection,[32] bacterial sex marks continual variation in evolution, where contagious matter is the mode of transmission of aimless life.

## Biotech Symbionts

By opening up the spectrum of mutations in evolution, endosymbiosis exposes an open field of transmission involving an *intensive*, rather than ultimately inert, matter. Crossbreeding and sexual reproduction sustain the logic of enrichment of matter: the addition of new traits in evolution. Endosymbiosis, rather, forces us to confront the microspeeds of transmission, the propagation of bacterial colonies, the reverse parasitism in cellular merging, the unpredictable hijacking of information. In other words, it discloses another, less reassuring, face of evolution that decentralizes individual species from nature.

Bacterial microvelocities animate the biotech reengineering of life. Biotechnologies, such as transgenesis (i.e. the transfer of genes across species), are not comparable to crossbreeding insofar as they do not simply add or exchange already actualized traits. On the contrary, biotechnologies modulate the ability of bacteria to take up and replicate any piece of DNA without treating it as foreign and rejecting it. As commonly known, bacteria do not have immune systems and are therefore highly conductible to replicating any gene.[33] Transgenesis modulates (i.e. it follows a process) bacterial transduction, in which the transfer of genetic material occurs through a virus. Although contained in cells and tissue cultures, such a virulent transfer is open to an unpredictable field of mutation,[34] which will not simply eventuate new hybrids. Hybridity mainly amounts to an addition of traits (the integration of differences) from two distinct species – animals and humans, insects and vegetables, fish and reptiles. Transgenesis, on the contrary, does not simply generate hybrids, but accelerates the generation of new symbionts: the emergence of an unprecedented mutation that does not resemble any of the parts out of which it was generated. It thus can be argued that symbionts, rather than hybrids, account for the transgenic assemblage of matter, which precedes and exceeds species differences of kind and degree.

Recently, biotechnologies such as mammal cloning have also raised questions regarding the Darwinian hereditary transmission of life defined by the Weissman's barrier between the germiline (nucleic DNA) and somaline (the cytoplasmic body of the cell).[35] As previously explained, this barrier excluded the reversal action of the environment on the organism and,

on the level of the cell, it assigned complete mastering to nucleic DNA on cytoplasmic material (proteins, mitochondria, etc.).

Mammal cloning involves the reprogramming of an adult diploid cell (i.e. eukaryotic cell equipped with 46 chromosomes) inserted into the cytoplasmic body of the anucleated egg cell.[36] In order to be cloned, eukaryotic cells are brought back to a virtual stage of growth, also defined as a zero degree of development. As some scientists argue, this cellular *reversibility* demonstrates that the biological development of cells is neither unilinear nor highly specific. Rather, the ageing time of adult cells can be reversed and reprogrammed for new functions.[37] This molecular time, however, is not chronological. It is not defined by regressive and progressive linearity where a return to zero is a return to inert inorganic matter: going backwards in order to obtain the same adult cell. In other words, it is not a question of designing from scratch so as to reproduce the same cellular function. On the contrary, the reversibility of cellular time entails the design of a turbulent pattern, the differential repetition of an ecology of relations declinating from a linear trajectory. Rather than suggesting a linear regressive passage from the present to the past – i.e. from the present state of an adult cell to its past state and forward again – this turbulent reversibility brings to the fore the virtual process of modification of the cell. The repetition of its pattern of development involves an action of the actual back on the virtual, an intensive modification of cellular time. The reprogramming of adult cells entails the re-emergence of mutations in life, where the present cloned state of cells lays out an intensified action of the future on the past. This is a break from linear continuity – a cut from the homogeneous river of time exposing indeterminate modifications in life.

After turning back the clock of growth of the diploid cell, the latter is electronically fused with an egg cell without nucleus.[38] After fusion, the egg cell, with a full complement of new DNA, starts, at some 'non-defined point', to divide and grow into an embryo. Scientists do not yet know how nucleated DNA is activated and reprogrammed by the egg cell. The fusion of the donor and the recipient's cytoplasmic material (the anucleated udder cell and egg cell) points to a new mitochondrial symbiosis, which does not characterize sexual reproduction or biotechnological reproductions such as IVF (in vitro fertilization).[39] The new cytoplasmic symbiont acts back on nucleic information, scrambling the Weismann's barrier between the germplasm and the somaplasm. Mammal cloning, far from designing life, relies on turbulent matter: the re-emergence of potentials in life.

Biotech does not reinforce Darwinism and neo-Darwinism. Rather, it suggests that the relation between evolution and life does not rest on notions of inert and entropic matter.[40] With endosymbiosis, we have seen how mutant matter defines an understanding of evolution and life beyond the metaphysics of the given – based on individual species, filiative inheritance, gradual progression, passive adaptation, survival of the fittest. Mutant matter is not simply at the service of the biotech market, using symbionts for profit whilst dematerializing life.[41] Rather, biotechnologies, such as transgenesis

and cloning, directly face virtual potentials in matter: an intensification of symbiogenesis.

Rather than re-designing units of life to enrich matter, the innovative aspect of biotech resides in its modulation and not pre-selection of molecular potentials. Modulation, indeed, has not to be confused with predeterminate design or advantageous selection. Modulation above all defines the capture of nonlinear movement that does not occur without generating new declinations from the trajectory of movement itself. In other words, modulation is immanent to the movement of matter. Thus, biotech, far from dematerializing life, catalyzes the re-emergence of potentials in matter. Biotech symbionts do not determine the next step in evolution. Their emergence does not cease to act back on actualized layers of material order whilst tending forward towards their virtual modification. This virtual link between singular symbionts lays out the machinic phylum of nature.

## Machinic Nature

This article has argued that in order to challenge the ontology of the given, biotech has not to be added to matter as if it were a new level of complexity in evolution. The problem is not evolution, but its predetermination. Biotech, thus, has to be re-thought in relation to a non-determinist process of mutation: endosymbiosis. To move away from the dualism between the material and the immaterial, information and organism, biotech has not to be placed outside nature as artificial, or outside matter as technology. This critical stance mainly risks reiterating the metaphysics of the given whilst trying to reject it. The ontology of given nature is predicated upon a predeterminate cause – a state of being – that always already knows its outcomes; a non-mutable cause that governs its effects. This article argues, rather, that causes do not resemble their effect in any way, anymore than an organism never resembles its genetic material, even though the causes are virtually present in their effect.[42] For real causes are not universal and a priori rules that the effect merely represents, in the way in which a member represents a species (or the genotype represents the phenotype). Causes are as singular as the effect, with which they are as if synergetically coexistent. These are quasi-causes laying out the contingent effective presence of those causes at particular moments.[43] Quasi-causes, as opposed to classical linear causality, are relational causes that participate in the actualization of their dynamic unity. Quasi-causes are not characterized by determination and by local connection between discrete parts (i.e. the adding of parts to enrich matter). On the contrary, they explain openness and dynamic unity in the virtual process of actualization. They point to the conditions of unexpected modifications that cannot be repeated without a turbulent transition from one order to another.[44] This article thus argues that biotech cannot be disentangled from *incorporeal* matter.[45] Borrowing from Spinoza, we argue that 'we do not yet know what matter can do'. Only if we start from the heterogeneous potentials of matter tending towards indeterminate modifications, and not from the progression of the one towards complexity, biotech can be

radically related to non-determinist metaphysics of nature devoid of given possibilities and anthropomorphic centrality. This article thus suggests that biotech partakes of *machinic* nature.[46]

The endosymbiotic assemblage of bacteria, eukaryotes, plants, animals and technology points to a heterogeneous process of relation and composition that defines the notion of machinic nature as that plane which precedes and exceeds the biological, cultural and technological determinants of nature. The Deleuze–Guattarian notion of *Mechanosphere* has not to be confused with cosmic or spiritual evolution. Indeed it does not coincide with a pre-design of nature. A mechanosphere entails processes of mutation: generating whilst unfolding a schizophylum of non-identical bodies. On this plane of machinic relations, distinctions are singularities emerging from a non-linear symbiosis virtually linking distinct layers of matter. 'The apparent order can be reversed, with cultural or technical phenomena providing a fertile soil, a good soup, for the development of insects, bacteria, germs, or even particles' (Deleuze and Guattari, 1987: 69). Each machinic relation entails the modification of all the parts of a new composition, opening up life to the becoming of matter – the continual doubling of the tendencies of life and matter. A machinic relation is indeed defined by a symbiotic merging of variables, the non-linear parasitism between the host and the guest generating an unrecognizable assemblage out of their coexisting differences.

Deleuze and Guattari's mechanosphere questions the vitalist and mechanist dualism that reduces nature to the linear chain of cause and effect.[47] A machinic phylum then privileges neither the organism nor the environment, internal nor external force, time nor space, nature nor culture. What comes first is neither the one nor the other. What comes first is the mutant relation: mutual feedbacks of contagion.[48] This phylum is crowded with pre-individual anonymous forces tending towards actualization – a process of individuation[49] crossing layers of order and amodally linking a singular layer to another, a heterogeneous composition to another, a collective body to another, without ceasing to re-engineer their distinction. These transitions across layers can be defined in terms of transduction:[50] the viral modification of molecules entering other molecules implies the mutual modification of their genetic pool composing a new molecular body, rather than the inheritance of the pool through filiative reproduction or constant self-replication.

From this standpoint, nature no longer can be identified with organic life. Rather, life cannot be detached from symbiotic assemblages that challenge what is defined as living and nonliving, individual and environment, simple and complex. Far from entailing linear transmission, where life passes from parents to offspring and moves from the inorganic to the organic to ensure heterogeneity in nature and therefore higher levels of complexity in matter, the microdynamics of endosymbiosis suggest that life is what does not cease to cross thresholds of microbial contagion, double parasitism and symbiotic merging. In this sense, biotech, rather than adding new

dimensions to inert matter, cannot be disentangled from potential mutations virtually linking distinct layers of order.

Machinic nature, thus, does not naturalize machines or the technological development of biotechnologies. This is not a question of re-naturalizing culture, technology and society, but of mapping a non-identical conjunction – i.e. a schizounity – between singular orders of variation. Indeed, this is a matter of laying out a heterogeneous nature–culture continuum, which shows that biological life as determined by genealogical inheritance through sexual reproduction or constant self-replication is embedded in an ontology of the given devoid of dynamical processes of virtual modifications. It is therefore important to change our starting point; to start in the middle of relations. Yet, this middle is not to be found in the space between two terms. It is not a problem of uniting two distinct forms as every dualistic thought will argue. This is a much more obscure path, which implies a much wider diagram of intensive connections. In other words, each relation has to be considered as an internal resonance of a vaster process of co-modification of virtual potentials and actual emergences. Thus, a relation above all marks a participation in a wider sphere, which, at the same time, constitutes only a dimension of such a sphere. This is why each actualization always entails a collective unity. This is why a biotech symbiont cannot be disentangled from a process of evolution of which it is only a dimension, an internal resonance that simultaneously participates in changing the indeterminate process of evolution. In the same way, the middle of relations also defines relations that are external to their terms. This middle partakes of a process not of terms, of the reengineering dynamics of molecular life, and not of the state of the biological and technological. The middle defines an interval of change, simultaneously tending towards two directions 'out of the actual (as past) into the actual (as future)' (Massumi, 2002: 59). The middle is a vibration: a movement that is too small and too quick to be contained in a state of time. Starting in the middle thus implies a pulling-out of virtual potentials from actual organization, tending towards new potential actualizations. In this sense, biotech cannot be considered in terms of equivalence (analogy or resemblance) between biology and technology as if it were adding new traits to given matter. On the plane of machinic nature, biotech becomes a portal for the proliferation of unprecedented symbionts at once acting back on the biological order of sexual reproduction and forward on the emergence of a new mode of transmission: a hyper-microbial sex. This is not regression to simpler forms and functions of life, but a virtual transition from one phase to another in the mutual generation of the new.

To conclude, it may be important to state that the revolution of the biotech market entails more than a simple celebration of higher levels of evolution on the one hand, and reaffirmation of the metaphysics of the given on the other. The biotech market is entrapped in the layers of stratification of endosymbiotic matter, in which the reengineering of life comes without

predeterminate design. In this sense, the increasing financial investments in biotechnologies will have to face the nonlinear process of evolution, according to which the manipulation of life comes with imperceptible microvariations cutting across all scales of matter. The biotech market, from pharmacogenomics, leading in drug design, to gene sequencing and cloning, and protein production software (among many others), is at the very core of the biotech business of life, where the biological becomes intertwined with the economic valorization of potentials. Egg cells, eukaryotic cells, bacteria, viruses, proteins, DNA and RNA have acquired capital value in the fast run towards patenting life.[51] It has been argued that the biotech struggle over the property of molecular matter entails not only the economic activity of the biotech industry, but more importantly the networked capacity of biotech to generate new economic value, and therefore what counts as life.[52] In this sense, the biotech market lays out a transparent link between capital and life. A nanochip, a stem cell, a cloned embryo, generate – i.e., actively produce – notions of life by generating new bodies of value. Each manufactured cell is a new artefact that is not simply produced but instead produces new capital value and new life. The biotech market thus regulates the transaction between life and property. Yet, each passage is not governed by a logic of linear exchange and reproduction, but rather marks a mutual or double-edged constitution of what counts as life, profit and property. Each transaction is a transduction: an immanent battlefield of contagion that refutes the binarism between life and capital.[53]

In this sense, the so-called 'real subsumption' of life to the capitalist machine of property and profit does not primarily define the reduction of life to an all-encompassing apparatus of economic valorization.[54] Real subsumption is not concerned with eliminating excessive value, but primarily operates by incorporating all useless flows. It proceeds by modulating virtual potentials of life rather than regulating its already actualized forms. As potentials enter conditions of probabilities and not possibilities, they remain indeterminate in their process of eventuation. Yet do not be fooled. The machinic ontology discussed so far would ultimately refute any naturalization of the biotech market – as if the biotech market were a given – but also any naturalization of the potentials of life – as if life would spontaneously resist the mechanisms of subsumption. The argument proposed here takes a different trajectory. The biotech affair demands an intensive participation in the virtual tendencies of life: a sense of belonging to mutant matter. Thus, it demands participation in the battlefield of what counts as life in the symbiotic experiments of the biotech market, which are closely re-engineering the present–futurity of evolution.

*Notes*

1. On biotech as the new business of life, see E. Thacker (2000) and H. Mae-Wan (2000b). See also the GenBank website at URL: http://ncbi.nlm.nih.gov/Genbank/index.html

2. On the understanding of evolution based the optimization of the fittest, see Lewontin (2000: 310–12).

3. Some biotech advocates such as Walter Truett Anderson argued that we have entered an era when the simple laws of Darwinian adaptation to the environment have passed. In his opinion, we are entering a new world, in which human species will redesign themselves. In his opinion, a species in which individual members can exchange organs with other individual members does not exist anywhere in the world other than the human species. See W.T. Anderson (1996). Thacker explains the current importance of the legacy of the classical model of evolution for biotech and genetic engineering through a detailed analysis of the models that count in the redesigning of life. In particular, he highlights the difference between gene centred and new systems biology evolutionary models that lead to distinct ways of engaging with the technology and its outcomes (2004: 156–9).

4. It is worth reminding the reader that most biotech companies have as their main priority the prevention of genetic diseases as well as the humanitarian promise of newly designed cells, tissues and ultimately babies. From Biogen to Genentech, biotech's advocates highlight the new possibility of intervening in the molecular potentials of life. For more details on biotech's 'humanitarian' mission, see Clark (1999). On the new relation between biotech's creation of economic and life values, see Thacker (2003a).

5. As Lewontin reminds us, the vision of natural selection as a process of global optimizing is also at the core of the work of engineers who write computer programs that model evolution by natural selection in order to find optimal solutions to design problems (Lewontin, 2000: 312).

6. The debate about biotech as a dematerializing tendency that increasingly separates the mind from the body is predicated upon a dualist conception of matter, in which two substances, *res cogita* and *res extensa*, account for the hierarchical difference in the world between the immaterial and the material. Recently, Thacker has instead argued that biotech needs to be considered according to a process of re-materialization and embodiment of the biological on specific levels, which implies a constant mediation of matter. For him, this rematerialization has become the medium itself (Thacker, 2004: 23).

7. By inert matter, I mean a metaphysical conception of matter as non-evolutive. As Whitehead reminds us: '[T]he non-evolution of matter has been a tacit presupposition throughout the modern thought. Until the last few years the sole alternatives were: either the material universe, with its present type of order, is eternal; or else it came into being, and will pass out of being, according to the fiat of Jehovah' (Whitehead, 1978: 95).

8. It is important to highlight here that a non-determinist process does not correspond to a non-causal process. On the contrary, this article's argument implies that it is crucial to engage with causality beyond determinism. Such causality is not pre-given, an absolute qualitative substance in which all outcomes are already pre-determined. Rather, indeterminate causality is a quasi-cause or co-causality, a field of compossible causes – and thus in Deleuze and Guattari's terms a multiplicity or a Body without Organs – which are themselves affected by the emergence of actual modifications. This is a process of becoming or individuation where rules are not pre-ordained, as in a transcendent cause, but are able to change according to circumstances, pressures, gradients and critical thresholds. On the quasi-cause,

see Deleuze (1990: 110–11). On the process of individuation as involving pre-individual forces undergoing singular variations in a dynamic ecology, see Simondon (1992: 300–2). On the causal movement from indetermination to determination, see also Whitehead (1978: 43–6).

9. By biotic ontology of life, I mean a qualitative notion of being that corresponds to carbon-based life: an already actualized and individualized form of life. Instead, in this article I argue for a machinic ontology of life starting from a causal yet indeterminate process of modification out of which carbon-based life has emerged.

10. In particular, it is worth specifying that the neo-Darwinist view of evolution may escape the biotic ontology of life insofar as it moves away from organic biology and holistic approaches to life by focusing on the capacity of the smallest units to self-organize and replicate. However, in the context of my argument, it is also important to notice that the neo-Darwinist model does not help to challenge the ontology of the given insofar it is predicated upon optimizing fitness of individualized units of life.

11. On this point, it may be worth quoting Dawkins on his notion of replicators:

> We can now see that less-favoured varieties must actually have become less numerous because of competition, and ultimately many of their lines must have gone extinct. There was a struggle for existence among replicator varieties . . . Survival machines got bigger and more elaborate and the process was cumulative and progressive. (Dawkins, 1989: 19)

12. On the history of endosymbiosis, see Sapp (1994).

13. On this point, see Monod (1972). See also Jacob (1973).

14. On the microbial network of organic and inorganic life, see McMenamin and McMenamin 1994).

15. It may be useful to clarify that for microrelations I intend the interrelations that compose actualized life in terms of internal differentiation – i.e. differential relations among elements that are prone to change according to certain pressures and environmental conditions. These interrelations are amodally linked to all singular actualizations according to increasing and decreasing intensity.

16. On the challenge of Darwinism, see DeLanda (2002). See also Gould (1991) and Deleuze and Guattari (1987: 47–8).

17. The notion of metamorphosis is not to be confused with the notions of symbiotic mutation or becoming that I use in this article. Metamorphosis, from the Greek *morphe* (form) and *meta* (across, after or between) is more adequately related to the Darwinian model of 'descent with modification' based on the function of sexual reproduction and crossbreeding. Indeed, in Darwinism, changes are limited to already actualized forms or traits, rather than being opened to unpredictable becomings, as I suggest is the case in symbiotic mutations.

18. Inspired by Malthus, Darwin defined natural selection as a mechanism whereby only few offspring of a given species would survive the competition for limited resources. See Gould (1991).

19. In the 19th century, Wallace associated Darwin's notion of descent with modification, with the term 'evolution', intended as organic progress. See Gould (1977, 1991).

20. On Mendelian genetics, see Gould (1991: 219). See also Shostack (1999: 7–8, 11–12, 32, 80).

21. For a more detailed discussion, see also Ansell Pearson (1999: 39–40) and Parisi (2004: 49, 77–8).

22. On natural selection as extermination of the ill-adapted variations, see Ansell Pearson (1999).

23. On the notion of evolution and virtual multiplicity, see Ansell Pearson (2002: 70–96).

24. Bergson's notion of evolution has to be related to the elastic tension between the èlan vital and matter: the tendencies of life and the tendencies of matter. Matter, far from being inert and passive, corresponds to different kinds and types. According to Bergson, life precedes by disassociation and division, explaining continuity and discontinuity in evolution (the immanence of matter and life). See Bergson (1983: 247, 249, 254–5.) See also Deleuze (1988a); Ansell Pearson (1999).

25. On this relation, see Simondon (1992: 296–319).

26. On the passage from hydrogen- to oxygen-based life and its implications for evolution, see McMenamin and McMenamin (1994: 36–46).

27. On the Master Molecule or DNA as a self-reproductive molecule, see Shrödinger (1944).

28. On the endosymbiotic emergence of eukaryotes, see Margulis and Sagan (1986a: 130–3).

29. On the variety of bacterial sex, see Margulis and Sagan (1986b: 89–90).

30. It may be interesting for the reader to note that bacterial immunity to drugs and their capacity to share information with all neighbouring cells is at the core of new research in nano and communication technologies. See, for example, Silberman (2003).

31. Colonies of bacteria have been considered as self-modifying networks. See J. Lederberg (2000). See also Jeong et al. (2000). On the increasing importance of bacterial network communication for digital technology, see Graham-Rowe (2000).

32. On this point it may be useful to remind the reader that Dawkins's emphasis on purposeless blind selection does not coincide with the way in which this article is arguing for aimlessness in endosymbiosis. Endosymbiosis does not presuppose the inertia of matter but rather its potential capacities of singular becoming that are not blind to selection but immanent to its forces. In Dawkins's blind selection we cannot help but remark that he starts from states of matter, arguing that the universe is what it is (1995: 133). On the contrary, the ontological process I am arguing for points to a heterogeneous process of becoming of a matter of fact, which challenges its 'givenness'.

33. On bacteria and immune systems, see Ewald (1996). See also Kaufman and Kabelitz (1998).

34. The debate about the risky containment of genetically modified cells, tissues, plants and animals is characterized by two main positions. According to biotech's advocates, all modifications can be secured within the walls of the laboratory, or according to highly specific selective procedures. On the contrary, scientists who embrace an autopoietic view of evolutionary biology argue that biotechnological

modifications will substantially impact on the biotic environment. See Mae-Wan Ho (2000a).

35. Mammal cloning indeed suggests that nucleic germlife is not the only actor in the genetic system of inheritance. Rather, the cytoplasmic material of the egg cell or soma plays a crucial role in genetic inheritance, as recently demonstrated by the cytoplasmic process of mammal cloning. This suggests that the transmission of life entails a much vaster field of relations that mutually link the germcells with the somacells and the genotype with the phenotype. On the importance of cytoplasmic material in cloning, see J.B. Cibelli et al. (2002: 45–6).

36. It is important to specify that this reprogramming does not imply a programming in advance. Instead, what happens in cloning is that reprogramming a genetic or cellular body entails a rematerialization of the ecological relations between genes, environment and pressures of selection. In other words, such a rematerialization suggests the emergence of a new pattern of relations, out of which potential modifications actualize.

37. For a more detailed explanation of this process, see Coghlan (1997: 4) and Cohen (1998: 26–37).

38. The reduction of the DNA of the donor cell occurs by starving the cell into a dormant (G0 or G1) stage of the cell cycle. See Pennisi and Williams (1997: 1415–16); Kahn (1997: 119); Lewontin (1997).

39. On the difference between IVF and cloning, see Parisi (2004: 155–9).

40. The notion of inert matter, as explained before, entails a non-evolutive conception of material processes of organization. On the contrary, the notion of entropic matter does account for a process of evolution. However, such a process is regulated by a principle of homeostatic constancy, according to which balance or collapse characterizes the dynamics of accumulation and discharge in a system. The evolutive process I argue for is instead closer to the far-from-equilibrium notion of matter, which does not involve an entropic dynamics of accumulation and discharge, but a metastable dynamics of change across thresholds. On the difference between entropic and far-from-equilibrium dynamics of evolution, see Prigogine (1997: 60–72).

41. On the use of the model of symbiosis in the biotech market, see Haraway (1995: xi–xx).

42. On this nondeterminist notion of causality see Deleuze (1994: 240, 1992: 172, 232–33).

43. See Deleuze (1992: 208–10, 212, 230, 238ff, 249–50).

44. For further explanation on the difference between linear classical causality and the quasi-cause in far-from-equilibrium dynamics and its philosophical implications, see Deleuze and Guattari (1994: 42, 205–8). See also Massumi (2002: 223–6).

45. On the thought of the incorporeal, see Foucault (1977: 165–99). See also Deleuze (1990: 4–11, 13–21, 12–22, 23, 35, 52–7, 67–73). See also Deleuze and Guattari (1987: 80–83, 85–88, 107–9).

46. Deleuze and Guattari's notion of the machinic is here entangled with Spinoza's notion of a nature that nurtures and is nurtured. See Deleuze and Guattari (1983: 283–89, 1987: 395–403, 409–11). See also Spinoza (1992: I, 29).

47. The vitalist conception of nature presupposes a self-sufficient organism enclosed in itself. The mechanical conception, rather, defines nature as an external system of selection. See Deleuze and Guattari (1983: 283).

48. This notion of mutual contagion derives from Spinoza's definition of 'common notions', stemming from the encounter between bodies and their immediate agreement. On common notions, see Spinoza (1992: II, prop. 11, 12, 19, 24, 25, 29, 37–40; def. 4; III, def. 2; IV, def. 30). See also Deleuze (1988b: 54–55, 103).

49. Simondon explains the process of individuation through the notion of transduction: the passage through different orders of magnitude linking pre-individual and individuated planes. See Simondon (1992).

50. According to Simondon: 'transduction represents a discovery of dimensions that are made to communicate by the system of each term such that the total reality of each of the areas' terms can find a place in the newly discovered structures without loss or reduction' (1992: 315).

51. On the patenting business, see Kimbrell (1997). See also Mae-Wan (2000b).

52. This point has been made by Thacker, who argues that the biotech market is characterized by an economy of valuation immanent to biotech practices. Thus the question is not how the biotech industry commodifies the knowledge and artefacts produced by scientific research. With the biotech industry, valuation operates axiomatically via an economic logic that must be connected with notions of biological life, even when the latter becomes information (Thacker, 2003a: 137).

53. For more details on the debate on biotech's link between life and economic value, see Thacker (2003b).

54. On the relation between real subsumption and molecular life, see Parisi (2004: 127–8).

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