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Natural Debts, Natural Dangers: An Ideology of Nation-State and Subject in an Immunology Text

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Natural Debts, Natural Dangers

AN IDEOLOGY OF NATION-STATE AND SUBJECT IN AN IMMUNOLOGY TEXT

Quinn Monette

May 5, 2017

The College of William and Mary

For Consideration of Honors in Interdisciplinary Studies

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~~~INTRODUCTION~~~

The language we use to understand science is the same language we deploy to make sense of the rest of the world. It is the way we position ourselves in relation to the world, the way we develop expectations of relationships and simultaneously act them out, and the way we call forth, in coordination with our never-fixed place and context, the objects and processes that in which these relationships are reinvigorated with significance. By highlighting the ‘social’ language used to understand ‘biological’ phenomena, I want to underline the hegemonic character of ideology—how it encompasses, without skipping a beat, all processes and forms of knowledge, including that which is claimed to be value-neutral or objective.

I keep ‘social’ and ‘biological’ between inverted commas because I want to emphasize the continuity and inseparability of the two putative domains. A significant component of the ideology of biology is the separation of biological/natural and social realms (Levins and Lewontin 1985). It is imperative to my analysis that I do not make that same distinction. My argument is that the same ideological formulations comprise the language of both ‘natural’ and ‘social’ spheres. But the framing of biology makes it seem *as if* there are separate natural and biological worlds (Latour 1987). Biology and the natural sciences are kept at a healthy distance from anthropology, sociology, and social studies. They are positioned differently with respect to knowledge. To commit briefly to the generalization and reification of academic fields, natural science aims to unveil, characterize, and name whereas social science aims to analyze, critique, and contextualize. One expands, the other turns inward. And the drawing of lines between the two is a key component of the discourse of objectivity. Undue penetration of the natural sciences by the social, it is thought, will sully the solemn and dispassionate reports of scientists on Nature (Haraway 2004).

Yet it would be misleading to argue that our ability to comprehend nature extends beyond the terms and relationships we use to organize it in, say, an immunology textbook. Science is a mode of perceiving and meaning-making (Bateson 1979). As such, it is inextricable from cultural schema that describe relation and order (Strauss 2005). The language of biology reiterates, alters, and produces these schemas. There is no way to translate ‘real objects in nature’—the red blood cell, for example, though unfortunately I can’t make one materialize here—into *communications* of that object without technologies that conjure the object into existence. The microscope is one such technology. Without it, there would be no cell to study, just red blood. Language is another technology. The phrase ‘red blood cell’ brings to mind an image (perhaps a microscope photo or a textbook sketch) and a set of characteristics (typically rounded with a divot in the center; carries oxygen from the lungs to the cells of the body; malformation causes sickle cell anemia and other health problems). There can be no red blood cell without the technology to isolate it, the words to speak of it, the blood bank and hospitals to bring it into circuits of extra-bodily distribution, the cartoons to teach about it, and the funding and institutional apparatus to research it.

In short: the red blood cell we (to speak imperfectly) comprehend is the same as the red blood cell embedded in our culture, but it is not the same as an *actual, pure, and objectively existing* red blood cell. Or rather: the latter can only exist insofar as we speak of it and mobilize it in social maneuvers. Finally: there is no objectively existing red blood cell, for as soon as we identify it, name it, give it meaning and utility, we have already precluded its autonomous self-generation, self-declaration, and self-expression. The red blood cell cannot speak for itself. There are necessarily acts of constitution and translation, and these are tasks for humans, as Latour and Woolgar describe in *Laboratory Life* (1979). Their work locates scientific projects within the

material, institutional, and discursive circuits that serve as their substrate. We have already done the work of ideology because there is no underlying objective truth *that we can access*. Our only tools for discovery (better yet, for world-reorganizing) are those provided to us by ideology.

I should be cautious to differentiate between ideology and culture, two concepts that are closely related but that merit independent discussion here. My interpretations of these terms won't be definitive but should give rough guidelines to my project. I borrow from Althusser's "Ideology and Ideological State Apparatuses" (1970, 1971), which describes ideology as the imagined relationship between the individual and the world which functions to "[recruit] subjects among... individuals" and "[transform]... individuals into subjects." Ideology provides a sort of framework or set of constraints (always negotiated, always subject to histories and relations of power) around and through which subjects are constituted. Ideology functions in a way that "hails" or "interpellates" subjects (ibid). Subjects are not prior or ontologically independent of hailing, but are constantly formed and re-formed through this interpellative relationship. Ideology is the "Hey, you there!" that propels the individual always into a geographically and historically situated system of relation (Butler 1993, 2013). It is the momentary but necessarily reiterated relationship which, temporarily but cumulatively, subjects are brought into being through their (imagined, yet material and consequential) relationship to material, discourse, and social formation.

A necessary caveat: this definition of ideology should not limit the capacity of the subject to negotiate these relations. Ideology is not a simple imposition of subjectivity upon the individual; it is a complex and reproduced accumulation of relationships in which the individual responds to and is shaped by their surroundings (spatial, historical, social, economic, political). Nor should this vision of ideology create a stark dichotomy between 'hegemon' and 'subaltern.'

While critiques of hegemony must exist at least in reference to the ideological framework of the dominant system, implicated subjects can perform strategic disarticulations, exploiting gaps and contradictions within the system to highlight or problematize parts of that ideology that don't sit well (Muñoz 1999). Ideology is affective as well as effective, and affect can be put to use to uncover and broadcast inconsistencies. In *The Woman in the Body* (1987), Emily Martin recounts how some female-bodied subjects were discomfited by the idea that menstruation is a monthly sickness, and childbirth as a sort of dirty, mechanical labor ripe for professional intervention and management. Some women turned to alternative methods of childbirth and/or produced new understandings of their body-processes. They centered this new discourse-production on their trouble with the dominant categories. Because ideology is that which is taken as a neutral presentation of the world-as-organized, any unsettling of ideological claims (which are presented as stable truths) does the valuable work of revealing the ideological grounding of truth-claims.

Culture, on the other hand, is the context in which the imagined relationships of ideology are envisioned and acted out. In her critique of Bruno Latour's Actor-Network Theory (ANT), anthropologist Emily Martin (1998) points to the need for a cultural view of scientific practice. Science is comprised of more than "accumulating, aggressive individuals born of capitalism, forming his networks and gathering his allies everywhere," as ANT would have it. This is too close to a description of the doing and proliferation of science as outside of time and politics. We have to reject the conceptualization of science as timeless or universal and reinsert it in its social, geographic, and temporal environs. What Latour's Actor-Network Theory is missing is *culture*. Culture incorporates practice, relationality, conceptualization, and temporality.

I will distinguish it from ideology—realizing that these two are never truly separate, and comprise nodes of the same approximately bounded region of discourses-practices—in the way

that ideology is a mode of envisioning the social formations, traditions, modalities, discourses, landscapes, and histories that make up culture. That is to say, ideology is a claim about what culture looks like, or what it should look like. In this sense ideology is normative and corrective. It calls forth subjects through the pull towards social intelligibility. Building from Foucault (1976, 2013) and Sunder Rajan (2006), I will focus on the dimension of power present in ideology—not always a coercive or imposed power, but always key to social and institutional legibility: what an individual must do and what discourses they must reproduce in order to be read as a subject.

So why describe my inquiry into science as a study of ideology rather than culture? The concerns driving my approach are both methodological and philosophical. I'm dealing with discourse: in this case, the systems of analogy used in an immunology textbook to make sense of the 'biological' world, but which also seem to reference aspects of the 'social' world. I'm also concerned with power, and the way fields of power are mobilized through discourse in the formation of subjects. Power comes into being and is reiterated through claims about what the biological, bodily subject looks like, and through the way immunological metaphors reify existing social formations. These 'biological' and 'social' forks are never essentially distinct, but emerge and interpenetrate as ideology.

I realize that metaphors are necessary tools for comprehending and communicating otherwise inexpressible phenomena. My purpose is not to bemoan the imprecision of scientific metaphor or to say that the use of metaphor represents a corruption of otherwise pure data. This type of claim isn't helpful—in fact, it reinforces the notion that scientific practice can stand outside of ideology and culture. Instead, I want to examine the politics embedded in these understandings of immune and body processes. What sorts of relationships do they describe?

What hierarchies do they establish? What categories do they reify as natural—and what are the implications of this rhetorical pivot in subject-formation? My project will be a sort of provisional map to the ideology of immunology, though not a definitive one by any means, nor suggestive of any origin or causality. Instead, I want to bring together what is often kept separate—rather, unveil the common ground, as it were, between society and biology as fields of knowledge and action, showing that these were never distinct to begin with.

One of the fundamental topics of my investigation is the place of the metaphor in the conceptualization and communication of scientific theory. As Richard Boyd (1979) argues persuasively in his “Metaphor and Theory Change,” the figurative and comparative mechanism of the metaphor is more than a literary device; it realizes the task in the empiricist scientific tradition of “[accommodating language] to the causal structure of the world.” A metaphor seems to reveal some basic, reducible structure of the world, a world made discoverable through multilevel parallelisms and atomizations. The metaphor does more than explain. It forms the basis of further investigation. In the scientific context, it is actually “constitutive of the theories [it expresses],” laying the groundwork for further investigation under this metaphorical model (ibid). As a system of metaphor is propagated in service of explaining a biological model, the biological seems to take on the same composition and relations of the figurative system.

The empiricist scientific model says that metaphor is little more than an explanatory device, a heuristic that can be later dropped in favor of a better model if the current state of science dictates it. This methodology must operate under the assumption that a metaphor is referencing some preformed, discoverable, universal essence rather than a contingent, relational, dialectically situated, and momentary observation. As Boyd’s analysis suggests, it’s more likely that a new scientific theory be accepted and proliferated if it maintains the component parts of

the former explanatory model, simply rearranging them. The metaphor does more than reference natural, prior biological categories; it constitutes and reshapes these categories (ibid) I would add to Boyd's analysis that it's not merely that the 'figurative' model constitutes the 'biological': these exist in conversation, in a relation of mutual constitution. The 'biological' also speaks about and reshapes the 'figurative.'

I'm interested in the claims implicitly made by these systems of metaphor about the way the world *is* and *should be* structured. Biology is similar to other human practice in the way knowledge is organized around and understood through biology, but, like other sciences, it has been separated from other modes of practice through the discourses of objectivity and neutrality (Richardson 1984). Science is supposed to be a neutral conduit through which the natural world can make itself know (Haraway 2004). Other sorts of knowledge-creating and -reproducing practices—religion, for example—are reducible in the modern gaze to the culture or cultures in which it is practiced. Not so for biology. Biology is supposed to be apolitical and ahistorical, the culmination (or perfection-nearing continuation) of centuries of slow unveiling, correction, and improvement of our understandings of natural truth. One of my goals is to trouble this trajectory—not through historical work (see Gould 1981 and Engles 1991 for two examples of this strategy), but by detailing the enmeshment of scientific knowledge-production in present-day modes of categorization, relation, and value-making.

I have not conducted an ethnography of scientists, science students, or a public that receives, produces, and reproduces scientific knowledge. I can't make any generalizations, at least from my own data, about the cultural practice of science. However, in the very restricted framework of an immunology textbook, I can inquire into the scope, particularities, and subject-

producing (interpellating) consequences of immunological discourse: what I refer to as the ideological formulations of immunology.

Working backwards from the conclusion that historically- and contextually-positioned orderings of ‘science’ and ‘society’ share the same language, constitutive relations, and political implications, the question unavoidably pops up: Is to invent a new system of biological understanding also to herald a new sort of society? Are the two processes—social change and biological-discursive change—interrelated? Are they part of the same whole?

If the affirmative holds, as I will argue it does, and there is a relationship between the conceptualization of social organization and the conceptualization of body-knowledge, this process doesn’t take place in a sequential or directional way, with one side driving and the other lagging. It is necessarily a process of mutual constitution (Haraway 2004). I don’t mean to suggest a momentary break in language and metaphor, a distinct epochal shift, but change in science and society incontrovertibly has happened and will happen. My goal is to highlight the ways these apparently independent changes are more than incidentally related. I aim to describe, in the limited context of the discourse of an immunology textbook, the embeddedness of science in culture. I center my investigation around a few basic questions: Why are understandings of immune processes formulated the way they are and not some other way? And what does it mean that they’re formulated that way?

I don’t mean to suggest that this work of formulation is done merely at the discursive level, if I limit my definition of discourse to the symbolic or abstract realm—that which is communicated or communicable. The signified requires a signifier. Neither pole exists without the other; their totality comprises the stuff of human practice (Kim 2004). Analogy is singularly relational. Absent *something out there*, even as that something is only made to coalesce and

endowed with meaning as it is perceptible (and comprehensible) through the saturation over time of representations in a social setting, a representation falls into disuse and nonsense. This is what I mean by material-discourses or discourses-practices. A discourse accrues authority through its proliferation (Foucault 1976, 1978). This is not a question of vacuum-actors constructing objects out of pure and unflagging volition. Discourse is powerless—it does not exist in any instrumental way—without the institutions, technologies, and epistemic underpinnings that procure select discursive schemas in service of their reproduction. Yet these institutions, technologies, and forms of knowledge are never divorced from the discourses that allow them to be read and give them social significance.

If I seem to be contradicting my previous argument, let me backtrack and give a relatively current example from the biological sciences. The gene is a metaphor. It is an abstraction: a generalized unit of form and function made up of select chemical building blocks. Though its boundaries and definitional standards are up for debate¹, it seems to be a settled biological object. And more than that: the gene is understood to be an already-existing, ontologically independent object capable of *producing* physical difference. The gene has been positioned in biological study as having a primary role in creating familial, phenotypic, behavioral, and even racial or group difference (Gould 1981). This attribution of primacy in

¹ There are several definitions of the gene, each useful to scientific inquiry in different contexts. The most basic definition describes the gene as a “unit of heredity”—basically, some unit within a chromosome that ‘produces’ a phenotype. But what does this look like? How does one gene interact with others, and how do genes interface with their biochemical environs? What sort of space does it occupy, what are its components and boundaries? As investigations of the gene have continued, more questions and qualifications have emerged than answers. To some, in some contexts, a gene is more than the set of DNA nucleotides transcribed into RNA and subsequently translated into a protein. There are regulatory regions within the DNA that affect the access of transcriptional enzymes. Not all DNA is transcribed—and of all the transcribed DNA, not all is fed through the ribosome to create a protein. And what of RNA sequences that are also inherited. So depending on focus and subfield (for example, molecular biologist vs. population ecologist vs. evolutionary geneticist), different definitions may be used. The gene is an abstraction whose use and definition is tied to the methodology and background of the investigator (Hopkin 2009).

phenotype production I will call gene fetishism. It is a popular mode of conceptualization in many subfields of biology (Levins and Lewontin 2007).

There is no gene fetishism without an academic-industrial-medical sphere that clamors for it, technology to give it form, a history of biological reductionism to give it unique explanatory, productive, and diagnostic capacity, and the profusion of a ‘lay-subject’ whose social viability requires lineage to take the form of allele distribution and body to be a concatenation of gene products (Sunder Rajan 2006). That is to say, gene ontology is the same as gene practice. An understanding of the gene as autonomous and self-productive (and similarly, the particle and the cell) only makes sense within a neoliberal political economy that atomizes social relations and restricts social and economic activity to the individual. As in capitalist networks, the biological agent must fend for itself or risk being discarded in the great Malthusian calculus of burgeoning populations and finite resources (Levins and Lewontin 2007). This is the work of ideology.

To return to my prior question, the proliferation of an ecological, evolutionary, phenomenological, holistic, or apocalyptic view of the immune system would require the proliferation of social formations and discourses that produce, reflect, and mobilize that view. It’s not enough to try to brute-force a change in metaphor. It won’t stick. Alone, it won’t dismantle repressive state apparatus, open borders, correct the exploitation of labor (including coded-feminine unpaid labor), or overturn the drudgery and anxiety of hyperspecialization and efficiency maximization under neoliberal labor regimes (Bazzul 2012). The language and relations through which subjects act out, always contextually embedded, an imagined world-organization—thereby making it ‘real’ by creating, manipulating, and reacting to objects of knowledge—is not totally abstract, nor is it attributable to already-existing objects and processes.

Words need to materialize in meaningful ways, in ways that imply and conjure and implicate the words at the same time they seem to be ‘produced’ (Foucault 1976, 1978). Wholesale discursive change requires wholesale social change and vice versa, and the two are bound up inextricably in ideology.

I don’t think it’s constructive to stray too far into hypotheticals of a new society in this project, but I hope you get the idea.

What does it mean for biology to be a materialization of ideology? If we are to say biology is unavoidably ideological, inseparable from a greater subject-making ideological project or domain, what does that suggest about the place of science in culture? To phrase it slightly differently, adding a wrinkle: What does it mean that ideology in biological understandings is lent the authority of objective science?

I don’t think it’s fair to say that the ideology in natural science is *hidden*. You don’t have to look far to see that immunology leans heavily on war metaphors, policing and surveillance metaphors, border metaphors, productivist metaphors, allusions to gender categories, and a whole array of representations indebted to the world-as-conceived (Martin 1991). People recognize and identify the ideological analogs called upon to describe, say, a body contending with infection (Martin 1994). They even produce their own, often divergent imagery, and realize the incongruity between received and self-conceived imaginings (Strauss 2006). In this incongruity subjects feel tension resulting from their alienation from hegemonic forms. They are told it is one way, but they feel it is another. Yet in socializing and medicalizing interactions, it is expedient or even necessary to reproduce the hegemonic forms (Foucault 1976, 1978). In visits to the doctor, for example, the common language to describe viral infection and its response it induces is *invasion and removal*. An AIDS patient is told *your body is attacking itself* (Martin

1994). The same general set of tropes are useful for the biology student trying to obtain an undergraduate degree or a research professor at a public university trying to secure a grant.

But by internalizing and reproducing the hegemonic form, the same subject who was earlier disconnected from social power by offering a nonstandard conception may be disconnected or unsettled in their self-knowledge and self-positioning. This is what it means for biology to have authority over bodies—never ‘biology’ in the abstract, but biology as mobilized as a *correct* or *normative* form of knowledge and action in social settings (Foucault 1976, 2013). Biomedicine doesn’t just hold authority over the body in a material sense, as in checkups or medical procedures; it maintains the prerogative to define the internal and outward-facing functions of the body (and to distinguish internal from social or interactive functions in the first place). Biomedicine can define, explain, correct, and intervene—and that intervention is predicated on its privileged access to body-knowledge (Jaye et al 2006).

I should note that ‘biology’ or ‘biomedicine’ is not a single powerful institution that executes its authority from above. It’s clustered in institutions to be sure, but better understood as a variable and multivalent field that permeates social life (Foucault 1976, 1978). With this, we’re getting closer to a more concise understanding of the significance of language and concept-formation/conception in biology. My attention to reproduction is not accidental. The metaphor may not create the institution, nor the institution the metaphor, but everything is tied up (not the best term—even *amalgamated* or *fused* hint at former disunity and prior essence) in an imperfectly generalizable system of knowledge-theory-practice (Engles 1991). The form that is contextually legible and reproducible in other contexts therefore tends to be the one expressed, always attentive to relations of authority and hierarchy which hold the power to define what is legible and control the means of (re)production.

So ideology may not be hidden, but it is socially necessary, close to inescapable, because of its proliferation and its intimacy with power. It is charged with actionable, realizable meaning by the way it seeps through and makes up the material of subject- and knowledge-making. It is this saturation, and not just the attribution of objectivity to science, that gives ideology in biology its privileged explanatory power. Perceived objectivity has a role to play, but I'd argue that it's limited to a (shifting) discursive form that exists within a greater (shifting) ideological regime. It is ideology that provides us the language to speak about cells as if they had human properties, especially as if they had some sort of unlocated purposefulness (the abstract agency of an immune system's "defense and eradication strategy," for example), and it is also ideology that makes it seem normal to talk about cells that way. Objectivity convinces us the project of empirical science is a gradual unveiling of the natural order (Richardson 1984). But it needs help from current and historical iterations of colonialism, racism, patriarchy, militarism, cis-heterosexism, capitalism, liberalism, ableism, and other manifest-discursive forms to show us what we should be looking for in the natural order (Martin 1994). What the immunology textbook authors describe is not a reflection of ideology, it is ideology—and one face of many. There is no 'outside' for scientists to hold a mirror.

Now the guiding question I'll consider throughout my analysis of the text and in my conclusion: What are the political implications of ideology-in-action?

It helps to think of biology as a system of knowledge about the world. The definition of ideology I've been circling around is the imagined relationship or order of things in the world, where ontology says what those things are (the formation of categories) and epistemology says how we know what we know (the formation of knowledge) (Althusser 1970, 1971; Bhaskar 1979). Ideology tells us the things we know and the things we perceive through certain

meaningful *frameworks of knowing* must be common sense. It congeals what is contingent, capturing a thing-in-the-making and transferring to it the properties of a thing-already-made (Foucault 1976, 1978). Biology certainly fits this definition of ideology. And more than that, biology is part of a greater web of knowledge-making that has the authority to decide what *constitutes* knowledge in the first place. So as a field it is eminently political. From this point of departure it gets a little easier to see the sort of work biology does and the socio-political networks in which it's imbricated. Though it's always open to negotiation and contestation, this is the foundation with which I'm working.

~~~BACKGROUND AND METHODS~~~

The first glimmers of this project appeared in the spring of 2015. That semester, the back half of my sophomore year, I was taking a range of classes: Organic Chemistry, two biology courses (Evolution of Organisms and Animal Behavior), a Spanish class called Critiquing the American Dream, and an anthropology course on Marx taught by my eventual project advisor, Prof. Bill Fisher. At that time I had decided I wanted to complete a biology major. This was only my fourth semester of biology classes, and the first in which I'd had the chance to choose outside the required introductory courses.

One of the more unusual and pronounced feelings I was beginning to notice that semester was a significant, disorienting overlap between my ostensibly-dissimilar courses. When the professor in Animal Behavior talked about breeding hierarchies, why did it sound like she was describing the same forms of patriarchy we'd discussed in Critiquing the American Dream? When that same biology professor talked about ATP as the unit of energy in the cell—something to be saved, accrued, banked, and optimized—why did it sound like she was couching her terms straight from “Wage Labour and Capital?” Why was Richard Dawkins talking about cells in *The Selfish Gene* as if they were reasoning individuals in productive competition? And the idea of natural selection in my Evolution class, ‘survival of the fittest’—where did that fit in?

I took my questions to Prof. Fisher, who turned me on to the often-collaborative work of Dick Levins and Dick Lewontin, two Harvard biologists whose scope of interest expanded far outside biology's often-narrow disciplinary boundaries. Among other things, these authors were (Levins is now deceased) mathematicians, ecologists, Marxists, philosophers of science, and social activists. Two of their works, *The Dialectical Biologist* (1985) and *Biology Under the Influence* (2007), brought to bear on many of the questions that had been emerging about the

interplay between biology and society, especially biology and capitalism. I was beginning to see the field of biology as something other than a monolithic set of procedures that happen *over there*.

More than that, their work gave me a new way of thinking about academic inquiry, a perspective that hadn't been available in many of my departmental courses, particularly not in biology. Rather than see phenomena as the combined output of small, self-contained units, I was introduced to the Marxian-Hegelian framework of the dialectical whole. Levins and Lewontin disturbed the assumption (my assumption) that scientific investigation could uncover categorical essences—natural truths, in other words. Instead of understanding a phenomenon as fixed across time and space, this framework had me see it as variable and contingent, always taking place within some greater context from which it could not be separated. I took this perspective and began to apply it to my biology courses, but also found it applicable to the classes I took in other natural sciences, history, Hispanic Studies, anthropology, sociology, and Latin American Studies. I had a new way to encounter practical and theoretical material—and this method helped me see connections across fields that had before seemed tenuous or nonexistent.

The next spring, the spring of my junior year, I worked on an interdisciplinary project with Prof. Bill Fisher, a fellow student in the biology department, and several faculty of the Virginia Institute of Marine Science (VIMS). The project focused on the interplay between food, energy, and water security in island communities (the island of O'ahu and Tangier Island in the Chesapeake Bay were our two case studies), climate change, and the social histories and contexts of the islands. It seemed to me to be the perfect way to get involved in the kind of cross-field, natural-cultural work Levins and Lewontin so favored. And it was, despite the messiness and constant negotiation that kind of work, it turns out, entails. The marine biologists sometimes

wondered why we (I include myself in the ‘anthropological side’) would bring up the colonial histories of O’ahu or the ecological schema of the Tangier crabbers who were often resistant intervention by the Chesapeake Bay Foundation<sup>2</sup>. They asked, How is it relevant to the science? Frustrations aside—or perhaps due in part to these frustrations—I became more committed to the idea of cross-disciplinary work, especially work in which I could translate between my experiences in biology and the social sciences.

The summer of 2016, between my junior spring and my senior fall, I began reading under the guidance of Prof. Fisher in science studies and the philosophy of science. It was a departure in some ways from Levins and Lewontin, but these authors proved to be an indispensable foundation. I began with Bruno Latour and Donna Haraway, whose works, especially Latour’s *We Have Never Been Modern* (1991) and a collection of Haraway’s essays (2004), especially her “Modest\_Witness@Second\_Millennium,” illuminated for me how scientific work is non-neutral, is embedded in social practice, and is able to be conceptualized only through the terms and relationships we see at play around us. This was a really profound point for me. I was especially impacted by Latour’s call for an “anthropology of the modern world,” or an anthropology of a West that claims, through colonial practice and transcendent technology, to have broken from “the anthropological matrix” (Latour 1991). Adding to this was Haraway’s image of the monastic empiricist observers, the “self-invisible, transparent men” whose “naked way of writing” seemed to remove any trace of themselves from the raw data they accrued (Haraway 2004). Of course, this image is meant to be ironic; the only way this kind of man is possible is

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<sup>2</sup> For example, “Why won’t the crabbers cooperate with the bay conservationists? They’re on the same side...they both want to bring back more fish and crab to the bay.”

As it turns out, the generally Protestant Christian Tangier crabbers tend to view the bay as a complex system managed by God. The bay is subject to God’s intervention, and human intervention, even if well-intended, might disrupt God’s delicate, deliberate balance. Humans do not have a complete perspective, therefore any actions might have unintended consequences.

through triumphalist historiography ('we have transcended our context and our environment') and a gendered dialectic of male purity and female pollutedness. I began to question the idea of neutrality in science.

Next I read Roy Bhaskar's *The Possibility of Naturalism* (1979), which taught me that positivism isn't the only mode of doing and thinking about science, though it's been hegemonic for much of Western modernity. He points out that such a science tends to reduce contingent, multiscale, and complex realities to basic, generalizable patterns. Open systems are closed off in order to establish causality, and in order to generate the fixed objects of knowledge which science is then capable of naming, tracking, and characterizing—the process of 'discovery.' Scientific claims are normative, he argues; they describe standards to which reality should tend to adhere. And yet science as a 'field of knowledge,' a meeting-point of ontology and epistemology, "does not exist independently of the concepts in terms of which agents think their own existence." It is always "in the middle of things." Knowledge is made up of "historically specific social forms," and these knowledge-forms, in turn, influence the composition of social histories (ibid). Scientific categories are neither unchanging nor ahistorical. The objectivity of science is just another story, I realized, and a story that has immense implications in so many more arenas of life than the laboratory.

I now had a general idea about the connection between science and society but no specific context with which to flesh it out. For that I needed my biology department upper-level seminar, Stress and Immunity. I took the class in the fall of my senior year. I was initially drawn by the interdisciplinary potential of the name—Where could stress come from but outside the body?—but was disappointed that the course mostly dealt with the bodily biochemistry of stress reactions. Sure, sources of stress were mentioned, but always as some already-formed input, an

independent variable that could be grouped, controlled for, and manipulated, never as an integral part of the biology itself. One paper assigned to the class wondered whether certain conditions in the body's stress pathway might predict the development of PTSD in soldiers—but never once addressed the traumatic conditions of war that lead to PTSD in the first place (van Zuiden et al 2012). There is no place for antiwar activism in science, apparently, even in the science of PTSD.

But I didn't end up writing about the content of my immunology course, as I had initially proposed for this project. Instead, I circled back to the question of metaphor and science—the same question I had been thinking about when I opened up Levins and Lewontin. Reading through my immunology textbook for background on the seminar course, I realized much of what I had been thinking about was present in the language. The metaphors stuck out to me. There was surveillance, policing, military action, national borders, gender roles, labor and production, family structure, communication, and education. The textbook seemed to be describing a whole society inside the human body. And that struck me as significant. What does it mean that biological concepts are theorized and communicated this way? What kinds of relationship does it suggest between science and society? And what are the political consequences of understanding the body through these terms?

I won't be able to describe immunology without slipping into the same language I call into view—the language that can be recognized and acted on in ranging and iterable contexts. This shouldn't limit the potential of my critique. Rather, I think it upholds it. Positioned as I am at a particular corner of a particular culture at a particular moment in time, it would be disingenuous to speak as if I stood outside it all. Consider this a grounding. There is no

Archimedean platform from which to move the whole of ideology. That's ok—I'll work with what I've got.

What is immunology? It's a subfield of biology—the study of life, as it were—concerning the evolution, development, and functioning of the immune system<sup>3</sup> (Owen et al 2013). Immunology is sometimes described as the study of the body's response to disease and infection. But immunological work focuses on more than just periods of activity. It is concerned with the organs, cells, and chemicals of the immune system: their evolutionary history, their development within an organism, their means of communication and proliferation, and the many ways the system can go wrong. The language included here covers many different aspects of the immune system. Assuming no prior knowledge of immunology on the part of the reader, I will occasionally interject while moving through the examples to elaborate on the terms and concepts whose meaning the text doesn't make apparent. Rather than undermining the language of the text, I will try to build it up so that connections between immunological objects are more readily visible. This is essential. I want to illuminate the context with which I'm working and give backdrop to my conclusions.

All textual examples come from a single source, *Kuby Immunology, 7<sup>th</sup> edition*.

Understanding the limitations of a single source, I take the textbook to be an approximation of the language used to disseminate and especially teach concepts in immunology. I make a few assumptions: that *Kuby's* language is standard or widely reproduced; that it is the same or similar to the language used by practicing immunologists; and that it is the same or similar to the language reproduced by students, doctors, patients, and other subjects interacting with reference

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<sup>3</sup> A final note—the immune system is a culture-specific category brought about by technologies and histories of discourse and practice that brought/bring it into being, named/name it as an object, and altered/alter its boundaries and characterization.

to the common medium of ‘the immune system.’ This may not be true; *Kuby* may be an anomaly among immunological discourses. Based on my prior exposure, it is not. Yet it still has a descriptive and instructive purpose. It shows one way of envisioning and organizing the world. It exists within an ideology and is co-constitutive of relationships of power and authority. I will argue in more detail later that this ideology is hegemonic.

A caveat: my method of interacting with the text is selective. Having read through the entirety of *Kuby Immunology*, I pick examples that best support my interpretation. I cannot reproduce or distil the language of an 800-page textbook in any readable fashion. Some content will be included; most will necessarily be left out. I’ve knowingly and intentionally subjected the text to my manipulation. Parts have been elided or bolded to draw your attention to what I understand to be pertinent. I’ve tried to include only the most relevant examples in the body of the essay; other useful examples can be found in the appendix, organized by theme and section. I’ve divided examples into thematic groupings to facilitate elaboration and contextualization. You may find that examples fit together in other ways that I haven’t discussed, or form a different overall image than what comes to my mind. That’s ok. I hope my categories and analysis may be helpful in examining the place of biology as simultaneously productive and reflective of world-ordering schema.

I take methodological inspiration from Eric William Engles (1991), who investigates biopolitics through an analysis of discourse in textbooks and polemical works produced by biology educators in pre-World War II United States. Aiming to destabilize the common conception of scientific knowledge as value-neutral or as a materialization of truth, Engles positions biological language within greater historical trends such as

commodification, capital accumulation, the bureaucratization of society, the strengthening of professional and technocratic authority, the marginalization of people of color and women, and the privileging of heterosexuality and the nuclear family. The ontological assumptions, political orientations, and class-, race-, and gender-specific values embedded and hidden in the language and metaphors used to represent the living world were responsible for reproducing biology educators' worldview in classrooms and textbooks as objective depiction of the way things are.

The contextualization of discourse helps us comprehend its political implications, its social mobilizations, and its function as subject-calling ideological apparatus. My method is similarly envisioned but applies to a different context, the era contemporary to the writing and distribution of the text, *Kuby Immunology, 7<sup>th</sup> Edition* (Owen et al 2013).

Though many of the themes listed above by Engles remain relevant to my project, their resonances should be grounded historically. The term *neoliberalism* is useful in understanding the political, economic, social, and intellectual environment of this era. Drawing from David Harvey (2007), neoliberalism is the extension of capitalist free-market logic into all domains of life. Free exchange is more than an economic logic or idealization; it becomes an ethic (a set of guidelines) through which behavior, sociality, organization, and knowledge can be modeled. Under this regime, market relations are not so much overt ideological claims as common sense seeming to exist outside of time and space. Calculations of efficiency and optimization predominate, as do notions of individualism, competition, entrepreneurship, and private property. In practical terms, this has signaled trade liberalization, border enforcement, privatization and financialization, decline in union membership and a basic shift in the relationship between workers and owners, criminalization of non-normative behavior and organization (for example,

the criminalization of poverty), and the diminishment or privatization of government welfare programs (Spade 2015).

These themes—the guiding ethos of individualism and choice, the state of equilibrium and efficiency to be found in the free market, and the atomization of otherwise structurally positioned relations—will emerge in readings of the immunology text. The implications of the interpenetration of ideology and biology can't be overstated. As Engles (1991) comments,

we live in an age of bio-politics, in a world where power is practiced to an ever-increasing degree through biological means, where bodies, genetic codes, and other objects of biological knowledge become commodities and sites of contestation and struggle. In the late twentieth-century United States, dominant ways of knowing and speaking about the world—and therefore, of making it—have intimate connections with the centuries-long practice of biological inquiry in the West. Thus bio-politics characterizes both material practices and discourse. It is integral to power relations in our society that everyday discourses—behavioral, social, political, economic, sexual—draw heavily on a cultural inventory of manifestly biological ideas, assumptions, explanations, definitions, and narratives.

So it is imperative to locate and uncover the ideological nature of biological discourse. Pauly (1991) performs a similar task to Engles and will also serve as methodological guidance, though he discusses the teaching of biology in a different era, the early 20<sup>th</sup> century United States.

Throughout this investigation I serve as my own subject. My understandings of biological concepts—informed always by prior exposure to metaphor—color my interpretation of the text. I am neither an expert scientist nor a specialist in the field of immunology. I confront the textbook language at face value, with my background as an undergraduate major in biology helpful to clarify concepts and terminology. Though my understanding of biology is admittedly (and

necessarily) ideological, it gives me some traction when trudging through the sometimes-dense textbook language. My subject and my history is always a filter. I use my own points of reference to discern the referent and constructed potential of each metaphor and locate them in a greater ideological array. Though I believe they are not totally unique, all interactions with the text are my own. Finally, my understanding of ideology and its relationship to subject- and knowledge-formation is my own, open to critique and renegotiation. I aim to demonstrate and even to convince, but nothing in this study is settled, and no conclusion is final.

I see my role as the interface between two areas of inquiry and knowledge, biology and the social sciences. I hope I've made this point clear, but I should reiterate that neither field is pre-made and originally distinct; each must be kept separate by boundary-work. Latour calls this the "work of purification" (1991). My task is translation. I intend to dirty that purity. I want the biologist to understand the social science, the social scientist to understand the biology, and for all parties to appreciate the intractable wholeness of it all. Neither kind of work can be done without referencing the other. I've talked in detail about the necessity for biology to be positioned as a culture-specific practice; this implicates both natural and social scientists along with the greater region of social formations in which their work is framed. Tracking the formations, consequences, and historical development of ideology is crucial to any understanding of politics. It is especially critical for those who wish to change it.

~~~TREATMENT OF THE TEXT~~~

Section 1: Inside and Outside, Self and Other

As a principal categorical opposition in dialogue with other categories mentioned in this investigation, self and other is nearly ubiquitous. It forms the foundation of—or, in less structuralist terms, exists in assemblage with—key discourses in immunology and in wider circulations of ideology. It maintains boundaries between objects, reifying each as independent and suggesting something about the relationship between them. As a way of ordering the world it has far-reaching applications and implications. I'll discuss its mobilization in discourses of private property and use of space, nationality and foreignness, and defense against external (and internal) threats. It deserves special consideration here.

The immune system, explains *Kuby*, is founded on the discrimination of self from nonself. Cells and tissues bear markers of identity that allow the immune system to characterize and sort them, eventually discarding or expelling that which is nonself.

In order for [immune] strategy to work effectively, the immune system must somehow avoid accidentally recognizing and destroying host tissues. This principle, which relies on **self/nonself discrimination**, is called tolerance, another hallmark of the immune response (Owen et al 2013, 15).

Normal tolerance processes governing **self/nonself discrimination** and immune engagement caused by danger signals (partially the result of the trauma caused by surgical transplantation) lead to the **rapid influx of immune cells and coordinated attacks on the new resident cells** (22).

Pathogens come in many forms and must first **breach natural barriers** (11).

The most obvious components of innate immunity are the external barriers to microbial invasion: the epithelial layers that **insulate the body's interior from the pathogens of the exterior world**... Skin and other epithelia provide a kind of living **“plastic wrap” that encases and protects the inner domains of the body** from infection. But these anatomical barriers are more than just passive wrappers. They **contribute to physical and mechanical processes that help the body shed pathogens and also generate active chemical and biochemical defenses by synthesizing and deploying molecules**, including peptides and proteins, that have or induce antimicrobial activity (143).

There is an incommensurable gap between self and nonself. The two are set up not only as differentiable, but as completely antithetical. The essence of one repels the other. There is a boundary between them—a “natural barrier,” as the text has it (11). There is no chance of mixture, no interpenetration. They are categorical opposites. They come preformed as basic identities, markers which the immune system simply has to identify. In that sense, they pre-exist the working, complete immune system. Immunity becomes a question of unveiling, discovering, or registering essence, and subsequently acting on that knowledge. The basic functioning of the immune system is predicated on the ability to do so.

Antigens, substances that induce an immune response, are defined by the text as “particular foreign materials” (9). Not only does the immune system identify, it “[discriminates]” (15). It makes a value judgment based on revealed essence: the self is good and nonself is bad. The functional self should be set apart from the dysfunctional, treacherous foreign. Foreign material is an inherent threat. Never assimilable, it must be expelled. “[P]hysical and mechanical processes” must be devoted to the creation of “chemical and biochemical defenses” in order to maintain the integrity of the surface boundary. The boundary itself is common sense, a taken-for-

granted feature of an ontology where inside stands clearly apart from outside, and where self must vigilantly keep out other. Failure to distinguish the two, and failure to remove nonself, results in infiltration or self-destruction.

Simply stated, autoimmunity results from some **failure of the host's immune system to distinguish self from nonself, causing destruction** of self cells and organs... (517).

The genes within the MHC locus⁴ exhibit a codominant form of expression, meaning that both maternal and paternal gene products (from both haplotypes) are expressed at the same time and in the same cells... Because such an F1 generation expresses the MHC proteins of both parental strains on its cells, it is said to be histocompatible with both parental strains. This means offspring are able to accept grafts from either parental source, each of which expresses MHC alleles viewed as “self” (Figure 8-10b). However, neither of the inbred parental strains can accept a graft from its F1 offspring because half of the MHC molecules (those coming from the other parent) will be viewed as “**nonself,**” **or foreign,** and thus subject to **recognition and rejection by the immune system** (271).

[see Appendix 1.1 for more examples]

⁴ I'll turn to the textbook for help explaining MHC, transplantation, and histocompatibility.

As a result of recombination and other mechanisms for generating mutations, it is rare for any two unrelated individuals to have identical sets of HLA genes [the human leukocyte antigen complex is the region of DNA that encodes the MHC, the major histocompatibility complex]. This makes transplantation between individuals who are not identical twins quite challenging! To address this, clinicians begin by looking for family members who will be at least partially histocompatible with the patient, or they rely on donor databases to look for an MHC match. Even with partial matches, physicians still need to administer heavy doses of immunosuppressive drugs to inhibit the strong rejection responses that typically follow tissue transplantation due to differences in the MHC proteins (Owen et al 2013, 273).

Each parent passes an HLA allele to a child. The child then expresses a combination of these as the MHC, a set of proteins that can be found on the surface of all cells, but that is usually present just on specialized immune cells. The MHC binds other particles or protein complexes. If the bound particle is not the self-MHC, an immune response follows. This becomes relevant in the preceding examples for tissue grafts. A tissue with unlike MHC expression will be rejected by the immune system with inflammatory and particular responses. **The MHC is the site of self/nonself discrimination** (ibid).

The capacity to identify and react to nonself or nonfunctioning (unproductive) self cells is here tied to survival. And who is making that identification? In ideological terms, it is the bird's-eye authority, whose access to knowledge and disarticulation from the making of knowledge permits clean discovery and neutral judgment. The authority works within material-discursive systems that require reiterations of authoritativeness: not only from their end, but on the part of the other who recognizes authority: the recipient, civilian, patient, and criminal (Foucault 1976, 1978). Two principal subjects come from the interaction, the knower and the known. Only the authority has been “trained” to recognize the markers of self and nonself. They have specialized knowledge. They have the technology to recognize and deal with foreign invasion. The subject of inquiry/the known may have access to knowledge too, but they are restricted to acting in reference to power. They are directed towards the hegemonic form—the form that can be read by the authority and that the authority inscribes on the subject (not excluding self-description by the subject, internalization of the ideological form). Knowledgeable action—and actionable knowledge—develop in reference to authority.

When self-tolerance processes are working correctly, **host tissues should remain undisturbed** by the immune system and **only foreign invaders should be attacked** (Owen et al 2013, 517).

The **innate**⁵ immune system includes **anatomical barriers against infection**—both physical and chemical—as well as cellular responses (Overview Figure 5-1). The main

⁵ There will be many references to the *innate* and the *adaptive* immune systems. Quickly, the innate immune system is comprised of the skin, internal tract lining, and all immune cells that exhibit a standard, unchanging response to infection, including phagocytes and natural killer cells. The adaptive or acquired immune system molds its response to a particular pathogen and has the capacity to ‘remember’ pathogen identifiers. The acquired immune system is comprised mainly of lymphocytes: T cells and B cells. What we know generally as ‘white blood cells’ include cells of both innate and adaptive systems (Owen et al 2013).

physical barriers—the body’s first line of defense—are the epithelial layers of the skin and of the mucosal and glandular tissue surfaces connected to the body’s openings; these epithelial barriers prevent infection by **blocking pathogens from entering the body**. Chemical barriers at these surfaces include specialized soluble substances that possess antimicrobial activity as well as acid pH. Pathogens that **breach the physical and chemical barriers** due to damage to or direct infection of the epithelial cell layer **can survive in the extracellular spaces** (some bacteria, fungi, and parasites) **or they can infect cells** (viruses and some bacteria and parasites), **eventually replicating and possibly spreading to other parts of the body** (141).

[see Appendix 1.2]

The defense system, the ‘lines of defense,’ are a logical outgrowth of the domestic/foreign opposition. The self is situated at the center of two concentric circles of defense in the immunological imaginary, the innate and acquired systems. The self is protected and must be protected by these layers. It is vulnerable: touched by the nonself, it loses its sovereignty. So the border becomes an ideological necessity. It is both the mechanism and the product of distinction-making.

In discourses of knowledge, the absolute border is reiterated to the point of reification. It seems like a logical successor to the self/other ontology, or the process of category-making essential to the making and communication of knowledge. Perhaps it is not so much a successor as it is a political, symbolic, and bodily manifestation of that opposition. The border constantly refreshes the viability of the inside/outside distinction. Notice prescriptive claims made in the first example, from p. 517: “host tissues *should* remain undisturbed” and “only foreign invaders

should be attacked.” There are rules to be upheld, and these rules appear to emanate from a fundamental, categorical, and seemingly unbreachable partition in the order of things.

How does the body go about enforcing these ontological rules? First, a pathogen must never be allowed entry. The skin and inner epithelia deal mostly with that, but some invaders are more tenacious. The “fairly benign” are dealt with by the innate defenders (17, Appendix 1.2). Past the first layer, a hardy pathogen can begin to establish itself. Newcomers give rise to more pathogens, which in turn proliferate and spread. The proliferation of countersubjects and counterdiscourses is a great danger. It threatens to undermine the “pervasively naturalized social arrangements whose coherence is still assured and legitimized in law and common sense by reference to an... other” (Hennessy 2002). The body, therefore, must be “defended by biochemical means” (Owen et al 2013, 145, Appendix 1.2). And in the process of defense, the immune system must never lose sight of the color of the other’s uniform—invaders, never self tissues, are to be attacked. Constantly on alert for danger, constantly poised for quick response, the fortified body moves through a world of strangeness and instability.

What is the border to which the text refers, or the border the text (re-)creates? It is not just the border between nation-states, though this is one of the more visible contexts of its ideological action. The border is the ontological barrier embodied as real, natural, and prior, enforceable by law but also seeming to *produce* difference in social contexts and in biological conceptualizations. The border is the determinist theory of race, the intractability of gender and sex in the high school bathroom, the transplantation of human sexuality in the clash of rams, and the chasm of power between boss and worker, sovereign and subject, knower and known. The border is made concrete by never appearing to be a site of contestation—or a site for which ideology tells us contestation is nonsensical. It has no history, no development. It simply is.

Yet the border must be reinforced in more ways than one. Material and discursive work is needed to back it up and renew its relevance (and its reality). The militarization of the U.S.-Mexico border is inseparable from imaginings and practices of a heterosexual capitalist white ethnostate, but it is also ideologically covalent with bathroom laws, police brutality, and the unquestioned primacy in policy and social life of private property and profit motive (Spade 2015). The border is the reification of disputed or uncertain claims as hard truths, always through relations of power and authority. Those with power get to decide who stays and who goes. Crucially, markers by which discrimination is to take place are reproduced through ideology. To the subject, they may not seem unnatural. They may appear calcified, as ahistorical truths.

Don't be swayed by the simplicity of my argument, though. It is never just a dominant group imposing its vision on another. There is more going on than passive acceptance of hegemonic categories and relations (see Martin 1994 and Muñoz 1999 for examples of subversion and construction of alternatives). Still, power relations are crucial to understanding the reproduction of ideology. The unremarkable relations-classifications that come together as ideology show all classes that the contemporary divisions are good and just, moreover that they are ideals to be strived for (McRuer 2002). These divisions must be mobilized and reiterated in social organization, implicating all parties *as meaningful and intelligible subjects* (Althusser 1970, 1971). I aim to trouble and historicize the dominant ideology, and to introduce a whisper of doubt into the common sense.

Section 2: Attack, Defense, and Strategic Positionings

With a self and other tenuously in place, the strategic eye of discourses-methodologies turns to maintaining the dividing line. The other cannot be relied upon to stay in its place. It is jealous, relegated to the perilous outside. It wants in. Only through defense of the boundary-line can the inside be kept safe and the external harm confined to the space beyond. And the mechanisms of exclusion make a greater ideological point—they prove the irrevocable otherness of the outsider. The doing of expulsion cements the essentiality of the other's identity, establishing it as antithetical to self. Moreover, keeping the other out is made to seem imperative: the outsider is willing to resort to violence to gain ingress. The host has no choice but to put up its defenses. This process begins with simple denial, but as the pathogen gets closer to the self and center, the host's defense becomes more ruthless, specific, and organized.

White blood cells naturally express a variety of receptors, collectively referred to as pattern recognition receptors (PRRs), that specifically recognize these sugar residues, as well as other common foreign structures. When PRRs detect these chemical structures, a cascade of events **labels the target pathogen for destruction**. PRRs are proteins encoded in the genomic DNA and are always expressed by many different immune cells. These conserved, germline-encoded recognition molecules are thus **a first line of defense for the quick detection of many of the typical chemical identifiers carried by the most common invaders** (Owen et al 2013, 14).

This **highly effective** first line of defense **prevents most pathogens from taking hold, or eliminates infectious agents within hours of encounter**. The recognition elements **of the innate immune system are fast, some occurring within seconds of a barrier**

breach, but they are not very specific and are therefore unable to distinguish between small differences in foreign antigens (16).

Despite the strong defenses of our protective epithelial layers, **some pathogens have evolved strategies to penetrate these defenses**, and epithelia may be disrupted by wounds, abrasions, and insect bites that may transmit pathogens. Once pathogens penetrate through the epithelial barrier layers into the tissue spaces of the body, an array of cellular membrane receptors and soluble proteins that recognize microbial components **play the essential roles of detecting the pathogen and triggering effective defenses against it**. Phagocytic cells make up the **next line of defense against pathogens that have penetrated the epithelial cell barriers** (147).

[see Appendix 2.1]

Here we have a military front or a sort of enhanced border, primed and bristling to the coming waves of would-be infiltrators. It isn't enough to turn back pathogens; they have to be recognized and killed—or, as it's told euphemistically, eliminated. Response must be immediate, or as immediate as feasible. Once the barrier is under duress, the immune system must be alerted and the defense apparatus prepped. The language of battle is front and center, hardly even adorned—“lines of attack,” “destruction” of trespassing pathogens (“infectious agents” in their more nefarious guise), and unquestioned “killing” of “common invaders.” Alien particles are spotted by white blood cells, which tag the pathogens with a label for easy visibility to phages and other soldier-like eradicators. How do they know which to label? Pathogens carry “chemical identifiers,” uniforms or nametags that establish their antagonistic agenda, so the immune system is never mistaken in the execution of duty. Again, the notion of essential nonself identity allows

the immune system to simply make visible what is already latent in the bacterium or virus—its unequivocal outside-ness and its deservingness of retribution.

The language of warfare goes beyond general historical terms. It is specific to a moment in space and time, the current iteration of strategy and material in the U.S. techno-military industry. The “quick detection” of the germ is imperative. The book speaks of “clearance” and “killing” and “[hostility]” as an officer of the U.S. military might. As it so happens, the immune system comes equipped with the same technologies for detection and eradication as the modern military.

[Natural killer cells] are **efficient cell killers** and **attack a variety of abnormal cells**, including some tumor cells and some cells infected with virus. **They distinguish cells that should be killed from normal cells in a very clever way: by “recognizing” the absence of MHC class I, which is expressed by almost all normal cells**, but is specifically down-regulated by some tumors and in response to some viral infections (40).

A CTL⁶ can kill a target in two major ways: either via the directional release of granule contents or via a Fas-FasL membrane signaling interaction. Rather than inducing cell lysis, both of these processes induce the target cell to undergo apoptosis, typically within a few hours of contact with the cytotoxic cell. Regardless of which method is employed, **CTL killing involves a carefully orchestrated sequence of events that begins when the attacking cell binds to the target cell** (431).

⁶ CTL stands for cytotoxic T lymphocyte, a type of immune cell that deals with infected or abnormal cells, including cancer cells. Release of granules and Fas-FasL membrane interaction are two different ways for the CTL to bring about the unraveling of a target cell. Both involve cell-cell communication (Owen et al 2013)

Complement proteins **actively engage in host defense** against infection by **forming the MAC⁷**, by opsonizing potentially pathogenic microbes, and by inducing an inflammatory response that helps to guide leukocytes to the site of infection (204).

[see Appendix 2.2]

Trained and specialized, even “natural,” killers take on the task of eliminating danger. They do their job efficiently, able to take down a wide range of assailants in all sorts of ways. Their arsenal is diverse. Killing is hardly indiscriminate; it takes place through a “carefully orchestrated series of events” (431). The key to locating targets is always abnormality, or the absence of markers of the self. In this calculus, self is both normal and normative, observable through a series of symbols or identifiers while also the part to police the norm. Only the “recognition of self inhibits the ability to kill,” an inborn drive, as it were, in these soldier cells (438-9, Appendix 2.2). This collection of defense cells is not unlike the military, the national guard, border patrol, or even the police or national intelligence, the focus of the next section. The underlying ideology is as thoroughgoing as it is consistent. It declares that there is an opponent whose nature represents an existential threat to the workings of the self, value, community, host, or nation, and that opponent should be stamped out by any means possible. To the reader or citizen (as the reader is assumed to be marked, perhaps interpellated), this logic presents at face value. There seems to be no ideology, only a unifying common sense in the patriotic bravery of immune cells and the necessity of armed military action.

⁷ The complement system is a part of the innate immune system and functions as a sort of cascade, where one protein product becomes the next through a series of reactions. The **membrane attack complex** (MAC) sits at the end of the cascade and boosts the activity of other innate immune cells like macrophages by splitting open (lysing via osmosis) a target cell (ibid).

All the while, the germs are preparing their own strategy. Locked in an arms race against the defenses of the host, the invader must innovate or else become obsolete. It survives only through infiltration. The outside is unfriendly to reproduction. It does not provide the correct conditions. So the invader must enter to survive and replicate, just as the host must keep out the invading horde to guarantee its own safety. Invaders develop their own strategies, looking to circumvent or penetrate the body's layered barricades. Pathogens hide, camouflage themselves, lie latent in self cells, or overwhelm through proliferation, always trying to outwit the body in a timeless evolutionary contest. Here, capitalist notions of competition meet nativist or nationalist ideas of belonging. These histories, it should be noted, have never been distinct (Golash-Boza 2015).

Ideologically the pathogen is the other, the anti-ideal that must always be kept distinct to maintain the integrity of the category—and in keeping it distinct by updating its response mechanisms in real (evolutionary) time, the self renews its power. Because the opponent is constantly evolving, always coming up with new mechanisms to sneak into the body and proliferate, the defense system must be kept on the cutting edge.

Host-pathogen interactions are an **ongoing arms race**; pathogens evolve to express unique structures that avoid host detection, and the host germline-encoded recognition system co-evolves to match these new challenges... [P]athogens can evolve rapidly to evade host encoded recognition systems. If this were our only defense, the host immune response would quickly become obsolete thanks to these **real-time pathogen avoidance strategies** (14).

[J]ust as adaptive immunity in vertebrates has evolved over many millennia, **pathogens have evolved a variety of strategies to escape destruction** by the adaptive immune

response. Some pathogens reduce their own antigenicity either by growing within host cells, where they are **sequestered from immune attack**, or by shedding their membrane antigens. Other pathogen strategies include **camouflage** (expressing molecules with amino acid sequences similar to those of host cell membrane molecules or acquiring a covering of host membrane molecules); **suppressing the immune response** selectively or directing it toward a pathway that is ineffective at fighting the infection; and **continual variation in surface antigens** (555).

The importance of complement in host **defense** is clearly illustrated by the **number and variety of strategies that have evolved in microbes**, enabling them to **evade complement attack** (see Table 6-5). Gram-positive bacteria have developed thick cell walls and capsules that enable them to **shrug off the insertion of MAC complexes**, while others **escape into intracellular vacuoles to escape immune detection** (214).

[see Appendix 2.3]

Germ is clever, deceptive, and probing, willing to try out any new method to beat the immune system at its own game. They can camouflage themselves and perform mimicry; they can cloak themselves in native cells; they can shift surface antigens (shift identities) so that the host can never get a good look; and they can steal genetic parts from the host in order to conceal themselves or deflect the inevitable attack. The other is not trustworthy. Any slight gap or weakness in the immune wall is exploitable; any delay in response has the potential to be catastrophic for the host. Even self cells can be made to betray their identity, hijacked and converted into reproductive capital for the pathogen. Clearly the germ is no simple opponent.

Crucially, it is never enough for the invader to infiltrate. Its ultimate intent is propagation—in fact, the evolutionary goal of the invader is to spread, to occupy as much territory and as many bodies as possible. There is always an element of reproduction and propagation in the immunological discourse. In contrast to the self in (homeo)stasis, the other is always in motion, moving and multiplying.

A virus is **more likely to thrive if it does not kill its host**, as sustained coexistence in the host favors the survival and spread of the virus. However, the mutability of the viral genome sometimes gives rise to lethal variants that **do not conform to this state of equilibrium** with their host. If such mutants cause the early death of their host, **survival of the virus requires that it spread to new hosts rapidly** (555).

Despite their restricted genome size, a number of viruses encode proteins that interfere with innate and adaptive levels of host defense. Presumably, the advantage of such proteins is that they **enable viruses to replicate more effectively amid host antiviral defenses** (556).

Physiologically, **neutralization is the most effective mode of protection against infection**. However, **because microbes proliferate rapidly, they can generate genetic variants able to evade neutralizing antibodies** (416-7).

Once one host is taken over and its cells are converted the disease must spread, transcending boundaries and seizing new identities. The discourse of reproduction comes with a patina of fear (Foucault 1976, 1978). The other must never be allowed in, or if it is let in it must be contained. The inside is safe and must be maintained as such, but even inconspicuous-looking cells can be agents for the other side. They must be surveilled, regulated, and checked (more on

this in the next section). Most of all, the defense system that is the body's immune network has to keep on its toes, always updating and innovating to match the inefficient but wildly prolific ingenuity of the invader. As the next series of examples demonstrates, immunity is addressed in language inextricable from U.S. American narratives surrounding national safety. These ways of conceiving the immune system uphold investment in military technology, notions of competition and trans-historical or linear evolutionary progress, and ideas of effectiveness, potency, diversity, and flexibility co-formed in the business world of war (Martin 1994).

While **innate** immunity is the most **ancient form of defense**, found in all multicellular plants and animals, **adaptive** immunity is a much more recent **evolutionary invention**, having arisen in vertebrates... **a high degree of interaction and interdependence has arisen between the two systems**. Recognition by the innate immune system not only kicks off the adaptive immune response but also **helps to ensure that the type of adaptive response generated will be effective for the invading pathogen** (Owen et al 2013, 142-3).

The adaptive arm of the immune response evolves in **real time** in response to infection and adapts (thus the name) **to better recognize, eliminate, and remember the invading pathogen**. Adaptive responses involve a **complex and interconnected system of cells and chemical signals that come together to finish the job initiated during the innate immune response** (16).

The vertebrate immune system has evolved a **clever, albeit resource intensive, response** to this dilemma: to favor randomness in the design of some recognition molecules. **This strategy, called generation of diversity**, is employed only by developing B and T lymphocytes. The result is a group of B and T cells where each expresses many copies of

one unique recognition molecule, resulting in a population with the theoretical potential to respond to any antigen that may come along (14).

In such **“guided missile” therapies**, the **toxic agents are delivered specifically to tumor cells**. This ideally **focuses the toxic effects on the tumor and spares normal tissues**. Reagents known as immunotoxins have been constructed by coupling the inhibitor chain of a toxin (e.g., diphtheria toxin) to an antibody against a tumor-specific or tumor-associated antigen. In vitro studies have demonstrated that these **“magic bullets” can kill tumor cells without harming normal cells, although none have yet been licensed for clinical use** (645).

[see Appendix 2.4]

The immune system is capable of more than haphazard reaction. The descriptions show it to be organized, conscientious, and capable of both overarching strategy and quick decision-making. Just as the military and other institutions of social and bodily control are ideologically conceived, it is both consolidated and situationally adaptable. Facing a series of choices—and evolution is here conceived in terms of choice, the forward-looking selection of one path out of many possible—the body will devote its resources to security and self-preservation. Likewise, human military standoffs are legible as scaled-up enactments of this same relational system of strategy, sizing-up, and irreconcilable opposition.

In this ideological framework, biological evolution leads to enhanced and increasingly efficient protection just as historical terms are thought to precede North American military might. In fact, the naturally militarized, evolutionarily honed immune system seems to predate and confirm the U.S. military. In addition to building up might and strategic diversity, the

immune system develops the ability to tailor its response to the specifications of a particular enemy. It can remember past confrontations and react more decisively if the pathogen arrives again. In this model there are echoes of the Cold War, the advent and permeation of the military-industrial complex and financial capital (the emphasis on flexibility and real-time response comes straight from the boardroom), and the ever-protean War on Terror. The threat is all around, outside but even within the borders, auguring decomposition and chaos. Of course “‘guided missile’ therapies” and “magic bullets” are appropriate for the host body—Have you seen what it’s like out there?

Section 3: Policing and Surveillance

Never distinct from the landscape of intra- and interbody violence are images of observation, tracking, detainment, and control. Where there is disorder the body looks to reinstate the norm, and where card-carrying criminals go the body sends out trained, deputized agents to bring them to heel. In this discourse, there are elements of the self/other distinction, but in addition there is a classification of dysfunctional or unproductive subjects originating from *within* the self as not-fully-self or as undeserving of the coded-self's privileges and protections, meriting spatial sequestration and eventually removal. Hiding in plain sight, never too far past the surface of this logic are assertions about race, class, gender, and family structure. The violence of the body/violence against the body is set against standards of productive, social, and sexual behavior. Even more, it takes for granted that force is permissible and even natural in upholding that standard (Foucault 1976, 2013). This is a modulation of discourses of violence and militarism—rather, it comes together with the militaristic discourse to describe an entity or polity capable of managing its internal boundaries as it does its perimeter. These examples seem to point to a different, though related, set of ideological analogues.

In very general terms, the job of MHC class I molecules is to **collect and present antigens** that come from intracellular locations. This is a form of **ongoing surveillance of the internal happenings of the cell**—in essence, a **window for displaying** on the surface of the cell snippets of what is occurring inside. Basically, **all cells in the body need this form of check and balance**, and this shows up in the fairly ubiquitous nature of MHC class I expression in the body (there are a few notable exceptions, which we will touch on later). Often, nothing other than **normal cellular processes** are occurring in the cytosol, and in these instances our cells present self-peptides in the groove of MHC class

I molecules. The expression of self-MHC class I (with self peptides) signals that a cell is healthy; absence of self-MHC class I (as can occur in virus-infected and tumor cells) **targets that cell for killing by NK cells** (see Chapter 13). When **foreign proteins** are present in the cytosol and begin to appear in the groove of MHC class I on the cell surface, this alerts CD8 T cells to the presence of this **unwelcome visitor**, targeting the cell for destruction. In this case, the cell is called a target cell because it becomes a target for lysis by cytotoxic T cells. Conversely, MHC class II molecules primarily display peptides that have come from the extracellular spaces of the body. **Since this sampling of extracellular contents is not a form of policing that all cells need to perform, only specialized leukocytes possess this ability.** These cells are collectively referred to as antigen-presenting cells (APCs), because their job is to present extracellular antigen to T cells, **charging them with the ultimate job of coordinating the elimination of this extracellular invader** (Owen et al 2013, 278).

Normal tissues **maintain homeostasis through a tightly regulated process of cell proliferation balanced by cell death. An imbalance at either end of the scale encourages development of a cancerous state.** The genes involved in these homeostatic processes work by producing proteins that **either encourage or discourage cellular proliferation and survival** (630).

[see Appendix 3.1]

The inner processes of the body are subject to constant, panoptic survey. The text speaks of “surveillance” and “window[s]” that the unnamed authority uses to check in on “what is occurring inside,” to make sure all is running smoothly. Dysfunction or unproductiveness can be spotted and eliminated. Within the body everything can be made visible. Everything can be

watched, corrected, and regulated to match some designated equilibrium. The hypothetical state of this metaphor carries out, in a literary but discursively essential way, the prerogative to “make live” through recognition via categories and social formations and “let die” through exclusion, extirpation, and categorical erasure, all this in addition to the traditional capacity of the sovereign to “take life or let live” (Foucault 1976, 2013).

Most notable are the institutional context and special capacities of the agents that carry out the tasks of surveillance and removal. A group of licensed, “specialized leukocytes” has been shaped by evolution, by natural processes, to take charge of the “ultimate job of coordinating the elimination of [the] extracellular invader” (Owen et al 2013, 278) Make no mistake: this is a police force. The perpetrator is armed and unpredictable and requires a specialist to apprehend. Even if the target were not a violent offender, even if it were merely an ineffective unit, no other figure would be appropriate to maintain the “check[s] and balance[s]” of the biological and political body. No other association could be entrusted with the responsibility of identifying and apprehending miscreants. The whole body is under monitor; the “signs of invasion,” irregularity, and unprofitability are there to be interpreted. The cop is an evolutionary necessity—inevitability, even, a natural response to threats that refuse the call of externality.

One recent re-envisioning of how tolerance is operationally maintained is called the **danger hypothesis**. This hypothesis suggests that the immune system **constantly evaluates** each new encounter more for its **potential to be dangerous to the host than for whether it is self or not**. For instance, cell death can have many causes, including natural homeostatic processes, mechanical damage, or infection. The former is a normal part of the everyday biological events in the body, and only requires a cleanup response to remove debris. The latter two, however, come with **warning signs** that include the

release of intracellular contents, expression of cellular stress proteins, or pathogen-specific products (16).

Within minutes after antigen is injected, crawling T cells “**arrest**” and **form stable contacts** with DCs expressing the antigen (468).

Verbalizing what was implicit in the previous example, the p. 16 description of tolerance centers the image of evaluation. Decisions—made by whom?—are executed in a nonlocal, unspecifiable manner, always privileging the needs of the entity. That is, choices are made in relation to an ideological center—the body, the community, the nation. And by virtue of its centeredness, without need of other justification than the need to maintain categorical boundaries, that center has some force it can deploy, that it is always deploying, to retain its identity as center and its control over the whole. That institutional force can arrest and detain. Although self/other has been replaced as a basis of evaluation in favor of danger, there is still a naming of ‘host’ as the entity to be protected, and an implied ‘unwelcome visitor’ to be denied. Any danger is that which destabilizes the boundary. The body will know when it is under duress; it will naturally release “warning signs” alerting the proper authorities. The problem will be dealt with because the body is always on guard.

Two broad categories of monocytes have recently been identified. Inflammatory monocytes **enter tissues quickly in response to infection. Patrolling monocytes**, a smaller group of cells that crawl slowly along blood vessels, provide a reservoir for tissue-resident monocytes in the absence of infection, and may quell rather than initiate immune responses (35).

When acting as **sentinels** in the periphery, immature dendritic cells take on their cargo of antigen in three ways... Through a process of maturation, they shift from an **antigen-capturing phenotype** to one that is **specialized for presentation of antigen to T cells** (37).

Three cell types are known to have these characteristics and are thus often referred to as **professional** antigen-presenting cells (pAPCs): dendritic cells, macrophages, and B lymphocytes... APCs are **specialized for their ability to alert the immune system to the presence of an invader** and drive the activation of T cell responses (279).

The center does not execute its oversight centrally; it has a widespread network of trained agents to do that. The responsibilities of the office include patrolling, posting as sentinel, and capturing antigens among other criminal types. Its professionalization should not go unhighlighted. The organization of the biological body, same as the organization of the social body, has developed as *evolutionarily optimal* and even obligatory a subset of members whose job it is to keep others in line, and to make sure no subversives are allowed to slip in and undermine an otherwise smooth-running, ordered, productive system. The police officer and intelligence personnel, like the patrolling monocyte, are unquestioned quantities. The body has eyes everywhere, not just in specialized antigen-capturing cells.

[V]iruses frequently expose unique chemical structures only during their replication inside host cells. Many of these can be detected via intracellular receptors that bind exposed chemical moieties while still inside the host cell. This can trigger an immediate antiviral response in the infected cell that blocks further virus replication. At the same time, this initiates the **secretion of chemical warning signals** sent to nearby cells to help them **guard** against infection (**a neighborhood watch system!**). This early categorizing

happens via a **subtle tracking system** that allows the immune response to **make note of which recognition molecules were involved in the initial detection event and relay that information** to subsequent responding immune cells, **allowing the follow-up response to begin to focus attention on the likely type of assault underway** (14).

Being a self cell means a certain type of relationship with the ‘self’ (never specified or located, always an ideological conceit). There is a constant link between the individual cell (the metonymic self), all other self cells (the atomic selves), and the entity (the whole self). Individual cells come together to serve as a diffuse, all-encompassing warning system. Each self cell is also a watchdog for the whole-body self. This relationship is built into the constitution of the identity of self cells. When a cell is attacked, the network will receive information about the location and nature of the event. With this information the network can call in specialized cells to initiate a response and shut down infection. It doesn’t matter whether the attacked cell is equipped for defense; even civilians, as part of a “neighborhood watch system,” participate in maintaining the purity of the body.

The political echoes are here to suss out: a ‘neighborhood watch system’ presupposes private property; the existence of the neighborhood; the safety and necessity of conducting biological and social reproduction through the typically heterosexual nuclear family, and the need to protect the nuclear family through legislation, policing, and social and paramilitary enforcement; a middle-class environment that values order and comfort; and an unstated but nonetheless present whiteness that finds people of color, especially men but also trans- and gender-nonconforming persons, as basically suspicious and meriting expulsion or even bodily violence, or perhaps meriting an assumption on the part of the neighborhood resident that the possibility of such violence against the ‘trespasser’ is exceptional or unexpected.

Each somatic cell has a natural inclination towards ‘public safety.’ And in more than a general sense of the term: this vision of public safety is unmistakably indebted to white, suburban, and heterosexual values and lifeways. These types of subjects are the members of the watch system—and the subjects expected or even normatively constituted by the watch system—and these are the bodies the defense network is meant to protect. As complements to or continuations of the police force, they share the ‘self’ identity from which the guiding framework of exclusion and detainment are established. Analogies to the police carry over into discourses of lethal force—or rather, the unquestioned application of lethal force as means to an end as has been hegemonically constructed, though consistently resisted, in the United States.

For over a century, the controversy over whether and how the immune system participates in cancer **recognition** and **destruction** has raged... To date, there are three proposed mechanisms by which the immune system is thought to **control** cancer: • **By destroying viruses** that are known to transform cells • **By eliminating pathogens and reducing pro-tumor inflammation** • **By actively identifying and eliminating cancerous cells** This final mechanism, involving **tumor cell identification and eradication**, is termed **immunosurveillance**. It posits that the **immune system continually monitors for and destroys neoplastic cells** (638).

The text has described mechanisms for establishing and policing a norm, for surveillance, and for strategic adaptations against a clever external foe. Now it recounts the abiding fear of the self transfigured (or disfigured) into the other. Through touch and proliferation, the other can transform what had been familiar into something alien. This is reason enough for the self to act with deadly force. This is the argument of the prevailing supremacist ideology. An independent association within the entity must exist to watch over the self, uphold its boundaries, and support

its needs. Toward these ends no tactic is excepted. The body must be protected. The common-sense applications of this ideology in the life of the U.S. American state, as in the life of the body, are manifest from ICE raids to Ferguson.

Section 4: Education, Work, Life, and Development

What is the productive internal life that the immune/defense system is protecting? How does that system of protection develop—how are its members educated, trained, and selected? And more to the point, in what light does the textbook see the subjects of that system? What behaviors are they performing, what standards must they meet, and how is their activity construed in relation to the body and the political unit? I'll focus on the values that come to the fore when the text discusses the development and regulation of body-process components, especially efficiency, innovation, and complexity. This language adds scope and complexity to an ideology that has already demanded subordination to surveillance and police authority and complicity in internal and external identitarian violence. The subjectivities of members must answer in reference to this basically shared vision of world- and subject-ordering. This is how members are constituted and re-constituted. Variable and shifting, the dominant ideology is not identical to authority nor is it an invention of the subjects of that authority. It is a conversation about each and between each that, in the process, produces each, or a set of expectations about how each should be.

I'll begin by focusing on a set of analogies that, when pieced together, describes the development and selection of the labor force, the member cells of the immune system. Other themes will come up in this set of examples. I'll touch on some and leave others for later analysis or fleshing-out.

A common mode of depicting the development of T- and B-cells is through the analogy of education. Even the textbook acknowledges that the commonality of the trope in descriptions of the immune system. Still, it leans heavily on language that bundles together education, maturation, and aptitude: the language of the school system extended into the body, or tucked

into the body. It is only once a cell has gone through the necessary steps that it is ready to provide its service to the body and to become a functioning and productive member of a directed system.

Mature B cells and T cells are ready to encounter antigen, but they are **considered naïve until they do so. Contact with antigen** induces naïve lymphocytes to **proliferate** and **differentiate** into both effector cells and memory cells. Effector cells carry out specific functions to combat the pathogen, while the memory cells persist in the host, and upon rechallenge with the same antigen mediate a response that is both quicker and greater in magnitude (38).

B- and T-cells are immature before differentiation, unprepared for their function as defense and memory units. Not until after the event or process of antigen exposure can they be of any use to the body. So the body—the unspecified authority, the ideological object at the end of every productive or defensive maneuver—has a vested interest in reproducing its workforce despite the cost of doing so (or does so, apparently, in a way that limits cost).

T-cell development is a particularly expensive process for the host. An estimated **95% to 98% of all thymocytes do not mature**—most die by apoptosis⁸ within the thymus either because **they fail to make a productive TCR gene rearrangement or because they fail to interact with self MHC**. Some (2%–5%) die, also via apoptosis, because they are negatively selected (318).

⁸ Apoptosis is controlled ‘cell death’—as opposed to cellular necrosis—in which chemical signals induce a cascade of reactions culminating in the degradation of the cell (Owen et al 2013).

V_H gene recombination⁹ is **energetically expensive** to the organism, as not all developing B cells are successful in undergoing **productive** V_H gene rearrangements, and those that **fail to do so are lost** by apoptosis. It therefore **seems logical that those B cells that have achieved productive heavychain expression should be allowed to proliferate**. Each individual daughter cell derived from this proliferative process is then **free to participate** in a different light-chain rearrangement event (344).

[see Appendix 4.1]

From the beginning the education, training, and selection of the workforce is couched in terms of value-maximization and cost-minimization. This is a competitive capitalist order the textbook is portraying, and a neoliberal one at that (Pierce 2015). Unproductivity is excess, and excess is to be sloughed off. The side of production has the prerogative to negotiate the terms of development and to direct the participants of development, but it also has authority over their behavioral capacities and even their lives. Cells that fail to pass standards of productivity are induced to die. Their existence is does not merit further investment; they simply die. This is the harsh fate of most would-be T cells; B cells at least get a second chance to rearrange in a new, more productive way. In words that recall, perhaps incidentally, Adam Smith, the remaining cells are “free to participate” in novel and beneficial interactions. Here’s more on the nursing, education, and selection of T cells:

Immature T cells, known as thymocytes (thymus cells) because of their site of maturation, pass through defined **developmental stages** in specific thymic microenvironments as they **mature** into functional T cells. **The thymus is a specialized**

⁹ V_H gene recombination is a part of the B cell development process (ibid).

environment where immature T cells generate unique antigen receptors (T cell receptors, or TCRs) **and are then selected on the basis of their reactivity to self MHC-peptide complexes** expressed on the surface of thymic stromal cells. Those thymocytes whose T-cell receptors bind self MHC-peptide complexes with too high affinity are **induced to die** (negative selection), and those thymocytes that bind self MHC-peptides with an intermediate affinity undergo **positive selection, resulting in their survival, maturation, and migration** to the thymic medulla. **Most thymocytes do not navigate the journey through the thymus successfully**; in fact, it is estimated that **95% of thymocytes die in transit**. The majority of cells die because they have too low an affinity for the self-antigen MHC combinations that they encounter on the surface of thymic epithelial cells and fail to undergo positive selection (Owen et al 2013, 42-3).

Each of the several million T cells circulating in the body expresses a distinct T-cell receptor. The **generation of this diverse population, with its diverse receptor repertoire**, takes place in the thymus, an organ both **required for and dedicated to the development of T cells**. **Immature cells entering** the thymus from the bone marrow express no **mature** lymphocyte features and no antigen receptors; those leaving the thymus are mature T cells that are diverse in their receptor specificities, and are both tolerant to self and restricted to self-MHC... The **innovation has paid off** and, although our understanding is not comprehensive, we now have a fundamental appreciation of the remarkable strategies taken by the thymus, the **nursery of immature T cells** or thymocytes, to produce a functional, safe, and useful T-cell repertoire (299).

[see Appendix 4.2]

As it is represented, the development process is comprised of a series of steps or trials, each a sort of checkpoint to ensure the right type and quality of cell is being produced. Present here are hints of Taylorist production, assembly-line inspections and specialized tasks, and a modern-day educational system in the U.S. centered on testing and quantification of progress. From the moment of their inception cells are observed and checked for quality. Growth and maturity are associated with standards of output. There is a role to be filled at the end of a linear sequence, rather a branching sequence, where at each node different commitments can be made towards eventual service in a niche.

T-cell development is **elegantly organized, spatially and temporally**. Different stages of development take place in distinct microenvironments that provide membrane-bound and soluble **signals that regulate maturation**... During the time it takes cells to develop in the thymus (1 to 3 weeks), thymocytes **pass through a series of stages** defined by changes in their cell surface phenotype (301).

Notice in the textbook examples how T cell development is conceived in terms of cellular choice and central administration. All niches are eventually filled that the body needs to maintain itself, but it is the individual decisions of cells that place them there. In this formulation individuals retain the essential character of self-definition but still work for the good of the body. This discourse is simultaneously individualist, nationalist, and productivist, and organized through the social unit of “lineages,” nuclear families.

At the late DN2 stage¹⁰, T-cell precursors fully commit to the T-cell lineage and reduce expression of both c-kit and CD44. Cells in transition from the DN2 to DN3 (c-

¹⁰ DN2 is a step in T cell differentiation; TCRgamma, -delta, and -beta are macromolecular structures on cells that inform lineage commitment (Owen et al 2013).

kitCD44CD25) stages continue rearrangement of the TCRgamma, TCRdelta, and TCRbeta chains and make the first major **decision** in T-cell development: **whether to join** the TCRgammadelta or TCRalphabeta T-cell **lineage**. Those DN3 T cells that successfully rearrange their beta chain and therefore **commit** to the TCRalphabeta T-cell lineage lose expression of CD25, halt proliferation, and enter the final phase of their DN stage of development, DN4 (c-kitlow/CD44CD25), which mature directly into CD4CD8 DP thymocytes (302).

What determines whether a self-reactive thymocyte dies or differentiates into a TREG cell is still an open question. Investigators are currently trying to understand if the **choice** is made based on subtle **differences in affinity for self or on differences in their maturation state** when they receive a high-affinity signal. Recent work suggests that TREGs develop in a unique microenvironmental niche within the thymus, and that the available **space for developing cells in this niche is limited**. These findings suggest that thymocytes that commit to the regulatory T-cell lineage are likely to receive unique stimulatory signals. These **natural** TREGs share the periphery with **induced** TREGs that can develop from conventional mature T cells that are exposed to TGF- and IL-10 cytokines (317).

[see Appendix 4.3]

The choices cells make are constrained by the needs of the body and the immune system. The body is both the substrate and the patron of development. It provides the resources that stimulate growth and so cells are beholden to its agenda. Development is costly; someone must pay for it. The body *invests*. It is the shareholder; it gets to set priorities, apportion capital, and cut costs. This is the ideological portrait that immunology implores us to see in the patterns of T

cells, in the relation of T cells to the inner sociality of the body. Just like in systems of neoliberal education, where the purpose, as determined by the source of funding, of education is to make good citizens and supply work (these are not distinct ends), so functions the education of T cells.

What is the **adaptive value** of positive selection? Why didn't we evolve a system that negatively selects but leaves the T-cell receptor repertoire otherwise intact? Some have suggested that the **paring down of the repertoire is important to increasing the efficiency of negative selection**, as well as to **increasing the efficiency of peripheral T-cell responses**. Without positive selection, the **system would be cluttered with a great many cells that are unlikely to recognize anything**, and reduce the probability that a T cell will find "its" antigen in a reasonable period of time. This is a reasonable speculation; however, positive selection may also offer more subtle advantages that have often inspired discussion in the field (310).

In fact, many of the circulating T cells with specificity for self antigens may be such regulatory cells. Some scientists postulate a **division of labor**, with nTREG cells **specializing in regulating** responses against self antigen to inhibit autoimmune disease and iTREG cells **controlling reactions** against benign foreign antigens at mucosal surfaces, where the immune system comes in constant contact with the outside world (e.g., gut commensals or respiratory allergens) (521).

What is remarkable is the power of evolutionary and adaptive discourses to make historically-specific, politically contingent realities like efficiency, regulation, and division of labor seem value-neutral—and more than that, timeless and un-ideological. After a historical delay, our biology has finally found polished form in our social configurations: managed liberal capitalism, rational and efficient division of labor, police authority in the bordered nation-state.

In fact, this is the endpoint, the analogy suggests. We have reached the state of organization prescribed to us by nature (Jameson 1991). When examined deliberately there such evident interpenetration of descriptive language, but that is the ability of ideology—to camouflage itself as common sense, to evince the “of course” reaction in readers and investigators. With the appendage of scientific objectivity, the language becomes close to impenetrable. There is no point critiquing what is already true on the face of things.

Remarkably, **the majority of newly generated thymocytes do not successfully engage** the MHC/peptides they encounter with their TCRs. Either they have not generated a functional TCRalpha combination or the combination does not bind MHC/peptide complexes with sufficient affinity. These cells have “**failed**” **the positive selection test** and die by apoptosis within 3 to 4 days (307).

Thus, the MHC haplotype of the thymus in which T cells develop determines their MHC restriction. T cells “learned” which MHC haplotype they are restricted to during their early days in the thymus. **Although once we referred to this process as “T-cell education,” we now know that it is the consequence of a brutal selection process** (305).

[see Appendix 4.4]

Development is a crucible: not all make it through. Only the deserving manage to snatch up the few available positions. In such a world, competition, testing, and strict quality oversight are the best means of determining merit. These are the values and the trials that must be promoted. It’s a tough system; only the best-trained make it. And those that have established their position must be deserving. The immune system is a meritocracy. It must be, the text

suggests, in order to be sufficiently equipped to contend with the mercurial outside. Through analogy and characterization, the text pieces together images of a severe, thoroughgoing management regime, a hierarchy of worth. If the best have won their spot, the left-behind also had it coming. They failed to demonstrate value. Such is the flipside of meritocratic discourse. We see the same system of analogy at work in the text's description of B cell education and administration, or rather variations on a theme.

B-cell development begins in the bone marrow with the asymmetric division of an HSC and continues through a series of **progressively more differentiated** progenitor stages to the production of common lymphoid progenitors (CLPs), which can give rise to either B cells or T cells (see Overview Figure 10-1). **Progenitor** cells **destined** to become T cells migrate to the thymus where they complete their maturation (see Chapter 9); the majority of those that remain in the bone marrow become B cells. As differentiation proceeds, the developing B cell expresses on its cell surface a **precisely calibrated sequence** of cell-surface receptor and adhesion molecules. Some of the signals received from these receptors induce the differentiation of the developing B cell; others trigger its proliferation at **particular stages of development and yet others direct its movements** within the bone marrow environment. These signals collectively allow differentiation of the CLP through the early B-cell stages to form the immature B cell that leaves the marrow to complete its differentiation in the spleen. For the investigator, the expression of different cell surface molecules at each stage of B-cell maturation provides an invaluable experimental tool with which to recognize and isolate B cells poised **at discrete points in their development.** 330: In this chapter, we will follow B-cell

development from its **earliest stages in the primary lymphoid** organs to the generation of **fully mature** B cells in the **secondary lymphoid** tissues (329).

[see Appendix 4.5]

There are familiar elements here: maturation in the context of the nuclear family; the migration of labor to meet demand; the differentiation and specialization of labor; management or administration of market demands; and success or even survival as a result of supposedly fundamental Malthusian scarcity and struggle. Where characterizations of T cell education skewed towards individual choice, B cells seem more centrally supervised. They are directed where to go. Some cellular logistics or mechanism finds where they would be most useful and sends them there, ensuring first they have the appropriate skills. Though apparently contradicting the notion of personal/cellular self-determination, this discourse fits neatly as its ideological complement. They come together as dialectical opposites, their interplay emerging as a sort of contingent common sense. From the point of view of the individual, choice is evident; top-down, managerial intervention is visible. Ideology is not the resolution of these contradictions, but their tenuous, variable, and negotiated coexistence, even their coproduction.

It's worth stepping back to examine other contexts where 'biological' and 'social' descriptors seem curiously similar. I'll finish out my examination of the text by running through some other common thematic areas. Each of these develops the 'social' reach of immunological language and begins to show the basic and inextricable situatedness of scientific understandings. For one, there's the permeation of terms from business and commerce.

The **key to success** for such a widely dispersed organ system is the ability of its various components to **communicate quickly and efficiently** with one another, **so that the right**

cells can home to the appropriate locations and take the necessary measures to destroy invading pathogens (105).

Cytokine **synergy** occurs when the combined effect of two cytokines on cellular activity is greater than the additive effects of the individual cytokines (107).

This description of the **complex and sophisticated apparatus** by which Ig genes are created allows us to understand how such an immensely **diversified antibody repertoire** can be generated from a finite amount of genetic material... The rearrangement of Ig genes occurs in an **ordered** way, and begins with recombination at one of the two homologous chromosomes carrying the heavy-chain loci. The **production** of a complete heavy chain and its expression on the B-cell surface in concert with a surrogate light chain... and, thus, only one antibody heavy chain **is allowed** to complete the rearrangement process (239).

Diversification of cell antibody portfolios—efficient communication—unwasted movement and tight execution—technological complexity—order—production—synergy: we get insight into what it is to be a tight-run, cutting-edge corporation. The body is such a corporation, the text tells us. These are the features history has sharpened to a fine point. They take up a distinct perspective, a way of ordering object and subject relations. The world is filtered and made through an economic optic. It makes sense to view the body as a corporation because, like the corporation, the body has little room for mistakes or inefficiencies. Errors reduce productivity, and a lack of productivity undermines survival.

Here the text discusses the immune system performing regulation, or depicts sequences of events as being under some regime of regulation even if the mechanism goes unspecified.

While our B and T lymphocytes are the **key producers of adaptive response effector mechanisms**— antibodies and cell-mediated immunity—it is becoming increasingly clear that our innate immune system plays **important roles in helping to initiate and regulate adaptive immune responses** so that they will be **optimally effective** (173-4).

Immune **dysfunction** occurs as a result of **improper regulation** that allows the immune system to either attack something it shouldn't or fail to attack something it should (19).

[see Appendix 4.6]

Regulation is tied closely to production and productivity. The body cannot produce efficiently without oversight and intervention by some actor outside of the productive process. The body needs complexity to thrive internally and fight off invasion, but complexity tends to break down and move away from optimal efficiency. It needs something to hold it together. Processes tend to slip into excess or deficiency without regulation. It is therefore the natural duty of the manager or regulator to stand outside of the process and step in when they spot a problem. On another level of abstraction immune processes are shown balancing a testy equilibrium. They require guidance to stay on course.

The healthy immune response involves a balancing act between immune aggression and immune suppression pathways. While we rarely fail to consider **erroneous attacks** (autoimmunity) **or failures to engage** (immune deficiency) as dysfunctional, we sometimes forget to consider the significance of the suppressive side of the immune response. Imperfections in the inhibitory arm of the immune response, present as a **check to balance** all the immune attacks we constantly initiate, can be equally profound.

Healthy immune responses must therefore be viewed as a **delicate balance**, spending much of the time with one foot on the brakes and one on the gas (19).

As you have learned, the immune response uses **multiple strategies to reduce damage to self** by turning off responses when pathogen is cleared and avoiding reactions to self antigens. However, these **checks and balances can break down**, leading to immune-mediated reactions that are more detrimental than protective. Some immune-mediated disorders are caused by a failure of immune tolerance (485).

The health of the body relies on an unflagging and precise set of checks and balances. It's a middle-school-civics phrase, but here it's absolutely crucial to the body's survival in a precarious world. The centrist, populism-weary, liberal-democratic government is just like the human body. The body, in turn, operates in the same way as this government. And not just any government—the United States, at least as ideologically conceived. In order to function properly and avoid political deviation or catastrophe (here they are understood to be the same thing), the political and/or biological body must have mechanisms to return it to a universal, acceptable equilibrium. The same language that taught us how government works and how to be good citizens is back to educate us on the body. Metaphors are more than literary devices, apparatuses that help us visualize and comprehend; they also call into being certain types of subjects. That subject comes to understand their world through these terms—not precisely, as an imposition of uniform or identical ideological schema, but individually and situationally variable—because the terms make the world intelligible to this subject, and the subject intelligible to the world. At the risk of repeating myself, textbook language is a political positioning just as it is pedagogical.

Adding to this picture (hopefully each step is a new dimension, a wider manifestation of ideology) is the idea that specialized immune tasks require “licensing” prior to their execution.

Immune cells are positioned as professionals, and their jobs a part of a wider administrative network that keeps the body in working order.

Even newly formed NK cells have large granules in their cytoplasm, and it was **traditionally thought that NK cells were capable of killing from the moment they matured. It is now thought that most NK cells need to be licensed before they can use their cytotoxic machinery on any target** (even with the proper activating and inhibiting receptor signaling). Licensing of an NK cell is thought to occur via a first engagement of their inhibitory, MHC class I binding, receptors. This event can be considered **a way for the immune system to test an NK cell's ability to restrain its killing activity** and an **important strategy for maintaining tolerance to self in this cell subset**. Specifically, **licensing allows only those cells that have the capacity to be disarmed via inhibitory interactions to be armed. Once licensed, NK cells are thought to continually browse tissues and target cells via their multiple inhibiting and activating receptors**. Engagement of activating ligands on the surface of a tumor cell, virus-infected cell, or otherwise stressed cell signals NK cells to kill the target cell. If the NK cells' inhibitory receptors detect normal levels of MHC class I on potential target cells, these inhibitor signals override the activation signals. This would not only prevent the death of the target cell but would also abrogate NK-cell proliferation and cytokine (e.g., IFN- and TNF- production). The overall consequence of this strategy is to spare cells that express critical indicators of normal self, the MHC class I molecules, and **to kill cells that lack indicators of self and do not express normal levels of class I MHC** (441).

[see Appendix 4.7]

This fits well within the discourse of (cellular) professionalism and specialization, a notable feature of neoliberal labor transformations (Harvey 2007). Certain tasks are too delicate to let just any cell perform, so it is imperative that cells be licensed only after they pass checks of quality and proficiency. The example talks about licensing with respect to cells that induce the differentiation of T cells. A second example (Appendix 4.7) mentions licensing as a requirement for the operation of “killing machinery” by natural killer cells. Violence isn’t conducted merely between cells or subject; it requires the use of machinery designed for the task. Once trained, cells are adept users of technology. The need for licensing is directly proportional to the specificity and importance of the task. The police force must be professional, the workforce trained, and the specialists licensed. In an evolutionary struggle where technology must constantly be reevaluated and updated to outcompete a do-or-die enemy, defense personnel must keep on top of innovations, and must be constantly evaluated for their aptitude in performing sensitive tasks.

For innate and adaptive immunity to work together, these two systems must be able to **communicate** with one another... A subset of these soluble signals are called chemokines because they have chemotactic activity, meaning they can **recruit** specific cells to the site. In this way, cytokines, chemokines, and other soluble factors produced by immune cells **recruit or instruct** cells and soluble proteins important for eradication of the pathogen from within the infection site (Owen et al 2013, 17).

Communication, like regulation, is indispensable in holding together a complex network. The phrasing of this example brings to mind images of long email threads exchanged between department offices, team meetings, runners with messages in hand: the everyday features of a well-coordinated, many-armed corporation. The body or corporation is made up of specialists, all

organized under systems or departments. Each member has a duty to fulfill, but these duties must be overseen so that they meet and continue meeting the overall needs of the entity, and so that they may be useful feedback or addition to work elsewhere. This requires the existence of a managerial class. There must be spatial and temporal organization, always supervised and administered by an overseeing party. In the language of the immunology text, that managerial class is presumed as part of a great, interlocking system.

In the same way, recruitment and training is an irreplaceable part of corporate life. As addressed in the examples discussing licensing and education, immune cells need to have qualified for their jobs by passing stringent tests of education, and must subsequently be licensed or receive on-the-job training through instruction. Chemical signals seek out qualified, receptor-exhibiting cells and “recruit” them to perform some function. The cell or worker, prior to this inactive or unemployed, is ripped out of stasis or unproductivity to aid in some greater project. Before they had received the necessary education; now they wait for the call that will realize their utility. The employer or authority sets the standards of employment. The worker’s functionality depends on their being hired. The texts renders as natural—more than natural, built into the human body—basic capitalist relations between owner and worker. Besides communicating a world-structure that *is* and *should be*, this has basic and essential consequences in the formation of subjects.

Leukocytes change their pattern of expression of chemokine receptors over the course of an immune response, **first migrating to the secondary immune organs, in which they undergo differentiation to mature effector cells, and then moving out into the affected tissues to fight the infection**, responding to different chemokine gradients with

each movement. As we will learn in a later section, chemokines are also capable of instructing cells to alter their transcriptional programs (106).

Mature thymocytes, which express only CD4 or CD8 and are referred to as single positive (SP), leave the thymus as they entered: via the blood vessels of the corticomedullary junction. Maturation is finalized in the periphery, where these new T cells (**recent thymic emigrants**) explore antigens presented in secondary lymphoid tissue, including spleen and lymph nodes (48).

At various points in their development, progenitor and precursor B cells must interact with stromal cells secreting particular cytokines, and thus the developing B cells move in an **orderly progression from location to location** within the bone marrow (334).

[see Appendix 4.8]

Cells move where they are needed. The body negotiates demand; cells follow along. Such is the mobility of labor in the biological body. It travels along circuits of blood and lymph, picking up and moving without protest or difficulty. The parallel—more than a parallel, a co-configuration—to migration is evident. Movement is embedded in development and productivity. Cells must migrate as they progress from step to step; different physical locations and variable timing are the path they take to their eventual role. The productive organization of the immune network depends on calibrated, demand-oriented movement.

Although the presentation of MHC molecules complexed with foreign antigen to T cells garners much attention (and space in this book!), most MHC molecules **spend their lives** presenting other things, and often to other cells (278).

We start the chapter with a general summary of the **behavior of innate and adaptive cells** before an immune response. We then follow the central themes of the previous chapters by first examining the **behavior** of innate immune cells after the introduction of an antigen and then by examining the **behavior** of the main cell types that regulate the adaptive immune system. We focus primarily on the **behavior** of the immune response in lymph nodes, the secondary lymphoid organ that has been most accessible to dynamic imaging techniques. Finally, we close with recent examples of immune cell **behavior** during the response to physiological antigen (pathogen and alloantigen) in vivo (454-5).

It is now known that T cells and DCs can **form stable interactions** quickly; transient interactions are not common to all responses. Rather, it appears as if the kinetics of early encounters differs depending on the quality, quantity, and availability of antigen as well as the activation state of a DC. Nonetheless, in order to proliferate and differentiate optimally, CD4 T cells **must ultimately become involved in committed, long-term relationships** (8 hours or more) with a DC (468).

Where before cells were mostly invoked in vaguely impersonal ways, undertaking tasks as a class or as a type, here they are given distinction as individuals. They are more fully anthropomorphized, having lives and behaviors and relationships. The immune cell has been a soldier, an officer, a worker, a citizen, and a subject. Now it is a being whose existence is marked by social engagement. How does the text describe the cell's relationships? How are cells organized?

Under conditions where the immune system is not being challenged by a pathogen (steady state or homeostatic conditions), most HSCs [hematopoietic stem cells] are quiescent. A small number divide, generating **daughter cells**. Some daughter cells retain

the stem-cell characteristics of the **mother cell**—that is, they remain **self-renewing** and able to give rise to all blood cell types. Other daughter cells differentiate into **progenitor cells** that lose their self-renewal capacity and become **progressively more committed to a particular blood cell lineage**. As an organism **ages**, the number of HSCs decreases, demonstrating that there are limits to an HSC's self-renewal potential (28).

Only the categories of contemporary sociality are useful in giving us a meaningful description of the propagation and differentiation of cells. So we end up with a gendered comprehension: reproduction is a female task done by lines of mothers and daughters (Martin 1987). The progenitor cell, unlike the daughter cell in that it has lost its “self-renewal capacity” (females are endlessly fertile, we are led to believe) and so is implicitly male, is more “committed to a particular blood cell lineage.” It is the head of that lineage. Females proliferate, males assume responsibility—this is the classic Western gendered family. Scaled to fit a microscopic genealogy, the nuclear family has found its way into the body.

Before we saw how it was made through ideological visions of bordering, subject-management and authority, policing, and military force. Though I've treated them as separate categories, they are hardly discrete. They coalesce under the umbrella of realized discourse, or imagined reality, a discourse that reaches backward and but is also fastened to the moment, a discourse that is made real. They are the many arms or branches of ideology, impossible to pin down precisely but, for our purposes, loosely generalizable. They share as a premise a set of assumptions, categories, and relations. My purpose here is to disentangle or demystify their involvement in understandings of body and immunity. They are culturally and historically embedded, not universal. They are not timeless truths unveiled to us by Western science and

technology. Ways of knowing and ways of organizing can never stand outside of the cultures that make and remake them.

This is my point—and it is not merely abstract or intellectual. The way knowledge is conceived and deployed is unavoidably political. The relations and formations that immunological language makes seem like common sense—these are politics. The language imagines subjects to be a certain way, exist in certain relations and hierarchies, and to engage in certain activities. Material-discursive formations (institutions of healthcare and education, family structure, modes of knowledge creation and transmission) are reified as natural not just because of their manifestation in biological truth-claims, but because of their appearance in the ‘social’ arena as ready-made, ahistorical features of humanity. Yet their appearance is totally political, the contingent and never fixed crystallization of a moment in geographically- and temporally-located human organization. Political struggle takes shape in the sphere labeled ‘politics,’ but to stop there is ineffectual as it is arbitrary. Politics shapes and implicates everything.

~~~CONCLUSION~~~

The images and representational devices that came out of my reading of *Kuby Immunology, 7<sup>th</sup> Edition* pointed to a coherent set of images: the body (always a human body, likely white, male, heterosexual, productive, and physically able) as a political unit (not just any polity, always the United States or modeled around the United States). There is a clear delineation of internal/domestic/known/peaceful/ordered and external/foreign/unknown/threatening/chaotic. That which goes on inside the body—inside the nation-state—is untroubled until invasion or infiltration. The body exists in homeostatic isolation, self-contained, self-sufficient, and self-perpetuating.

This is the ideal the immune system is meant to defend; it is also the ideal the subject is meant to approximate (Butler 1993, 2013). When barriers are breached, production is disrupted, units are hijacked, and an omnipresent surveillance network alerts the relevant centers to send out their troops. A professional class of killers and cops must be educated, trained, and primed to be deployed when the time comes. And above all, the whole defense system must be equipped with the latest innovations in the evolutionary arms race. Using cells and organs as their brace, the textbook authors ascribe ideological roles to new, microscopic subjects.

What does this mean for the body? The implicit human subject of the immunology text (the reader, perhaps, though these discourses propagate beyond classroom textbook readings) is made to see their body as a stage on which are acted out the very violences, fast and slow, to which the body is subjected as the price of personhood in the state and dominant political economy. The often-nonwhite subject of police violence is taught that latent within them are the same mechanisms through which they are made suspicious and less worthy—that make them

criminalizable and, at worst, disposable. The subject may be made to feel helpless or inadequate against such violence.

As they are made to see the same processes and violent, supremacist relationships playing out within them, seeming to hold biological primacy in their very composition, they may be alienated from their own body-processes, or powerless to define and control them (Martin 1994). A multi-sited network of power, hierarchical and clustered but also diffuse and hegemonic, recedes into the background, nearly beyond critique, as immune cells become militarized cops and the lymphatic system a surveillance apparatus. Resistance—to medicalization, to state power, to the prerogatives of capital—is not only foolhardy and dangerous but also goes against the body's *essential design* (Martin 1987). After all, isn't the body simply upholding the natural order?

The same discourse of and about the body, its status as a productive site, and its aggressive posture towards inefficiency, dysfunction, and its position relative to (and categorical separation from) 'the outside'—a discourse we can roughly delimit as immunology, a differentiated site of practice, knowledge production, and dissemination within biology—is part of the ideology that also speaks about bodies as implicitly raced, gendered, and classed subjects—that engage in relations of production and reproduction and perform the norms of that ideological social unit (Levins and Lewontin 2007). The connection is there for us to make. We are invited to see ourselves in the political milieu of T cells, B cells, macrophages, and natural killer cells (Williams 2006). We perceive ourselves as we act in complex and varied and occasionally unpredictable ways in relations of labor and socialization, as we are conceived ideologically. We fix in our stare a replica of society—but a society that was never there.

The society that the immune system supposedly mirrors was always an abstraction, or better, an idealization, never an objectively existing *thing* (Strauss 2006). Actionable, and producing real effects (like police violence, the nuclear household, and the swath of institutions producing knowledge about the immune system and intervening in bodies in coordination with a standardizing vision of the immune system), but never independent or prior. The immunological drama that plays out in the conversation between antibodies and antigens is a version of society as ideologically conceived. On one side cops, on the other criminals. Complexity is pared down. The story is reduced to tropes (Schulman 2012). The virus hijacks the machinery of an otherwise productive factory, some innocent somatic cell, co-opting it so that the virus can reproduce itself. Lymphocytes receive instructions from some unnamed command detailing their strategy of attack. An arms race rages—not only between bodies and bacteria, but between species with diverging interests across time and empty, depopulated space. In this history, the body is vulnerable to co-optation by forces antithetical to its functioning and its very identity. All this in the language of a textbook, upheld as natural and proliferating in real ways.

So the textbook can be said to play a normative function. Because of the cultural value attached to ‘nature’ and ‘natural,’ biological schema take on a congruent significance (Martin 1987). But ‘naturalizing’ doesn’t go quite far enough to explain its ideological potency. I want to pay special attention to discourses of evolution, particularly a vision of evolution in which natural selection and adaptation drive historical change. The histories of humans and natural organisms—separated by dint of ‘society’—coalesce into a series of lines on a chart. Evolution is mappable in Cartesian space. Some lines fall off; those that last to the present have reached that point by moving constantly upwards. By virtue of their presence, they must have had a positive trajectory, an unbroken and accomplished genealogy. If they are not already at some optimum,

then they on the path to perfectibility (Levins and Lewontin 1985). The society present in the nation-state, like the society present in the body, is understood to be the culmination of generations of evolutionary honing, but also to presently stand outside the process that brought it to that point. As Levins and Lewontin put it in their *Biology Under the Influence* (2007), “like modern bourgeois social thought, modern evolutionary thought denies history by assuming equilibrium.”

This strain of thought goes beyond neo-Darwinism. It is a logic: a unity of concept and value. Species survive and dominate because of ruthless and optimizing genetics; societies endure and expand for the same reasons. This kind of discourse is slightly different than naturalization. It functions within the same ideological drive, but it historicizes (rather, creates teleology, a history where each generation and process builds to the present). It reaches backward in time to explain—and most of all, pour value into—the present (Foucault 1976, 1978). *This is the way things were meant to be*, it says. It is a historiographical discourse couched as a biological one. If naturalization explains the way things are in relation to an imagined present, adaptationism creates an imagined past to explain the way relations and categories came about, and why their hegemony is both sensible and inescapable.

The implications of these various discourses extend beyond individual subjects. I want to place emphasis on the way ideology establishes the terms or constraints of relations between subjects. I should note that these subjects do not come pre-formed, but are shaped and re-shaped by their participation in relations at several levels of abstraction, including institutional, interpersonal, and internal interactions (again, these are neither solidified nor pre-formed categories) (Althusser 1970, 1971).

A theme that seems to hold constant throughout the text is the differentiation of self and other, where ‘self’ is understood to be bounded, autonomous, and singularly focused. Internal processes are driven to meet whole-organ benefit. This is true for bodies as much as nation-states. Outside, however, threats seem to materialize out of nowhere, having no know origin, causation, or catalyst. Once the self is separated, the undifferentiated outside looms gray and abnormal, worthy of perpetual suspicion for the potential it has to undermine what is *already* whole and stable. ‘Individualism’ mostly captures this idea, but in addition of envisioning society as an array of discrete persons, it goes beyond to suggest the individual is a microcosm of social organization (Levins and Lewontin 2007). Hegemony is latent within, it says. The discourse of individualism is rounded off. And importantly, the ontology of self and other that privileges the individual as a robust social and biological unit in ideological formulations of world-organization (and, therefore, in scientific inquiry) is made the business of T- and B-cells. The business of knowledge formation and proliferation is reduced in scale and tucked into bodies themselves (Martin 1994).

With the self now carrying, in an essentially embedded way, the knowledge and relational categories of the whole, the envelopment of epistemology is almost complete. Key to the miniaturization of knowledge-categories is the philosophy of reductionism. Reductionism suggests that a whole (‘the society’ or ‘the body’) can be broken into constitutive parts, each of which articulate in a mechanical and processional way to build the whole (Levins and Lewontin 1985). Nothing new is added in the process of articulation. The process of making the whole is merely additive. Therefore, each building block contains in part or miniature the basis of the whole. Formation is a question of essence rather than relation (Bhaskar 1979). You can see how this might apply to the discourses of immunology. We cannot ask question about immune cells

as agents with purpose and internally-contained quality without envisioning them as such in the first place (Bateson 1979). Immune cells are actors in an ideological landscape in the same way that individuals are imagined as basic, self-generating units in a social system. Each abstraction is made in invariably ideological terms.

The reductionist framework, part of the regime of Western scientific imagination-practice since the time of Descartes, says scientists are supposed to receive packets and pieces of the natural world; their only intervention is to assemble them into replicas of the natural order (Bhaskar 1979). Relationality and contextual variation are replaced with congealed and codified laws. The scientific method—*if...then* investigations of direction, correlation, and causality—tends to reject or mute multidirectional, multilevel, and looped effects (towards a dialectical totality), and demands a paring-down of scope and complexity (Levins and Lewontin 2007). Moreover, the *if...then* model is only really useful in a closed system—a system must be arbitrarily circumscribed in order for causality to be established—yet the world ‘out there’ is an open system and rejects simple causal relationships (Bhaskar 1979). This brand of positivist modeling through enclosure, which has a historical development and is manifest in sites ranging from biology departments to political discourse, pervades the hegemonic ideology. Ideology does more than give definition and meaningful quality to knowledge (‘knowledge is/approaches the whole’). It serves as the pathway to investigate and establish knowledge. Through the constitution of subjects, it provides the guidelines of action.

Let’s now call this whole ‘truth.’ I mean truth as it is conceived ideologically, as a realm of objects ‘out there’ whose nature awaits discovery and characterization. Truth is supposedly enclosed yet all-encompassing, accessible and transmissible through certain technologies (Latour 1991). The last part is crucial. A foundational tenet of Western empiricist/positivist knowledge-

creation is that 'our' episteme is capable of encapsulating and explaining 'the real' (even if it has not necessarily achieved this yet). Indivisible from the body of technology, theory, and practice is the assumption that there is a 'real' out there independent of our probing, which reaches to increasing depth as our technology and capacity for understanding grows (ibid). In this imaginary, 'the real' can be conceived a sphere with a defined perimeter. Inside of the sphere is reality; outside is the not-real, the superstitious, and the purely imagined (Bateson 1979). The sphere represents the material world, the world-as-is. There is another sphere, this one with negotiable and changing boundaries: this sphere is knowledge of the world, and its boundaries represent the limits of what is acceptable as knowledge.

In Western discursive history, technology and rational scientific procedure have pushed the knowledge-sphere out towards the fixed boundaries of the reality-sphere (Latour 1991). Our epistemology exists in relation to technology, matter, and procedure, assemblages of analog, digital, and discursive material. It has everything to do with the technoscience that allows discovery and progress, or that encourages the propagation of these narratives (Haraway 2004). These make up a field of practice but also a history replete with the values and meanings we repeat to ourselves and to each other—a history that has been reproduced well past the threshold of self-evidence. It patterns past slopes—we have come from there to here using these innovations and are better off for it—and extrapolates, extending them into the future (Layne 2000).

The cultural episteme allegedly approaches a one-to-one correlation with the array of all knowable data. Our knowledge edges closer to encapsulating and explaining all that is real. Our claims about the nature and the organization of the world take on the heft of truth (Bateson 1979). The internal and external situations in which those truth-claims are brought to bear

therefore seem to reflect (through their mobilization) and produce (by historical tendency toward a social architecture where truth can be located, echoed, valued, and possessed) an un-ideological cosmology, or at least a correct ideology (Althusser 1970, 1971). The narrative/practice that emerges from this attitude—I'll call it epistemic superiority or epistemic privilege—centers technological and institutional innovation and the *accumulation* of knowledge (Sunder Rajan 2006). Applied hegemonically, this epistemology, which also has a historical genealogy, is indistinguishable from the historical phenomenon of colonialism, and more inclusively the ideology of supremacism in which it is common sense that the knowledgeable authority has control over bodies, resources, social formations, and knowledge itself (Foucault 1976, 2013).

The continued enclosure of reality, as it is ideologically considered, is co-constitutive of the continued enclosure of material relations, bodies, landscapes, and forms of human organization and knowledge-making (Ahuja 2016). 'Enclosure' recalls capitalism primitive accumulation and colonialism in their various forms—this is no accident. These histories overlap significantly. Our Western epistemology is hegemonic in the way that it is bestowed, vis-à-vis material-discursive coercion, co-optation, and incorporation, the authority to evaluate the reality of other epistemologies (ibid). To return to the sphere analogy, *other* epistemologies of *other* cultures are thought to incompletely describe, partially overlap, or lie totally outside the sphere of reality (Latour 1991). Thus, the condemnation of brutes, rubes, and the chronically uncivilized (Layne 2000). This never excludes those within our territory, nor those within our social organizations and our regimes of knowledge creation and resource apportionment ('our' takes on a segregating tenor).

The neutrality of scientific practice and knowledge is a key discourse among many within a greater ideological project (Martin 1987). I'm not arguing that science is the sole substance of empire, but the way science is conceptualized and practiced is inextricable from the ideology of empire and the ideology of supremacy. Race and racism make up another key region of action in this process. It establishes a phenotypic basis of differentiation, creates a racial typology in access to knowledge, and guides social participation in power-saturated social relations (Blakey 1991). In assembly with sexuality, gender, and class exploitation, science and racism permit the subordination of bodies and relations within and outside their practical reach. This is as true for domestic technocracy as it is neocolonial charitable projects (Spade 2015). Lest these examples give you a false sense that this power is centralized and delimited, I maintain that it permeates all spaces: the classroom, the doctor's office, the nuclear household (Foucault 1976, 1978).

To clarify: the articulation of (totalizing) epistemology and colonialism (and a whole host of other processes) reinforces the notion that our access to reality is best and most correct, free of ideological skew, and enactable/enforceable in all corners of the world. And not just that our world-organization is enforceable, but that it must be enforced and proliferated. Immunology can't help slipping into politics because the way we understand it is political; its relationship to knowledge and truth-claims is political; and its historical and current deployments are political. As a shifting agglomeration of discourses-practices concerning the body, it is implicated in—and inextricable from—fields of social power.

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~~~APPENDIX~~~

Section 1: Inside and Outside, Self and Other

1.1

One unintended consequence of robust self-tolerance is that the immune system frequently ignores cancerous cells that arise in the body, **as long as these cells continue to express self structures that the immune system has been trained to ignore.**

Dysfunctional tolerance is at the root of most autoimmune diseases (Owen et al 2013, 16).

From an immunologic perspective, **cancer cells can be viewed as altered self cells that have escaped normal growth-regulating mechanisms** (627).

1.2

The capacity of skin and other epithelia to produce a wide variety of antimicrobial agents on an ongoing basis is important for controlling the microbial populations on these surfaces, as breaks in these physical barriers from wounds provide routes of infection that would be readily exploited by pathogenic microbes if not **defended by biochemical means** (145).

Adaptive immunity thus provides a second and more comprehensive **line of defense**, informed by the struggles undertaken by the innate system. It is worth noting that some infections are, in fact, eliminated by innate immune mechanisms alone, especially those that remain localized and involve very low numbers of **fairly benign foreign invaders** (17).

Section 2: Attack, Defense, and Strategic Positionings

2.1

[T]he innate immune system **is the first line of defense against infection**, and has **two roles**: (1) to initiate the **clearance or killing of pathogens** and (2) to **alert the adaptive immune system to the presence of pathogens** (464).

Granulocytes¹¹ are at the **front lines of attack** during an immune response and are considered part of the innate immune system (33).

With every meal, we ingest huge numbers of microorganisms, but they must run a **gauntlet of defenses** in the gastrointestinal tract that begins with the antimicrobial compounds in saliva and in the epithelia of the mouth and includes the **hostile mix of digestive enzymes and acid** found in the stomach (144).

2.2

NK cells are preprogrammed to respond immediately to appropriate stimuli, releasing from preformed secretory granules effector proteins that kill altered cells by inducing apoptosis. This mechanism of cell-mediated cytotoxicity is also carried out by cytotoxic T cells, which appear days later (168-9).

Because [natural killer] cells do not express antigen-specific receptors, the mechanism by which these cells recognize tumor or infected cells and distinguish them from normal body cells baffled immunologists for years. Klas Karre advanced an interesting

¹¹ Granulocytes are a type of white blood cell that includes several subtypes: neutrophils, eosinophils, basophils, and mast cells. They are distinguished from other white blood cells by the presence of granules in the cytoplasm, or the space within the cell membrane between organelles (Owen et al 2013).

hypothesis that formed the foundations for our understanding of how NK cells distinguish self from non (or altered) self. He proposed that **NK cells kill when they do not perceive the presence of normal self-proteins on a cell, the missing self model**. The implied corollary to the proposal is that **recognition of self inhibits the ability to kill...** The investigators “clinched” a role of MHC class I by transfecting the B-cell tumors with human MHC class I genes. NK cells were no longer able to kill the cells (438-9).

Here we focus on the effector cells and molecules of both the cell-mediated and the humoral (antibody-mediated) immune responses that **directly rid the organism of pathogens and abnormal cells**. These effector responses are arguably the most important manifestations of the immune response: they **protect the host from infection and rid the host of pathogens that have breached defenses** (415).

2.3

In the complex pathways that follow, we can gain a glimpse of the current state of what is actually an **ongoing evolutionary struggle on the part of host organisms to combat microbial infection**, while minimizing damage to their own cells (190).

Most bacteria, viruses, and fungi replicate at high rates and, through mutation, **may alter their components to avoid recognition or elimination by innate immune effector mechanisms**. Other pathogens have **evolved complex mechanisms that block normally effective innate clearance mechanisms**. A strategy employed especially by viruses is to **acquire genes from their hosts that have evolved and function as inhibitors of innate and inflammatory responses** (173).

A number of viruses **escape immune attack by constantly changing their surface antigens** (556-7).

One clear example of negative regulation of MHC comes from viruses that **interfere with MHC class I expression** and thus **avoid easy detection** by CD8 T cells (280).

In addition to generating complement regulatory proteins, it should be noted that **some viruses actively induce regulatory complement components within the cells that harbor them**. Other viruses **camouflage** themselves during budding from the host cell by hiding within regions of the host membrane on which regulatory complement components are expressed. And finally, some viruses **mimic** eukaryotic membranes... (215).

[S]ome viruses have developed **strategies to exploit cytokine activity**... [S]ome pathogens have evolved ways in which to **circumvent cytokine responses, by mimicking molecules and pathways used by the host** (134).

2.4

Present in both invertebrates and vertebrates, complement straddles both the innate and adaptive immune systems, indicating that it is **ancient and important** (150).

[T]he immune response quickly becomes **tailored to suit the assault**... An **effective defense** relies heavily on **the nature of the invading pathogen offense**. The cells and molecules that become activated in a given immune response depend on the chemical structures present on the pathogen, whether it resides inside or outside of host cells, and the location of the response. This means that different chemical structures and microenvironmental **cues need to be detected and appropriately evaluated**, initiating

the most effective response strategy. The process of pathogen recognition involves an **interaction between the foreign organism and a recognition molecule** (or molecules) expressed by host cells (12).

[T]his limited number of MHC molecules must be able to present an enormous array of different antigenic peptides to T cells, permitting the immune system **to respond specifically to a wide variety of antigenic challenges** (263).

While our **B and T lymphocytes are the key producers of adaptive response effector mechanisms**—antibodies and cell-mediated immunity—it is becoming increasingly clear that our **innate immune system plays important roles in helping to initiate and regulate adaptive immune responses** so that they will be **optimally effective**. In addition, the **adaptive immune system has co-opted several mechanisms by which the innate immune system eliminates pathogens**, modifying them to enable antibodies to clear pathogens (173-4).

To be **optimally effective** in keeping us healthy, innate and inflammatory responses **should use their destructive mechanisms to eliminate pathogens and other harmful substances quickly and efficiently, without causing tissue damage or inhibiting the normal functioning of the body's systems** (169).

MHC molecules have **opted** for a combination of peptide binding promiscuity (discussed above) and the expression of several different MHC molecules on every cell (described below). Using this **clever combined strategy**, the **immune system has evolved a way of maximizing the chances** that many different regions, or epitopes, of an antigen will be **recognized** (267).

Adaptive immunity is slower partly because **fewer cells possess the perfect receptor for the job**: the antigen-specific, randomly generated receptors found on B and T cells. It is also slower because parts of the adaptive response rely on prior encounter and **“categorizing” of antigens** undertaken by innate processes... Although slow to act, once these B and T cells have been selected and have honed their **attack strategy**, they become **formidable opponents** that can typically resolve the infection (16).

The **diversity** generated by these new MHC molecules likely **increases the number of different antigenic peptides that can be presented and is therefore advantageous to the organism in fighting infection** (273).

This **evolutionary pressure to diversify** comes from the fact that both need to be able to **interact with antigen fragments they have never before seen**, or that may not yet have evolved... Thus, the generation of T- and B-cell receptors is **dynamic**, changing over time within an individual. By contrast, the MHC molecules expressed by an individual are fixed. However, promiscuity of antigen binding ensures that even “new” proteins are likely to contain some fragments that can associate with any given MHC molecule (274).

This results in many T and B cells specific for the antigen, with the latter releasing antibodies that can **attach to the intruder and direct its destruction**... **The adaptive response leaves behind memory T and B cells available for a future, secondary encounter** with this antigen (18).

Section 3: Policing and Surveillance

3.1

Dendritic cells perform the distinct functions of **antigen capture** in one location and antigen **presentation** in another. Outside lymph nodes, immature forms of these cells **monitor the body for signs of invasion by pathogens and capture intruding or foreign antigens**. They **process** these antigens, then **migrate** to lymph nodes, where they **present** the antigen to naïve T cells, initiating the adaptive immune response (37).

NK cells can **kill a cell that has stopped expressing MHC class I** on the surface, presumably because **this suggests that the cell is no longer healthy or has been altered by the presence of an intracellular invader** (279).

Section 4: Education, Work, Life, and Development

4.1

If the attempts at light-chain immunoglobulin gene rearrangement are **not successful, the nascent cell is eventually lost** at the immature B-cell (2nd) checkpoint... However, given the availability of four separate chromosomes on which to attempt rearrangement, and the opportunity for light-chain editing in the case of **unproductive** rearrangement, most pre-B cells that have successfully rearranged their heavy chains will progress to the formation of an immature B cell (344).

4.2

T-cell **development occurs in the thymus and begins with the arrival of small numbers of lymphoid precursors migrating from the bone marrow and blood into the thymus**, where they **proliferate, differentiate, and undergo selection processes** that result in the development of mature T cells (301).

4.3

Vertebrates generate two broad categories of T cells: those that express TCRalpha and beta receptor chains and those that express TCRgamma and delta receptor chains.

TCRalphabeta cells are the dominant participants in the adaptive immune response in secondary lymphoid organs; however, TCRgammadelta cells also play an important role, particularly in protecting our mucosal tissues from outside infection. Both types of cells are generated in the thymus, but how does a cell **make the decision** to become one or the other? To a large extent, the **choice** to become a gammadelta or alphabeta T cell is dictated by when and how fast the genes that code for each of the four receptor chains successfully rearrange (302).

As thymocytes are being screened on the basis of their TCR affinity for self-antigens, they are also being guided in their **lineage decisions**. Specifically, a positively selected doublepositive thymocyte must **decide whether to join** the CD8 cytotoxic T-cell lineage or the CD4 helper T-cell lineage. Lineage commitment requires changes in genomic organization and gene expression that result in (1) silencing of one coreceptor gene (CD4 or CD8) as well as (2) expression of genes associated with a specific lineage function (314).

4.4

520: Although our understanding of the precise molecular mechanisms mediating central tolerance in T and B cells is not complete, we do know that these cells undergo a **developmentally regulated event called negative selection**. This **results in the**

induction of death in some, but not all, cells that carry potentially autoreactive TCR or Ig receptors (520).

Normal tissues **maintain homeostasis through a tightly regulated process of cell proliferation balanced by cell death**. An **imbalance** at either end of the scale encourages development of a cancerous state (630).

4.5

Once the B cell expresses IgM on its membrane (mIgM), it is referred to as an **immature** B cell. This B cell is ready for export to the spleen, where it completes its **developmental program** (345).

Following the completion of their **maturation program** (see Chapter 10), B cells **migrate** to the lymphoid follicles (Figure 2-8). They are **directed** there by chemokine interactions between CXCL13, which is secreted by follicular dendritic cells (FDCs) and its receptor, CXCR5, which is expressed on B cells. It is important to recognize, however, that once mature B cells have reached the follicles, they do not just remain there; rather, **they recirculate through the blood and lymphatic systems** and back to the lymphoid follicles many times over the course of their existence. **B-cell survival in the follicle is dependent on access to the TNF-family member cytokine B-cell activation factor (BAFF)**, otherwise known as B lymphocyte survival factor (BLyS), which is secreted by the FDCs, as well as by many types of innate immune cells, such as neutrophils, macrophages, monocytes, and dendritic cells. Mature B cells **unable to secure a sufficient supply of BAFF die by apoptosis** (388).

4.6

The expression of a receptor on the surface of a B cell is the end result of a **complex and tightly regulated** series of events. First, the cell must ensure that the various gene recombination events culminate in **productive** rearrangements of both the heavy- and light-chain loci. Second, only one heavy-chain and one light-chain allele must be expressed in each B cell. Finally, the receptor must be **tested** to ensure it does not bind self antigens, in order to protect the host against the generation of an autoimmune response (242).

The MHC locus can respond to both positive and negative **regulatory pressures**. For instance, MHC class I **production** can be **disrupted or depressed** by some pathogens (279).

4.7

To help explain how **cross-presentation is regulated and tolerance is maintained**, scientists have proposed that DCs might first **need to be “licensed”** before they can crosspresent. The cell type postulated to supply this licensing role is activated CD4 T cells. The way this is believed to work is that, first, the classical exogenous pathway of antigen processing in DCs leads to presentation of antigen to CD T cells via class II, leading to activation of these cells (Figure 8-22a). These activated helper cells might then return the favor by inducing costimulatory molecules in the DC and by cytokine secretion (e.g., IL-2), supplying a **“second opinion”** that, respectively, **licenses the DC to present internalized antigens via MHC class I** and helps activate naïve CD8 T cells (Figure 8-22b). This **requirement for licensing** by a TH cell could **help avoid accidental induction** of CTLs to nonpathogenic antigens or self-proteins. If this is the case, any **unlicensed** DCs that cross-present antigens may serve the opposite and equally important

purpose. Since they have not received the go-ahead from the TH cell to activate CTL responses, they may instead induce tolerance in the CD8 T cells they encounter, helping to dampen reactivity to these antigens (292).

4.8

Recent data show that B cells that have successfully engaged and processed antigen **change their migration patterns** and move to the T-cell-rich paracortex, where they increase their chances of encountering an activated CD4 TH cell that will recognize the MHC-antigen complex they present (51).

Most skin lymphocytes appear to be either previously activated cells or memory cells, many of **which traffic to and from local, draining lymph nodes that coordinate the responses to pathogens that have breached the skin barrier** (57).

Furthermore, since the bone marrow appears relatively late in development, the **whole process of blood-cell generation must shift location several times before moving into its final home** (330-1).