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Naturecultures of immunological principles: A discussion on the politics of the CLONALG algorithm from a feminist materialist perspective

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ABSTRACT
This article examines one object emerging from the field of the Artificial Immune System (AIS), namely the CLONALG algorithm, from a feminist materialist perspective. It traces the naturecultures of this object by asking how the computational technique of the CLONALG implements immunological principles in Artificial Intelligence (AI) and how, through this, the CLONALG operates as a discursive-material agent in negotiating the boundary between artifice and nature. This involves mapping the politics of, firstly, algorithms as sorting techniques and secondly, immunity as an organizing principle. The suggested approach of entangled naturecultures allows "us" to develop an account of the politics of the CLONALG that traces the normative dimensions of the knowledge exchange between computational techniques and immunological theory that follows from bringing the concepts and practices of immunological principles into use within AI. It also encompasses a consideration of the mutual inspiration between biology and AI as a process of materializing—that is, as world-making practices. Thus, this article illustrates the entangled politics of the CLONALG as they figure in the naturecultures of immunological computational techniques.

KEYWORDS

naturecultures; immunity; AI; feminist materialism; algorithms

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INTRODUCTION

This article explores the CLONALG algorithm as a political object. It examines the algorithm as it emerges from the "field of [the] Artificial Immune System" (AIS) (Dasgupta, 2006, p. 40), in relation to the politics of "biologically inspired" (Bongard, 2009) computational techniques.[1] The AIS depicts one contemporary strand of Artificial Intelligence (AI) that displays practices of knowledge production situated at the intersection between two seemingly separate fields of knowledge: biology and computer science. Furthermore, in the case of the AIS, biological inspiration mainly involves drawing on "immunological principles" (Dasgupta, 2006, p. 40) as a resource with which to re-conceptualize strategies of computation. This kind of biologically inspired AI, however, does not opt for synthesizing life, as the strand of Artificial Life does. Rather, the AIS envisions the generation of more advanced algorithms that mimic functional principles of the organism with the goal of solving computational problems and realizing complex cognitive—that is, adaptive—behaviors. Furthermore, this approach can be contextualized within the larger field of "Computational Intelligence" (Kramer, 2009) or "Soft Computing" (de Castro & Timmis, 2003).

The AIS is one field of contemporary computing in which the boundary between the biological and non-biological is negotiated, based on the use of immunological principles across diverse disciplinary fields. This article asks firstly: how does an exchange of knowledge between biological theories and computational techniques pave the way for the practice of applying immunological principles to both fields? Secondly: how does such a practice of exchange between clonal selection theory and algorithms negotiate the boundaries between nature and artifice, self and other, organism and environment, given the case of the CLONALG algorithm? Finally: how can "we" account, from a feminist materialist perspective, for the politics that emerge from those boundary shifts?

Both phenomena—the immune system with its centralized immunological principles, namely those of recognition and defense, and artificial intelligence with its centralized method of formalizing as algorithms—at this specific intersection between biology and computer science have been of ongoing interest to feminists. There exists a long-standing feminist focus on the concept of immunity and the concomitant historically specific norms of health, the self, and the body (Cohen, 2009; Haraway, 1991; Jamieson, 2015; Martin, 1994). Of special interest to these studies are the mechanisms of power at work within the concept of immunity. These are traced along with their concomitant entanglements of medical, political and social norms. Feminist concerns with these entanglements include the ways in which immunity is constitutive of bio-political power and its regulation of bodies and bodily experiences in ways that move beyond the realization of "purely medical" standards of health and hygiene. In addition, and in line with Lucy Suchman

(2008), feminist approaches to (information) technology and computational techniques explore “the shifting boundary of nature and artifice” (p. 139) by asking how these shifts transform the very grounds of “our” Western thought in their relations of power and domination.

In the following, I will first present the AIS in the context of a fusion between clonal selection and algorithms in more detail. Proceeding, I will develop my feminist materialist framework of analysis. What does it mean for established concepts and the lived experience of organisms and bodies when hierarchically ordered, dichotomous categories and id/entities of “our” thinking in their gendered structure of oppression and domination seem to become permeable in AIS research? The example of the CLONALG will provide points of departure from which to grapple with the figuration of the clonal selection algorithm, not only as one key technique of the AIS, but also as a political object.

AIS RESEARCH: ON THE USE OF IMMUNOLOGICAL PRINCIPLES IN AI

AI research under the rubric of the AIS was initialized around the early 1990s (Twycross & Aickelin, 2007, p. 300). At its core, the AIS uses “the biological immune system as inspiration for solutions to problems in non-biological domains” (Twycross & Aickelin, 2007, p. 300). What immediately becomes apparent in this phrasing is that, firstly, the biological immune system is regarded as a system that can be defined through its problem-solving qualities and, secondly, that these qualities can be transferred—as functional principles—into other domains. The AIS adapts what is defined as the qualities of the biological immune system in order to build “distributed, robust, dynamic, diverse and adaptive” (Forrest & Hofmeyr, 1999, p. 1) computational systems. More precisely, the immune system is referred to as “tuned to the problem of detecting and eliminating infections” (Forrest & Hofmeyr, 1999, p. 1). Furthermore, AIS research emphasizes another “striking feature of the immune system” that encompasses the ability to “remember . . . the patterns of previous infections” (Forrest & Hofmeyr, 1999, p. 1). In this regard, the immune system becomes an idealized model for a set of strategies of detection, reaction and memory in the interaction between a system and an environment.

The main work in AIS is described as finding a way in which “the properties” of the immune system—namely the capacity to solve problems in a manner that is “distributed, flexible, adaptable, robust, degrades gracefully, and is resilient to errors and subversion” (Forrest & Hofmeyr, 1999, p. 1)—can be transferred to a computer system. Notably, the AIS cannot be captured through one computational modeling technique, but is characterized by the development of a variety of different strands and corresponding “immune-based models and techniques” (Al-Enzi, Abbod & Al-Sharhan, 2010, p. 118). These models can be differentiated through the implementation of varying algorithms. I have selected the CLONALG algorithm as an example representing a number of models and techniques. CLONALG stands for Clonal Selection Algorithm. This acronym displays the fusion between biological and non-biological domains based on immunological principles. However, before delving into the specificities of the CLONALG, it is important to ask and clarify what algorithms actually are. In short, algorithms have been building the basis for computational methods and processes—even "before there were computers" (Cormen, Leiserson, Rivest & Stein, 2009, p. xiiv). Algorithms are "a sequence of computational [or mathematical] steps that transform the input into the output" (Cormen et al., 2009, p. 5). Further to this, an individual algorithm implies a specific relation between input and output, and is thus used as a "tool for solving a well-specified *computational problem*" (Cormen et al., 2009, p. 5, emphasis in original). One core operation performed by many existing algorithms is the handling of data through sorting operations.

One example of such sorting operations is the area of "The Human Genome Project" (Cormen et al., 2009, p. 6). Here, algorithms help with "identifying all the 100,000 genes in human DNA, determining the sequences of the 3 billion chemical base pairs that make up human DNA, storing this information in databases, and developing tools for data analysis" (Cormen et al., 2009, p. 6). Algorithms thus help in reading, storing and visualizing the sequence data of the human genome (it is worth noting here that the estimated number of human genes has been revised since 2009 from 100,000 to around 20,000). Importantly, as Adrian MacKenzie (2003) notes, data sequences are the result of "extensive processing" (p. 315) and while the results might become publically visible, the practices of ordering inherent to this information processing remain unknown—a practice of knowing that is not part of the public discussion of issues such as bioethics. At the same time, following MacKenzie's argument, information processing is transforming the grounds of biological knowledge. This involves not only knowledge of what counts as nature, but also, importantly, the ways in which this nature can be known.

In his work *Mythos Algorithmus*—which translates as "the algorithm myth"—Thomas Bächele (2015) even argues that "the logic of contemporary patterns of knowing and of experiencing the human, his cognition and his self-concept, is the algorithm" (p. 11).[2] Here, the algorithm appears to become the predominant model for knowledge production—one that is always experimental and precarious (cf. Knorr-Cetina, 1981); entangles the epistemological and ontological (cf. Barad, 2007; Haraway, 1991); and promotes a culture of thinking about what it means to be human and experience oneself. Donna Haraway (1991) famously postulated that, towards the end of the second millennium, "[t]he cyborg is our ontology; it gives us our politics" (p. 150). Now, at the dawn of the third millennium, is the algorithm "our" advanced cyborgian ontology, giving "us" "our" politics? And, if so, what are the implications for critical knowledge production across disciplinary boundaries? In order to tackle these questions, I will examine the case of the CLONALG at the boundary of the knowledge exchange between computational science and biology, investigating the ways in which this algorithm naturalizes certain knowledge and objects over others. As I will demonstrate, this inevitably demands an engagement with the CLONALG as a political object.

The CLONALG: AIS in practice

The CLONALG is an algorithm that was developed to implement "learning and optimization" (Al-Enzi et al., 2010, p. 119) in computational processes. It performs a variable number of possible steps, through which it runs in a loop. This specific

AIS algorithm emerged from the work of the computer scientists Leandro N. de Castro and Fernando J. von Zuben (2002). They describe their CLONALG as proceeding through eight successive steps with small variations in steps one and eight, through which they differentiate between the cases of "pattern recognition" and "optimization" (de Castro & von Zuben, 2002, p. 243, p. 244). The first version "assumes a set *S* of patterns to be recognized, while the OPT version assumes a function" (de Castro & Timmis, 2002, p. 89, emphasis in original). Furthermore, the steps that the CLONALG runs through are derived from clonal selection theory and can be described as "essentially evolv[ing] solutions to problems via repeated application of a cloning, mutation and selection cycle to a population of candidate solutions (B Cells)" (Hart & Timmis, 2008, p. 195). More precisely, these cycles mimic the clonal selection and, through this, the CLONALG enacts a behavior comparable to the "affinity proportional reproduction and mutation" (de Castro & Timmis, 2002, p. 80) of the immune system.

AIS literature often refers to clonal selection theory as coined by the immunologist Frank Macfarlane Burnet. This theory basically describes an adaptive immune response during which an organism produces specific antibodies when exposed to a certain antigen. They furthermore identify two core principles: affinity and mutation. Affinity describes the capacity of a cell to recognize and bind with an antigen. Affinity results from "the surface composition" (Kramer, 2009, p. 63) of both the antigen and the antibody. De Castro and von Zuben (2002) state that "[t]he set of features that characterize a molecule is called its generalized shape" (pp. 242–243). This shape becomes key in recognizing and binding, while the search area between antigen and antibody is referred to as the shape space. The idea of the shape space translates the quality of the interaction between antigen and antibody, and concomitantly the determination of their position, features and capacities—in other words, their *affinity*—through mathematical terms. Understanding affinity as a mathematical problem of calculating positions, features and capacities transfers the concept from theoretical immunology to computer science. More precisely, it allows a binary coding of the "Ag-Ab" (the antigen-antibody relation) through which "their spatial representation and a distance measure is used to calculate the degree of interaction between these molecules" (de Castro & von Zuben, 2002, p. 243). Thus, the Ag's and Ab's can be represented by binary strings (a sequence of 0s and 1s). As the authors further highlight, "the precise physical meaning of each attribute is not relevant to the development of computational tools" (de Castro & von Zuben, 2002, p. 243).
Another major principle of clonal selection theory is that the binding between antigen and antibody stimulates proliferation. As de Castro and Timmis (2003) point out, "[t]he cellular reproduction in the immune system is based on cloning" (p. 528). This cloning is also a selective process through which the lifespans of emerging antibodies are determined: the higher the affinity between the slightly differing clones and the antigen, the longer they will live. Thus, clonal selection is divided between plasma cells (lower affinity) and memory cells (higher affinity).

Against the backdrop of clonal selection theory, the steps of the CLONALG can be described as follows:

> 1. *Initialization*: create an initial random population of individuals (*P*);
> 2. *Antigenic presentation*: for each antigenic, do:
> 2.1. *Affinity evaluation*: present it to the population *P* and determine its affinity with each element of the population *P*;
> 2.2. *Clonal selection and expansion*: select n_1 highest affinity elements of *P* and generate clones of these individuals proportionally to their affinity with the antigen: the higher the affinity, the higher the number of copies, and vice-versa;
> 2.3. *Affinity maturation*: mutate all these copies with a rate inversely proportional to their affinity with the input pattern: the higher the affinity, the smaller the mutation rate, and vice-versa. Add these mutated individuals to the population *P* and re-select the best individual to be kept as the memory *m* of the antigen presented;
> 2.4. *Metadynamics*: replace a number n_2 of individuals with low affinity by (randomly generated) new ones;
> 3. *Cycles*: repeat Step 2 until a certain stopping criterion is met. (de Castro & Timmis, 2002, p. 80, emphasis in original)

In modeling an algorithm that proceeds along these steps, the CLONALG is understood as a method of applying concepts of theoretical immunology. Furthermore, this application involves the translation of immune system cells into a binary code represented by strings. Importantly, the workings of the CLONALG are described as evolutionary, whilst, in contrast to other evolutionary computing techniques, the CLONALG is thought of as operating on the level of "cellular evolution" (de Castro & von Zuben, 2002, p. 248). Nevertheless, the operations of the CLONALG appear to be illustrating the principle of species evolution in neo-Darwinian terms. De Castro and von Zuben underline that

> [t]he similarity between adaptive biological evolution and the production of Ab's is even more striking when one considers that the two central processes involved in the production of Ab's, genetic recombination and mutation, are the same ones responsible for the biological evolution of species. (de Castro & von Zuben, 2002, p. 242)

Clonal selection as one major immunological principle that enables an adaptive immune response is regarded as "a remarkable microcosm of Charles Darwin's theory of evolution" (de Castro & von Zuben, 2002, p. 242). Theories on how this microcosm works, however, can be transferred to computer science and these in turn are viewed as demonstrative for how the algorithm behaves (cf. de Castro & Timmis, 2003, p. 533). In this way, the process of clonal selection theory is drawn upon as a general learning strategy: The antigen is turned into an information unit with the capacity for adaptive proliferation, which is regulated by selection (affinity maturation). The emerging clones (plasma and memory cells) are held to be illustrative of an evolutionary adaption between information units and their environment.

Framing the qualities of the immune system in terms of strategies of recognizing, cloning, mutation, selection, and memory as a set of evolutionary strategies in the system's interaction with an environment is a good illustration of the practice of finding the core attributes of contemporary AI in nature. The computer scientists Stephanie Forrest and Steven A. Hofmeyr (1999), for instance, argue that "there are compelling similarities between the problem faced by the human immune system and that of computer security" (p. 2). They name one of these similarities as the interest in "highly complex, dynamically changing systems against intrusions from a wide variety of sources" (Forrest & Hofmeyr, 1999, p. 2). In this way, the complex, adaptive character of the immune response is regarded as an inspiration, not only for creating more robust computational techniques, but also for establishing a common metaphor for how to organize the confrontation between biological and non-biological entities with a growing number of toxins, viruses and bacteria as much as growing data and information flows. Both biological and non-biological entities appear to constitute "our" nature.

The relation between entity and environment in the use of immunological principles in AI seems to reinforce an understanding of computational and biological systems as similar. Thus, the computational use of these principles has the effect, not only of transferring the biological into non-biological domains, but also of involving reciprocal forms of inspiration. When immunological principles are translated into computational strategies, this verifies both as being inherently natural. I suggest analyzing this as a strategy for naturalizing knowledge (theoretical immunology) and objects of knowledge (clonal selection and CLONALG). Such a naturalization has the effect of denying the role of historically and socio-culturally specific constraints, such as values, power relations and emerging discursive-material formations that otherwise condition knowledge production, and thus also blurs the boundary between the contingent nature of knowledge and the objects of knowledge. The CLONALG appears at first sight to be a value-neutral and objective application of a proven theory in immunology, namely that of clonal selection. However, it seems important to trace the effects of such naturalization, as briefly outlined above, in order to challenge this initial impression. Thus, the next subsection will propose a critical engagement with the AIS, and the CLONALG as one of its objects.

ENGAGING WITH THE CLONALG: A FEMINIST MATERIALIST PERSPECTIVE

One important insight into the historical discursive-material formations of the mutual inspiration between biological and computational concepts and models of thought can be illustrated by what the feminist science technology society studies (STS) scholar Sarah Kember (2003) frames as a "convergence between biology and computer science" (p. 2). She explains:

> The keywords here are "adaptive," "robust," "flexible" (and "friendly") and to achieve these characteristics, the principles of AI must literally be turned on their heads. Adaptive, robust, flexible and friendly artificial intelligence is now in the process of being *grown* biologically (from the bottom up) rather than built or programmed from the top down (Kember, 2003, p. 2, emphasis in original).

The idea of realizing cognitive behavior in AI by growing it from the bottom up displays the historically specific entangled "naturecultures" (Haraway, 2003) of biologically-inspired AI. While biology is held to be a resource for understanding the complex behavior of organisms, the emerging computational techniques and artefacts in turn become examples of the workings of those principles and, thus, a further resource through which to gain a deeper understanding of organisms. The CLONALG has clearly been developed as an adaptive, robust and flexible computational technique through which, for instance, processes of machine learning can grow biologically. The immune system response (clonal selection) is turned into the ideal model for dealing with information units (antigens) by learning (affinity maturation and memory cells). My argument is that when the CLONALG is defined as the application of theoretical immunology through computational—specifically algorithmic—techniques, this process of biological inspiration becomes more than just one example of a convergence between biology and computer science. In addition, it also points towards the underlying process by which the boundary between what counts as nature and what is categorized as culture is negotiated. However, the question remains; how can we grapple with these negotiations?

The traditional perspective of "Cyborg feminism" (Lykke, 2010) encourages critical engagements with the multiple, powerful fusions between organism and machine. It suggests firstly, that the sorting operations between nature and artifice are political and, secondly, that there is a need for a map of knowledge production as a relational and contingent process. However, it also acknowledges that such a focus on sorting operations by its very nature must encompass an inquiry into "the relationship between the material and discursive dimensions of power relations" (Barad, 2007, p. 229). When Haraway (1991) declared that the cyborg is "our" ontology that gives "us" "our" politics, she opened up the possibility of challenging the technoscientific reinvention of nature through a critical, feminist engagement with the material and discursive dimensions of how a transformation of existing power relations redefines "our" ontology by shifting the boundaries between nature/artifice, organism/environment, and self/other. In addition, Suchman (2011) considers the artefacts of technoscientific innovation, such as humanoid robotics, from which knowledge on "the human" is extrapolated as a "model (in)organism" (p. 119). The idea of the model (in)organism highlights entangled naturecultures, and thus also the politics implied by its shifting boundaries.

In line with this, my feminist engagement with the selected AIS algorithm builds on an understanding of knowledge and object production based on immunological principles across disciplinary domains deployed as sorting practices. Exploring the politics of the CLONALG as a model (in)organism, however, involves more than simply analyzing the normative dimensions of knowledge and artefact production, which "classify persons in structural hierarchies" (Ernst, 2014, p. 147). In addition, such an understanding of knowledge production encourages a "[r]ethinking [of] materiality's dynamism—materiality as force—[and] directly involves the way we think its politics" (Hinton & van der Tuin, 2014, p. 1). Hence, materiality's dynamism informs my analysis of the CLONALG as a model (in)organism.

Finally, and in agreement with Haraway (1991), I suggest using the term "apparatus of bodily production" (p. 200) as a means by which to engage with the naturalization of knowledge and the objects of knowledge—such as, for instance, both algorithms and antibodies as defensive mechanisms of an entity—while taking into account materiality's inherent dynamism. I draw on Haraway's term as a thinking tool that incorporates the feminist and queer politics of exploring the normative dimensions of an object of study while also enabling an illumination of "the generation—the actual production and reproduction—of bodies and other objects of value in scientific knowledge projects" (Haraway, 1991, p. 200). As she further emphasizes, bodies and other objects are "an active, meaning-generating axis of the apparatus of bodily production" (Haraway, 1991, p. 200). This encompasses taking into account the fact that the convergence of biology and computer science is constitutive of world-making practices of sorting between nature and culture, while the objects that emerge are not passive, but rather active parts of this production.

So, how then might we analyze the AIS as a complex apparatus of bodily production? In the following two subsections, I first develop an account of algorithms as an apparatus of general bodily production and then of the immune system specifically. Finally, I will bring my insights from both subsections into conversation and proceed to map the politics of the CLONALG.

The algorithm: An apparatus of bodily production?

The success of the algorithm as a computational technique of sorting used for identifying the human genome seems to have become emblematic as a way for thinking of organic life as code. Here, the relation between knowledge and the emergence of objects of knowledge—including the body—is clearly one of co-constitution—a specific theory, or practice of using algorithms and "the human" co-emerge.

One other well-researched example of the role of algorithms as constitutive of (the logic of knowing) "the human"—apart from the human genome project—is the field of visual technologies. Algorithms have become increasingly important in bringing into use new technologies of visualizing "the human" on varying scales—from the brain to the genes (Fitsch, 2014; Schmitz, 2006; Waldby, 2000). These visualizations have the effect of seemingly speaking for the object they are supposedly representing, while also resembling the truth about this object. At the same time, as many feminist and queer scholars have argued, the complex technologies that lie behind the production of this visuality of "the human" as a coherent, representable object of medicine and biology are neglected (e.g. Kaiser, 2010; Schmitz, 2006). They remain the invisible laborers behind the picture, as it were. Additionally, they have the effect that gender differences in brain activities become "our" human nature. The kind of formalization of data offered by, for instance, the algorithms implemented in visualizing brain activities, is not value-neutral, but rather incorporates a gender politics (cf. Schmitz, 2006). In this view, algorithms become a central part of a contemporary biopolitical gendering device, namely brain imaging. In addition, these devices carry a politics of making visible, including the choice of a specific set of algorithms as a preferable methodology for collecting and analyzing data, and the concomitant emerging threshold of activities. This choice is just as important as the pre-conceptions of binary gender difference.

As Anelis Kaiser (2010) emphasizes, "[t]hese notions and associations [of sex/gender] become real, they take on materiality, during experimentation, i.e. during the neuroscientific experiment itself" (p. 192). She continues to explain that, "during the fMRI [functional magnetic resonance imaging] experiment, we do sex/gender by means of *measuring*" (Kaiser, 2010, p. 192, emphasis in original). With Schmitz and Kaiser, the algorithms implemented in the fMRI experiment can be understood in terms of a gender apparatus of bodily production that produces a binary sex/gender difference. However, and importantly, as Kaiser (2010) further argues, the challenge in contemplating the politics of the fMRI and its computational techniques as those of a complex apparatus of sex/gender production is to explore the possibility of "a sex/gender studies-oriented critique of sex/gender biases and heteronormative predictions and conclusions, without the result being that science is made ridiculous—as it is not science itself, but the way in which science is carried out" (p. 193). Instead of simply rejecting the fMRI experiment, Kaiser challenges our understanding of how science is conducted and suggests an understanding of measuring as a discursive-material practice that acknowledges the material dynamics of such an experiment. This becomes her point of departure for thinking about "[t]he experiment [as] . . . the moment when new conceptions of sex/gender can be transformed into a new measurable and concrete research materiality" (Kaiser, 2010, p. 208). Practices of measuring thus become key to processes of transformation of "our" sexed/gendered mattering.

Furthermore, alongside problematizing the interrelations between the input and output of such artefacts as visualization algorithms, a number of studies have emerged that offer alternative ways in which to engage with algorithms. For instance, the work of the cultural theorist and STS scholar Ted Striphas (2015) on "algorithmic culture" provides this examination of algorithms with two important insights: Firstly, the epistemological roots of algorithms are rooted in Claude E. Shannon's theory of communication. In short, Shannon deploys the laws of thermodynamics as a means by which to engage with the nature of communication itself and to develop an overarching theory of information (Striphas, 2015, p. 405). Furthermore, Shannon's take on entropy as the key to understanding the dissemination of information is based on the idea that "order could not be taken for granted but instead needed to be engineered" (Striphas, 2015, p. 405). Thus, algorithms became one mode of engineering such order. Secondly, Striphas (2015) describes the contemporary phenomenon of the "offloading of cultural work onto computers, databases and other types of digital technologies" (p. 395). He argues that the effect of the latter can be described as a process in which a "mysterious entity is responsible for imbuing people and objects with shape, quality or character" (Striphas, 2015, p. 407). As numerous feminist science and technology scholars have demonstrated, this process of imbuing people and objects with shape, quality or character is not a neutral or objective computational procedure, but rather is deeply entrenched in gendered, racialized and classed power relations (e.g. Haraway, 1997; Suchman, 2007).

Algorithms constitute a computational technique for solving problems by working towards the goal of bringing order to chaos. Exactly this quality has led to a rich body of work on the relations between algorithms and society, and specifically on algorithms and individuals. As already briefly described above, here, algorithms are analyzed as a "modern myth" and "have been depicted as powerful entities that rule, sort, govern, shape, or otherwise control our lives" (Ziewitz, 2016, p. 3). From this perspective, algorithms become political actors that exercise power in ways that rely on already-established gendered, racialized and classed relations of domination and oppression. However, with the concept of the apparatus of bodily production in mind, I suggest challenging any thinking that has the effect of further mystifying algorithms. Instead, the question is how to acknowledge the algorithm as a generative axis of world-making and bodily production—a perspective that resonates with Kaiser's work as outlined above.

The information scientist and STS scholar Malte Ziewitz (2016) identifies "two distinctive acts" of what he calls the "algorithmic drama" (p. 5)—that is, the current paradigm of analyzing the socio-technical workings of algorithms. The first act, he explains, encompasses thinking of "algorithms as powerful and consequential actors in a wide variety of domains" (Ziewitz, 2016, p. 5). Such an understanding of algorithms can be contextualized within "earlier work on the politics of computer code, neatly expressed by the slogan 'code is law'" (Ziewitz, 2016, p. 5). The second act in Ziewitz's (2016) conceptualization consists of concerns with the "opacity and inscrutability" (p. 4) of algorithms. Following this line of thought, the algorithm is depicted as a black box—an approach that also leads to different methodological suggestions for how to open it, such as "the black box algorithm" (Ziewitz, 2016, p. 6). By deploying the term algorithmic drama, Ziewitz emphasizes that current hegemonic ways of scrutinizing the politics of algorithms show a tendency to apply a notion of both politics and algorithms that is too simplistic, in terms of their workings as well as their relations. He further identifies with this a "line of stubbornly reductive stories about the origins of order" (Ziewitz, 2016, p. 7). I regard Ziewitz's insights into the algorithmic drama as an intervention into seemingly obvious practices of analyzing politics on the one hand, and opaque algorithmic processes of bringing order to chaos on the other. In the preceding sections, I have already opened the black box CLONALG, illustrating how it synthesizes immunological order. In the proceeding subsection, I will develop a more complex understanding of power and politics, as deriving from feminist engagements with the immune system—one that avoids both mystification and drama. This encompasses questioning, not only the algorithmic as seemingly the "new law," but also the workings of its formative power, including practices of dis- and re-entangling nature and culture.

The immune system: A core apparatus of bodily production

Haraway's (1991) work on immunity provides several important insights into how the workings of the immune system and those of power are interconnected. Furthermore, she frames these interrelations as the postmodern biopolitics of an unequal experience of sickness and death as it evolved around the HIV/AIDS crisis.

In order to do so, she discusses the ways in which the immune system became a popular, material-discursive figure in the United States during the 1980s.

To begin with, Haraway (1991) develops an account of biopower as not being a "fixed and permanent" form of power, but rather a practice of power that is "more vulnerable, more dynamic, more elusive, and more powerful than that" (p. 204). In this way, she provides an account of the workings of power that resonates, for instance, with Barad's work. Barad (2007) suggests rethinking "power . . . in terms of its overall materializing potential" (p. 230). However, and importantly, this potential is "not merely social, and the bodies produced are not merely human" (Barad, 2007, p. 230). By acknowledging this materializing potential as a means by which to explore the workings of power as they are constitutive of things such as "our" bodies and the possibilities to experience them—that is, the productive and more-than-human forces at work—this account of power avoids linear causalities and the creation of a hierarchical order of discourse and matter, or the socio-technical and natural.

Carefully collating the genealogy of the immune system as a powerful figure, Haraway (1991) notes an "equation of Outer Space and Inner Space" that has become tangible through images that show "blasted scenes, sumptuous textures, evocative colours, and ET monsters of the immune landscape [that] are simply *there*, inside *us*" (p. 222, emphasis in original). Remarkably, these "strangers" within us are at the same time what "sustain[s] our integrity and individuality, indeed our humanity in the face of a world of others" (Haraway, 1991, p. 222), while these strangers themselves are invaders. In line with Haraway, this image is constitutive of the discursive-material context of understandings of the self as they were established during the 1990s. She explains that "[t]he residue of colonial tropical medicine and natural history in late twentieth-century immune discourse should not be underestimated" (Haraway, 1991, p. 23). Accordingly, the major task for the immune system becomes to secure or re-store "the harmony of the organism" through "the aggressive defence of individuality" (Haraway, 1991, p. 23). Thus, she analyzes the immune system as an "elaborate icon" that establishes "systems of symbolic and material 'difference' in late capitalism" (Haraway, 1991, p. 204).

Furthermore, the insights into the politics of the immune system assembled here resemble the work of other scholars on the co-constitution of the (adaptive) immune system; (the political entity of) the self; and a model of the body as adaptive in nature (e.g. Cohen, 2009; Jamieson, 2016; Martin, 1994). For instance, Ed Cohen (2009) explains that, through the concept of "'immunity-*as*-defense'" (p. 3, emphasis in original), a worldview that thinks the self/the organism in relation to others/the environment is established. Jamieson (2016) very poignantly describes the corners of this worldview when she explains that the logic of discriminating between self/non-self (antibody/antigen) in particular works with a concept of "the body as an embattled 'self'" (p. 3). This is further reinforced by the use of "military metaphors such as war, defence, battle and invasion," which "promote . . . a view of the organism as a defended, discrete biological entity that is only capable of interacting with others in violent or antagonistic ways" (Jamieson, 2016, p. 3). This mode of interaction even appears to be idealized as a pattern of behavior that has to be remembered in order to secure the entity's survival in a perpetually hostile world. For Cohen (2009), biomedicine "incorporate[s] 'defense' as properly 'natural' and thereby anoint[s] it as a natural property" (p. 5). Jamieson (2016) frames this process of incorporating defense as properly natural in terms of "mistaking the political for the natural" (p. 3). My argument is that, in the case of the AIS—and especially the CLONALG—this mistake finds its continuation. By taking nature as their model, biologically inspired computer scientists also take on the role of "simply copying" what nature does. Alternatively, if algorithms are the practices of organizing order in the same way that nature has been doing all along, then algorithms such as the CLONALG become a natural property while nature itself can be known—and perhaps even re-coded—through these very same practices.

Here, the CLONALG algorithm becomes tangible as a biopolitical, antagonistic ordering device. I consider the immune system with its centralized organizational units—namely antigens and antibodies—to be carrying a politics of differentiation, and thus also a distinct politics of valuing. Relations of self/other and organism/environment are reduced to those of intrusion, defense and embattlement. From a feminist materialist perspective, I understand the immune system as an apparatus that produces forms of (embodied) vulnerability within sociocultural categories of ordering. Thus, on the one hand, the CLONALG carries the politics of ordering implied by the immune system. On the other, algorithms also bring with them the quality of making the gendering of bodies a question of engineering order, as shown in the subsection above with the example of brain imaging. In this convoluted meaning, the core function of bringing order to chaos can also be regarded as the act of entangling naturecultures in algorithms, constituting reciprocities, for instance, between immunology and computer science. Similar to the question of how to engage with the algorithm as an apparatus of (gendered and antagonistic) bodily production, one analytical challenge then becomes to open up a perspective that permits the reconfiguring of this apparatus in its discursive-material forces beyond well-worn binaries. One point of departure could be to bring forward possibilities of working with the origin and organization of order that move beyond heteronormative, binary, sex and gendered relationalities and relations of intrusion, defense and embattlement.

TOWARDS A FEMINIST MATERIALIST ENGAGEMENT WITH THE ENTANGLED NATURECULTURES OF THE CLONALG ALGORITHM

From a feminist materialist perspective, the AIS can be considered as constitutive of a strong field of knowledge that entangles sociocultural, technical and biological norms in new ways. In this paper, I have explored the use of immunological principles as a biological inspiration for new computational methods of problem solving. These allow a convergence between biology and computational theories—specifically, between immunology and AI—that propels a transfer of the properties of antigen-antibody interaction into binary strings.

Algorithms emerge in this field as the computational technique for solving the problem of organizing chaos, whereas the immune system functions as the ideal model for how the organism organizes chaos. Thus, the CLONALG is regarded as an application of clonal selection theory. This application, however, not only transfers immunological principles to computational strategies, but also transfers an accompanying worldview. Reading insights from the previous subsections together, the CLONALG operates as the apparatus of production of clonal selection. More precisely, I argue that in the CLONALG three worldviews are aligned: the so-called Darwinian microcosm; the microcosm of immunity-as-defense; and the microcosm of biologically grown AI. The reasoning behind this alignment and its concrete mode is based on bringing these differing concepts of organization, and in particular of engineering order, into conversation with each other. Reclaiming the CLONALG as a political object thus means, firstly, to contest the value-neutral, objective status of this object of knowledge and, secondly, to acknowledge its quality as a generative axis in the production of "our" ontology as organisms that are organized by evolution and clonal selection.

The naturalization implied in the alignment of these three microcosms (evolution, immunity, and biologically grown AI) has the effect of making all three unquestionable and granting them the status of being part of a linear process geared towards not only species survival, but also progress. Thus, the narrative around the AIS and its computational techniques supposedly promises more robust, hence more biologically grown, hence more natural forms of computing that—in a true sense—advance into a force for the biological defense of life. They seem to develop into one condition of survival in a world of ever-growing data flows that reinforce what nature is (evolution and immunity) and how "we" can know it (through mathematical terms).

However, and as my analysis has shown, thinking about the AIS as an apparatus of (bodily) production also suggests tweaking the notion of power by taking into account materiality's dynamism. This involves opening up opportunities to investigate established norms—for instance, the deployed logics of relating through normative forces. Notably, it also involves pondering the ways in which those very discursive-material forces of normalization always already implicitly generate opportunities for deviance and transgression.

The technoscientific formation of immunological defense, mutation and memory as organizational principles that extend beyond the biological in new ways carries a specific set of politics of, firstly, defining the self in its relation to others. Immunity-as-defense, however, "restricts the complex, contradictory, and yet entirely necessary intimacy of organism and environment to a single salient type of engagement: aggression/response" (Cohen, 2009, p. 5). Secondly, it carries the somewhat contradictory politics of formalizing "the human" and offloading cultural work, both of which are implied by contemporary algorithmic cultures. Exploring this set of politics, I emphasize—with Barad—that the relation between nature and culture, as well as between facts and values, is "cooked together as part of one brew" (Barad as cited in Juelskjær & Schwennesen, 2012, pp. 15–16)—that is, as part of the scientific practices of world-making. However, and notably, even though "cooked up together," the politics of the CLONALG as a biopolitical force and, hence, the generative potential of the AIS for (bodily) production are neglected. A feminist materialist approach to these politics insists on the onto-epistemological entanglement of facts and values, nature and culture, and biology and computer science in the CLONALG.

The CLONALG carries the politics of an algorithmic engineering of order that takes the immunological model of responsiveness between self and other, and organism and environment, as its blueprint. From this perspective, it depicts a form of "engineering order," as it is assumed to exist within the operations of a healthy immune system. Haraway (1991), however, challenges us to re-think the orderly operation of the immune system as that which constitutes a unified self, precisely by highlighting its adaptive quality and concomitant capacity for mutation. She argues:

> The genetics of the immune system cells, with their high rates of somatic mutation and gene product splicings and rearrangings to make finished surface receptors and antibodies, makes a mockery of the notion of a constant genome even within "one" body. (Haraway, 1991, p. 218)

With Haraway, clonal selection theory can be revisited, but specifically not as an instance of the organism restoring order in the manner of an aggressive response to intruders. Rather, the very mechanism of mutation subverts the idea that processes of discriminating between self and non-self lie at the core of the immune system. It also generates a view of the immune system through which the latter appears much less robust and not as good at problem solving as anticipated in the AIS. After all, it seems that the function of the immune system cannot be pressed into neat categories of political thought, nor into those of computational techniques, both of which focus on differentiating between, and relating, self and non-self. Thus, I suggest an approach to the phenomena represented and the process performed by the CLONALG that pays attention to the insight that "[t]he immune system is everywhere and nowhere" (Haraway, 1991, p. 218). Following this line of thought, I argue for a first step in accounting for the politics of the CLONALG that consists of not mistaking the political for the natural, and allowing "the natural" to make sense and materialize outside of established humanistic terms of difference and aggressive responsiveness between self and other, organism and environment. How can we develop algorithms that break with the alignment of the three microcosms in favor of imagining order, including relations of responsiveness, differently? My suggestion is to open up the black box of the CLONALG further and to find ways of developing computational techniques that refuse to simply work as a reinforcement of, for instance, the entangled naturecultures of immunological principles such as detection, defense and memory.

ENDNOTES

[1] The fundaments of this article emerged from many productive discussions during events of the COST Action IS1307, for example, with Prof. Iris van der Tuin and Dr. Jan Broersen (Utrecht University). In addition, I am very grateful for the comments and advice from the reviewers, as well as the guest editors of this special issue and the chief editors of the journal with whose input this article took shape.

[2] All translations from German are by the author. Notably, Bächele speaks of "the human" as inherently male. As Haraway (1991) reminds us, this carries not only a peculiar understanding of the human, but also the "great historical constructions of gender, race, and class" (p. 210). She continues to analyze this figure of the human as inhabiting the position of the "fictive rational self of universal, and so unmarked, species man, a coherent subject" (Haraway, 1991, p. 210). Thus, Bächele not only perpetuates existing power relations along the category of gender, but also reproduces the figure of the human as a rational, coherent subject as well as the intersectional power relations inherent to it.

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