Ghost in the Machine: A Genealogy of Phantom-Prosthetic Relations

by

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Ghost in the Machine: A Genealogy of Phantom-Prosthetic Relations

Cassandra S. Crawford

Situated at the intersection of science and technology studies (STS), medical sociology and the sociology of the body, this work is a genealogical analysis of phantom-prosthetic relations or the historically multifarious and dynamic relations between dismemberment and prosthetization understood through psychological, medical and biomedical constructions of phantom limb syndrome. I trace the major shifts in knowledges and discourses about phantom limb etiology, nosology, and epidemiology from the late-1800s through 2005 revealing how this amorphous, ethereal object became material or socially substantive over the 20th century.

I further situate psychological and (bio)medical constructions of phantom limb in the larger socio-cultural and historical context of the modernization of dismemberment, including: the establishment of synchronic practices and principles between amputation surgery and prosthetic science; the state-sponsored rapid coalescence and professionalization of the field of prosthetic science; the elaboration and sophistication of prosthetic technologies and techniques; the institutionalization of post-surgical rehabilitation including pain treatment; and the use of visualizing technologies to situate phantom limb in the brains of amputee.

One of the central concerns of the dissertation is historical changes in *corporeal ideology* or those ideas, knowledges, institutions and practices that make up what is taken for granted about the body, its use, its capacities, its "nature." I explore the implications of corporeal ideology for governing and disciplining partial-ized bodies and spectral parts. However, I also demonstrate how phantoms have also functioned as a window into *corporeal resistance*. I detail the ways in which phantoms have resisted attempts at biomedical domestication, as well as how they have been the force behind many transmutations within the field of phantom research, within bodies, and between bodies and technologies.

Data included ten months of observation at a San Francisco bay area orthotic and prosthetic clinic, observation at an annual Amputee Coalition of America conference, eight in-depth semi-structured interviews with key researchers and practitioners in the field, and an interpretive content analysis of 439 articles published in the medical literature from 1930 to 2005.

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1 INTRODUCING PHANTOM-PROSTHETIC RELATIONS

The conference was seemingly like all others. A literal swarm of us had taken over the lobby and many of the rooms in the Fairmont Dallas in the middle of August. We were all signing in, collecting, meeting, orienting --- all of those registration-day musts. I was given a "first-timer" sticker. But, unlike other first-timers, I was one of a very few at the conference who was not an amputee. The 2005 Amputee Coalition of America's Annual Education Conference and Exposition was officially devoted to changing direction, to the technology, prevention, information, and support needed to make that happen. However, another theme was more conspicuous. I found it in the sessions, the workshops, the informal gatherings, and most prominently in the exhibit hall where attendees spent the majority of their time watching presentation, having their gait analyzed by prosthetists other than their own, collecting swag and mingling. Prosthetization, it seemed, was tantamount to rebirth.

The conference schedule included two days of technology sessions with presentation on issues such as "phantom pain reduction", "cutting-edge advances that will change the way you live and work" or "choosing a microprocessor knee"; workshops on issues such as fitness and state advocacy; networking rooms; panels addressing issues such as psychological health and finding community resources; a gait analysis clinic; and the very large exhibit hall that included hundreds of exhibited products, as well as exhibitor product-theater presentations such as Freedom Innovation's "Join the Revolution" or College Park Industries' "Maximizing Yourablity."

Figure 1. Photo of Sarah Reinertsen at the 2005 annual Amputee Coalition of America Conference.

Manufacturers of prostheses and prosthetic paraphernalia were all vying for our attention. Össur, whose slogan is "life without limitations" had world-class amputee athlete, Sarah Reinertsen, center stage. She and her biking-leg were a seamless extension of the stationary show-bike that she literally rode for hours on end. Sarah was a principle member of Team Össur whose mission was public awareness; the team's message was "with the help of modern technology, amputees can lead the kind of lives they want, achieving things that were almost unimaginable in previous generations" (2005). Össur's prosthetic line included the Mauch® a hydraulic knee which presumably transforms the user into a force to be reckoned with. Freedom Innovations showcased the Revolution Series ™ including the Renegade,[1] which apparently enables its wearer to reject tradition and break away from the pack (FI 2005). Freedom Innovations also offered attendees the

[1] The series also includes the Runway which encourages female amputees to "exercise your freedom of style" with its adjustable heel-height for fashion shoes (FI 2005).

chance to meet Chad Crittenden, the only amputee to ever appear on the TV show *Survivor*.

They made photo opportunities available with Chad,[2] but more importantly, they offered freedom - the kind of freedom that allowed Chad to survive in Vanuatu, freedom from a partial-ized body. "Technology for the human race" was the College Park Industries' slogan; they presented, among others, their Venture ™ is a prosthetic foot that promises transition with ease. The pain, the performativity, the abandonment and adoption of embodied technique, the many problems associated with bio-technological seaming were each and all hidden behind shiny and beautiful prostheses, slogans, and sales people.

These manufacturers, and some forty others, inundated attendees with messages of technologic transcendence. Prosthetization is about rebirth. In fact, the state of the science was touted as remarkable, amazing, extraordinary, cutting-edge, futuristic and we were all identified as potential beneficiaries; we were invited to "join the revolution." It is the discourse of the transformative nature/power of prostheses – conspicuously present at the conference, heard in the orthotic and prosthetic clinic where I observed, read in the prosthetic science and medical journals, uttered by practitioners and researchers, found in the technophilic (or at least, techno-friendly) arguments of academics and journalists. It is this discourse that has animated my work.

I could not help but ask: exactly *how* and in *what ways* does prosthetization transform bodies, especially those bodies that prostheses are intended for, those who have been

[2] I love to show off my photo of us.

accidentally or surgically partial-ized? Although selves, identities and populations are assuredly "transformed" by prosthetic innovation and elaboration in myriad and complex ways, my particular interest lies in the implications of prosthetization for embodiment. And although I appreciate the productive potential of using the narratives of prosthetized-amputees or prosthetists as a point of entry, I chose rather, to map out embodied part-replacement through what is know as the "disease of part-loss," phantom limb syndrome. In other words, my project is a genealogy (Bouchard 1977)[3] of what I call phantom-prosthetic relations that traces the historically multifarious and ever-evolving relationship between dismemberment and prosthetization through phantom limb syndrome.

Official biomedical constructions of disease communicate as much about what is normative, what is "natural" or what is moral, as they do about what has "gone terribly wrong"; these constructions communicate/establish what we "know" about bodies, their capacities, their potentialities, their weaknesses. The experience of phantom limb syndrome is (at least partly) an outcome of the organization of medical knowledge about amputation, and the scientific knowledge about how prosthetization can transform dismemberment. Thus, my works seeks not to explore the idiosyncratic ways in which bodies of various stripes "do" prosthetization, but rather, to explore the biomedical discourse about how prosthetization is to be "done."

[3] Hewitt (1983:227) describes a genealogical project as one in which "the process of discursive formation is traced to produce a fuller understanding of presently constituted knowledge, a history of the present, and of its deployment as an instrument of power to promote authoritative pronouncements and mask criticism." And as Lash (1984) argues, "Genealogy patently, all are agreed, concerns knowledge; it concerns power; it concerns probably above all the body."

Phantom limb syndrome is the experience of continued sensation of/in an amputated or deafferentated[4] part of the body, including both painful and non-painful sensations. Ostensibly in specific reference to limbs, phantoms have been documented in cases of the loss of a tongue, teeth, face, nose, ear, penis, testicles, breast, eyes, as well as bladder, rectum, stomach, uterus, and others (see *Appendix C: Phantom Parts*).

Embodying Dismemberment: *Body Curious.*

Scholars have been unable to resist asking why, over the last two or three decades, the body has proliferated as an explicit object (as well as site) of intellectual inquiry.[5] Many structural and ideological drifts have been credited as causally contributing to the "body craze" (Davis 1997), including: 1) the defacement of the Cartesian mechanistic body (in at least some circles) and the erosion of durable binaries;[6] 2) feminist engagements with the issue of embodied difference (Shilling 2005; Turner 1991);[7] the emergence of bio-

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[4] Deafferentation: "A Loss of the sensory input from a portion of the body, usually caused by interruption of the peripheral fibers" (Stedman 2000).

[5] Little agreement exists as to the degree to which sociology had been "interested" in the body prior to the contemporary "body craze" (Davis 1997). Turner (1991: 7) characterizes sociology's disregard as rooted in four tendencies: 1) analytical interest in industrial capitalism; 2) employment of an economic framework manifesting in a "preoccupation with matters of utility, commodities and equilibrium"; 3) hostility toward Darwinism; 4) and a preoccupation with historicity. Conversely, Williams and Bendelow (1989) suggest that it is sociology's interest in rational economic action, as opposed to ontological concerns, that resulted in, not an absence of the body, but an "implied presence." Similarly, Shilling (2003:10) argues that the body was always an "absent presence" in the work of Marx, Weber and Durkheim.

[6] Western conceptual separation of the mind and body, reason and embodiment is typically associated with the work of Rene Descartes. He postulated that being was composed of two distinct substances, and suggested that the calculable body was the proper subject of science, while the mind, devoid of measurable substance, was the domain of theology. He envisioned mental and physical processes interfacing in the penal gland, where the rational mind could overcome faulty senses and emotion (Tarnas 1991; Welton 1999). As Grosz (1994b:7) argues, the implications of the dominance of Cartesian thought have been both extensive and grave: "Since the time of Descartes, not only is consciousness positioned outside of the world, outside its body, outside of nature; it is also removed from direct contact with other minds and a sociocultural community." Theorists of the body have grappled with Descartes' legacy in a number of ways including: proposing single-substance (monist) arguments, inverting the dualism, espousing an embodied approach, or employing dialectical or co-constitutive frames.

[7] Central to the development of second wave feminism was the issue of difference; many feminist scholars asserted that bodily-based differences were key to the appreciation of embodied experience and perspective

political issues of demographic change such as the graying of the population (Turner 1991; Williams and Bendelow 1998); the emergence and elaboration of the health regime (Crawford 1987; Crawford 2004; Crawford 1994); the "growing awareness of changes in modes of governmentality, changes which highlight human physicality as an object of various forms of control" (Lupton 1999a; Shilling 2005: 3); the cultural contradictions of capitalism and the amplification of consumer culture (Bell 1976; Crawford 1984; Falk 1994; Featherstone 1991; Shilling 2005; Turner 1991; Williams et al. 1998); the proliferation of risk-pervasive environments (Armstrong 1995; Beck 1992b; Beck 1994; Crawford 2004; Giddens 1991); and reflexive late-modernization and the concomitant swell of ontological and epistemological uncertainty (Frank 1991; Shilling 2003; Shilling 2005; Turner 1991; Webster 2002; Williams 1997).

Within the sociology of the body, two central (and overlapping) concerns have surfaced: the issue of bodily order, both individual and aggregate, and the issue of transgression, both corporeal and at the level of the population-body. These concerns have provoked questions such as: How and why are individual and population bodies governed and constructed? What are the implications of performance and representation for embodiment? Why do bodies resist forms of governance and/or representation? What forms do corporeal transgressions take? Some scholars have, thus, been interested in the disciplining (Balsamo 1995; Balsamo 1996; Bordo 1993), commodification (Crawford

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(Beasley 2005). Subsequently, in an effort to deconstruct patriarchal accounts of institutionalized difference based on biology, many third wave feminists have chosen to reject bodily-based difference as the centerpiece of argumentation and change efforts, because "a focus on bodily-based difference goes hand in hand with essentialism and homogenization" (Davis 1997:8). Feminist scholars during the second and third waves initiated investigations into power relations and their consequences that brought attention to the body as a site of oppression.

1984; Falk 1994; Faurschou 1988; Featherstone 1991; Giddens 1991), beatification/enhancement (Davis 1995; Gilman 1999; Glassner 1988; Glassner 1995; Lasch 1979; Wolf 1990), and/or civilizing (Elias 1978; Freund 1983; Kuzmics 1987; Mennell 1987; Mennell 1989; Shilling 2003) effects of contemporary institutions, knowledges, discourses and practices. Scholars have been interrogating "body projects" (Brumberg 1997; Giddens 1991; Shilling 2003; Williams 1997), perfect performances (Butler 1993; Goffman 1971), and the body as "cultural capital" (Bourdieu 1984; 1986). However, other scholars have been engaged with the "enigmatic" (Shilling 2005), "transgressive" (Falk 1994; Williams 1998a; Williams et al. 1998), "leaky" (Shildrick 1997; Shildrick 1999), and "recalcitrant" (Williams 1998b; Williams and Bendelow 2000) aspects of bodies and embodiment, which acknowledge that there "is always a material residue that resists incorporation into dominant symbolic scheme" (McNay 1999:98).

One of the central tensions within the literature, then, concerns the degree to which the body is constituted by/through discourse, and/or the degree to which the body has foundational, purely material or essential attributes. Some scholars propose that there are aspects of corporeality that are a-historical, a-cultural and essential, while others assert that the body is inscribed by/through institutions, discourses/knowledges, and practices. I am in agreement with Berg and Akrich (2004a), who argue that science and technology studies (STS) is in a unique position to adjudicate between the a-cultural body and the body *tabula rasa*. Berg and Akrich (2004a:2) write:

> STS has emphasized the central role of 'objects' and 'materiality' in any viable social theory. It has emphasized the material heterogeneity of the networks that constitute

> society, and has stressed the active, mediating role of objects and artifacts in shaping categories previously deemed to be 'purely social'…STS's emphasis on the material heterogeneity of practices and its struggle with the concurrent historicity and durability of 'objects' and 'matter', when applied to the body…provides the analyst with theoretical tools adequate…to acknowledge the body's active status as agent without implying its immediate, pre-fixed presence.

Specifically, they argue that *embodiment* operates a "fruitful bridge between the historical specificity of bodies and the lived, 'first-person' experience of having/being a body" (Berg et al. 2004a:3). Many other STS scholars have also, over the last decade, elaborated on various aspects and effects of embodiment (Armstrong 1983; Balsamo 1996; Berg and Harterink 2004b; Berg and Mol 1997; Cartwright 1995; Epstein 2004; Haraway 1991; Hayles 1999a; Latour 2004; Lock 1997; Lock 2004; Lupton 1994; Mamo and Fishman 2001; Mol and Law 2004; Mol 2002; Moore and Clarke 2001; Walby 2000a; Walby 2000b).

Because embodiment encompasses both process and outcome, the term acknowledges the socially constructed nature of bodies (both the amenability of the body to constructions of all kinds and the lived implications of those constructions), as well as the always already recalcitrant nature of having/being a body. In other words, embodiment is a conceptual bridge that allows critical interrogation of, for example, the biomedicalization of dismemberment and phantom limb syndrome, while also acknowledging the myriad ways in which the body reacts back to biomedical attempts at domestication, categorization, quantification, and rationalization.

Embodying Dismemberment: *Corporeal Ideology*.

My work explicitly takes as a central concern historical changes in *corporeal ideology* or those ideas, knowledges, institutions and practices that make up what is taken for granted about the body, its use, its propensities, its capacities, its "nature." Specifically, I explore how shifts in the relative import of the economy (what bodies can and should do) and the aesthetics (what constitutes achieved or ascribed beauty) in governing bodies can be read through phantom limb. I begin mid-1800s with what Lisa Long (2004) calls a *postbellum corporeal ideology*, characterized by the glorification of physical wholeness and its productive capacities. During this period, amputation was thought to upset the overall economy of the male body, and because manifestation of phantom limb was conceived as symptomatic of irrational psychic resistance to this loss, amputees became emasulated and their bodies "fractured."

By the mid-1900s, after the medical management of the wounded from the two World Wars, I argue that the emergence and entrenchment of a new militarized masculinity ushered in a *postwar corporeal ideology*, marking a shift in the relative import of aesthetics and economics in governing the body. The beautiful body was the body in motion that eviced the quality of one's character. Within this context, phantoms continued to be conceived as psychical replacements. However, they were no longer viewed as representative of unconscious attempts at the reparation of fractured bodies/selves, but rather were understood as wish-fulfilling hallucinations, an unconscious desire for beauty in wholeness.

By the turn of the twenty-first century, a *de-structured corporeal ideology* began to take shape. I argue that by the end of the "decade of the brain", from 1990 to 2000, researchers investigating the neuroscientific foundations of phantom phenomena were arguing that the body was simply epiphenomenal. Ramchandran (1998a:58 original emphasis), for example, wrote "*Your own body* is a phantom, one that your brain has temporarily constructed purely for convenience."[8] Within this context, the economy and aesthetics of the body have become conflated; bodies that are used, practiced, and sculpted are beautiful, and bodies that are beautiful are those engage in various *body options*. As Leder (1990) asserts, contemporary "body options can be defined as technologically-informed methods of restructuring human embodiment which extend the possibilities associated with having a body, through a direct and radical assault on the limitations connected to being a body." I detail how, in effect, phantoms have become increasingly "distorted", unlike human limbs. Phantoms had long been thought to be mimetic of fleshy limbs in form and function. However, as neuroscientific constructions of phantoms as brain-based, rather than body-based, became accepted wisdom, phantom parts became increasingly confused and "detached" from "normal" morphology.

Embodying Dismemberment: *Phantom-ed Resistance.*

My work also details how phantoms have functioned as a window into what might be called *corporeal resistance*. I engage with what Olesen (1992:209) refers to as the reciprocity of the inside (the physical, corporeal, emotive) and the outside (the context,

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[8] It is not just that the body is "all in the brain", but the self is too. Dr, Brugger, phantom limb expert is quoted in the New York Times as saying "The research shows that the self can be detached from the body and can live a phantom existence on its own, as in an out-of-body experience or it can be felt outside of personal space" (Blakeslee 2006).

representation, institutionalization) of bodies, foregrounding the fact that what is often "rendered collective" are those events that originate *on the inside*. In other words, I argue that phantoms are not objects that can be either made "explicit" once and for all, nor can they be endlessly modified and retailored. The qualities and peculiarities of phantoms are not simply uncovered or discovered, nor are the vagaries of phantoms wittingly or unwittingly "manufactured" or fashioned. Rather, I argue that phantoms are *actants*[9] in that they have been the force behind many transmutations within the field, within bodies, and between bodies and technologies. In the case of distortion, for example, I argue that the profusion and elaboration of distorted phantoms, in turn contributed to the (partial) rejection of innate cortical structures, the abandonment of the "hardwired" notion of the physiology of the brain, and a rethinking of mind-body relations. Throughout the dissertation, I show how phantoms have resisted attempts at biomedical rationalization; they certainly have never been acquiescent to single, fixed, "origin stories"(Haraway 1991). In fact, I detail how over time the strategic emphasis upon or attenuation of particular aspects of phantom phenomena actually caused their proliferation, and argue that it was the spread of phantom limb syndrome to "vulnerable populations" that resulted in the recent reinvention of phantom etiology.

[9] "Taking seriously the agency of non-humans (machines, animals, texts and *hybrids*, among others), the ANT network is conceived as a heterogeneous amalgamation of textual, conceptual, social and technical actors. The 'volitional actor' for ANT, termed *actant,* is any agent, collective or individual, that can associate or disassociate with other agents. Actants enter into networked associations, which in turn define them, name them and provide them with substance, action, intention and subjectivity. In other words, actants are considered foundationally indeterminate with no *a priori* substance or essence, and it is via the networks in which they associate that actants derive their nature. Further, actants themselves develop as networks. Actors are combinations of symbolically invested 'things', 'identities', relations, and inscriptions, networks capable of nesting within other diverse networks" (Crawford 2005:1).

The Biomedicalization of Phantom Limb Syndrome.

Historically, phantom limb syndrome has been highly contested. During the nineteenth and first half of the twentieth century, phantoms were indicative of poor adjustment to part loss, asserted to be rooted in denial or wish-fulfillment; they were "all in the mind." In fact, amputees who reported persistent sensation in absent body parts were at times equated to the hysteric, and at times the neurotic or the psychotic. Although the syndrome ostensibly fell under the purview of medicine in the mid-1950s through inclusion in the *Index Medicus*, phantoms were predominantly theorized from a psychological perspective. Circa 1960, overt critiques of the psychologiz-ed phantom began to appear in the medical literature. By the mid-1960s, phantom limb was predominantly thought to be physiological in origin. This shift from psychologization to medicalization of phantom limb, I argue, had a number of significant effects.

First, I show how the quality, morphology, temporality, and kinesthesia of phantoms consequently changed. I argue that the medicalization of phantom limb altered the kinds of stories that could be told (by researchers, practitioners and amputees themselves) about how phantoms felt, about their size and shape, about when they materialized, and about what they did and how they could be used. This change was particularly pronounced in the case of phantom limb pain. I argue that consonant with the invention of pain medicine and the emergence of a culture of pain in the US circa 1980, phantoms literally became painful through the promotion of a specific medical language of phantom pain. Prior to this period, pain was rarely considered a sequela of phantom limb syndrome.

Second, I argue that by the turn of the twenty-first century, phantoms had been constructed as exceedingly natural phenomena, now rooted in the neurology of cortices (a byproduct of the reorganization of the cortical topography of the brain after the loss of sensory input); phantoms were no longer "all in the mind," but rather all in the brain. This etiological shift had a host of implications for "understanding" phantoms and their peculiarities, which resulted in a number of astonishing "discoveries" including phantoms in previously unreported populations (for example, paraplegics, congenital aplastics and young children), phantoms associated with new body parts (tongues, breasts, penises, noses, and others). Perhaps most significantly phantoms that mapped themselves onto far-removed body parts: phantom fingers lay nimbly across the contours of faces; phantom toes were stretched over genitalia; and phantom breasts were mapped across the lobes of ears.

Third and most notably, phantoms today are considered by researchers in the field to be the key to answering some of the most fundamental questions of neuroscience. The truly obscure has become exceedingly valuable. For example, Ramachandran (1998b:1626) writes:

> It is clear now that this phenomenon provides a valuable experimental opportunity to investigate how new connections emerge in the adult brain, how information from different sensory modalities, e.g. touch, proproception and vision, interact, and how the brain continuously updates its model of reality in response to novel sensory inputs…the situation in neuroscience today is analogous to a parthenogentic (asexual) Martian zoologist spending five decades studying the structure and function of the human testicles while not knowing anything about sex.

Phantoms are hyped as providing neuroscientists in the field with remarkable opportunities --- exceptionally fruitful objects that have much to tell about the mind-body connection. In fact, one of the key figures in the field, Dr. Ronald Melzack, proposed that phantoms have taught us that "you don't need a body to feel a body" (Melzack 1993:620). Ironically, the obdurately embodied phantom has lead researchers to propose that corporeality is simply epiphenomenal.

I also detail how and why the medicalization of phantom limb occurred in and through the larger socio-cultural post-WWII context. I argue that the rapid coalescence and advancement of the field of prosthetic science occurred as a consequence of unprecedented state-sponsored intervention and investment, transforming what dismemberment and prosthetization "symbolized" in the cold-war years. As Serlin (2002a:54) writes "What made new prostheses different was how they represented the marriage of prosthetic design to military-production." Through the militarization of prosthetic science, dismemberment became associated with what I call *techno-liberation*; an association that, I argue, was incompatible with a continued conflation of amputation with psychosis vis-à-vis phantom limb syndrome.

In the literature, this incongruence played out in the postulations that phantom limb had psychological origins but nevertheless amputees universally experienced phantom limb syndrome. As increasing numbers of soldiers returned from combat dismembered, one could surmise that war and the state invariably caused psychosis. The state was responsible, then, for both physically compromising young men and with actualizing permanent psychosis as manifest in phantom limb. It was set against this backdrop that phantom limb was medicalized and reported prevalence rates began to decline. In other words, the medicalization of phantom limb syndrome vividly reflected the postwar/cold war political context in which it occurred.

Phantom-Prosthetic Relations: *The Modernization of Dismemberment.*

Further, in this dissertation I argue that until circa 1980 militarized men were central to the construction of amputation and dismemberment, as well as the appreciation of phantom phenomenon. Because of the association of amputation with war, phantoms were material manifestations of loss and disruption. By mid-century, the US government had become the central player in the transformation of the prosthetic industry from a loose assemblage of uncoordinated craftsmen to an increasingly organized and legitimated profession. In conjunction with advances in the technologies and techniques of amputation surgery, and the growing collaboration of the two fields, dismemberment was modernized. With the *modernization of dismemberment*, amputees became icons of the liberatory promise of science/medicine/technology, and phantoms per se were consequently re-conceptualized as productive phenomena, with properties capable of exploitation in the pursuit of prosthetization.

Directly following WWII, the circulation of amputee imagery in the popular media had the effect of constructing the male veteran amputee as a superior category of disability. This functioned in certain ways as propaganda, useful in countering public anxiety about the disruptive potential of the demobilized war-wounded and circumventing the emasculation of amputees. In the aftermath of WWII, images of amputees were widely circulated in a propagandist effort to promote patriotism, "persuade able-bodied

Americans that the convalescence of veterans was not a problem", and demonstrate a commitment to rehabilitation, while foregrounding American technological ascendancy (Serlin 2002a:28). The association of amputees with the burgeoning and increasingly influential US military industrial complex resulted in the re-conceptualization of amputees as icons of national prowess.

In a move that de-centers "abled embodiment," I suggest that it is because amputees have come to signify the reconstructive and liberatory potential of medicine, science and technology, that they may occupy a position of primacy in our *corporeal imaginary*. We may look to the prosthetized amputee as a model of biotechnological coupling, enacting how these couplings are successfully lived and embodied. I argue that consequently, amputees are inextricably implicated in future corporealities.

Phantom-Prosthetic Relations: *Prosthetic Transformations.*

Prostheses in the post-WWII years were designed with specific intentions. The prosthetized amputee was envisioned as recovered citizen while also representing the productive and invulnerable "cyborg." However, as Lucy Suchman aptly argues, technologies are not simply tools, objects, appliances, or machines that impose themselves on actors, selves, bodies, or populations; rather, human-machine interfacing is an ongoing practice of "technologies-in-the-making" (Suchman 1994b; Suchman 2000; Suchman, Blomberg, Orr, and Trigg 1999; Suchman, Trigg, and Bloomber 2002). Technologies, she argues are practiced, negotiated, accomplished, yet they are never "innocent" (Suchman 2005). The "imagined user" of prostheses, for example, can have profound implication for the kinds of sociality available to those designing, doing, modifying, or implicated in those technologies. In the case of prostheses, I argue that it was the very embodiment of the technology --- veteran “interfacing” with prostheses and the state --- that eventuated in the masculinization of dismemberment. In other words, the demobilized veterans who “did” prosthetization effectively masculinized dismemberment. I argue that this new masculinity functioned to severe amputation from its prior connotation with psychosis and emasculation, eventuating in a significant shift in phantom-prosthetic relations.

Although the discourse on phantoms has, since the mid-twentieth century, included what I call phantom-prosthetic relations, by the mid-1980s, this discourse emphasized the transformative role of prosthetic replacements and underscored the utility of phantoms. Prosthetists and researchers had historically assumed that prosthetic replacement was eminently desirable. The early accounts of prosthetic use, as necessary for combating stigmatization or resolving body scheme confusion, were replaced by accounts of prosthetic usage as central to restoring mobility, independence and productivity. The phantoms that animated lifeless prostheses were constructed as integral to proper use. Capable of occupying prostheses, phantoms enabled amputees to embody their artificial limbs. However, prosthetic structure also became a necessary means of “taming” the phantom. In other words, by the mid-1980s, prostheses were as remarkable as phantoms always had been.

In many respects, then, this shift in phantom-prosthetic relations also testifies to the contemporary biomedical trend toward technological fetishism (Blume 1997; Clarke, Shim, Mamo, Fosket, and Fishman 2003; Webster 2002). The shift from medicalization allowing enhanced control over part loss to biomedicalization allowing highly technologically-mediated *transformation* (Clarke 2003) has played out in the prosthetic sciences in a number of ways. Design is no longer inspired by the desire to return bodies to "normal" states, but rather by the desire to transcend the inadequacies of the human body. Prosthetists have also begun looking toward animal and mechanical models with the intention of expanding human biomechanics. But more importantly, in the neuroscientific research on phantom limb syndrome, prostheses have been re-worked as key to understanding, preventing, and harnessing the capacity of the human cortex to reorganize itself, potentially with grave theoretical implications for phantoms.

Phantom-Prosthetic Relations: *Phantom Extinction.*

> "Some diseases change their expression; new diseases arise and *some die out*" (Klepinger 1980:481 emphasis added).

By the turn of the twentieth century, researchers had begun to assert that prostheses that provide an adequate degree of "replacement" sensory information could essentially prevent changes in the topography of the human cortex brought on by deafferentation (the loss of sensory input from a portion of the body). Hypothetically, cortical "remapping" can be both prevented and reversed. That is, because phantom formation is hypothesized to be a consequence of cortical remapping, phantoms formation too could be arrested or undone. In other words, the contemporary biomedical construction of phantom-prosthetic relations is one that predicts reduced prevalence rates as prostheses become more sophisticated and more physically integrated. A question remains: will phantoms be theorized into extinction? Throughout the dissertation, I highlight the myriad ways in which phantoms have been what I call *shape-shifters*, morphing just as they are catalogued, categorized, "captured by the camera", and causally accounted for. Indeed, their protean nature is their quintessence.

Research Methods, Data Sources, and Data Analysis.

This project employs what Olesen (2000) has referred to as feminist qualitative research methods, an approach that foregrounds the construction of scientific knowledge qua politics. Thus, I critically engage medical and other discourses presented within the literature, as well as offered by practitioners and researchers in interviews, in an attempt to uncover the effects of such discourses/knowledges. Toward this end, I employ both situational mapping and grounded theory modes of analysis, and utilize interview, observation and, what I call *interpretive content analysis* as methods of data collection.

Research Methods, Data Sources, and Data Analysis: *Situational Mapping*.

Situational analysis, as Clarke (2005) argues, revitalizes traditional grounded theory by bringing it around the postmodern turn and displacing of its positivist inclinations. Using Clarke's (2005:xxii) cartographic approach to data analysis and interpretation, situational mapping was employed as the predominant means through which various data sources were read together, and as a means through which the major actors and elements of the research were research context-identified and situationally-related (see *Appendix A: Situational Map of Phantom-Prosthetic Relations).* My project takes seriously the role of discourses and the non-human, prostheses and phantoms, in the construction of bodies, knowledges and relations. It is precisely because situational analysis provides an approach which "simultaneously address[es] voice and discourse, text and the consequential materialities and symbolisms of the nonhuman, the dynamics of historical change, and, last but far from least, power in both its more solid and fluid forms" that is was an ideal analytic approach for this project.

Research Methods, Data Sources, and Data Analysis: *Interpretive Content Analysis.* Content analysis appreciates artifacts/materials that exist for consumptive, instructive or other purposes, as also communicative of aspects of socio-cultural arrangements. What is particularly productive about this type of analysis is that it captures the taken-for-granted, "naturalistic, 'found' quality" of materials, artifacts and texts (Reinharz 1992:147). The coupling of "found" and "produced" data in a single study acts as: 1) a means of evaluating the produced data according to a number of possible criteria including generalizability or reliability, 2) a type of triangulation, 3) and a way of increasing robustness (Bouma and Atkinson 1995; Reinharz 1992).

However, traditional content analysis is typically considered an objective, quantitative method with a number of typical features including a hypothesis (Neuendorf 2002), and two or more operationalized key variables (Babbie 1998). In contrast, my approach to content analysis is inspired by grounded theory and is an interpretive, inductive process that is also characterized by revision. Thus, this approach is more amenable to the qualitative tendency to "read" various kinds of data together, and to allow data to emerge from texts (as opposed to the imposition of preconceived categories on textual data). The categories that I developed, the codes that were used, *emerged from* the published medical literature through using grounded coding procedures. These categories represented patterns found across the articles and were systematically observed. For example, articles, regardless of the journal of publication, described the population under investigation and gave the reader a set of "relevant" characteristics of the study sample. Although these characteristics changed over time, the code category was found in nearly every article. A series of dimensions were then identified as they emerged; gender, age, type of amputation, level of amputation, occupation, etc. Each of my categories was generated in this manner.

Journal articles published between 1930 and 2005 on phantom limb syndrome were analyzed. The sample included 439 articles. Using the database Pubmed, I did a key word search for journal articles in English that included the term "phantom" in the abstract or title. I excluded letters, correspondence, commentary, and editorials, as well as articles of the following nature: 1) those that merely mentioned that the research conducted had implications for phantom limb syndrome; 2) those articles reporting on pain treatment where phantom limb pain was one of a number of pain conditions included in the study and no conclusions were drawn that were specific to phantom limb; 3) those that reported on deafferentation in animals; 4) those that focused on causalgia generally and presented phantom limb as one type of causalgia; 5) those articles that including phantom limb as simply one example of visual or sensorimotor deficit; and 6) those articles reporting on neuroma formation or nerve damage that simply mention phantom limb as a confounding factor.

I began by reading a sub-sample of 30 articles, extracting general themes and relevant identifiers. These themes and identifiers constituted the initial set of code categories. However, the emergence of new themes created the need to expand the number of code categories throughout the analysis (see *Appendix B: Medical Literature Coding Scheme*). The following is a summary of the code categories generated:

1. <u>Review of previous literature</u>: Citations to the previous literature typically framed the "problem" or "question" under study and operated as a kind of on-going conversation among members of the field interested in similar aspects of the phenomenon. References to previously published literature included: phantom limb prevalence rates and quality, phantom pain prevalence rates and quality, phantom-ed populations (either "known" to experience phantoms or "known" to not experience phantoms), treatment attempts (either successful or not), and causal mechanisms or theorizing relevant to phantom limb or phantom pain.

2. <u>Study sample</u>: The typical article included a sample (case study or n>1) and referenced relevant characteristics of that sample. For example, the amputation level was of interest as was the part amputated (finger, hand, arm, leg, etc.). Other relevant characteristics of the study sample often included time since amputation and population characteristics (veterans, children, etc.).

3. <u>Phantom Characteristics</u>: Studies generally attempted to contribute to the growing pool of "knowledge" concerning phantoms, including documenting the breadth of qualities associated with the phenomenon including: prevalence rates (either cited from previous data or derived from the study sample), the introduction or reiteration of phantom experiences associated with a particular body part (eyes, breast, tongue, etc.), onset of sensations (immediate, delayed, etc.), duration and frequency (intermittent brief, constant mild, etc.), and quality (for example, "super added sensation" like a watch or sock, or distortion similar to the pre-amputated limb).

4. <u>Phantom Pain</u>: During the mid-1980s there was an increase in the number of articles interested in some aspect of phantom pain. These articles tended to include information regarding: the prevalence of pain, the introduction or exacerbation of phantom pain associated with particular body parts, onset,

duration and frequency, quality, and treatment (either successful or attempted) of their sample.

Within these broad categories, dozens of codes were identified, and examples, narratives, and exemplars were extracted. Codes were then summarized using tables indicating the author and date; all of the compiled tables are included as appendices. For example, in *Appendix C: Phantom Parts*, references to phantom parts other than limbs or digits were recorded, including the author of the article, year published and the body part identified. From this, I was able to plot on a time-line the "discovery" of particular phantom-ed body parts and associate these discoveries with other events (for example, etiologic shifts or changes in pain prevalence rates). Each code was developed in the same manner.

Research Methods, Data Sources, and Data Analysis: *Observation.*

My observations included ten months of participant observation at an orthotic and prosthetic clinic in the San Francisco Bay area, as well as attendance of an annual Amputee Coalition of America Conference. I began observing at a relatively large clinic in September of 2000 and continued weekly observations until June of 2001. The clinic provided evaluation, design, custom fitting and manufacture all types of orthoses and prostheses to pediatric and adult patients, offering both in-hospital and outpatient services. The staff included two certified orthotists and three certified prosthetists. I was able to observe clinical interactions, as well as the prosthetic design and fitting processes.

In addition, I attended the annual Amputee Coalition of America Conference in Dallas Texas August 11-13th 2005, observing as well as conducting both formal and informal interviews. I attended all of the conference sessions, panels, “networking rooms”, and workshops, as well as a special session for women only. When events were not scheduled, I observed at the gait analysis clinic, where amputees could have their gait assessed by prosthetists, or in a large exhibit hall that included hundreds of exhibited products, as well as exhibitor product theater presentations. I also took part in many of the informal gatherings.

Research Methods, Data Sources, and Data Analysis: *Interviews.*

I conducted eight in-depth, semi-structured interviews with key American and Canadian researchers investigating some aspect of phantom limb or phantom limb pain. *Appendix D: Map of Respondents* provides a list of respondents, as well as their affiliated institutions. The professional participants were offered “on-the-record” or “off-the-record” options regarding the use of their names and attribution of ideas and options. All chose to be “on the record”. My respondents included one behavioral neuroscientist (Dr. Edward Taub), four psychologists (Dr. Joel Katz, Dr. Ronal Melzack, Dr. Dawn Edhe and Dr. Mark Jensen), one nurse practitioner (Kellye M. Campbell), one psychobiologist (Dr. Richard Sherman), and one physician (Dr. Joseph M. Czernieki). A copy of my “general” interview protocol can be found in *Appendix E: General Interview Protocol*. However, each interview was tailored to the particular respondent, a process consistent with the flexible, iterative nature of semi-structured interviewing (Rubin and Rubin 1995). Thus, although the major themes were consistent across respondents, the specific questions varied. For an example of a tailored protocol see *Appendix F: Interview Protocol for Dr. Edward Taub*.

Overview of the Dissertation.

Chapter Two "Part Loss" offers a brief history of amputation, highlighting the establishment of common restoration goals between amputation surgery and prosthetic science. I suggest that advances in limb replacement technologies have appreciably contributed to the disciplinary re-conceptualization of amputation as reconstructive rather than destructive, despite modern fatality rates. I argue that this re-conceptualization of amputation surgery is partly a consequence of the association of prosthetic science with the postwar Military Industrial Complex, as named by General of the Army Dwight D. Eisenhower, and US technological ascendancy. However, this shift is also reflexive of a broader set of trends indicative of the late/post modern biomedical context, what I refer to as a *milieu of malleability*. Bodies have become understood as malleable, and functional, aesthetic, and sensory replacements have become increasingly normative.

Next, I argue that the cyborg has emerged as a figurative and literal icon of post-modern malleability, and because of the association of the amputee with militarized prosthetic science, the amputee has become symbolic of what I call *techno-liberation*. In the post-WWII context, the amputee surfaced as a superior category of disabled person. Following the Korean, Vietnam and especially current Iraq war, the amputee was increasingly associated with the fetishized cyborg; an association that I argue has significant implications for current and future *corporeal ideologies*.

Chapter Three “Contextualizing Relations” beginw the chapter by situating the bodies of war amputees within a *postbellum corporeal ideology*, characterized by the lionization of physical wholeness and productivity. Because amputation was thought to upset the overall economy of the male body, and because phantom manifestation was conceived as symptomatic of irrational psychic resistance to this loss, amputees became emblematic of the physical and mental weaknesses that feminize. Next, I argue that the emergence and later entrenchment of a new masculinity within a *post-WWII corporeal ideology* marked a shift in the relative import of aesthetics and economics in governing the body. Within this context, phantoms continued to be conceived as psychical replacements. However, they were no longer viewed as representative of unconscious attempts at the reparation of fractured selves, but rather were understood as wish-fulfilling hallucinations (unconscious desires for beauty in wholeness). At this time, a concern for the aesthetics or “look” of phantoms themselves originated.

Next, I argue that directly following WWII, the circulation of amputee imagery in the popular media had the effect of constructing the veteran male amputee as a superior category of disabled person. This functioned in certain ways as propaganda, useful in countering public anxiety about the disruptive potential of the demobilized war-wounded and circumventing the then traditional emasculation of amputees. Also contributing to the destigmatization of amputation was more extensive state investment in the rehabilitation of veterans, engendering what has been termed the *modernization of dismemberment* (O'Connor 2000). Through the sophistication and elaboration of prosthetic technologies, amputees came to represent techno-induced liberation, and these events jointly contributed to the escalating influence of the amputee in shaping corporeal ideology especially vis-à-vis disability.

I propose that the association of amputees with the burgeoning and increasingly influential US military industrial complex, through state-sponsored prosthetic development, resulted in the re-conceptualization of amputees as icons of national technological prowess, representative of the rehabilitative potential of militarized capitalism. This association contributed to the reevaluation of the mental stability of dismembered veterans, which was ultimately paralleled by a shift in the asserted etiology of phantoms.

Last, I argue that prosthetists and researchers had historically assumed that prosthetic replacement was eminently desirable. But, with the modernization of dismemberment and the medicalization of phantom limb, the discourse evolved. General accounts of prosthetic use as necessary for combating stigmatization or resolving body scheme confusion were replaced by accounts of prosthetic usage as central to restoring mobility, independence and productivity. Moreover, the phantoms that animate the lifeless prostheses were reconceptualized as integral to proper use and integration. In other words, a reciprocal relationship between prosthetics and phantoms emerged, and the productive aspects of phantom materialization became increasingly emphasized.

Chapter Four “Characterizing Phantoms” details how the amorphous phantom “syndrome” has taken shape and been (re)contoured within (bio)medical contexts from circa 1930 to the present. I show how phantoms, as shape-shifters, have been sensitive to: 1) attempts at re-visioning the neuro-scientific research on phantom phenomena; 2) socio-historic interpretations of the natural form and function of bodies; 3) reinterpretations of the neuro-physiology of the brain; 3) the biomedical institutionalization of pain; and 4) the sophistication and elaboration of prosthetic technologies. At the same time, I argue that phantoms are not simply objects that can be either made "explicit" once and for all, or can be endlessly modified and retailored. In other words, I embrace what Barad (1999:3) has referred to as "agential realism," an approach that acknowledges the "material-discursive" nature of a "world [that] kicks back."

This chapter presents the breadth of sensual and functional features of phantom limbs. I have organized the discussion along qualitative, temporal, morphologic, and kinesthetic dimensions. In the section on phantom quality I argue that consonant with the invention of pain medicine and the emerging epidemic of pain in the US circa 1980, phantoms literally became painful through the advance of a specific language of pain vis-à-vis the adoption of the McGill Pain Questionnaire for assessing the qualitative dimensions of phantoms. The discovery of *pain memories* circa 1990 corresponded with burgeoning phantom pain prevalence rates, which rose to a high of ~85% (see *Appendix I: Phantom Pain Prevalence*). Consequently, the "pleasurable" tingling associated with phantom onset was re-conceptualized as a pre-pain sensation, and the phantom became commodified through the establishment of a specialized industry devoted to the treatment of phantom pain.

In the section on phantoms in time, I show how knowledge about the onset, development and duration of phantom sensation has been influenced by assumptions about prevalence and etiology. I argue that interest in onset emerged during the 1960s as phantom limb prevalence rates began to decline, a trend that corresponded with a splintering of the concept of denial. Further, I demonstrate how the elaboration of neuronal reorganization as an explanatory frame for phantom formation starting in the 1980s prompted a reconsideration of the universal nature of phantom phenomena.

In the section on phantom morphology, I demonstrate how the considerable increase in phantom pain and the discovery of *mislocation* correlated with a significant etiological shift made possible through new visualizing technologies. These technologies allowed phantom distortion to become more intelligible. The profusion and elaboration of distorted phantoms, in turn, contributed to the (partial) rejection of the concept of innate cortical structures, the abandonment of the "hardwired" notion of the physiology of the brain, and a rethinking of mind-body relations.

In the section on phantom kinesthetics, I argue that consonant with the twentieth century celebration of movement and its restorative qualities, an interest in cataloguing the kinesthetic features of phantoms emerged. While willed phantom movement was lauded, involuntary movements became maligned. I suggest that *phantom paralysis* or frozen phantoms were problematized both because of their association with immobility and because of their tendency to (theoretically) disrespect materiality when relating to objects. Finally, I show how purposive movement, phantom exploitation, emerged circa 1980 because of the surfacing of a discourse that emphasized phantom utility or *phantom potentiality*. This discourse suggested that phantoms could be harnessed for the purposes of facile prosthetic use and pain reduction, among other functional purposes.

Chapter Five “Contested Territory” presents the major etiological debates within the field. I argue that, in the first half of the twentieth century, the “organicists” (proponents of the physiological origins of phantoms, whether attributable to peripheral or more central mechanisms) were depicted as engaged in a “long and bitter” controversy with the “psychopathologists” (advocates of the psychogenic origins of phantoms). Over the second half of the twentieth century, the “peripheralists” (champions of nerve irritation theory or the supposition that nerve and other tissue damage was causal) were engaged in impassioned debate with the “centralists” (exponents of the primary role of the central nervous system in phantom formation, including the spinal cord and/or cortex). Finally, since the turn of the twenty-first century, phantom etiology has been situated squarely in the brains of amputees. Although remnants of earlier debates remain, dispute has primarily focused on exactly which structure/s are implicated (the localizationists versus the deffusionists), as well as precisely how change in cortical cartography occurs (the exponents of neural sprouting versus the proponents of unmasking). I address each of these divisions in turn.

Ultimately, phantoms became both the effect of cortical plasticity or reorganization, and the means of its prevention. Through the potential of phantom exercise to reverse cortical reorganization and through the potential for prosthetic animation to prevent phantom pain, phantoms were transmogrified into conspicuously productive phenomena. And, it is via this discourse of *phantom potentiality* that phantoms have emerged as vital to the seamless coupling of amputees and prostheses.

Chapter Six "Phantom-Prosthetic Relations" traces the shifts in what I call *phantom-prosthetic relations*, highlighting the dynamic and processual nature of this techno-corporeal coupling. I show how phantom-prosthetic relations are based on what actor-network theorists call *relational materiality* (Law 1999). Here the very substance of phantoms and prostheses have emerged out of the interplay of the social interestedness of each. The negotiation or *translation* of these social interests have over the last half of the twentieth century and into the present given rise to a shift from what I call the *phantomization of prostheses* to the *prosthetization of phantoms*.

I argue that the in the post-WWII years, phantoms were thought to have the capacity to animate prostheses, a process vital to successful rehabilitation. Phantoms had the natural power to vivify, and it was at this time that phantom sensations were most commonly found to be exacerbated by prosthesis use. Over the last half of the twentieth century and into the twenty-first, phantom-prosthetic relations changed significantly. The vital phantom that had animated the passive prosthesis gradually became dependent on the prosthesis to provide the kind of structure necessary for phantom refinement; the phantom needed taming if its animating potential was to be fully realized. This shift in phantom-prosthetic relations, I argue, is attributable to three concurrent trends, increased collaboration between prosthetic science and amputation surgery, the rise in phantom limb pain prevalence rates, and the elaboration and sophistication of prostheses.

As pain prevalence rates became epidemic, researchers began to attribute the emergence of the pathological phantom to a failure to properly domesticate or civilize the phantom. Phantoms that were not tamed were at risk of becoming either pathological or disappearing altogether. By the turn of the twentieth century, researchers demonstrated that prosthetic use decreased cortical reorganization and that decreased/reversed reorganization was correlative with pain reduction/elimination. However, it was not just prosthetic use that researchers considered to be most efficacious for ameliorating or even preventing phantom pain, but the use of functional prostheses. In other words, the curative power of prostheses was correlated with both extensive use and prosthetic sophistication. And, it was at this time that researchers' reports of phantom disappearance and phantom fading were interpreted as demonstrative of both the curative properties of prosthesis and the potential for prostheses to cause "absolute synchronicity."

In this chapter, I also elaborate on what I call the discourse of *phantom potentiality*. Phantoms became potentially productive phenomena, through the possibility of phantom exercise to reverse cortical reorganization and through the potential for prosthetic animation to prevent phantom pain. It is via this discourse of phantom potentiality that phantoms emerged as vital to the rehabilitation of the prosthetized amputee. Phantoms have surfaced as central to taping into the functional, the beneficial, and the adaptive aspects of cortical plasticity.

Finally, by the turn of the twenty-first century, researchers began to argue that cortical reorganization could be prevented or reversed through prosthetic use. Because phantom formation is hypothesized to be a consequent of cortical reorganization and because prosthesis use is thought to prevent or reverse cortical reorganization, phantom manifestation can hypothetically be impacted by innovations in prosthetic science. The sophistication of prosthetic technologies, further physiologic incorporation, in conjunction with increased use, greater adaptability, and biomechanical elaboration are implicated in the decline of phantom prevalence rate. Phantoms have consequently become theoretically vulnerable to extinction.

Chapter Seven "Conclusion" highlights significant theoretical and substantive contributions of this work to the sociology of the body, science and technology studies, medical sociology, and sociology more generally. I further detail a number of potential directions for my future work, elaborating on a number of next-stage projects.

Interfacing The Body and The World.

> "Amputation is one of the meanest yet one of the greatest operations in surgery" (1978:1).

Curtailing disease or minimizing trauma through the imposition of functional, psychological and social losses had historically distinguished amputation from other surgical procedures (Pike and Nattress 1991); amputation had historically represented the failure of medicine to cure, repair or prevent, and demarcated the limits of surgical promise (Smith 2001; Williamson 1992). Today amputation surgery is often considered a constructive practice. In my interview with practitioner Kelly Campbell (July 19, 2005) she argued, "sometimes people, amputees and their friends and families, see it as a destructive surgery, but it is really a constructive surgery that allows people to get on with their lives." Similarly, Dr. Burgess, orthopedic surgeon and founder of the Prosthetic Outreach Program, described the procedure as "creating a new interface between the body and the world" (Smith 2001:1, quoting the late Dr. Ernest Burgess).[10] In this chapter, I argue that it was only through synchronic practices and principles, which have revolutionized limb replacement, and hence, altered the degree and quality of functional, psychological and social losses incurred as a result of limb removal or loss, that amputation surgery emerge as a constructive surgical procedure.

[10] Dr. Burgess also established, in collaboration with the US Veterans Administration, the Prosthetics Research Study (PRS), considered one of the leading centers in the world for developing post-operative innovations including: immediate post-operative fitting (IPOF) of a prosthesis; the Seattle Foot ® with an internal spring for active amputees; and the Seattle ShapeMaker ® software used to design check sockets (POF 2005).

I begin this chapter with a brief history of amputation, emphasizing the interdependent relationship that developed between amputation surgery and prosthetic science. In the "Chapter Three: Contextualizing Relations," I discuss in detail the maturation of prosthetic science in the US and make explicit the implications of US military investment in prosthetic science for the coalescence and rapid sophistication of the field. I suggest in this chapter that advances in limb replacement technologies have appreciably contributed to the disciplinary re-conceptualization of amputation as reconstructive, despite modern fatality rates. I argue that it is through the development of common restoration goals, central to *the modernization of dismemberment*, that the two fields have been able to collaborate in fashioning a *working* interface between the (amputated) body and the world.

Next, I argue that although the characterization of amputation surgery as constructive is partly a consequence of the association of prosthetic science with the postwar Military Industrial Complex and US technological ascendancy, it is also reflexive of a broader set of trends indicative of the late/post modern biomedical context. Bodies have become increasingly malleable, and functional, aesthetic, and sensory replacements, as well as *augmentations*, have become ever more normative. In other words, I situate the transformation of amputation surgery from a destructive to a constructive procedure within the context of the militarization of prosthetic science but also within a *milieu of malleability* in which techno-human couplings have became both more intelligible and more permissible.

In the last section, I argue that the cyborg has emerged as the figurative and literal icon of post-modern malleability, a dominant representation of the future potential and present realization of biomedical body modification, revision, and transcendence. I further argue that the amputee has been transformed into a superior category of disabled person, both because of the association of the amputee with cutting-edged militarized prosthetic science and because of the association of the amputee with cyborg-warriorship. Thus, I suggest that the alliance of the fetishized cyborg warrior with the amputee has/will have significant implications for future corporeal ideologies.

A Very Short History of Amputation.

Amputation has been practiced since the earliest of times as a last resort effort to managed severely crushed and mangled limbs.[11] Because the person was likely to die from blood loss and sepsis,[12] these early efforts were always desperate measures. Porter (Porter 1997) characterizes the incidence of hospital gangrene, one of the most troublesome of the septic diseases during the 19th century, as epidemic.

With the birth of the science in Egypt, Greece and Rome, surgical amputation and prosthetic science were established as fields of study (NU 2002). The first surgical account of amputation, for the treatment of vascular gangrene, was the Hippocratic treatise *On Joints* in the 5th century BCE (Engstrom and Van de Ven 1985; Rang and

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[11] However, there is evidence that amputations were performed in ancient civilizations for juridical reasons (Northwestern 2002).

[12] Sepsis: "The presence of various pathogenic organisms, or their toxins, in the blood or tissues" (Stedman 2000:1619). Sepsis is essentially the systemic response to infection that occurs today in about 1-2% of all hospitalizations and accounts for 20-60% of intensive care unit deaths (Martin, Dannino, Eaton, and Moss 2003). Approximately 5.5% of below knee and 6.7% of above knee amputations feature infection as a complication (Aulivola, Hile, Hamdan, Sheahan, Veraldi, and Skillman 2004).

Thompson 1981; Vitali 1978; Wagensteen, Smith, and Wangensteen 1967). Later, surgical amputation was also advocated for tumors, injuries and deformities by some Roman surgeons (NU 2002), as well as for chronic ulcers (Rang et al. 1981). Hippocrates (460-370 B.C.) was known to perform amputations through dead tissue to reduce hemorrhage,[13] a practice that continued though the 1500s. The residual limb was then cauterized[14] with red-hot irons or boiling oil or tar, which theoretically helped with homeostasis,[15] excessive bleeding, and rot (Rang et al. 1981; Wagensteen et al. 1967). Measures were also often taken to induce suppuration;[16] at this time, puss was considered "laudable," a normal part of the healing process (Rang et al. 1981; Wagensteen et al. 1967).

Ambroise Paré (1510-1590), "the father of French surgery" (Engstrom et al. 1985:1), is touted as the most significant figure from this period. Paré was the first known to use linen ligation[17] (tying off blood vessels) without cautery during surgical amputation, prior to the advent of the tourniquet, which significantly humanized the procedure (Rang et al. 1981; Vitali 1978).[18] He is also attributed with recognizing the need for coordination between amputation surgery and prosthetic fitting (Rang et al. 1981;

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[13] Hemorrhage: "An escape of blood from the intravascular space" (Stedman 2000:806).
[14] Cautery: "An agent or device used for scarring, burning, or cutting the skin or other tissues by means of heat, cold, electric current, ultrasound, or caustic chemicals" (Stedman 2000:304).
[15] Homeostasis: "The state of equilibrium in the body with respect to various functions and to the chemical compositions of the fluids and tissues" (Stedman 2000:827).
[16] Suppuration: "The formation of puss" (Stedman 2000:1731).
[17] Ligation: "The act of binding or annealing" (Stedman 2000:1010).
[18] He also performed an elbow disarticulation (Rang et al. 1981), introduced site selection based on post-operative prosthetic fitting, a modern surgical doctrine (Rang et al. 1981), and invented both upper and lower extremity prostheses (Engstrom et al. 1985; Rang et al. 1981).

Thomas and Haddan 1945).[19] Unfortunately both of these principles would remain unappreciated for some time (Vitali 1978; Wagensteen et al. 1967).

In the case of ligation, the sheer number of blood vessels involved ensured that the practice was unfeasible. Thus amputation continued to be most commonly lethal; the procedure required surgical speed and dexterity (Porter 2002; Rang et al. 1981; Sachs 1999; Shurr and Cook 1990). The ability to amputate in under three minutes, a key to shock reduction and minimal blood loss, became "for many surgeons an objective in itself" (Vitali 1978:3; see also Wagensteen et al. 1967). Consider the case of Dr. Robert Liston (1794-1847) who graduated from Edinburgh University and was considered the great northern anatomist of his time. It was said that with his "usual blood stained operating frock…when he amputated the gleam of his knife was followed so instantaneously by the sound of sawing as to make the two actions appear almost simultaneous" (Wagensteen et al. 1967:112,110).

> [In] Liston's most famous case, [he] amputated the leg under 2 ½ minutes (the patient died afterward in the ward from hospital gangrene)…He amputated in addition, the fingers of his young assistant (who died afterwards in the ward from hospital gangrene)…He also slashed through the coattails of a distinguished surgical spectator, who was so terrified that the knife had pierced his vitals he dropped dead from fright. That was the only operation in history with a 300 percent mortality (Gordon 1983:19-21).

It was not until William Harvey's (1578-1657) discovery of the circulation of blood in 1616 (Engstrom et al. 1985), Etienne J. Morel's invention of the tourniquet in 1674

[19] Two other figures are noteworthy, the French Baron Dominique Larrey (1766 to 1842) and the English military surgeon George Guthrie (1785-1856) (Rang et al. 1981). Larrey is credited with the first hip disarticulation through the joint in 1803 and with theorizing the procedure for shoulder disarticulation. Pre-anesthetic and asepsis surgical advancements "reached their peek" through the circulation of the work of Larrey, Napoleon's personal surgeon touted as capable of performing 200 amputations in one day (Rang et al. 1981:5). Guthrie advocated immediate amputation of mutilated limbs and post amputation "open treatment" or leaving the skin open for a time to prevent infection (Rang et al. 1981:6).

(Meier 2004; Rang et al. 1981) and subsequently, J.L. Petit's (1647-1750) advent of the compression tourniquet for amputation in 1718 (Helling and Kendall 2000; Meier 2004; Vitali 1978), that surgeons began to more commonly use ligature (Sachs 1999; Wagensteen et al. 1967).[20] Consequently, patients no longer routinely bled to death. Unfortunately, infection continued to be a significant barrier to survival and most patients during this period died as a direct result of the surgery (Vitali 1978).

The introduction of antiseptics[21] in the mid-1800s by Joseph Lister (1811-1886) significantly improved survival rates (Engstrom et al. 1985; Meier 2004). Prior to their use, surgeons did little to curtail the onset of infection. "It is difficult to realize that surgeons seemed almost to glory in avoiding even normal social cleanliness in their professional work" (Vitali 1978:3). Despite surgical advances in terms of blood loss, infection, and the advent of anesthesia (c. 1850) (Meier 2004), the practice of amputation through the late-19th century remained frequently fatal.[22] "It was said that it was less dangerous for a patient to have his thigh amputated by gunfire than by a surgeon" (Vitali 1978:3).

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[20] It was during this period that Edward Alanson, in 1782, began the practice of flap amputation (NU 2002), although there is record of this technique being used earlier by Yonge and Lowdham in 1679 (Vitali 1978), Verdun of Amsterdam in 1696, Rovaton in 1739 and Vermale in 1765 (Rang et al. 1981).
[21] Antiseptic: "An agent capable of preventing infection by inhibiting the growth of infectious agents" (Stedman 2000:105).
[22] Statistics on mortality rates following amputation prior to the mid-19th century are difficult to find. A study of nine Paris hospitals published in 1842, reported an overall mortality rate of 39%, 52% for major amputations and 62% for thigh amputations (Wagensteen et al. 1967).

Quite surprisingly, although modern surgical technique has improved post-operative survival rates, the procedure still remains extremely risky.[23,24] The five year survival rate for lower extremity amputees is less than 50 percent, 40 percent for diabetes-related amputations, the most common cause of amputation today (Bloomquist 2001a). And, of the diabetic amputees who survive, approximately half will lose the second leg within five years, subjecting the patient to the same statistical probability of death (Bloomquist 2001a). Given modern infection[25] and survival rates, the characterization of amputation surgery as eminently reconstructive seems unfounded. I argue that it is because of the establishment of a collaborative relationship between amputation surgery and prosthetic science that this depiction has circulated widely within the field.

A Very Short History of Amputation: *Vitalizing Amputation Surgery.*

Until relatively recently, if one survived limb removal, few and often crude prosthetic options were available. This began to change somewhat after the Civil War (1861-1865) when over 60,000 amputations were performed (Figg and Farrell-Beck 1993).

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[23] In 1981, Fernie (1981) reported that 2/3 of amputees died within the first five years. In another study published four years later, 58 patients who had undergone amputation for peripheral vascular disease were contacted for a follow-up after two years. The study found that 41% of the original sample had died (Jensen, Krebs, Nielsen, and Rasmussen 1984). A study the subsequent year investigated both vascular and traumatic amputations performed between 1970-1977. During this period, 624 amputations were performed, and at the time of investigation only 95 patients were still alive, a 15% survival rate (Krebs, Jensen, Kroner, Nielsen, and Jorgensen 1985). Van der Schans et al. (2002) reported the survival rate for amputation due to end-stage vascular disease as 15-33%.

[24] The data available on amputation incidence, etiology and population characteristics in the US are extremely ambiguous and often conflictual. The U.S. does not maintain a national database (Sherman and Sherman 1985), and the structure of the healthcare delivery system has precluded researchers from conducting an accurate census (Wilson 1998). Reports of incidence have ranged from 75,000 in 1945 (Thomas et al. 1945), to 40,000 in 1947 (CPD 1947), 30,000 in 1986 (Dernham 1986), an average of 133,235 annually between 1988 and 1996 (Dillingham, Pezzin, and MacKenzie 2002a), 47,300 in 1992 (Rounseville 1992), 185,000 in 1996 (Bloomquist 2001b) and 203,000 in 2001 (Bloomquist 2001a). Reports of prevalence have ranged from 925,000 in 1945 (Thomas et al. 1945), 275,000 in 1977 (Shurr et al. 1990), 450,000 in 1982 (Stein and Warfield 1982) 1,285,000 in 1996 (ACA 2002), and 413,000 in 1998 (Wilson 1998).

[25] Bloomquist (2001a) reports the rate of infection as 15%.

Government provision of prosthetics to Union Army Civil War veterans (Figg et al. 1993) after 1862, spawned the entrepreneurial design of manufactured limbs (NU 2002; Thomas et al. 1945). Consequently, between 1851 and 1873, eighteen patents were granted for artificial upper limbs, 76 were granted for artificial legs, and a total of 133 for amputation-related technologies (Figg et al. 1993). In addition, figures like J.E. Hanger, a Civil War amputee, and A.A. Winkley founded mail-order limb companies (Pike et al. 1991). These events, though, were thought to have detrimentally affected surgical advancements (Vitali 1978). Specifically, the use of muscle-flaps to increase weight-bearing potential and the practice of disarticulation[26] (amputation through the joint) were abandoned because both resulted in bulbous stumps that were not compatible with the conical shape that limb manufacturers preferred.

However, the abandonment of previously accepted surgical technique can also be attributed to "battlefield revisioning"; the demands made on the surgeon specific to these contexts necessitated the prioritization of particular aims over others. On the battlefield, where most amputations of the period were performed, the principle aims were simply to stop bleeding and prevent infection (Helling et al. 2000), an approach which neglected post-operative concerns, including the shape and condition of the residual limb. As a result, many veterans were unable to wear prostheses because of problems with fit (Figg et al. 1993:464), an outcome that negatively effected how the procedure was perceived by the public. Amputation was considered to be lifesaving but fundamentally barbaric. A field surgeon in 1864 explained:

[26] Disarticulation: "Amputation of a limb through a joint without cutting of bone" (Stedman 2000:508).

> It seems but a sorry remedy to lop off a hand or a foot; and the public at large are apt to call amputation the opprobrium of surgery. But it is not so, for an amputation is necessarily conservative. Life is better than limb; and too often mutilation is the only alternative to rapid and painful death (Figg et al. 1993:456).

During WWI (1914-1918), the principle concerns of amputation were bleeding and shock, “truly a damage control philosophy” (Helling et al. 2000). Once again, the result was the surgical construction of residual limbs that were frequently incompatible with prostheses. On the other hand, following WWI, some “gains” were made in the art of limb manufacture that were considered to have “outstripped” the “surgeon’s art” (Vitali 1978:4). For example, the suturing of muscle over divided bone was replaced by allowing muscles to retract in an effort to produce a conical shape. Amputation through the joint, the Symes amputation, which resulted in a bulbous residual limb, also became taboo (Cottrell-Ikerd, Ikerd, and Jenkins 1994).

Massive amputation casualties during WWII (1941-1945), and related governmental intervention in the field of prosthetics (see “Chapter Three: Contextualizing Relations” for a detailed history of these developments), prompted the collaboration of surgical and prosthetic processes, and the generation of common restoration goals, including *mobility* and *appearance* (Vitali 1978), what I later refer to as aspects of the economy and aesthetics of the amputated body. Prior to this point, the two specialties had fundamentally conflicting objectives. Surgical efforts prioritized speed and the maintenance of viable tissue at all costs, while prosthetists’ efforts to ensure post-operative mobility necessitated the loss of viable tissues when the shape of the residual limb would be incompatible with subsequent prosthetic replacement (Hughes 1996). Further, surgical amputation produced a residual limb that was simply a passive attachment site for the prosthesis, a site that did not "actively" participate in ambulation or aid in prosthetic use (Ertl 2000). From the prosthetist's perspective, despite the circulation of knowledge concerning the import of stump shape and health in terms of post-surgical prosthetic fitting during the first half of the 20th century, amputation surgery was commonly performed without such considerations. In fact, prescriptions provided by surgeons often simply read "fit with artificial leg" (Pike et al. 1991). This lack of concern with post-operative developments has long characterized all kinds of surgery.

In the post-war years, following the rapid sophistication of prosthetic science though substantial governmental intervention and investment, common restoration goals were established. For example, Bloomquist (2001a emphasis added) suggests that surgical technique began to "develop in relation to the two goals: the removal of diseased tissue and the construction of a stump *conducive to prosthetic use*." No longer fundamentally barbaric, the practice was instead regarded as essentially reconstructive. As Dr. Ronald Slocum (Slocum 1949), who published *An Atlas of Amputations* based on his WWII experience, indicated in 1949: amputation was "no longer ghoulish cutting off of a part, but rather it is a phase of reconstruction" (Meier 2004).

Although I discuss in prosthetic innovations in "Chapter Six: Phantom-Prosthetic Relations", I would like to point out here that over the second half of the 20th century, restoration efforts expanded to include finer degrees of *movement*, and the renewal of *sensation* (Vitali 1978). Innovations have included the use of microprocessor knees, external power sources, and the harnessing of remaining nerves and musculature.

Twenty-first century restoration efforts are centered on increased prosthetic *responsiveness* and functional *enhancement* through: 1) direct neural interfacing with the brain; 2) improved interfacing between the residual limb and the prosthesis, using among other technologies the growth of tissues; 3) the revitalization of proprioception[27] by attaching prostheses directly to bone; and 4) the application of non-human biomechanical models to augment performance, for example the cheetah leg.[28] This level of advance in limb replacement has been possible because of the synergistic efforts of amputation surgery and prosthetic science, and importantly resulted during the post-war years in the re-conceptualization of amputation surgery.

Postmodern/Human Malleability.

In this section, I argue that conceptualizing amputation surgery as re-constructive is partly a consequence of the association of prosthetic science with the postwar Military Industrial Context and US technological ascendancy (see "Chapter Three: Contextualizing Relations"). However, I also argue that this shift is reflexive of a broader set of trends happening in the late/post modern biomedical context. Bodies have become increasingly malleable, and functional, aesthetic, and sensory replacements, as well as *augmentations*, have become normative. In other words, I situate the

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[27] Proprioception: "A sense or perception, usually at a subconscious level, of the movements and position of the body and especially its limbs, independent of vision; this sense is gained primarily from input from sensory nerve terminals in muscles and tendons (muscle spindles) and the fibrous capsule of joints combined with input from the vestibular apparatus" (Stedman 2000:1458-9).

[28] Serious departures from the "natural" form of human limbs is not new in prosthetic design. For example, Koven (1994:1195) argues that post-war "work arms" did not look like human arms. In fact functional upper-limb prostheses never have. "The requirements of form and function were not always compatible. Artificial arms best suited for highly skilled labor usually bore little resemblance to the limbs they replaced. The most effective arms resembled complicated pieces of machinery that they were individually adapted to the particular industrial task and set of movements the disabled worker performed. Prosthetic arms or 'artificial members' literally joined the working man to his machine and hence made his body an extension of the machine he used" (Koven 1994:1195).

transformation of amputation surgery from a destructive to a reconstructive procedure within the context of the militarization of prosthetic science but also within a *milieu of malleability* in which techno-human couplings of these kinds have became both more intelligible and more permissible.

As Giddens (1991:20) in his *Modernity and Self-Identity* argues, a core feature of post-late modernity is institutionalized reflexivity, or "the susceptibility of most aspects of social activity, and material relations with nature, to chronic revision in light of new information or knowledge." Late modern reflexive institutions/institutionalizations are at their core constituted through the continuous gathering/generating of information and knowledge that is then utilized to renew institutional practices. In other words, contemporary institutions do not just gather knowledge/information/data that is then dispersed (i.e. knowledge is always <u>updated</u>), but instead reflexively (re)employ that knowledge to transform the nature, practices, and 'data needs' of the institution itself (i.e. knowledge is always <u>changing</u> and for a purpose). One of the features of these kinds of institutions is the generation of multiple, and often competing, authorities that produce 'best guesses.' Williams and Bendelow (1998:68) suggest that, "Within this context, systems of accumulated expertise become pluralized, contested and divergent in their implications: even the most 'reliable' authorities can only be trusted 'until further notice.'"

One of the more significant implications of institutionalized reflexivity, then, is the undermining of certainty; what may have previously been considered fixed, whether social or natural, is necessarily thrown into *radical doubt* (Giddens 1994a). Late-modern knowledge is at all times tentative and corrigible in a system in which expertise multiplies and the best information is just hypothesis (Tarnas 1991). No-'thing' is spared reflexive (re)organization; even the natural and fundamental aspects of, or knowledges about, bodies have been thrown into question.

> The body was a 'given', the often inconvenient and inadequate seat of the self. With the increasing invasion of the body by abstract systems all this becomes altered. The body, like the self becomes a site of intersection, appropriation and reappropriation, linking reflexively organized processes and systematically ordered expert knowledge. The body itself has become emancipated – the condition for its reflexive restructuring. Once thought to be the locus of the soul, then the centre of dark, perverse needs, the body has become fully available to be 'worked upon' by the influences of high modernity (Giddens 1994c:218).

The body, increasingly understood as "plastic," (Deitch 1992; Featherstone 1991; Gray, Mentor, and Figueroa-Sarriera 1995b), notational (Prasad 2005:293), fragmented (Wegenstein 2002:225), communal/interchangable (Elshtain 2005; Hogle 1995; Synnott 1993; Williams 1997), or as a "work of art" (Eckermann 1997) has no essential quintessence, nor obdurate core, no ontological foundation and is thus amenable to transformation and re-transformation, to being "worked upon." And, "worked upon" it has become; biomedicine has certainly provided the tools. Just some of the myriad ways in which the body is more and more subject to extraordinary degrees of manipulation include: genetic alterations, reproductive interventions, implantations, transplantations, aesthetic modifications, pharmaceutical adjustments, technologic augmentations, etc; all of which make us into "some body new" (Glassner 1995:161).

Postmodern/Human Malleability: ***Re/de/sign and Transformation.***

Clarke (1995a:140), in her *Mommy, where do cyborgs come from anyway?*, distinguishes between modern and postmodern approaches to biomedicine,[29] arguing that postmodern approaches are characterized by the expansion, application and increased legitimation of science in medical matters. Further, the transition from modern to postmodern has had weighty implication in terms of the nature of and impetus for medical intervention. "Postmodern approaches are centered on *re/de/sign* and *transformation*" and postmodern bodies are manipulated and augmented rather than controlled (see also Clarke 2003).[30] Prosthetic science is certainly an exemplar of the postmodern approach in that design is no longer inspired by the desire to return bodies to "normal" states, but rather by the desire to transcend the inadequacies of the human body. For example, prosthetists have begun looking toward animal and mechanic models with the intention of expounding on human biomechanics. Referring to the cheetah leg worn by many professional amputee athletes, Ott (2002b:24-25) argues that:

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[29] The conceptualization of illness as a kind of mechanistic malfunction defined and treated using objective scientific experience and practice (Weitz 1996:129), the instantiation of a legitimate monopoly on defining pathology and normality (Conrad and Schneider 1980), the expansion of the scope of the medical gaze (Zola 1972), the shift from cure to prevention and the medicalization of lifestyle (Hughes 2000), and the individualization of the responsibility for wellness (Turner 1996), characterize the medicalization thesis, which laid a foundation for what Clarke, Shim, Mamo, Fosket, and Fishman (2003) term the new biomedicalization. As Clarke et al. (2003) argue, the corporatization and privatization of services and products, the global distribution of invention, the amplification and embellishment of risk, and the fundamental shift from control to transformation distinguish today's biomedicine. With the instantiation of what the authors have termed "The Biomedical TechnoService Complex," biomedicine manufactures technologies, services and discourses that advance healthy living and beautiful bodies in the pursuit of profit. New markets are uncovered and fabricated across the globe and inside bodies. And, selves are increasingly purchased and sold as patient/consumers are offered the option and desire for body, life and living extensions.

[30] Pickstone (2000) suggests that there has been a shift from 'biographical medicine' to 'techno-medicine'. Techno-medicine is driven by the pharmaceutical and medical device industries. "According to some represents a fundamental shift from a public health social-hygienist framework for medical provision, to one which has become increasingly obsessed with 'miracle technology' – the creeping fetishization of technology, hardware and gadgetry" (Webster 2002:444).

> This design trajectory of a technology – from mimicry to modification and then to disassociation with the original – has happened many times in history…Many prosthetic makers in the late twentieth century took a turn into visionary engineering, where parts replicated neither form nor function of the human body.

As one example of the instantiation of what Clark et al. term "The Biomedical TechnoService Complex" (2000:2) prosthetic science has contributed to a social and cultural context in which techno-human hybridization has become regularized. And as Hayles (1999a:2-3) argues, although critically, this regularization is indicative of the post-human epistemological shift, which rests on the assumption that: 1) biologic embodiment is purely incidental; 2) consciousness is epiphenomenal; 3) the body is the "original prosthesis"; and 4) and thus humanity is amenable to "seamless…articulat[ion] with intelligent machines." The addition or replacement of parts is logically conceived as congruent with the "self-as-amalgam," acquiescent to beautification procedures, functional alterations and mechanic/technologic coexistences. Reading Clarke et al. (2000) and Hayles (1999) together, the contemporary milieu is a convergence of the actualization and acceptability of corporal transformations.

Postmodern/Human Malleability: *Pathetic Vulnerability.*

> Western science and technology have arrived…at a new, postmodern imagination of human freedom from bodily determination. Gradually and surely, a technology that was first aimed at the replacement of malfunctioning parts has generated an industry and an ideology fueled by fantasies of rearranging, transforming, and correcting, an ideology of limitless improvement and change, defying the historicity, the mortality, and, indeed, the very materiality of the body…in place of God the watchmaker, we now have ourselves, the master sculptors of the plastic (Bordo 1997:335).

Care of the body through appearance/behavior/use modifying and transforming products/services/practices is quite simply a feature of the postmodern episteme.[31] Corporeal indeterminacy contributes to an undermining of the finitude of selves because selves are increasingly constituted through body-centered practices and projects. The body has become central to the self as a reflexive-modern-project, vital to identity construction and renewal in a context within which other forms of meaning have declined, such as master narratives, tradition, ritualized knowledge, etc. (Shilling 1993).[32] As Williams and Bendelow (1998:68) suggest this "sets up something of a paradox, namely: the greater our ability to control the human body, the more uncertain our sense of what precisely it is, what is 'natural' about it and, perhaps most worryingly of all, what it might become" (See also Shilling 1993).

The emergence, proliferation, and elaboration or risk discourses is a also core feature of late modern reflexivity (Beck 1992a; Beck 1992b; Beck 1994; Beck 1995; Beck 1996;

[31] In contrast to the modern mechanistic body whose processes and products were given over to capitalism via a discourse of triumph over inefficiency (Kimbrell 1993), the contemporary body-as-prosthetic is understood as amenable to transformation, an ideation that has encouraged the very real trafficking of parts, including organs (Das 2000; Elshtain and Cloyd 1995; Fox and Swazey 1992; Haddow 2005; Lock 2000; Scheper-Hughes 2001a; Scheper-Hughes 2001b), cadaveric parts (Hogle 1995), reproductive materials (Bridges 2002; Clarke 1995b), DNA (Everett 2003), and stem cells (Franklin 2005; Ganchoff 2004; Lock 2001; Scheper-Hughes 2005) among others. As Hogle (1995) proposes body parts are becoming 'Widget'-like. Joralemon (1995) and others suggest that these harvesting procedures necessitate an objectification process. However, other scholars argue that the scientific-rational objectification of body parts and tissues has never been totalizing (Lock 2001; Seale, Cavers, and Dixon-Woods 2006). See for example Lock (2001) and Sharp (2000) for a discussion of "cell memory" in the cases of organ donation as a means of retaining the wholeness, individuality and meaning attached to bodies and their parts.

[32] Blum (2003:42) uses the term *body landscape* to emphasize surface and to suggest that the body is lived as "transformative topography." Thus, we each have an embodied landscape that is bounded (we have an understanding of where our bodies end and where they begin); hierarchicized (we differentially invest in and value parts of our bodies); and transformable/transformed (we each have a appreciation of our bodies as amenable to alterations of different kinds, a threshold of transformation). In other words, "our bodies are held together with the residues of everything they have been, should have been, were not, could be, are not" (Blum 2003:43).

Giddens 1991; Giddens 1994b; Lash 1993; Lash 1994),[33] and the fleshy, soft birthed bodies of the past, are "known" and "felt" to be vulnerable and week. The modified body, by contrast, appears to be as somehow less exposed, less at risk (O'Mahony 2002:18). Although she is addressing predominantly aesthetically-motivated surgical alterations, Blum (2003:49) argues, body modification contributes to and is a consequence of a post-body culture in which "the material body seems to lose all its pathetic vulnerability in the face of a host of medical/technological advances meant to keep you perfect from the beginning to the end." This is imaginary of the clinic that, as Bogard (1996:61) suggests, has "escaped the clinic and become a cultural obsession"; it is a imaginary which "dreams of replacing it [the body] with a superior product, a 'double' that would eliminate, once and for all, all its troubling and worrisome defects."[34] In the case of prosthetization, Eerikainen (2001:56) "being human anew."

Postmodern/Human Malleability: *Cyborgology*.

> With every tool [man] is perfecting his own organs, whether motor or sensory, or is removing the limits to their functioning…man has, as it were, become a kind of prosthetic God. When he puts on all his auxiliary organs he is truly magnificent (Grosz 1994 on Freud 1929:90-92).

[33] The risk literature is vast and includes just some of the following themes: the lack of any tangible culpability for risky living; the role of experts in generating risk discourse (Beck 1994; Lupton 1999a); the implications of risk discourse in terms of *othering* particularly from a purity and contamination perspective (Douglas 1966; Douglas 1985; Douglas 1992); the role of risk discourse in governmentality and surveillance (Crook 1999; Harding 1997; Lupton 1999b; Lupton 1999c; Lupton 2005; Nettleton 1997; Petersen 1997; Turner 1997); and the role of risk in buttressing neoliberalism in the form of the individualization of the responsibility for health and wellness (Bunton 1997; Dean 1999; Nettleton 1997; O'Malley 1996; Petersen 1997).

[34] In our *culture of the copy*, we cannot help but ask if the copy will transcend the original (Schwartz 1998b). Grenvile (2001:21) argues that this why the cyborg is understood as uncanny; he writes "I argue that the cyborg is uncanny not because it is unfamiliar or alien, but rather because it is all too familiar. It is the body doubled-doubled by the machine that is so common, so familiar, so ubiquitous, and so essential that it threatens to consume us, to destroy our links to nature and history, and quite literally, especially in times of war, to destroy the body itself and replace it with its uncanny double."

In this section, I argue that the cyborg is the figurative and literal icon of post-modern malleability (Tofts 2002), a dominant representation of the future potential and present realization of biomedical body modification, revision, and transcendence. I further argue that the amputee has been transformed into a superior category of disabled person, both because of the association of the amputee with cutting-edged militarized prosthetic science (Serlin 2002a:55) and because of the association of the amputee with cyborg-warriorship.

The cyborg has emerged as a "pleasurably tight coupling" (Haraway 1985) between bodies and technologies, a coupling intended to enhance self-autonomy, self-control, and reassembly, while simultaneously subverting the pathetic vulnerability of flesh. By the 1980s the idea of bio-technological mergers "had infiltrated the imagination of western culture such that the cyborg – the 'technological-human' has become a familiar figuration of the subject of postmodernity" (Balsamo 1995:215). With its origins in post-war cybernetics (Clynes and Kline 1995; Gray and Mentor 1995c; Hayles 1999b), cyborgs[35] have certainly proliferated over the last half of the 20th century (Casper 1995; Clarke 1995a; Davis-Floyd and Dumit 1998; Hogle 1995). Still, the cyborg will always have affinities with the US military (Gray 1995; Gray 2002; Gray 2003; Haraway 1995; Sofoulis 2002), particularly through the figure of the prosthetized soldier or the cyborg warrior.[36] As I argued in the chapter "Contextualizing Relations", the image of the

[35] The term cyborg typically refers to a "cybernetic organism," a human-technological hybrid or coupling (Gray, Mentor and Fiueroa-Sarriera 1995), a "merging of the evolved and the developed, …[an] integration of the constructor and the constructed, …systems of dying flesh and undead circuits, and of living and artificial cells. (Gray et al. 1995:2).
[36] Ulf Mellström (2002) argues that technology in general is more commonly associated with masculinity than with femininity and that these kinds of man-machine couplings represent what she calls homosociality, a techo-masculine sociability.

cyborg warrior was circulated in post-war America in propagandist efforts to communicate a national commitment to the rehabilitation of veterans. It continues to circulate today as a symbol of the liberatory promise of biomedicine.

The cyborg warrior is a powerful figure with transformative potential. The body in all of its carnations has operated at various times as a symbol of purity or perversion, the sacred or the profane.[37] However, cyborg embodiment is unique in that it promises to blur those distinctions first and foremost because cyborgs are nature-culture, fleshy-techno, object-subject couplings (Haraway 1985), whether augmentation is pursued for normalizing, reconfiguring, restorative or enhancing purposes (Gray et al. 1995b). As Hayles (1995:322) argues quite critically of our posthuman future: "When cyborg subjectivities are expressed within cultural narratives, traditional understandings of the human life cycle come into strong conflict with modes of discursive and technical production oriented toward the machine values of assembly and disassembly."[38] For example, Jamie Goldman, Paralympic athlete who made herself five inches taller, seems to marvels uncritically at her new cyborg body:

> I jumped up and down on my 'cheetah legs,' my carbon flex sprinting prosthetics…when I wear them, especially when I run, they make me feel more like a robot than a human being…these carbon flex legs were a force to be reckoned with, it was hared to stand still on them, and when I wanted to stop moving, I had to grab on to someone or catch myself

[37] The body as a "natural symbol" has consistently been a central metaphor employed in sense making (Douglas 1966; Douglas 2003). For example, Shepard Hughes and Lock (1987) have examined nonwestern and non-industrialized cultures and have uncovered a tendency for intimate metaphorical exchange between the body and nature. They have also considered industrialized capitalist cultures, with their divisions between manual and mental labors, and in these contexts, "symbolic equations" tend to equate body with machine.

[38] Lenor Madurga (1979:152) in her autobiography even likens her prosthetist to Frankenstein's creator; she writes of her first dance with him, "It isn't often, I would imagine, that a prosthetist has the opportunity to dance with one of his inventions! Fred was overwhelmed with my dancing abilities and I was elated to be able to give life to the 12-pound contraption that adamantly clung to my hips – to make it perform, to do its best for its creator."

> against a wall… they really put that speed underneath me…I marvel at them still, at how carbon fiber and metal has changed my life so dramatically and given me a new way to challenge myself and become a stronger and more capable human being (Goldman and Cagan 2001:5,153,166).[39]

Let me be clear on one point. The cyborg warrior who inhabits popular discourses and circulates as a powerful icon of posthuman futures is far from the 'statistical' amputee. The typical prosthetized amputee[40] is likely to be a male,[41] below-knee (BK) amputee,[42,43] who is older,[44] African American,[45] and has lost his leg to vascular disease.[46] However unrepresentative of the 'statistical' amputee, the fetish-ized cyborg

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[39] Jamie Goldman has appeared in *Women's' Sports Illustrated, Sports and Fitness Magazine, USA Today, Los Angeles Times, CNN, Time*, 'O' Oprah Winfrey's magazine, and a nationally televised Adidas commercial (Goldman et al. 2001). Jamie chose to make herself five inches taller (Goldman et al. 2001).

[40] The term amputation can be used to include accidental, surgical or congenital amputations. Further, those born with congenital deformities, may go on to surgically amputate a partial or distorted limb in an effort to make the body amenable to prosthetic fitting (Engstrom et al. 1985).

[41] Fernie (1981) suggests the ratio of male to female amputees is approximately 9 to 1. Davidson (2002) reported the ratio as 4 to 5 in 2002. The majority of war and trauma-related amputations effect men in the US (Legro, Reiber, del Aguila, Ajax, Boone, Larsen, Smith, and Sangeorzan 1999).

[42] In, 1986 the percentage was 85% (Dernham 1986). In 1990, 90% of amputations were lower limb; 50% below-knee (BK), 40% above-knee (AK), and 10% were hip disarticulation (Winchell 1995). In 1992, 85% of amputations were lower-limb (Rounseville 1992). That same year, Williamson (1992) reported that upper-limbs accounted for 8.3% of all amputations, and lower 91.7%; hip disarticulation 2%, above-knee 32.6%, knee disarticulation 0.7%, below-knee 53.8, and ankle disarticulation or Symes 2.6%.

[43] In 1989, the international standards organization adopted terms applicable to amputation levels, congenital limb deficiencies and prosthetics. Terms describing the amputation level of acquired amputees (commonly referred to as AK, BK, AE, and BE) were replaced by trans (across axis of long bone), disarticulation (through center of joint) and partial (hands and feet below the ankle and wrist). Descriptive terms of amputation level for congenital aplastics include transverse (normal development beyond deficiency) or longitudinal (absence of skeletal anatomy within the long axis of the limb) (Schuch and Pritham 2002).

[44] Davidson (2002) reports that U.S. amputees are typically between the ages of 15 and 30. However, one of the most comprehensive Public Health surveys of the amputee population, conducted by Glattly in 1964 and updated by Kay and Newman in 1975 (Fernie 1981), demonstrates a distribution highest for those ages 51 through 80 (Wilson 1998).

[45] The risk of amputation increases with age, particularly among African Americans. For example, in 1996 African Americans represented 12% of the US population, but accounted for ¼ of vascular amputations (Dillingham et al. 2002a). Among persons with diabetes, African Americans, Hispanics, and Native Americans were at higher risk for lower-limb loss than whites, but vascular amputation rates for African Americans were twice that of other races (Dillingham, Pezzin, and Mackenzie 2002b).

[46] The vast majority of amputations are related to vascular disease, estimated by Derham (1986) at 85%, by Bohne (1987) at 80%, by Shurr and Cook (1990) at 70%, by Rousenville (1992) at 80%, and by Williamson (1992) at 74%. Dillingham, Pezzin, and MacKenzie (2002a) found that vascular amputations between 1988 and 1996 increased 3% annually (an overall increase of 27%), while the amputation rate attributable to trauma declined 5.6% annually, and malignancy (cancer-related) declined 4.7% annually. Congenital amputations, which accounted for less that 1% of amputations, remained stable. Comparably,

warrior nonetheless maintains a particular power in its primacy as a popular icon. As Balsamo (1995:216) argues, "techno-bodies," are believed to be exceptionally "health[y], enhance[d] and fully functional – more real than real." It is not my intent here to dismiss the work accomplished by disability theorists and activists who have argued against discourses which reify the pitiful child - supercrip dichotomy (Linton 2006).[47] Instead, I want to echo the sentiment of Casper and Talley (2005:118-9), who argue that:

> How disabilities gets framed in cultural production is key to understanding the broader implications of representing and thus constructing disability…it is precisely because descriptions of disabilities act to shape our cultural imaginations about what disabilities are and what it is like to experience disability that these questions point to the political ramifications of popular representations about disabilities and the political strategies that might result from how we answer them.

Prosthetized amputees, as "enabled cyborgs" (Gray 2002:100,103) who often do not self-identify as disabled,[48] it has been argued, may help others to "overcoming traditional fears of machinery" or as Kaufert and Locker (1990) describe it "modify culturally grounded beliefs about depending upon technology." Others too have advocated for the acceptance of technologically mediated embodiment (Haraway 1992), or prosthetically-

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in 1938, 28% of 42 amputations were a result of trauma, 36% of vascular disease, 16%, infection, 8% tumor, and 12% miscellaneous (Livingston 1938).

[47] Thomson (2001:339, 340) suggests there have been four visual rhetorics that characterize the treatment of disability: the wondrous, the sentimental, the exotic, and the realistic. She argues that "not only do they configure public perception of disabled people, but all visual images of disabled people either inadvertently or deliberately invoke these visual rhetorics and the cultural responses that have come to be associated with them…consequently, the visual – whether it is looking toward or away – is the major mode that defines disability in modernity" (Thomson 2001:339, 340).

[48] One study found that 61% of amputees forgot they were amputees "most of the time" (Silber and Sydelle 1958). Almost half of the respondents said that they could do "as much" as non-amputees, and 14% reported that they were able to do "somewhat more." In another study, 156 amputees were asked, "do you feel handicapped?"; 72% of BK, 62% of AK, and 40% of bilateral amputees reported that they did not (Kegal et al. 1977). In another study of 45 amputees, Sherman (1999) found that 6 respondents did not consider themselves disabled, 15 considered themselves mildly disabled, 4 felt quite disabled and none felt very disabled. Furst and Humphrey (1983) found that able-bodied people often overemphasize the degree and role of disability in amputees lives; able-bodied respondents rated amputees as highly misfortunate, while amputees rated themselves as only marginally less fortunate after amputation (see also Horgan and MacLachlan 2004). Other scholars have also written about the process, implications or tendency for amputees to reject the "disabled" label (Kurzman 2003; Watson 2002).

enabled disabled (Betcher 2001), and some have suggested that we should embrace the fact that we may be the last of the "pure" humans (Deitch 1992).[49]

Still others scholars are interested in how these couplings are accomplished and with what implications. For example, Kurzman (2003:5) acknowledges the increased intimacy with which American amputees have come to embody prostheses, but cautions against abstracting the prosthetized-amputee out of lived contexts. More importantly however, Kurzman (2003:5) asks us to reflexively consider the implications of conceptualizing prostheses as "enabling agents." Bordo (1995:216) too outlines what she calls the elements of the "paradigm of plasticity" and exposes a series of "effacements" including the homogenizing/normalizing/disciplining effects of cyborgian bio-technological couplings. Although I acknowledge both sides of this debate, it is not my intent to position myself within it. Rather, I want to suggest that "real" or not, "lived" or not, the popular association of the fetishized cyborg warrior with the amputee has/will have significant implications for future corporeal ideologies.

Postmodern/Human Malleability: *Imagined Corporal Futures.*

> Scholars have both imagined the "machine as a liberating force that would produce new social and economic configurations and…the machine as uncontrollable monster that would crush the human spirit and transform it subjects into automatons. It is here, in this untenable gap between a utopian and dystopian vision of the machine, that the cyborg was born" (Grenville 2001:27).

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[49] Others however argue that bio-techno couplings have deleterious effects. Druckrey (Druckrey 1994:3) suggest that "while the individual effects of technology are clothed in both fascination and desire, a reliance on new forms of technology assaults individual autonomy: Technology concentrates power as it deconcentrates and insubstantiates the individual."

The amputee, with visible fuchsia-tinted titanium tibia and fibula, is less an alien in contemporary contexts than an overt reminder of the cyborg nature of humanity in the milieu of malleability. All bodies are increasingly embedded in contexts where body projects go beyond simple replacement. All bodies are increasingly coordinated with the technologic to extend potential, to extend beauty, and to extend health. But as some of the literal cyborgs among us, amputees are/represent pioneers at the edge of techno-fleshy unionization, at the edge of the aesthetic/moral[50] acceptability and potentiality of human bodily form and function. I argue that as cheetah legs, osseointegrated prostheses and neural interfacing are sampled by the partial-ized, the prosthetiz-ed body becomes increasingly equated with the transformed and transformable. As innovations push beyond the boundaries of replacement, transforming (some) bodies through mechanic and animal hybridization, partial-ized bodies have become living representations of techno-induced liberation and models of human/animal/mechanic hybridization.[51] Amputees have become symbolic of the liberatory promise of science and technology, as well as the actualization of this promise, a freedom from the species body.

Again, I do not want to celebrate part-loss, nor do I want to neglect the real disability imposed by dismemberment (and somehow suggest the seamless articulation of artificial parts and human bodies). Yet, I do want to argue that (some) amputees are/will be the first to run with cheetah speed, share common musculature with animals, and synapse

[50] As Rapp (1999) argues, those people engaged with medical innovations that are characterized by uncertainty, necessarily operate as "moral pioneers."

[51] Kurzman (Kurzman 2003) argues that the primary problem that prosthetist and limb manufacturers face is not how to extend or exceed the human body but rather how to integrate bodies and technologies. However, whether innovations employ mechanic and animal models in an effort to extend or interface, they are still new structural and functional modes.

with computer chips. In fact, I argue that amputees are in a quite distinctive position relative to techno-human hybridization and as a consequence have become central to the imaged ideal of future corporeality and embodiment. [52]

In an attempt to de-center "abled embodiment," I suggest that it is because amputees have come to signify the reconstructive and liberatory potential of medicine, science and technology, it is because they have surfaced as icons of post-human malleability, that they have/will occupy a position of primacy in our imaginary. Although the fetish-ized cyborg warrior is hardly representative of the 'statistical' amputee, the figure nonetheless maintains a particular power in terms of both the economy and aesthetics[53] of the post-modern/human embodiments; we have/will look to the prosthetized amputee - the cyborg warrior - as a model of biotechnological coupling. Prosthetized amputees are imagined as heroes, as invulnerable, as actualized/librated, as pioneers of posthuman form. Amputees, I argue, are inextricably implicated in the possibilities of future corporeality.

Conclusion.

With the coalescence and rapid sophistication of the field of prosthetic science, as well as the establishment of common restoration goals and synchronic practices among amputation surgeons and prosthetists, amputation surgery was transformed from a destructive to a reconstructive procedure. Advances in limb replacement technologies have appreciably contributed to the disciplinary re-conceptualization of amputation,

[52] "having served as technologies 'poster children' "thereby giving it figural legitimation, while disguising its hidden militarism, we now find ourselves socially expendable" (Betcher 2001:37). Some actively resist prosthetization (Frank 1986; Frank 2000; Hillyer 1993).

[53] Eerikainen (2001:59, 60) argues that the prosthetized body is that which is sexy, seductive, a "vehicle of libidinal fantasies…the prosthesis is sexualized and sexuality if prosthetized."

despite the reality of modern fatality rates. Conceptualizing the surgical removal and replacement of body parts are constructive, I argue is consistent with broad shifts in postmodern biomedicine. In other words, I situate the transformation of amputation surgery within the context of the militarization of prosthetic science but also within a *milieu of malleability* in which techno-human couplings have become normative. The cyborg, I posit, has emerged as the figurative and literal icon of post-modern malleability, a dominant representation of the future potential and present realization of biomedical promise. Further, because of the association of the amputee with militarized prosthetization and cyborg-warriorship, the amputee has become central to imagined future corporeality.

In the next chapter, “Contextualizing Relations,” I examine prosthetic science in the US in greater detail and make explicit the connection between US military investment and the transformation of field. I show how militarized men have always been central to the construction of amputation, dismemberment, and phantom phenomena, at least until circa 1980. With the modernization of dismemberment and the medicalization of phantoms, these constructions shifted considerably and phantoms emerged as *productive* phenomenon.

3 CONTEXTUALIZING RELATIONS

This chapter contextualizes phantoms and renders visible the provocations of unseen parts. Phantoms represent at once an unsettling alienation from the body, as well as a profound sense of embodiment. They alienate through feminization, emasculation, misbehavior, fraudulence and lunacy among others. Yet, phantoms also thwart forgetting. They are lived facsimiles that are at times faithful representations of parts and at other times vehement distortions. Thus, phantoms remind through attempts to suppress, to make submissive, to tame, to harness, and to arouse.

Often considered in isolation from the very bodies they evoke and mimic, phantoms have historically been severed, disconnected from the contexts in which they materialize. This chapter intends to reattach phantoms to ambulating bodies and to locate phantom-ed bodies within an aesthetics and economy of embodiment. I argue that the disciplined flesh of militarized men was central to the construction of amputation and lived dismemberment, as well as the appreciation of phantom phenomena, until circa 1980. Some version of idealized masculinity informed early ideas about phantom formation, and, because of the association of amputation with war, phantoms connoted loss and disruption of one kind or another, while simultaneously demonstrating at best moral virtuosity and at worst a form of physical vulnerability. With the modernization of dismemberment and the medicalization of phantoms, amputees became icons of the liberatory promise of science/medicine/technology, and phantoms were re-conceptualized as productive phenomenon, with properties capable of exploitation in the purist of elaborating bodies with technologies.

I begin the chapter by situating the bodies of mid-19th century amputees within a postbellum corporeal ideology, characterized by the lionization of physical wholeness and productivity. Because amputation was thought to upset the overall economy of the male body, and because phantom manifestation was conceived as symptomatic of irrational psychic resistance to this loss, amputees became emblematic of the physical and mental weaknesses that feminize.

In the section that follows, I argue that the emergence (during WWI) and later entrenchment (during and after WWII) of a new masculinity within a postwar corporeal ideology marked a shift in the relative import of aesthetics and economics in governing the body. Within this context, phantoms continued to be conceived as psychical replacements. However, they were no longer viewed as representative of unconscious attempts at the reparation of fractured selves, but rather were understood as wish-fulfilling hallucinations (an unconscious desire for beauty in wholeness), and it was at this time that a concern for the aesthetics of phantoms themselves originated.

Next, I argue that directly following WWII, the circulation of amputee imagery in the popular media had the effect of constructing the veteran male amputee as a superior category of disabled person. This functioned in certain ways as propaganda, useful in countering public anxiety about the disruptive potential of the demobilized war-wounded and circumventing the emasculation of amputees. Also contributing to the destigmatization of amputation was more extensive state investment in the rehabilitation of veterans, engendering what has been termed the *modernization of dismemberment*. Through the sophistication and elaboration of prosthetic technologies, amputees came to represent techno-induced liberation, and these events jointly contributed to the escalating influence of the amputee in shaping corporeal ideology especially vis-à-vis disability.

Then, I propose that the association of amputees with the burgeoning and increasingly influential US military industrial complex,[54] as named by General of the Army Dwight D. Eisenhower, through state-sponsored prosthetic development (Serlin 2002a; Serlin 2002b), resulted in the re-conceptualization of amputees as icons of national progress, representative of the rehabilitative potential of militarized capitalism. This association contributed to the reevaluation of the mental stability of dismembered veterans, which was ultimately paralleled by a shift in the asserted etiology of phantoms.

And finally, I argue that prosthetists and researchers had historically assumed that prosthetic replacement was eminently desirable. However, with the modernization of dismemberment and the medicalization of phantom limb, the discourse evolved. Early accounts of prostheses use, as necessary for combating stigmatization or resolving body scheme confusion, were replaced by accounts of use as central to restoring mobility, independence and productivity, and the phantoms that animate the lifeless prostheses integral to proper use and integration. In other words, a reciprocal relationship between prosthetics and phantoms emerged, and the productive aspects of phantom materialization became increasingly emphasized.

[54] The establishment of the National Security Council, the National Security Agency, the Pentagon, the Strategic Air Command, the Central Intelligence Agency, the Defense Department, the Army Special Forces Group, and The Green Berets along with the arms race and the stationing of millions of soldiers abroad testify to the predominance of the American war-culture during this period (Farber 1994).

A Ghost Story.

In 1551, Ambrose Paré (1509?-1590),[55] the exalted French barber-surgeon to four kings, noted a most curious phenomenon in his patients after amputation, persistent sensation in "the part which is cut away" (Paré 1649:457).

> Verily it is a thing wondrous strange and prodigious, and which will scarce be credited, unless by such as have seene with their eyes, and heard with their ears the Patient who have many moneths after the cutting away of the legge, grievously complained that they yet felt exceeding great paine of that Leg so cut off (Paré 1649:773 sic).

Herman (1998) reports that subsequent to Paré's reference, this ethereal phenomenon disappeared from the medical literature for the next 320 years until its resurrection in a publication by famed American surgeon Silas Weir Mitchell (1829-1914) in the mid-1800s.[56,57] It was hypothesized that reports of the phenomenon within medical literature prior to this period were omitted by practitioners, what Foucault (1978:55) refers to as a

[55] Ambrose Paré (1510-1590), the towering father of French surgery (Engstrom et al. 1985:1; Porter 2002), was the first known to use linen ligation without cautery in amputation surgery, prior to the advent of the tourniquet (Vitali 1978), and to perform an elbow disarticulation (Rang et al. 1981). In addition, he introduced the practice of amputation site selection based on post-operative prosthetic fitting, a modern surgical doctrine (Rang et al. 1981). He also invented both upper and lower extremity prosthetics (Engstrom et al. 1985; Rang et al. 1981).

[56] As Finger and Hustwit (2003:675) argue, the assumption that phantom limb was absent from scholarly and literary writings until Pare's reference, is an "historical shortcoming [that] still dominate[s] the literature." For references to the phenomena's obscuration see for example (Frederiks 1963). Lamarier published work on the pathophysiology of sensation from separated parts in 1778 suggesting that this interval is likely much more narrow (Olry and Haines 2002). Other significant references to phantoms include Rene Descartes 17th century public writings and private correspondences (Finger et al. 2003), William Porterfield's self-report in his *A Treatise on the Eye* in 1759 (Wade and Finger 2003), John Hunter's description of two cases of phantom penis in 1786 (Wade 2003), Eramus Darwin's interpretation of phantoms within empiricist philosophy 1794 (Wade 2003), Albercht von Haller's comment in a book published in 1762 (Finger et al. 2003), Aaron Lemos's volume on *The continuing Pain of an Amputated Limb* published in 1798 (Frederiks 1963), and Johannes Muller's elaboration of 13 causes of sensation after amputation in 1826 (Wade 2003). For both a comprehensive overview of 18th and 19th century references to phantom limb and a detailed presentation of early descriptions from Ambrose Pare, Rene Descartes (Wade 2003), Aaron Lemos, Charles Bell (Furukawa 1990), and Silas Weir Mitchell see (Finger et al. 2003). Also see, Price and Twombly's (1972) published manuscript on case study, short description and classification references of phantoms from 1610 to 1798.

[57] Mitchell is perhaps better known for his work with hysterics and the implementation of the rest cure (see for example Long 2004).

"stubborn will to non-knowledge"(Foucault 1978:55), or were the secrets of amputees, because to have made such a report…

> Would [have been] tantamount to losing one's reason and/or admitting that the devil or some other supernatural forces had gained entrance into the body. This would, because of the status of medicine and society in general prior to the 19th century, leave one's self wide open to all kinds of punishments (Hoffman 1954b:261).

Mitchell is attributed with coining the phrase *phantom limb* (Postone 1987), first appearing in a fiction article published under a pseudonym in *The Atlantic Monthly* (Mitchell 1866) and again in a scientific article published as himself in 1871 (Herman 1998; Mitchell 1871; Nathanson 1988; Siegfried and Zimmermann 1981). In Mitchell's initial fiction article, George Dedlow, an assistant surgeon with the Tenth Indiana Volunteers, experienced an unfortunate series of amputations and developed a mass of sensory ghosts. After removal of all four limbs, Dedlow became a fraction of himself, "a useless torso, more like some strange larval creature than anything of human shape" (Mitchell 1866:4). The following conversation with a hospital orderly reveals his phantoms to the medical staff and the reader for the first time:

> "Just rub my left calf," said I, "if you please."
> "Calf?" said he. "You ain't none. It's took off."
> "I know better," said I. "I have pain in both legs."
> "Wall, I never!" said he. "You ain't got nary a leg" (Mitchell 1866:5).

Dedlow's story resolves through the use of a medium, who contacts the spirit of both amputated legs during a séance (identified by assigned Army Medical Museum numbers[58]), and facilitates a brief reunion. Unaware of the fictitious nature of George

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[58] Goler (2004: 163-4) details the war-hastened practice of recording battlefield wounds and conditions, which resulted in the collection of severed limbs. The parts were processed by the curator of the Army Medical Museum in Washington, who preserved them in alcohol or salt water. See Goler (2004) for a description of the museum, its collection practices and specimens.

Dedlow, Mitchell's main character, the public sent donations to the "Stump Hospital"[59] on Dedlow's behalf prompting Mitchell to publish a clarifying article in Lippincott's magazine (Mitchell 1871:4; Patterson 1992; Whitaker 1979:273).[60]

Mitchell's subsequent nonfiction article presented a discussion of the physiology of the stump and an elaborate typology of phantom limb that included the sensory ghost, the life-like phantom, the painful and painless phantom, the limb facsimile and distorted phantom, and the "negative phantom or phantom of absence" (Mitchell 1871; Sacks 1987:66). "Apparently the literary 'limbs invisible' became the medical 'phantom limbs,' and the term has been with us since, reaching the status of a single category in the *Index Medicus* in 1954" (Patterson 1992; Whitaker 1979:273).

Body Consciousness and Fraudulent Bodies.

George Dedlow was a fictional representation of the loss incurred during the Civil War; the loss of bodies, souls, and selves. By April of 1865, over 600,000 men had died, an additional 500,000 were injured, and the Union Army alone recorded 30,000 amputations (Shurr et al. 1990; Thomas et al. 1945).[61] These men were very visible[62] reminders of the price paid for battle (and disease) who "provoked a profound mixture of love and horror, fascination and anxiety…Ambiguous figure[s], simultaneously epitomizing survival and death, victory and bereavement" (Goler 2005:161).

[59] The stump hospital was the common name for the United States Army Hospital for Injuries and Diseases of the Nervous System located outside Philadelphia in 1866 (Goler 2005).
[60] In addition to donations, the public attempted to visit George Dedlow during his recovery. The story also prompted the Surgeon-General's office to search their records, as well as amputation records, for this quadruple amputee (Finger et al. 2003).
[61] Kurzman (2003) reported that 60,000 total amputations were performed during the Civil War and that approximately 35,000 soldiers survived the procedure.
[62] The Civil War is depicted by historians as the first modern war, characterized by exceptional brutality (Cervetti 2003) and a more faithful representation in the media (Goler 2004).

As Elaine Scarry (1985) argues in *The Body in Pain*, the war-wounded body is symbolic of the enemy's commanding power, the actuality of defeat, and a source of legitimation for the battle's impetus; representational of *what is had*. However, war-wounded bodies also symbolize *what is lost*, standing in for: 1) national and personal wounds (the penalties of war); 2) detachments from the deleterious quality of the past (as Lincoln described it during the Civil War, the "diseased limb" that was the south) (Long 2004); and 3) only partially realized futures (a dreamed emancipation and inclusive citizenry).

War-wounded bodies are reminders of *what is had* and *what is lost*, but as Lisa Long (2004) in her *Rehabilitating Bodies: Health, History, and the American Civil War* argues, the war-wounded also donate to *what is effectuated*.

> The alarming magnitude of illness, mutilation, and death sustained by the American citizenry during the war and the physical and psychological deprivations required even of those who did not serve on the front lines were partly responsible for the body consciousness ushered in during the war (Long 2004:23).

The devastation of the Civil War made people mindful of bodies in new ways and cultivated what Long (2004) calls a *postbellum corporeal ideology*. It was not simply sharing in the wretchedness of the war's aftermath that ushered in a new corporeal ideology. Rather, the war itself had made a spectacle of bodies in novel ways, denuding their resolute, as well as uncertain aspects. Soldiering bodies were seen, literally viewed by the onlookers who picnicked on hills next to these performances. Moreover, they were spectacles because they represented an embellished state of embodied discipline. Because of the strictness and precision, the exactitude of these performances, men who fell simply disappeared into the well-ordered coats that closed ranks around them;

soldering bodies were made to seem, and in effect became, homogenous. Yet, when the dust had settled and these bodies, idiosyncratic in their varied physical and psychical incarnations of personage, expressed the ills of war (causalgia,[63] phantom limb, hysteria, etc.), they revealed a fundamental uncertainty[64] about the body and, in the case of phantom limb, these bodies provided evidence of the possibility that corporeality could be persuasively fraudulent.

As O'Connor (2000) reflects in *Fractions of Men: Engendering Amputation*, phantoms were assumed to be psychical replacements of lost physical parts, facsimiles that materialized through unconscious attempts at the reparation of fractured bodies/selves. These men were partial-ized through the heroic sacrifice of body parts, publicly recognized as selves deserving of profound gratitude. However, the Civil War amputee, as Goler (2004:174) suggests, was also an "ambiguous citizen," invested with heroisms while also becoming "an object of anguish and horror to himself." Exemplified by the torso of George Dedlow, the amputee was imagined as fractioned. In his case, 1/5 the weigh, 1/2 the skin and "truncated" in all the kinds of movement that mark persons and express selves. The character Dedlow reflects:

> About one half of the sensitive surface of my skin was gone, and thus much of [my] relation to the outer world destroyed. As a consequence a large part of the receptive central organs must be out of employ, and like other idle things, degenerating rapidly. Moreover, all the great central ganglia, which give rise to movements in the limbs, were

[63] Causalgia: "Persistent severe burning pain, usually following injury of a peripheral nerve (especial median and tibial) or the brachial plexus, accompanied by tropic changes" (Stedman 2000:303).
[64] As Long argues, the legacy of the Civil was uncertainty, expressed by the desire for rehabilitation (a kind of stabilization of bodies in medicine and history through an appeal to a "preceding authenticity"), and a desire to make/have fact (but which ironically always requires the unknown, the yet unfolded).

> also eternally at rest. Thus one half of me was absent or functionally dead. This set me to thinking how much a man might lose and yet live (Mitchell 1866:6).[65]

Through reflection of the origin of the lived implications of dismemberment and the "limbs invisible," Mitchell exposes the Victorian sentiments concerning embodiment, personhood, and part-loss. The supposition of the era was that the very core of personhood was the physical body, which communicated, especially for males, both strength and productivity (Laqueur 1990). As O'Connor (2000:104) explains:

> Victorian ideals of health, particularly of male health, centered on the concept of physical wholeness: a strong vigorous body was a primary signifier of manliness, at once testifying to the existence of a correspondingly strong spirit and providing that spirit with a vital means of material expression.

The dismembered male not only lacked masculine productive potential, compromising the core of his personhood, but was also equated to the female hysteric: both made false (and insane) claims about their bodies. Mitchell (1872b), in his *Injuries of Nerves and Their Consequences*[66] published in 1872, describes how phantom pain reduced even the "strongest man [to] scarcely less nervous than the most hysterical girl."

> Like the hysteric, the dismembered man seemed to speak a fraudulent body language…Phantom limbs…raised the unsettling possibility that the material body could be profoundly inauthentic…[and] lead to a falsification of the self (O'Connor 2000:104).

It was at this time that phantom manifestation was deemed both symptomatic of irrational psychic resistance to loss, and emblematic of the physical and mental weaknesses that feminize. The economy of the male body was upset by falsification after amputation and

[65] Mitchell's story of George Dedlow was written in response to a friend's inquiry of "How much of a man would have to be lost in order that he should lose any portion of his sense of individuality" (Finger et al. 2003; Goler 2004; Mitchell 1871).
[66] Mitchell reported on a series of 90 cases in this unprecedented volume.

little could be done to return a man with a diminished sense of himself to productivity or sanity.

Following Mitchell's popular and scholarly publications, few references to phantom limb in either medical or popular literature can be found until circa 1930, and none with the descriptive and exploratory depth of that provided by Mitchell.[67] Several researchers comment on and speculate about the dearth of written material on phantom limb until well after the turn of the century. The following account is reminiscent of that offered by Hoffman (1954b) to explain the previous lacuna during the 1700s:

> It is surprising to note the obscuration in medical literature until relatively recent times, because the phantom limb must have occurred in the past as well as the present. A different attitude of the layman towards mental defects – once regarded as of a mysterious or magic nature – is the only explanation. In cases where the existence was felt of a part of the body that did not exist any more, the earlier attitude was highly effective, since the individuals in general were psychically and physically healthy persons. So the existence of the phantom must often have been the secret knowledge of the amputee only (Frederiks 1963:73).

Organizing and Reorganizing Bodies.

The period following WWI (1914-1918) marked the end of Victorian epistemological and ontological certainty. Economic depression existed on a global scale and was coupled with massive unemployment. Labor uprisings and other forms of mass civil unrest, as well as the clash of feminism with what Bourke (1996:14) called "the new masculinities of the inter-war years" all suggested significant turmoil and engendered a number of transformations. The emergence and later entrenchment of a *new masculinit*y seemed to be "…a response to the perceived need to reassert manliness in a society

[67] Jules Amar wrote on the phenomenon in France in 1917 (Panchasi 1995).

undergoing rapid change" (Bourke 1996:14; Higonnet, Jenson, Michel, and Weitz 1987) and was typified by the archetypal militarized male, a commanding response to the uncertainties of life, as well as to what some men felt were feminist attempts at the dilution of masculine ideals.

The militarized body has historically been resolutely male (Gray 2003; Hearn 2003; Peniston-Bird 2003), an expression of a *hegemonic masculinity* (Connell 2000; 2001; Connell and Messerschmidt 2005; Hopton 2003; Peniston-Bird 2003), epitomized by the stoic warrior (Higate 2003; Peniston-Bird 2003) and calculable bodily precision. But the *new masculinity* was different in that it celebrated the pulchritude of the warrior-in-action, which "disturbed the relative import of aesthetics and economics in governing the male body" (Bourke 1996:14). Bourke (1996:40) suggests that a war-inspired aesthetic and economy of the body returns home with soldiers after combat.[68] However, the modern ideal of the militarized male was unique because he was poignantly conspicuous and because he was represented by both intact and dis/re-organized bodies. It is logical to assume that a society-at-war adopts visual imagery and embodied practices that emulate citizens engaged in combat, and that these inspire changes in corporal ideology. However in the modern context, this tendency was exacerbated as a consequence of the

[68] Although in reference to the English experience of the Great War, Bourke's (1996) argument is equally applicable to the US context.

	Mobilized	Dead	Wounded	Missing/POW
Great Britain	8,904,467	908,371	2,090,212	191,652
US	4,355,000	126,000	234,300	4,526

In both WWI and WWII, 1.2 % of WWI wounded in action (WIA) sustained a major limb amputation. In the Korean War, the rate was 1.4% and in the Middle East, the rate was 2.4% as of 2004 (US House of Representatives 2004). However, these figures do not account for survival rate after amputation. Finger and Hustwit (2003) report a 28% post-surgical fatality rate.

unparalleled brutality of modern warfare and advances in modern medicine that contributed to the increased survival rate of the war- injured.

Soldiers in modern combat were intended for disfigurement via the technologies-of-mutilation indicative of warfare from WWI onward (Bourke 1996; Koven 1994). These soldiers contributed to a corporeal ideal because of their conspicuousness and their primacy as icons, but also because they altered the look of disability and deformity more generally. War-maimed bodies are distorted and reorganized in accordance with the grotesque brutalities of war, not the subtleties of nature or the precision of surgery. Thus, war-disturbed bodies have disruptive potential particularly when circulating in the social terrain in increased numbers. In addition, a short-lived transfer from individual to collective responsibility for the disabled occurs in the years after warfare, further politicizing the war-maimed body (Koven 1994). Recovering nations typically endeavor to memorialize the dead and injured (while also working toward normalization), forcing partial-ized bodies into public view and into the public consciousness. In the case of post-WWI, remembering and forgetting were aims only tenuously held together, aims that contributed to a re-weighting of the degrees of import between beautiful bodies and behaved bodies (Bourke 1996).

The management of bodies began to be subordinated to the look of bodies for the first time, as Bourke (1996) argues, and as a consequence of the elaboration of this trend during WWII (1941-1945), a post-war corporeal ideology was ushered in, one which differs from Long's (2004) *postbellum corporeal ideology* in that the latter gave emphasis to the productivity and wholeness of bodies, while the former was punctuated by the laudable presentation of bodies and their management in the services of that pursuit. In other words, there was a reweighing of the relative import of the economy and esthetics of militarized and civilian bodies alike. The productive, efficacious body, a body visibly behaved - meticulous, precise, explicit - became subordinated to the beautiful body, visibly resplendent and refined.

Just as bodies became "reorganized" as a consequence of shifts in corporeal ideology, so too were phantoms. The phantom came to represent a "wishful hallucination having its function in the denial of the loss of the part and the painful effect related to this loss" (Kolb 1950:469). These hallucinations materialized and became apparent in forms that accentuated the aesthetics of these psychical replacements. Just after WWII, the first references to distorted phantoms (Pool and Bridges 1953), incomplete phantoms or phantoms with "gaps" and "holes" (Bors 1951), and phantoms that telescope or withdrew toward or into the body (Bors 1951; Kolb 1950a) occurred. That is not to say that there was a complete absence of interest in the function of phantoms – what phantoms did or could do. On the contrary, the topic of phantom-object relations (how phantoms reacted when confronted with objects) also appeared in the literature during this period (Jalavisto 1950). However, the predominant interest was in the degree to which phantoms "looked" like their fleshy counterparts and in what ways they were not qualitatively mimetic. [For a more complete discussion of the peculiarities of phantoms see "Chapter Four: Characterizing Phantoms"].

The Modernization of Dismemberment: *They All Must be Mad.*

Gerber (1994) suggests that WWII veterans evoked "a sharply divided consciousness" in the American public, both a sense of honor and a palpable fear of the possibility that veterans could consciously and effectively disrupt American post-war re-normalization efforts. Experts in the military, religion, social work and the social sciences had been working on "the veterans problem," formulating a plan for the reintegration of demobilized soldiers disabled from war. Yet, they collectively still predicted a postwar "demobilization crisis" (Gerber 1994; Hartmann 1978; Serlin 2002a; Serlin 2002b).

> The former soldiers – low in rank, poorly educated, and accustomed to obeying orders – some argued, had lost the capacity to think for themselves…putty in the hands of demagogues seeking to exact revenge on civilians who had profited from the war and calling for violent political mobilization (Gerber 1994:547).

Despite the unparalleled efforts of the American government to recruit the well-adjusted and compose an army of the sane through pre-induction psychological testing,[69] it is argued that millions (three times the casualty rate) suffered debilitating psychiatric symptoms (Roeder 1996).[70] American veterans had been wounded physically and psychically in heretofore unimaginable numbers, prompting the VA Director of Social Work to anticipate an unprecedented national psychiatric problem (Gerber 1994).[71] In the case of dismembered soldiers, the emasculating affects of amputation exaggerated this suspicion (Ott 2002a; Peniston-Bird 2003), and amputees who told of sensation in their missing limbs, particularly those who communicated painful phantoms, were

[69] The military had excluded 970,000 men on the basis of "neuropsychiatry disorders and emotional problems, approximately 1 out of every 18 man tested (Roeder 1996:62).
[70] The Office of the Surgeon General conducted a secret study of active soldiers which concluded that "on average an infantryman could 'last' about two hundred days before breakdown" (Roeder 1996:62).
[71] Gerber (1994) suggest that two sets of solutions were considered to address the reintegration problem: public welfare actualized in, for example, the G.I. Bill of Rights, and public education in the form of an expansive literature instructing women to do their part in restoring traditional roles in American households.

considered psychically compromised. For example, Beller and Peyser wrote (1951:432), "his personality, his emotional tension and his psychic attitude toward his physical incapacity are the basis for the development of a painful phantom." The disruptive potential of dismemberment is evidenced by the moniker given to the phantom during this period, "the misbehavior ghost" (Li 1951:524).

Although phantom sensations were considered universally experienced after amputation dismembered soldiers were made discrete through qualitative distinctions, distinguishable from civilians who lost parts. For example:

> In the case of amputations in peace-time it often lasts for only a few days or weeks, whereas, when amputations are carried out under war-time conditions, the feeling of the phantom limb, or the hallucinatory feeling of pain, may last from the moment of the amputation onwards, and its regression is often very slow (In Der Beeck 1953:224).[72]

The "most satisfactory" remedies for such misbehaving ghosts were psychotherapy, electroshock therapy and prefrontal lobotomy[73] (Beller et al. 1951:433). In fact, between 1945 and 1950, these were the only treatments published in the American medical literature with the exception of neuroma injection or percussion. Further, lobotomy continued to be advocated until 1953, electroshock until 1968, and psychotherapy (as a sole or joint therapy) until the mid-1980s [see "Chapter Four: Characterizing Phantoms" for elaboration of therapeutic approaches to phantom pain]. Dismembered men who reported phantom sensation in missing parts were considered psychically compromised, diagnosed as suffering from hallucinations (Hoffman 1954b; Lunn 1955); psychosis

[72] This study of 75 amputees wounded during the WWII was actually conducted in Germany. Translation into English was done by the Palria Translation Bureau in London, published in the *Arquivos De Neuro-Psiquiatria*, available in 1953.
[73] For a comprehensive history of the use of lobotomy see Pressman (1998).

(Pisetsky 1946); an infantile psycho-physiological state (Pool et al. 1953:183); a regressive phenomenon (Zuk 1956); a form of denial (Noble, Price, and Gilder 1954; Simmel 1959b); "a kind of mourning for a part object" (Bressler 1956); or a manifestation of the unconscious (Zuk 1956).

The Modernization of Dismemberment: *Nice Pictures and the New Visual Culture.*

The Office of War Information (OWI) was established by executive order in June of 1942, mandated to coordinate the dissemination of war information intended to facilitate understanding of war-related progress and policy (Blum 1976; Roeder 1996).[74] The OWI emphasized both the production of particular themes within wartime media (including movies, comics and magazines) (Blum 1976) and the censorship of what Roeder (1996:51-62) categorized as confusing, disrupting and disordering imagery. Censored material was housed in the then new Pentagon in a room referred to in internal documentation as the "chamber of horrors" (Roeder 1996:49). Efforts to eliminate disordering imagery included the deletion of photographs depicting dismemberment, because images…

> could document meaningful sacrifices that Americans made for the larger cause, eventually including even death, but could not demonstrate how thoroughly war could disorder – rip asunder – their individual lives and bodies (Roeder 1996:59).

In the War's aftermath, in an ever more visual culture as television began to be marketed circa 1950, images of amputees were widely circulated in a propagandist effort to: 1)

[74] The OWI's Office of Censorship was given the authority to review all international communications not reviewed by the military, as well as domestic communications from military installations and some industrial plants. This included review of photographs taken by military photographers (working in combat zones where access was denied to non-military photographers), as well as personal photographs taken by soldiers.

promote patriotism; 2) "persuade able-bodied Americans that the convalescence of veterans was not a problem;" and 3) demonstrate a commitment to rehabilitation, while foregrounding American technologic ascendancy (Serlin 2002a:28). What made these images so potent was their relative absence from public consumption during most of the war. Although in references to images circulated after WWI, (Koven 1994) argues "Such photographs are powerful because they appear to telegraph all their meaning to the viewer; they are immediately identifiable signifiers and substitutes for the war itself. The dismembered veteran embodies the ambiguous meanings and memories of war."

Against the backdrop of depictions of the workingman's body, found in abundance in mass culture, images of amputees were decidedly provocative. Serlin (2002a:29-30) gives the example of Jimmy Wilson, a quadruple amputee, who became a "poster boy" for American rehabilitation. Jimmy was the sole survivor of a ten-person flight that crashed over the Pacific Ocean. He was found an incredible 44 hours later, after which all four of his limbs were amputated (a story reminiscent of George Dedlow's). A *Philadelphia Inquirer* campaign raised $105,000 for Jimmy testifying to his celebrity status, which peaked when he posed with Miss America 1945, Bess Myerson, to advertise the new *Valiant*, a General Motors special designed specifically for lower-limb amputees,[75] and named to glorify them.

Representations of resilient war-wounded veterans were increasingly disseminated as Cold War tensions rose, which "transformed amputees into powerful visual and rhetorical

[75] Congress allocated funds to support the manufacture of 10,000 of this model to be circulated to needy veterans in September of 1946 (Serlin 2002a).

symbols" (Serlin 2002b). As Serlin (2002b:33-35) deftly argues in his *Replaceable You*, the circulation of these entrancing images had myriad effects, not the least of which was the resultant hierarchization of disability. Bodies disabled by modern-warfare were considered remarkable, demonstrative of individual service and commitment to the state, while bodies disabled from birth, by accident or as a consequence of self-mutilation were either associated with the antiquated notion of the "monstrous birth," or were considered inept. "In the aftermath of the war…veteran male amputees constituted a superior category on an unspoken continuum of disabled bodies" (Serlin 2002b:35). And, I would argue remain so today.[76]

The Modernization of Dismemberment: *The Militarization of Prosthetics and Techno-Induced Liberation.*

Postwar America celebrated the most wealth and prosperity the country and the world had ever known, evidenced by the flourishing stock market, the rising gross national product, the doubling of the median family income between 1946 and 1960, as well as many other positive economic indicators (Farber 1994). Americans considered the modern world to be one "in which people would be free to create themselves anew…the world of new opportunities, new possibilities, and limitless hopes" (Farber 1994). Within this milieu of abundance, the then entrenched war-culture became material in numerous ways, including the maturation and formalization of prosthetic science. The late 1940s to the mid-1950s are considered the peak of prosthetic innovation in the US, during which

[76] A number of authors have argue that disability emasculates, for example Robert Murphy (1990) in the case of paraplegia, or that male disability, also in the case of paraplegia, represents a kind of double consciousness and that masculinity must be either reformulated, relied upon or rejected (Gerschick and Miller 1994).

quantum leaps were made in technique and technology (Northwestern 2002),[77] a crucial stage for any emerging science (Latour 1987). The "key findings from this era still provide the conceptual basis for virtually all contemporary techniques" (Michael and Bowker 1994:100).

The US government was the central player in the transformation of the prosthetic industry from a loose assemblage of uncoordinated craftsman[78] typically considered ambulance chasers to an organized and legitimated profession.[79] In April of 1945, US Surgeon General Norman T. Kirk requested that the National Research Council establish The Committee on Prosthetic Devices (CPD), a prosthetics research and development program to be funded jointly by the Veterans Administration (Northwestern 1995) and the war department (Kurzman 2003).[80] The CPD established the Advisory Committee on Artificial Limbs (ACAL) in July of 1947 which initiated the Artificial Limb Program (ALP) (CPD 1946; Rang et al. 1981; Thomas et al. 1945).

[77] For a comprehensive overview of the history of prosthetics see Northwestern (2002).

[78] Historically in rural areas, the barber or pharmacist typically functioned as the prosthetist. After measuring, taking a casted-impression of the stump and obtaining a shoe, the barber would prepare a box to be mailed to a limb company and instruct the amputee to toughen his stump skin (Pike et al. 1991). Road salesmen were employed by limb companies, who used newspapers or roamed hospitals to search for recent amputees (Pike et al. 1991).

[79] Initially financial support for the CPD came from the Office of Scientific Research and Development through its committee on Medical Research and the Office of the Surgeon General of the Army. After 1946, this obligation was fulfilled by the Army and the Veterans Administration (CPD 1946).

[80] The US Department of Veterans Affairs (VA) was created in 1930 to organize the activities of the government on behalf of US veterans and was established as a Cabinet-level position in 1989 (VA 2002a). The Veterans Health Administration (VHA) is one of 21 organizations that exist within the VA (VA 2002a). The VHA manages the largest health care system in the nation, is one the largest providers of graduate medical education, and is one of the nation's largest medical research organizations (VA 2002b).

The Surgeon General had also gathered prosthetists, surgeons and engineers together in Europe in 1946 to discuss the state of the art (Northwestern 2002).[81] "This meeting, no doubt, contributed more to the development of the science of prosthetics than any other occurrence in its history" (Thomas et al. 1945:11), and marked the establishment of the American Orthotic and Prosthetic Association (AOPA) (Pike et al. 1991). The founding of the AOPA acted as a stimulus for the instantiation of ethical standards, educational programs, and university-based scientific research in the field of prosthetics (Northwestern 2002). Sixteen universities and industrial laboratories were enlisted or organized and funded under the ALP, including Northrop Aviation, Catranis, the U.S. Navy Hospital, as well as labs at the University of California, Berkeley and the University of California, Los Angeles (Rang et al. 1981).[82] State intervention into prosthetics was consistent with a larger trend in the US at the time, the blurring of the boundaries between science/medicine and the state (Goodman, McElligott, and Marks 2003:5; Pickering 1995). The authors write:

> Medical men and scientists were absorbed into the wider machinery of the state in ever-increasingly numbers. In this process, medical science became a constitutive force in the creation of a 'knowledge society' built around the functionality of the body (Goodman et al. 2003:5).[83]

"What made new prostheses different was how they represented the marriage of prosthetic design to military-production" (Serlin 2002a:54). Through the sophistication

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[81] The impetus for this meeting was the fervent public outcry that prosthetic provision, guaranteed to all amputee veterans since the post-civil war period, was wholly inadequate (Kurzman 2003).

[82] Subsequently, these and other campuses began offering coursework and later credentials in the field. These programs were formalized under the National Association of Prosthetic-Orthotic Educators (NAPOE), an educational organization representing the academic programs credentialed by National Commission on Orthotic and Prosthetic Education (NCOPE), that assures the continuity of orthotic and prosthetic education (NAPOE 2002; NCOPE 2002). The American Board for the Certification in Orthotics and Prosthetics (ABC) was created in 1949 and is recognized as the preeminent national accreditation and certification body responsible for the competency of orthotists and prosthetists (ABC 2002).

[83] The authors argue that process was occurring throughout Europe and North America.

and elaboration of prosthetic science and amputation surgery, or what O'Connor (2000:105) terms the "modernization of dismemberment," the male amputee came to embody the liberatory potential of modern medicine and military technology. O'Connor (2000) explores the time frame from the mid-1800s through WWI, suggesting that the modernization of dismemberment occurred during this period. However, I use the term to refer to the post-WWII context because in the US what are touted as the most significant modern prosthetic advancement occurred circa 1950.

As a result of state-sponsored cross-pollenization of biomechanics, cybernetics, materials science, and industrial robotics, the then fledgling field of prosthetics was catalyzed into a biomedical discipline (Serlin 2002b:25). Prosthetic science emerged as a "sociocultural network" (Oudshoorn 2003), a heterogeneous assemblage of people, ideas and things, of technical, political, social and institutional processes (Callon 1986a; Callon 1986b; Latour 1987; Latour 1991; Law 1991; Law 1997).

I would like to highlight here the social rather than technical construction of prostheses and foreground the fact that technologies are always constructed with *user representatives* in mind (Akrich 1994; Akrich and Latour 1994; Woolgar 1991), while also acknowledging that technologies are always situated within *actor networks* (Latour 1987). Prostheses in the post-war years were designed with specific intentions; the prosthetized amputee was envisioned as recovered citizen while also representing the militarization of prosthetization. However, like all technologies, prostheses are also subject to (re)negotiation in use, to relational translation (Akrich 1995; Clarke 1990;

Clarke and Fujimura 1992; Clarke and Montini 1993; Mamo et al. 2001; Moore 1997; Pinch and Bijker 1984). For example, Terry and Calvert (1997:4 original emphasis) write:

> Technology is defined more appropriately in terms of machine/human interface, that is, in terms of how particular machines and mechanisms accomplish tasks of configuring, effecting, mediating and embodying social relations. In this definition, machines do not necessarily *determine* social relations, but are situated in networked social relations, subject to uses and creative misuses by the humans (and other machines) that surround them (Terry et al. 1997:4 original emphasis).

Yet, I do not want to argue simply that prostheses were unintentionally or cleverly transformed or renegotiated by amputees through everyday use (which they often are), or that amputees accepted (or resisted) the denotation of militarized prosthetization. Rather, I argue that amputees came to represent what I call the cyborg warrior because of the militarization of prosthetics and the masculinzation of dismemberment, both of which were realized because veteran amputees embodied prostheses. It was the very embodiment of the technology, veteran "interfacing" with prostheses and the state, that I argue, eventuated in the masculinization of dismemberment. Nelly Oudshoorn argues, users come to share a *Technosociality*, a collective identity based on a shared intimacy with a particular technology (Oudshoorn 2003). I argue that cyborg warriors were proficient and invulnerable, embodying a form of idealized masculinity (Cohn 1995), which was epitomized at the time by physical grandiosity and strength (Glassner 1988; Kimmel 2004), as well as by self-mastery and efficiency (Franklin 1988).[84]

[84] For example, Connell (Connell 1995:126) asserts that the glorification of male efficiency is apparent in the warrior-hero. "One of the central images of masculinity in the Western cultural tradition is the murderous hero, the supreme specialist in violence".

Technologies are not simply tools, objects, appliances, prostheses (as attachment), or machines. Lucy Suchman argues that technologies are only contingently complete assemblages of fantasies and politics, interests and techniques, knowledges and practices, stories and performances, reputations and misbehavior (Suchman 1994b; Suchman 2000; Suchman et al. 1999; Suchman et al. 2002).[85] Thus, as Suchman (2002:164) aptly brings to the fore, human-machine interfacing is an ongoing practice that is never "self-evident" (Suchman et al. 1999); technologies are situated practices, understood as socio-material "technologies-in-the-making." She writes:

> Making technologies is, in consequence, a practice of *configuring new alignments* between the social and the material that are both localized and able to travel, stable and reconfigurable, intelligibly familiar, and recognizably new…Integration, local configuration, customization, maintenance and redesign on [sic] this view represent not discrete phases in some 'system life cycle,' but complex, densely structured courses of articulation work without clearly distinguishable boundaries between (Suchman 1994b:24 emphasis added; Suchman et al. 2002:164).

I want to acknowledge that technologies are practiced, negotiated, accomplished. Yet, simultaneously recognize that they are not "innocent" (Suchman 2005), not without purpose. User representatives can have profound implication for the kinds of sociality available to those designing, doing, modifying, or implicated in (Clarke et al. 1993) those technologies. However sociality is never disembodied, and in the case of prostheses, the demobilized veterans who "did" prosthetization affectively masculinized dismemberment, which I argue functioned to severe amputation from the previous connotation of fractioning, psychosis, and vulnerability.

[85] Lucy Suchman's work resides at the intersection between technological design and what she calls artifacts-in-use; she wants to unveil or recover the work, interests and identities central to the practice of both design and use (Suchman et al. 1999). She argues, for example, that technologies "are situated through and inseparable from the specifically situated practices of their use" (Suchman et al. 1999:399).

In conjunction with the masculinization of dismemberment, the militarization of prosthetics functioned to profoundly alter the "signification" of the postwar amputee. In the "hyperpatriotic" (Serlin 2002a:35) "Victory Culture" (Engelhardt 1995) of postwar America, the alliance between the US military and amputees was commensurate with renormalization efforts and a national commitment to the rehabilitation of veterans. Because of the correlation of military prowess and power with prostheses, amputated bodies became extraordinary; at once "tools for consensus building, apotheosis of domestic engineering," and representatives of technologic liberation (Serlin 2002b). "The association between amputees and state-of-the-art prosthetics research may have been an intentional strategy to link disabled veterans with the cutting edge of new scientific discoveries" (Serlin 2002a:55).

The conflation of dismemberment with cyborg warriorship and *techno-liberation* was incommensurate with the association of dismemberment with emasculation or mental instability. In the literature, this incongruence played out in the postulations that: 1) the phantom had psychological origins; 2) phantom limb was universally experienced by amputees; and 3) the phantoms could persist indefinitely. Because amputees were thought to invariably develop phantoms, one could surmise that amputation, and hence war and the state, caused psychosis. The state could, then, essentially be construed as responsible for physically compromising young men and with actualizing permanent psychosis.

It was at this time that phantoms began to be reconceptualized not as demonstrative of mental instability, but as fundamentally physiological phenomenon. From both sociology of knowledge and sociology of science perspectives, it is interesting to note that this reconceptualization vividly reflected the postwar/cold war political context in which it occurred. Although the phantom ostensibly fell under the purview of biomedicine in the mid-1950s, through inclusion in the *Index Medicus*, phantoms were predominantly theorized from a psychological perspective until circa 1960, at which time overt critiques of the psychologized phantom began to appear in the literature. In an early example, Simmel (1959b) argues against the application of the theory of wishful denial in the case of phantom limb, because the universal and persistent qualities of phantoms dissuade acceding to this interpretation. She also offers up the distorted phantom (telescoping) in order to substantiate her critique. “If denial leads to such distortions, then, I would think, this turns out to be a very inefficient defense which does not even protect the individual at the level at which it is supposed to” (Simmel 1959b:605).

This period, then, marks a shift from the psychologization to medicalization of phantom phenomena and much of the research conducted throughout the 1960s actually functioned to normalize phantoms. From this point forward, phantoms were not to be found in the dark recesses of the disturbed mind but in the tangible physiology of bodies (or neurology of brains), and consequently, the mysteriousness of phantoms began to fade.

Normalization of phantom limb phenomenon took the form of efforts to proliferate phantoms. For example, as is demonstrated in *Appendix G: Phantom Populations*, once associated only with amputees, researchers "discovered" a number of other susceptible populations including: people with spinal cord injury (Frederiks 1963; Gangale 1968b; Maloney and Darling 1966; Pollock 1957a; Pollock 1957b; Simmel 1967; Wilson, Person, Su, and Wang 1978), congenital aplasics (Maloney et al. 1966; Mayeux and Benson 1979; Riscalla 1977; Simmel 1962; Weinstein and Sersen 1961), individuals with breaks or lesions of the brachial plexus (Gangale 1968b; Simmel 1959b; Simmel 1967), children as young as 37 months old (Esson 1961), people with mental impairment or developmental disabilities (Simmel 1959a), those experiencing absorption caused by leprosy (Price 1976; Wilson et al. 1978) and in cases of multiple sclerosis (Mayeux et al. 1979).

Phantom-Prosthetic Relations.

Early researchers and practitioners working with amputees to address issues related to rehabilitation or post-operative care advocated the use of prosthetics to prevent or minimize social stigma. If amputees could hide their deformities, they would give others little reason to be judgmental or disapproving.[86] For instance, Hoover (1964b:48) writes, "in general, there is very little prejudice toward an amputee who learns to function well with his prosthesis." In addition, there was early recognition that amputees became invested in their prostheses; an amputee who readily adapted to prosthetic use would find himself integrating his new limb into his self-concept or body scheme.

> Phantoms of the lower extremities often coincide with the prosthesis; that is, the patient comes to experience the prosthesis as a living member, much as he experiences his leg on the other side, and is literally walking on the phantom (Simmel 1956b:644).

[86] Erving Goffman's *Stigma* (1968) details the process of stigmatization indicative of the period stressing the significance of the visibility of disability for identity change.

The concept of body scheme was proposed at the turn of the 20th century by Head and Holmes (1911). Despite having various incarnations over the next sixty years when applied to phantom phenomena, it remained one of the chief explanatory frames employed to account for phantom sensations until circa 1970. Head and Holme's usage portrayed the body scheme as predominantly a *model*, built up from kinesthetic, sensory and visual stimuli, the function of which was to register changes in the posture of the body. By the mid-1960s, the scheme had evolved into an allusive psychological organ [for a detailed overview of body scheme/ body image see "Chapter Five: Contested Territory"].

Hoover (1964b:47), for instance, suggested the amputee developed a confused body scheme because of a "psychological reaction to deficiency or incompleteness." This line of argumentation, the confused body scheme, was somewhat homologous with psychological accounts that attributed phantom formation to wish fulfilling hallucinations or denial, mentioned above. What differentiates the two is body scheme theory's emphasis on physical deficiency and the economy of the body (the body is naturally and most productively lived as whole), rather than on partiality and a spoiled aesthetics of the body (beauty is lived wholeness). Informed by this interpretation of body scheme, researchers advocated the use of prosthetics in order to resolve body scheme confusion, and return competence to the amputee or in the following case of a child amputee, ensure developmentally secured competence.

> The method of fitting upper-extremity amputees at 5, 6, or 7 months of age is ideal. This is about the time when…the pattern of hand use is established, and our experience has been to see the children rapidly acquire a sense of possessiveness toward the prosthesis as if it were literally a part of themselves. If the fitting is delayed, they have the opportunity

> to establish a pattern of use of the stump, which has to be unlearned order for them to get good use from the prosthesis (Kyllonen 1964:20).

That is not to suggest that the discourse of wholeness began to abate; in fact it did not. However, wholeness was no longer about fooling others (making the body look both normal and functional). Wholeness enabled the amputee to secure or maintain proper body comportment and thus was more about fooling oneself.

> Early return of function is of paramount importance in the post-operative care of amputees. The lapse of time between amputations and prosthetic fitting appears to be crucial in preventing many psycho-physical problems. The amputee is forced with the concept of himself as a whole person in his amputated state (Gangale 1968a:428).

During the mid-1980s (and through the 1990s), the discourse on prosthetic desirability and phantom-prosthetic relations began to change, emphasizing instead the restorative function of prosthetic replacements in terms of mobility, productivity and independence, while also underscoring the utility of phantoms. The literature began to introduce productive aspects of phantoms and speculate on how these aspects might be harnessed to aid in prosthetic facility (Williams and Deaton 1997). Derman (1986) argued that “PLS is actually useful as a proprioceptive aid when individual begins learning to use a prosthesis.”

By the 1980s, he phantom’s presence was considered tantamount to recovery. Enormously useful to the amputee, the phantom’s practical status had been elevated significantly becoming a marker of potential and of achievement (Sacks 1987). For example, those whose phantoms failed to develop were thought to have difficulty managing prosthetic devices. Considered restorative, prosthetic replacement was assumed to be a necessary first step to rehabilitation, and the phantom that animated the prosthetic was viewed as integral to proper use.

In fact, "a properly functioning individual is one who has coupled his phantom to his prosthesis" (Abramson and Feibel 1981:111). Reporting that one feels naked without one's prosthetic became considered a sign of successful execution and integration (Lundberg and Guggenheim 1986). Prosthetic replacement was assumed critical for the rehabilitation, universally desirable, and universally desired. Lenor Madurga writes in her autobiography, a communication had with her prosthetist:

> Fred explained to me once the crippling alternatives I would have faced if I had not been fitted for a prosthesis soon after my amputation and worn it faithfully. Severe scoliosis – curvature of the spine – most likely would have developed; arthritis could have set in; discs may have slipped, necessitating a spinal fusion. I would have become lopsided (Madruga 1979:142).

This assumption was certainly evidenced by the introduction of such practices as immediate post-surgical fitting of temporary prostheses[87] (Abramson et al. 1981; Lundeberg 1985).

> Technology can provide a new amputee with sophisticated prosthetic devices which perform many functions as adequately as the original…the adjustment work an amputee faces may be ameliorated by successful use of a prosthesis. Almost all recent amputees, regardless of age or state of health, want an artificial limb (Lundberg et al. 1986:199,206).

The coupling of phantoms to prostheses was thought to facilitate prosthetic adaptation. By slapping his stump, one of Sacks' patients resurrects his phantom each morning. "On

[87] Patients will actually awaken after amputation surgery with a temporary plaster cast and pylon. Immediate prostheses are asserted to provide both physiological and psychological functions. The absence of a limb-less period, the restoration of function, reduced rehabilitation interval, pain reduction and limb maturation are purported advantages, weighted in opposition to fewer site inspections, a reduced ability to manage early complications, early weight bearing (as opposed to progressive tissue loading), and "technical difficulties in the proper application of the rigid dressing and prosthesis" (Burgess 1981:21). See also (Abramson et al. 1981; Lundeberg 1985).

the fifth or sixth slap the phantom suddenly shoots forth, rekindled, *fulgurated*" (Sacks 1987:67 original emphasis). This ritual of phantom awakening and prosthetic animation demonstrates a reciprocal functional relationship between phantoms and prostheses. While the prosthetic is roused by the phantom, the phantom is tamed by its structure.

> There's this *thing*, this ghost-foot, which sometimes hurts like hell – and the toes curl up, or go into spasm…It goes away, when I strap the prosthesis on and walk. I still feel the leg then, vividly, but it's a *good* phantom, different (Sacks 1987:69 original emphasis).

Further, a disturbed phantom could actually be renormalized by donning a prosthetic, returning to "normal" size and shape. In the case of telescoping:

> The most astonishing feature of the phantom limb is its 'reality' to the amputee, which is enhanced by wearing an artificial arm or leg; the prosthesis feels real, 'fleshed'. Amputees in whom the phantom leg has begun to 'telescope' into the stump, so that the foot is felt to be above floor level, report that the phantom *fills the artificial leg* when it is strapped on and the phantom foot occupies the space of the artificial foot in its shoe (Melzack 1990:89).

Thus, phantoms themselves needed discipline, for example, exercising the phantom or practicing movement (Rosen, Willoch, Bartenstein, Berner, and Rosjo 2001b) and "working" to return a phantom to normal size[88] in order to fully animate the prosthesis (Muraoka, Komiyama, Hosoi, Mine, and Kubo 1996). Able to flesh-out prosthesis (Saadah and Melzack 1994), phantoms were appreciated as facilitating the use of prosthetics, while prosthetics were considered curative. Prosthetic use was, and still is, correlated with the reduction of phantom limb pain (Abramson et al. 1981; Finnoff 2001; Flor 2003; Iacono, Linford, and Sandyk 1987; Kooijman, Dijkstra, Geertzen, Elzinga, and van der Schans 2000; Lotze, Grodd, Birbaumer, Erb, Huse, and Flor 1999; Postone 1987; Ribbers, Mulder, and Rijken 1989; Weiss, Miltner, Adler, Bruckner, and Taub

[88] Others have tried purposively shrinking the phantom in an effort to alleviate pain (Oakley, Whitman, and Halligan 2002)

1999; Whyte and Carroll 2002), particularly with functional (versus cosmetic) prostheses (Lotze et al. 1999; Weiss et al. 1999) and is also correlated with "reversing" phantom limb pain (Flor 2003). The pathological phantom, the distorted, twisted, pained phantom, consequently results from disuse and neglect. In other words, phantoms *not* productively harnessed became categorically pathological.

It is to the issue of *phantom potentiality* that we turn next. Through an elaboration of the principle permutations in symptomatology, nosology, etiology, and epidemiology, I show how phantoms surfaced as conspicuously productive phenomenon.

4 CHARACTERIZING PHANTOMS

Shape-Shifting

Phantoms are at once vital body parts and defunct human remains. Like all body parts, phantoms are embodied, used, practiced, pained, appraised. And, like all remains, phantoms are strangely foreign, traces of what was "mine" and that which is no longer "me".

This chapter, in conjunction with the next "Chapter Five: Contested Territory," characterizes phantom limb, punctuating some of the most idiosyncratic and protean aspects of the phenomenon, while also exposing the principal permutations in symptomatology, nosology, etiology, and epidemiology. These chapters detail how this amorphous "syndrome"[89] has taken shape or become contoured within biomedical contexts from circa 1950 to the present. I show how phantoms, conceived as shape-shifters, have been sensitive to: 1) attempts at re-visioning the neuro-scientific research on phantom phenomena; 2) socio-historic interpretations of the natural forms and functions of bodies; 3) reinterpretations of the neuro-physiology of the brain; 3) the biomedical institutionalization of pain; and 4) the elaboration and sophistication of prosthetic technologies. At the same time, I argue that phantoms are not simply objects that can be either made "explicit" once and for all, or can be endlessly modified and

[89] Typically "diseases" are classified by etiology, pathogenesis, organ system, or symptomatology. In the case of phantom limb, the etiology and pathogeneses have consistently been unknown, the afflicted or implicated organ system variable, and the symptomatology idiosyncratic. As is indicated in *Appendix P: Phantom Nosology*, researchers and clinicians have adopted the terms phantom limb syndrome, phantom limb phenomena, phantom limb experience (PLE), or phantom limb sensation (PLS), to categorize phantoms. However, today the most widely used terms are phantom limb, phantom limb pain (PLP) or phantom pain.

retailored. Rather, phantoms are at once "work objects" (1998a; Casper 1998b)[90] and *actants* in that they have been the force behind many transmutations within the field, within bodies, and between bodies and technologies (Callon 1986b; Callon 1999; Latour 1987; Latour 1991; Law 1992; Law 1997). In other words, I embrace what Barad (1999:3) has referred to as "agential realism," an approach that acknowledges the "material-discursive" nature of a "world [that] kicks back."[91]

This chapter presents the breadth of sensual and functional features of phantom limbs, which I have organized along qualitative, temporal, morphologic, and kinesthetic,[92] dimensions, rather than chronologically. This entails that the reader be, at times, uncomfortably yanked back and forth through time. However, this time-warping is intended to enhance the visibility of the shape-shifting of phantoms historically.

In the first section on phantom quality, I argue that consonant with the invention of pain medicine and the "emerging epidemic of pain" in the US circa 1980, phantoms literally became painful through the promotion of a specific language of pain vis-à-vis the adoption of the McGill Pain Questionnaire for assessing qualitative dimensions of phantoms. The discovery of *pain memories* circa 1990, thus, corresponded with burgeoning phantom pain prevalence rates, which rose to a high of ~85%. Consequently, the pleasurable tingling associated with phantom onset was re-conceptualized as a pre-

[90] Casper defines a work object as "any material entity around which people make meaning and organize their work practices…[the] constructions of [which] vary depending upon who cares about it, who is attributing meaning, what the work goals are, and material contingencies."
[91] This line of argumentation is also consistent with an appreciation of the leaky (Shildrick 1997; Shildrick 1999), recalcitrant (Williams 1998b; Williams et al. 2000), and transgressive (Falk 1994; Williams 1998a; Williams et al. 1998) body and the acknowledgment that there "is always a material residue that resists incorporation into dominant symbolic scheme" (McNay 1999:98).
[92] Kinesthesia: "The sense perception of movement; the muscular sense" (Stedman 2000:950).

pain sensation, and the phantom became commodified through the establishment of a specialized industry devoted to the treatment of phantom pain. I also show how the demobilization crisis, in the postwar years, resulted to a shift from the psychologization to the medicalization of phantoms.

In the section on phantoms in time, I show how knowledge about the onset, development and duration of phantom sensation has been influenced by assumptions about prevalence and etiology. I argue that interest in onset emerged during the 1960s as phantom limb prevalence rates began to decline, a trend that corresponded with the evolution of the concept of denial. Further, I demonstrate how the elaboration of neuronal reorganization as an explanatory frame for phantom formation starting in the 1980s prompted a reconsideration of the universal nature of phantom phenomena.

In the section on phantom morphology, I demonstrate how the considerable increase in phantom pain and the discovery of *mislocation* correlated with a significant etiological shift made possible through new visualizing technologies, while also allowing phantom distortion to become intelligible. The profusion and elaboration of distorted phantoms in turn, contributed to the (partial) rejection of innate cortical structures, the abandonment of the "hardwired" notion of the physiology of the brain, and a rethinking of mind-body relations.

In the section on phantom kinesthetics, I argue that, consonant with the 20th century celebration of movement and its restorative qualities, an interest in cataloguing the kinesthetic features of phantoms emerged. While willed phantom movement was lauded, involuntary movement became maligned. I suggest that *phantom paralysis* or frozen phantoms were problematized both because of their association with immobility and because of their tendency to (theoretically) disrespect materiality when relating to objects. Finally, I show how purposive movement, or “phantom exploitation,” emerged circa 1980 as part of the emergent discourse emphasizing phantom utility or *phantom potentiality*; this discourse suggested that phantoms could be harnessed for the purposes of facile prosthetic use and pain reduction, among other functional purposes.

The Phantom Complex.

The medical and psychological literatures on phantom limb are replete with contradictory and often “transient” knowledge about phantom formation. Recently, scholars have attempted to explain these drifts, discontinuities and dismissals, to explicate why phantoms have so persistently eluded biomedical characterization, classification, explanation and intervention. Many scholars in the recent past have advanced arguments about the discrepancies in the “state of the knowledge.” They have put forward reviews, as well as provided fresh data, intended to parse the valid and reliable from the mythical or the messy. I argue that these works are also illustrative of attempts at legitimating and re-visioning neuroscientific research on phantoms, of doing “boundary work” in Gieryn’s (1999) terms. Study devoted to this illusive and obscure phenomenon, as it is now argued, has provided heretofore unimaginable and invaluable insights into the functional reorganization of the brain. Phantoms have proven to be exceedingly fruitful experimental “objects” unlike any that could be purposively simulated, and the researchers dedicated to their investigation "serendipitously" in a position of exploitation. Ramchandran (1998a), arguably the most widely-known contemporary figure in this field, proposed in his popular science text, *Phantoms in the Brain*, that the study of phantoms allows us to:

> address loft 'philosophical' questions about the nature of the self…what brings about the seamless unity of subjective experience?… Philosophers love to debate questions like these, but it's only now becoming clear that such issues can be tackled experimentally. By moving these patients out of the clinic and into the laboratory, we can conduct experiments that help reveal the deep architecture of our brains. Indeed we can pick up where Freud left off, ushering in what might be called an era of experimental epistemology…and start experimenting on belief systems, consciousness, mind-body interactions.

In an interview in a few years earlier appearing in *Discove*r, Ramachandran is quoted by Shreeve (1993:2) who writes,

> While chasing the phantom, neurobiologists have thus been led to a solid revelation: the sense of touch, and the physical world it ushers into existence, has much more to do whit what is going on in our heads than at our fingertips. The illusory sensations may even be on the verge of revealing one of the brains most powerfully guarded secrets. If neuroscientists like Ramachandran and Kass are correct, the exotic phenomenon of phantom limb offers one keenly magnified perspective on what routinely happens in the brain as we engage the world around us…Were looking are a new route to the Holy Grail of neurobiology, says Ramachandran.

In an interview with Dr. Joel Katz, who is a professor in the Department of Psychology and School of Kinesiology and Health Science at York University in Toronto, he said, "I think that whoever solves the puzzle or problem of the phantom limb will also solve the problem of perception….that's what I like so much about the phantom, I think of it as a window into the central nervous system."

Ostensibly about addressing inconsistencies and incompatibilities, efforts to revision phantoms are ultimately scientific acts of reclassification (Bowker and Star 2002). Such acts required sifting and sorting, sometimes necessitating re-reading findings and sometimes requiring their dismissal altogether; categorization, after all, is always a political project (Bowker et al. 2002; Suchman 1994a). For example, Ribbers, Mulder, and Rijken (1989) attributed the extraordinary degree of ambiguity, vacillation, and incongruity that exemplifies the literature, to terminology confusion, sloppy sample selection, differences in both patient reporting[93] and patient experience (tolerance), as well as in observer (mis)interpretation. In short, some studies have been reread as suffering from poor science and others from unreliable respondents. At the close of the twentieth century, researchers and clinicians have further suggested that past studies confounded the distinctive elements of what Jensen and Nikolajsen (2000; 1999; 2001) call the *phantom complex*, which is asserted to have three components: 1) *phantom limb pain* or pain that does not originate in the missing limb but is "referred" to it; 2) *phantom limb sensations* or sensation referred to the missing limb; and 3) *stump pain* or pain that is localized to the stump (see also Finnoff 2001; Fraser, Halligan, Robertson, and Kirker 2001; Halbert, Crotty, and Cameron 2002; Sherman, Arena, Sherman, and Ernst 1989; Sherman, Sherman, and Parker 1984; Weinstein 1998; Woodhouse 2005).[94,95] Employing this same explanatory framework, an earlier had study proposed that amputees themselves had difficulty differentiating between these three facets of

[93] For example, Shukla et al. (1982:56) attributed delayed reporting to a lack of education; they write, "our patients, being educationally backward and rather unsophisticated, were slow to recognize its presence."

[94] Others argue that back pain should be included in the phantom complex as part of a more comprehensive clinical picture (Ehde, Czerniecki, Smith, Campbell, Edwards, Jensen, and Robinson 2000; Ehde, Smith, Czerniecki, Campbell, Malchow, and Robinson 2001; Jensen, Smith, Ehde, and Robinsin 2001; Marshall, Jensen, Ehde, and Campbell 2002; Smith, Ehde, Legro, Reiber, del Aguila, and Boone 1999; Smith 2002a; Smith 2002b).

[95] A few years later, Hunter, Katz, and Davis (2003) elaborated the phantom complex, distinguishing between 1) *phantom limb sensation* or somatic feelings such as warmth and pressure; and 2) *phantom limb awareness* or a kind of corporeal "consciousness" of a limb, limited to an impression of size and position. In other words, the authors suggest that an amputee may be cognizant of a phantom, generally aware of its presence, and/or he or she may have the capacity to literally feel sensations originating in the absent limb.

embodied experience (Davis 1993; Hazelgrove and Rogers 2002). Dr. Joseph Czerneicki (Interview July 21 2005) describes the differentiation problem:

> You may have a condition where there is a pathophysiologic process in the residual limb that causes pain in the stump and pain in the phantom. So, there is a kind of overlapping process that can cause some confusion in discerning stump, phantom, phantom only, stump only, stump and phantom pain. It can be complicated. I often hear people say, "my phantom pain is driving me nuts." I say, "Okay point to where it is" and they point right to their stump. That is stump pain, not phantom pain. Sometimes, they just think that if it is pain after amputation, then it is phantom pain.

Whether attributable to bemused clinicians or undiscerning amputees, at least some of the shape shifting that has characterized phantoms over the last half of the twentieth century has been ascribed to the failure to discriminate between the flesh and its ghosts.

Within the scientific field, then, these debates about "messiness" reveal that re-visioning efforts (explaining inconsistencies and incongruence, distilling and culling the body of research devoted to phantom limb) have led researchers to differentiate between phantoms of the past and those of the present. Past phantoms have been reworked as problematic, as poor copies of the genuine thing, because they had not been suitably uncoupled from bodies analytically. In other words, past phantoms are problematical conflations of specter and soma. In contrast, present phantoms are more "real" because they are analytically clear and because they are now properly situated in brains. In effect, past phantoms have been measured against present phantoms in an effort to sort the authentic from the chimerical, to rationalize phantoms, and to distance contemporary scientific work in the field from its fanciful history.

Phantom rationalization was requisite to the re-writing of the origin story in which phantom etiology has moved from the psyche to the periphery (severed nerves), and now to the center (cortical reorganization). Although I reserve an in-depth examination of phantom causal theorizing for the "Chapter Five: Contested Territory", I do want to point out here that contemporarily, neuroscientists have begun to propose that "you don't need a body to feel a body" (Melzack 1993:620), and the phantom, it is asserted, is quite compelling evidence of the epiphenomenal quality of corporeality. Dr. Ronald Melzack, one of the most significant figures in the recent history of phantom limb, has posited that current studies demonstrate "the brain itself can generate every quality of experience which is normally triggered by sensory input" (Melzack 1989b; Melzack 1993:620), and "that the brain is a structure which generates *and creates* everything we feel" (Interview, August 2005 emphasis added). Similarly, Dr. Vilayanur Ramchandran (1998a:58 original emphasis), wrote "*Your own body* is a phantom, one that your brain has temporarily constructed purely for convenience."

In the late or post-modern context, the body is increasingly constructed as malleable, and the work being accomplished in this area of the neurophysiology of the brain – particularly the work on neuronal reorganization and the discovery of novel cortical structures like the neuromatrix - is certainly contributory to and demonstrative of this inclination. In the following sections, I use the research on phantom limb to make visible the emergence of a *de-structured corporeal ideology*, which I argue, has informed assertions of the morphologic, kinesthetic, qualitative and temporal possibilities and promises of brain-based body parts. I suggest that past phantoms were imagined as faithful copies of fleshy limbs, whereas present phantoms are imagined as parts that are not accountable to gravity, symmetry, time, or morphology, thus not answerable to the physicality of bodies, but rather to the potentialities of brains. That is not to say that past phantoms were faithful copies; in fact they often were not. But these distortions, as I detail below were constructed as anomalous. As Roth (2005:30,32) argues, researchers within a field co-construct shared knowledge in an effort to found some kind of certainty and the unclassified/able cases, the "'crosses', 'mongrels', or even 'monster' that are inherently out of bounds," become part of a disturbing "pea-soup" (see also Star and Gerson 1987 on the management of anomaly in neuroscience). In the past, the distorted phantom was conceived as mongrel or monster, while today the protean nature of phantoms is their quintessence.

The Qualitative Peculiarities of Phantoms: *Substantive Variation.*

Everything that is felt by the body can also be felt through the phantom. Phantom sensations consist of the entire range of sensory qualities of the flesh including touch, pressure, vibration,[i] tactile texture, as well as itch,[ii] tickle,[iii] wetness,[iv] numbness,[v] pain and fatigue.[vi] In Der Beeck (1953:225) writes of one of his subjects:

> Immediately after the amputation I felt the left leg throughout its whole length…it was a prickling sensation, as though the leg were hanging down with the hollow of the knee on one edge of the bed. It was an itching, furry feeling, a continual to-ing and fro-ing.

Phantoms are uncanny imitators that frequently respond to modality specific stimuli, warmth, pressure, etc. Sherman et al. (1997) detail a case of an amputee whose phantom foot felt wet when walking in water. Others report sensations that seemingly vary relative to fluctuating environmental stimuli, such as subtle changes in the weather.

Buxton (1957:500) reported "The foot was never quite normal…weather conditions affected it, so that the toes might feel crushed if it was frosty or feel immersed in moving water before a rain came." Or, Ramchandran and Hirstein (1998b:1618) write: "One patient told us that he could use his phantom as a 'barometer' to predict rainfall well ahead of, and more accurately than, the TV weatherman!"

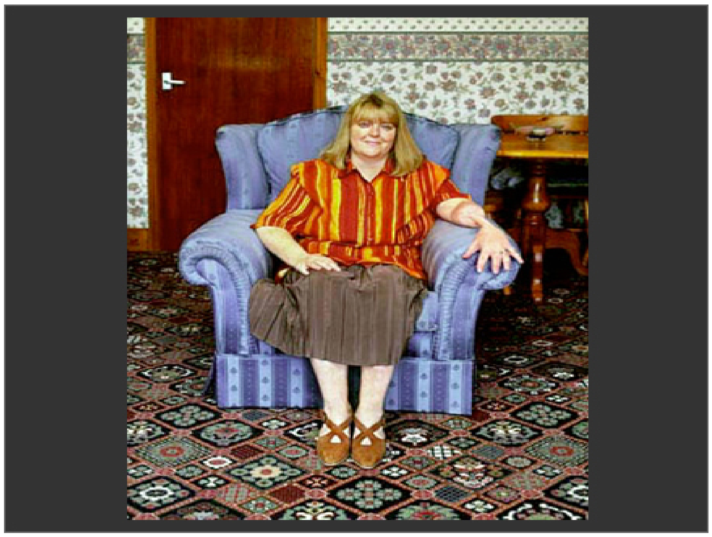

Figure 2: The Distorted Phantom. During collaborative work with neurologist Dr. John Kew and neuropsychologist Dr. Peter Halligan, English visual artist Alexa Wright manipulated photographs to enable the "visualization" of phantoms described by amputees. JN's phantom is often experienced as larger, heavier and flatter than her intact limb. The wrist is virtually absent but the joints are large and stiff. Her phantom finger still wears an engagement ring. Taken with permission from Alexa Wright's 1997 *After Images*.

Phantoms may also incorporate what have been termed "superadded" features (Harber 1958a; Henderson and Smyth 1948; Katz and Melzack 1990),[96] including a bandage,[vii] a tourniquet,[viii] a cast,[ix] a ring or watch,[x] a shoe,[xi] a cane,[xii] or blood in a boot.[xiii] Jackson (2002) writes of the phenomenon, "they feel the pressure of a nonexistent ring on a missing finger…[and] The sensation is said to be almost holographic."

[96] Some amputees have reported that their phantoms integrated "multimodal superadded" sensations (Harber 1958a), such as a "white sock and a black patent leather shoe with straps" (Katz et al. 1990:328). Harber (1956) also relayed the case of an amputee who was quite irritated by the fact that the his phantom wore two watches at the same time.

Still, amputees do report that their phantoms are exceptional or unusual in certain respects; they may be sensed as particularly vivid or vague,[xiv] hot/warm,[xv] cool/cold,[xvi] light or heavy,[xvii] and/or dense or hollow.[xviii] For example, Grosz (1994a:71) writes that the phantom "is commonly perceived as flatter than the healthy limb…[and the] movement of the phantom is fundamentally different from the movement of the healthy limb insofar as the weight and gravity of the real limb is considerably stronger than that of the phantom. Patients refer to its 'husklike', weightless, and floating character."

As is demonstrated by *Appendix H: Phantom Quality*, the many sensations that characterize phantoms include those that are seemingly common sensory experiences. Yet, phantoms may also be described in ways that seem quite foreign, even incomprehensible. It is the language of phantom quality that I explore in greater detail.

The Qualitative Peculiarities of Phantoms: *Recounting Phantom Quality.*

In 1975, Dr. Ronald Melzack published his now seminal article introducing the McGill Pain Questionnaire (MPQ), an instrument that became key to assessing the quality of phantom sensation (Bittar, Otero, Carter, and Aziz 2005; Bone, Critchley, and Buggy 2002; Dougherty 1980; Ehde et al. 2000; Fisher and Hanspal 1998; Halbert et al. 2002; Harden, Houle, Green, Remble, Weinland, Colio, Lauzon, and Kuiken 2005; Hill 1993; Hill 1999; Hill, Niven, and Knussen 1995; Katz 1992a; Katz et al. 1987; Katz et al. 1990; Katz et al. 1991; Lundeberg 1985; Marshall, Helmes, and Deathe 1992; Nikolajsen, Ilkjaer, Kroner, Christensen, and Jensen 1997b; Robinson, Czerniecki, Ehde, Edwards, Judish, Goldberg, Campbell, Smith, and Jensen 2004; Whyte and Niven 2001a; Whyte and Niven 2001b). The MPQ established a set of descriptors ostensibly to give people a shared language to express the indescribable, and to pin down pain for diagnostic purposes, to constitute a "workable object" through the development of a documentation and assessment tool (Whelan 2003:464). The design and implementation of the instrument was one of the many means through which pain was institutionalized in the US circa 1975 (Baszanger 1992).

> Working on pain implies knowing how to recognize it, how to interpret its diversity. It requires classification…classification plays an essential role in creating a community of practice and can become a common basis for physicians to communicate among themselves and with others (Baszanger 1998a:34).

The advent of the MPQ contributed to the legitimation of the nascent field of pain medicine (Melzack is of course a significant figure in the history of pain). However, it also proved to be a noteworthy event in the history of phantoms (of which Melzack is again one of the most significant figures). The MPQ has been central to the reification of phantom limb in the sense that this one event effectively homogenized sensation and essentially froze phantom quality linguistically and temporally. As *Appendix H: Phantom Quality* shows, when studies after 1975 considered the qualitative dimension of phantoms, whether the MPQ was an element of the study design or not, the terminology used has overwhelmingly been consonant with the set of descriptors included in Melzack's tool.[97] In other words, the (past and present day) portrayal of phantom sensation as knifing, smarting, wretched, lancinating or dreadful, for instance, is more an artifact of the language advanced by the widely accepted instrument used to measure

[97] Two peculiar exceptions are Jankovic et al. (1985) and Jacobson et al. (1989). Janovic et al. (1985:433) write, "after the left shoulder amputation, she noted a feeling of 'champagne bubbles and blisters' in the phantom left arm." Jacobson et al. (1989:984) report that their patient felt as if he had been bitten by a giant crab.

phantoms (and the dissemination of that terminology), than it does an "accurate accounting" of the quality of those sensations. Even those studies that did not use the MPQ typically made use of its descriptors (whether the narrative was provided by the researcher or the amputee). Also telling are the exceptions, the accounts of phantom quality that did *not* advance terminology homologous with the MPQ. The gritty, raw, and petrified qualities of phantoms, for instance, were largely documented prior to 1975, prior to the institutionalization of the MPQ.

In my interview with Dr. Ronald Melzack (Jul 25 2005), he suggested that the language of phantom pain was quite different from other pain conditions. Melzack states, "One of my students did a study on the patterns of words chosen by people with different kinds of pain. Phantom pain was one of those unique pains with a different distribution than other pain conditions." Interestingly, Melzack acknowledges that amputees use a distinctive language to describe their pain, but he attributes this difference to the "nature of phantom pain" rather than the linguistic structure provided by the MPQ.

I next suggest three significant implications of the advent and adoption of the MPQ for the purposes of assessing phantom quality. First, descriptors used to express the qualitative dimensions of phantoms before 1975 included sensual qualities that could be classified as non-painful (glowing or wrinkled for example) while later terminology concordant with the MPQ was prodigiously evocative of pain. The utilization of a pain questionnaire to assess phantoms, partially in an effort to capture what was increasingly understood as an underestimated facet of phantom quality, effectively accentuated pain.

Consonant with the invention of pain medicine (Baszanger 1992; Baszanger 1998a), the instantiation of the pain clinic (Baszanger 1992; Baszanger 1998a), the institutionalization and codification of pain (Baszanger 1998a; Rey 1993; Vrancken 1989), and the emerging epidemic of pain in the US (Morris 1991), phantoms literally became painful,[98] and through the advance of a specific language of pain vis-à-vis the MPQ, phantoms became cruelly, gruelingly, exhaustingly so.

Subsequently, Dr. Richard Sherman's phantom triad (he argues that there are three distinct kinds of phantoms; burning, cramping and lancinating)[99] not only unabashedly takes its language from the MPQ, but also borrows from the instrument's organization or parsing of the descriptors (see for example Sherman 1989; Sherman et al. 1989; Sherman 1994; Sherman and Sherman 1983). Through the advance of separate etiological mechanisms[100] for each of the triadic points (Interview, May 2005), as well as different treatment approaches for each, Sherman has done much to naturalize this terminology.

The tendency for some treatments to work "on" some phantoms but not others has been offered by Sherman as validation of his classificatory scheme; idiosyncrasy purportedly testifies to the fact that phantoms are more appropriately conceptualized as a symptom class. But, this has not been uncontested. For example, Dr. Joel Katz and his colleagues (Hunter et al. 2005:308) have been outspoken opponents of this classification scheme,

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[98] As Deuchar (1981:117) described it, "most patients are brainwashed into accepting pain as inevitable."

[99] Sherman argues that phantom limb pain should not be considered a unitary syndrome. Rather, it should be understood as a symptom class, with each phantom type corresponding to different etiological mechanisms.

[100] For other reference to the separate etiologies hypothesis see: Bowser (1991), Brown (1968), Dangel (1998) Gangale (1968a) and Glucklick (2001).

suggesting that it "may be a misleading step in the search for specific mechanisms underlying postamputation sensory phenomena." [101]

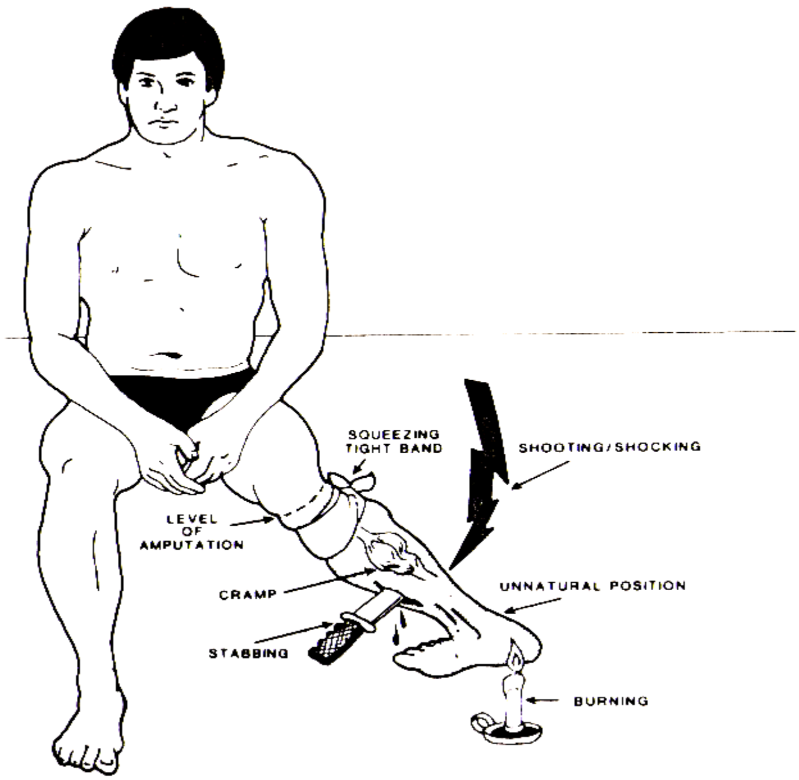

Figure 3: Sherman's Typology. The illustration is a composite of phantom pain sensations highlighting the three classes of symptoms associated with Dr. Richard Sherman's phantom typology; burning, shooting and lancinating or stabbing. Taken with permission from Sherman's 1989 article *Stump and Phantom Limb Pain*.

The second implication is that, as painful phantoms proliferated, their painless counterparts were re-conceptualized. For examples, the tingling, prickling sensation, interpreted in the past by some as pleasant, was re-classified as a "pre-pain sensation" (Knecht, Henningsen, Elbert, Flor, Hohling, Pantev, and Taub 1996). Pleasant phantoms became increasingly scarce (at least until circa 2000), and a painful-painless continuum emerged along which all phantoms sensations could be plot. Early literature posited the two as distinct phenomenon (see Stone 1950 review of the literature) which differed

[101] Katz (1992a) did support the supposition in an earlier article.

markedly in terms of their characteristics (Kolb 1950b; Maloney et al. 1966). For example, Brown (1968:304) argued "phantom pain has its own language – a language different from that reported for the non-painful phantom." By circa 1980, the two were considered the same phenomenon with differences in intensity (Abramson et al. 1981; Bowser 1991; Carlen et al. 1978; Nikolajsen et al. 2001; Postone 1987; Sherman et al. 1989; Spross et al. 1985).[102] For instance, Carlen (1978:215) writes, "It would be wrong to consider the patients during this acute phase as falling into two classes, those with and without pain. Painful complaints were all amplifications of disorders apparent in the noncomplainers."

And in my interview with Dr. Joseph Czerniecki (Interview July 21st 2005), he describes how sensation may intensify lapsing into pain:

> For some [amputees] the [phantom] sensation may be non-painful. These sensations do not create an avoidance response at low levels, low frequencies, or for shorter durations. But if they persist, the patient interprets them as nociceptive; you end up with a transition from sensation to pain. I think there are also factors – the patient's state of mind, their level of anxiety, their level of distress – that change the way they interpret that sensory phenomena. It can actually shift between a painful and a non-painful sensory phenomenon.

The third implication concerns the rationalization of phantoms, which I argue, has contributed to their demystification. Some part of their phantom-ness was derived from their illusive and idiosyncratic nature. The biomedical rationalization of phantoms, the codification and homogenization of the qualities of spectral parts, has at least partially quelled fears that minds can betray bodies. In fact, through these rationalization processes, phantoms have become at worst a product of biophysical dysfunction, and at

[102] An exception is the work of Sherman et al. (1989) who argued that the two phenomenon were distinct and that the underlying causal mechanisms differ for each.

best the byproduct of the functional reorganization of the cortex (see "Chapter Five: Contested Territory").

The Qualitative Peculiarities of Phantoms: *From Phantom Pleasure to Phantom Pain.*

Throughout the mid to late 1950s, phantom formation was predominantly thought to be a consequence of the amputee's favorable attachment to their body. For example, Kolb (1954) argued that phantom materialization was a healthy response to the experience of amputation, a psycho-somaticization of loss, which was considered congruent with an appreciation of, or a healthy "attachment" to, the body. He proposed that the extent of an amputee's denial would correlate with the amount of import or value attributed to the lost part. As an exemplar, he speculated that the low incidence of (at the time, reported) phantom breast could be ascribed to this tendency.[103] As the conventional logic went, breasts were inconsequential, were unlikely to be denied, and thus were infrequently experientially-sustained in the form of a phantom.

It is not surprising then that phantoms at the time were often described as pleasurable,[xix] pleasant,[xx] welcome,[xxi] not unpleasant, [xxii] and "quaint, even laughable" (Connolly 1979:13).[104] In essence, if phantoms were fantasy, wouldn't they necessarily be pleasant or pleasing? Simmel (1956b:641) writes:

[103] Later studies demonstrated much higher phantom breast prevalence rates more similar to phantom limb (Jamieson, Wellisch, Katz, and Pasnau 1979; Jarvis 1967).

[104] In a study of 76 upper limb amputees, 50% said they would prefer not to have them, 41% didn't mind them, and 9% would prefer to keep their phantoms (Fraser et al. 2001).

> The foot of the amputated leg may tingle and itch, and, as the patient reaches down to scratch it, he reaches for an empty space. He may feel the bedsheets on the arm or leg; he may feel a mild, perhaps pleasant tingling…thus one patient told me that "the leg felt good…real good."

From about 1970 onward, only a small number of studies documented pleasurable phantoms, and in the rare instance when phantoms were depicted as pleasurable, the account was always juxtaposed to their favorable role in prosthetic use. For instance, Hill (1999:125) argued that the phantom was "seldom distressing…in fact, welcome[ed, because]… it allows them [amputees] to use a prosthesis naturally." The abatement of the pleasurable phantom, I suggest, is an effect of the rise in phantom pain. Pleasure, then, could only be associated with improved functionality within the biomedical frame; it could not be pleasure for its own sake.

The Qualitative Peculiarities of Phantoms: *Phantom Pain*.

> After the surgery, my amputated legs and feet still hurt…it was another item on a long list of things that didn't seem fair. If I have no legs, why should I have to suffer them hurting me (Goldman et al. 2001:84)?

Phantom pain[105] is a particularly mystifying example of neuropathic[106] pain (Mailis and Israelson 2005), a pain produced by the nerves themselves as opposed to some external physical cause (Jensen et al. 2000). Most amputees who will develop phantom pain are thought to do so within the first few days after amputation (Blankenbaker 1977), although the onset can be delayed for many years (Blankenbaker 1977; Devor and Seltzer 1999; Maroon and Jannetta 1973). Concordant with non-painful phantoms, the sensation is

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[105] I do want to acknowledge the inherent difficulty in writing about pain in a way that is sensitive to its embodied experience. Morris (1991) argues that "the writers who give voice to an otherwise inarticulate discourse about pain also create a body of error and misrepresentation along with their knowledge. Pain passes much of its time in utter inhuman silence, and writers who describe something so inherently resistant to language must inevitably shape and possibly falsify the experience they describe."

[106] Neuropathy: "A classical term for any disorder affecting any segment of the nervous system" (Stedman 2000:1211).

often most distinct in distal parts, the hands and feet, fingers and toes (Jensen, Krebs, Nielsen, and Rasmussen 1985; Jensen et al. 2000),[107] and is reportedly correlative with the maintenance of detail (Sherman et al. 1997).

And, just as painless phantoms vary in terms of experiential vibrancy, their painful counterparts have been varyingly portrayed as mild and transient sensations, or as incessant and "exquisite torture" (Ament et al. 1964:2907). Rosen et al. (2001b:41), for example, write of their patient:

> He described the phantom pain like a warm radiation out into his arm and fingers. Sometimes he felt his fingers crumbling together with a cramping pain. He also sensed pain in a band around his wrist, and he often had contractions in his absent forearm.

Often when amputees describe their pain, one cannot help but squirm; they seem to struggle with a language that is deeply inadequate,[108] describing impossible embodied experiences, such as "the thumb…being pushed through the palm of the hand" (Bailey and Moersch 1992:1961),[xxiii] "50 devils…stabling needles into my foot…[the] feeling that the entire limb is splitting" (Nikolajsen et al. 1997b:398), or the sense that

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[107] Recognition that the distal parts of phantoms are sensed as the most vivid and are the most persistent sensations has been documented every decade. Researchers have at times suggested that amputees are more "attached" to these parts, or that as phantoms "naturally" fade or disappear, these are simply the "last parts to go." As I argue in "Chapter Five: Contested Territory", researchers today propose that the distal vividness purportedly reflects the fact that these parts occupy larger neuronal areas on Wilder Penfield's *Homuncular* map of the body.

[108] Elaine Scarry (1985:4-5) writes of pain and language: "Physical pain does not simply resist language but actively destroys it, bringing about an immediate reversion to a state anterior to language, to the sounds and cries a human makes before language is learned…Its resistance to language is not simply one of its incidental or accidental attributes but is essential to what it is…for physical pain - unlike any other state of consciousness - has no referential context. It is not of or for anything. It is precisely because it takes no object that it, more than any other phenomenon, resists objectification in language."

"something [is] trying to escape out of the end of the stump" (Parks 1973:99). The following account is particularly macabre:[109]

> The pain feels like someone is taking a red-hot knife, running it between every bone in my foot." "The burning in my phantom limb does not come like the burning that occurs when one comes [briefly] in contact with a live coal; rather, it eats away at my phantom like a corrosive chemical ravages flesh (Williams et al. 1997:75).

Quite disturbingly, what was once thought to be a relatively rare occurrence for a very few amputees is today considered widespread (see *Appendix I: Phantom Pain Prevalence*). A number of researchers and clinicians have speculated as to why this incredible discrepancy exists in the literature, largely arguing that 'earlier studies grossly underestimated the incidence of this dreaded phenomenon" (Davis 1993:79; Enneking, Scarborough, and Radson 1997; Sherman, Ernst, Barja, and Bruno 1988; Spross et al. 1985).[110] They attributed this underestimation to methodological issues (Bach, Noreng, and Tjellden 1988; Enneking et al. 1997; Halbert et al. 2002; Hazelgrove et al. 2002; Sherman 1989; Stannard 1993; Whyte et al. 2004), particularly the choice of study population (Grouios 1999; Halbert et al. 2002; Nikolajsen et al. 2001; Postone 1987;

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[109] Rybarczyk, Edwards, and Behel (2004:949) present the case of a woman who described her sensations as "worms between her toes; a bird flapping its wings on top of her foot; spikes and a tight iron band clamped around her foot; cats playing on her feet; very large burrs pressing against both sides of her foot; raw liver transforming into a 'furry creature' as the pain intensified; and things 'too frightening to describe'."

[110] For example, White et al. (2004) demonstrated that general practitioners underestimate the prevalence, intensity and duration of phantom limb pain, and that when a specialist referral was made, there was incredible variation in approach to pain management; referrals were made after prescribed medication proved unsuccessful at ameliorating pain to prosthetic clinics, pain clinics, or psychological/psychiatric services. Others suggest that the information patients obtain about phantom limb is insufficient and inconsistent, owing partially to the fact that some practitioners believe that encouraging the expectation of pain may actually cause it (Mortimer, MacDonald, Martin, McMillan, Ravey, and Steedman 2004). Practitioners also tended to differentiate between genuine pain and the misinterpretation of sensation. For example, one practitioner claimed "if you make clear, the difference between phantom sensation and phantom pain, to them then I think the number of people that claim to have phantom pain is much less because they are aware of sensation if you actually take genuine pain on a scale of 1 to 10 as being 8 to 10, I think you are probably looking at 35-40%" (Mortimer et al. 2004:223)

Ribbers et al. 1989; Whyte et al. 2004),[111] terminological confusion or differing operational definitions of pain (Borsje, Bosmans, van der Schans, Geertzen, and Dijkstra 2004; Hazelgrove et al. 2002; Postone 1987; Ribbers et al. 1989; Stannard 1993), patient recall (Hazelgrove et al. 2002), and/or observer (mis)interpretation (Ribbers et al. 1989). Dr. Joseph Czerniecki (Interview July 21st 2005) elaborated on the latter:

> I think it [prevalence] depends on how the question is asked. Some of the early data looked at people who presented with phantom pain at their clinical visits. Results will differ if you count the prevalence of phantom limb pain based upon that clinical context, as opposed to asking somebody "Do you ever have pain in the part of your limb that is missing?" Ever is a very broad statement. Even if you had someone who had a transient electric jolt six years ago, they would have to answer yes to that question. So, now you've got a much more sensitive means of detecting phantom limb pain than waiting for somebody to come to you with problematic, symptomatic, functionally- limiting phantom limb pain.

Others have suggested that the discrepancy is a result of changes in patient reticence to report inexplicable pain (Flor 2002b; Hazelgrove et al. 2002; Machin and Williams 1998; Sherman 1989).[112]

> Poor understanding of how pain could be perceived in an absent body part led many physicians to believe that such pain was a psychological phenomenon and led many patients to believe that reporting such pain would make their physician think they were mentally ill (Hsu and Sliwa 2004a:659).

In fact, the fear of being thought foolish or insane by friends, family or physicians is a theme that repeatedly appears in the literature (Blankenbaker 1977; Bowser 1991; Dernham 1986; Finnoff 2001; Flor 2002b; Fraser et al. 2001; Herman 1998; Hsu et al. 2004b; Kwekkeboom 1996; Machin et al. 1998; Mayeux et al. 1979; Middleton 2003; Mortimer, Steedman, McMillan, Martin, and Ravey 2002; Nikolajsen et al. 2001;

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[111] For example, studies have estimated pain prevalence rates based on amputee populations who sought treatment (Postone 1987).

[112] One study demonstrated that 50% of amputees did not consult their general practitioner about their pain (Whyte et al. 2002). "Patients who once admit a phantom do not later deny it; however, may patients who first deny it frequently recant" (Weinstein et al. 1961:909).

Rounseville 1992; Sherman 1989; Sherman et al. 1985; Sherman, Sherman, and Bruno 1987b; Sherman et al. 1984; Sherman 1994; Sherman et al. 1983; Shukla et al. 1982; Simmel 1959b; Wall and Heyneman 1999; Weinstein 1998; Weiss et al. 1996; Williams et al. 1997). In the mid-1960s, Simmel (1967:64) wrote:

> The wise patient quickly discovers that he had better not talk about the phantom. While most physicians and surgeons know about phantoms, they seem to have an almost universal antipathy towards them. They too think of sensation in terms of concurrent stimulus input, and when the patient reports sensation in an absent limb they too accuse him of not playing by the accepted rules. Add to this the fact that surgeons tend to hear about the phantom primarily qua painful phantom, and any complaint of pain might be regarded as some sort of operative failure, i.e., the surgeon's failure…For somewhat different reasons, the patient's family and friends often react in much the same way. They are ready to discuss what they regard as the realistic aspects of the situation, and the phantom does not belong among these. The family may be full of sympathy about the loss of a leg but they resent what seems to them the loss of the mind. The former is a misfortune; the latter reflects on the family honor and possibly the genes.

Sherman, likewise, wrote in the mid-1990s:

> We asked why they [amputees] did not discuss their phantom pain with health care providers. Most very bluntly said that they were afraid that their providers would think they were crazy and would then ignore other problems involving…the residual limb and prosthetic fit. Their view that this would be the reaction was probably accurate because most patients who did report phantom pain to their physicians were either told that they had a psychological reaction, were 'nuts', or were ignored. Many were sent for psychiatric evaluations (Sherman 1994:96).

Even today amputees report having been told that their pain is "all in their heads" by their physicians[113] and others (Hazelgrove et al. 2002; Whyte et al. 2004; Woodhouse 2005), leading some to question their own sanity (Hazelgrove et al. 2002).

By the 1990s, variation and disagreements about pain prevalence within the literature were asserted to be a problem of the past. For instance, Ribbers (1989:177) stated, "In

[113] In Sherman et al.'s (1985) study of 2,700 veteran amputees, 60% reported that their physicians had either stated directly or clearly implied that their pain was 'just in their heads.' See also (Sherman et al. 1988)

recent literature this extreme variation, however, is no longer present. The recent findings suggest that between 60% and 80% of all limb amputees are hindered by phantom pain."

In fact, reported pain prevalence rates continued to change. Prior to the 1970s, the pain prevalence rate was typically reported as between 1% and 15%. The rise in pain prevalence circa 1970, as I argued above, (to between 35% and 50%) was correlative with an intensifying culture of pain medicine in the US broadly speaking, and more expressly, with the adoption of the MPQ. Phantom pain had been medicalized.

By 1980, pain became a common sequela of phantom manifestation, and "phantom limb pain [became] one of the most terrible of all the pain phenomena" (Prasad and Das 1982:30). Circa 1985, prevalence rates were reported as between 66% and 85%, the peak of phantom pain prevalence, which continued throughout the 1990s. Today the rate is reported to be between 70% and 80%, a decrease that I attribute to the discovery of pain memories,[114] in addition to the widespread acceptance of neuronal reorganization as the predominant causal mechanism for phantom manifestation. Let me turn briefly to the former before addressing the latter.

> The amputation of the right lower leg was carried out on 28th September, 1942. Before the amputation there were great pains in the ankle-joint and on the outside of the upper part of the foot. These pains continued after the amputation exactly as before. In my right ankle I have a continual fiercing feeling, as if there were a knife stuck in it and

[114] The research community is not in agreement on the issue of pain memories. For example, Joseph Czerniecki (Interview June 21 2005) argues that pain memories do not exist; "for years people thought there was a relationship between the phantom pain experience and the pain experience prior to amputation. It was an excepted fact; a dictum that people believed for decades that a memory of pain you had beforehand would sit in your brain somewhere. But under objective scrutiny and study, there is actually no relationship between the two."

> always being turned round. In this spot I had in 1941 a perforating wound from an infantry gun shell (In Der Beeck 1953:225).

A number of early works documented pain sensations that seemed to emulate the pain of an injury that occurred prior to amputation (Frederiks 1963).[xxiv,115] However, it was Ronald Melzack and Joel Katz who coined the term *pain memories* in 1990 (Katz et al. 1990), inspiring a literal windfall of articles on the subject.[xxv] What distinguishes thier article from earlier references to the phenomena is the authors' explicit proposition that the vast majority of amputees, possibly as high as high as 79% (Katz 1992b; Melzack et al. 2001), experience the revivification of the quality, location, and intensity of a pain that occurred in the intact limb prior to amputation. A sliver under the nail,[xxvi] a bunion,[xxvii] a corn,[xxviii] a blister,[xxix] an ingrown toenail,[xxx] carpel tunnel,[xxxi] an ulcer,[xxxii] gangrene,[xxxiii] or a cut[xxxiv] such as that sustained while "stepping on glass" (Harber 1958b:634) may continue to be felt long after the limb has been removed. Research on pain memories has demonstrated that post-operative pain is more significant in patients who experienced either long lasting pre-operative pain or pain just prior to amputation (Jensen et al. 1985). Still others have documented pain memories that include "long lost" reminiscences of an injury which transpired many years before amputation and of injuries unassociated with the cause of amputation (Ramachandran 1998; Ramachandran et al. 1998b).

The "discovery" of pain memories in the vast majority of amputees corresponded with what I have referred to as the "peak of pain", the period from 1985 through the 1990s. As phantom pain was not only medicalized but institutionalized via the advent of intervention and prevention strategies (the instantiation of a service industry devoted to

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[115] Simmel (1956b:641) referred to these as "the 'last moment of life of the limb.'"

and dependent on phantom limb pain) pain memories emerged as a causal explanation for the increasingly widespread experience of pain after amputation. Because pain was thought to be “etched in memory” by pre-operative pain, and because amputation, whether surgical or traumatic, was and continues to be commonly accompanied by pre-operative pain, phantom pain was asserted to be pervasive. However, pain prevalence reports subsequently indicate a declined circa 2000 *despite*, as I demonstrate in the following section, the inadequacy of treatment and prevention efforts. This decline, I propose, is attributable to a shift in theorizing phantom manifestation, a shift largely due to the application of new visualizing technologies to the phantom problem.

Because I reserve my in-depth discussion of cortical reorganization for “Chapter Five: Contested Territory” I will only skeletally reproduce the hypothesized implications here. As the research investigating the capacity for the cortex to reorganize after the loss of sensory input (as in the case of amputation) has diversified and elaborated, a significant “finding” surfaced: there is purportedly a direct correlation between the onset, duration, and quality of phantom limb pain and the extent of cortical reorganization (Condes-Lara, Barrios, Romo, Rojas, Salgado, and Sanchez-Cortazar 2000; Flor, Elbert, and Muhlnickel 1998; Flor, Elbert, Knecht, Wienbruch, Pantev, Birbaumer, Larbig, and Taub 1995; Soros, Knecht, Bantel, Tanya, Wusten, Pantev, Lutkenhoner, Burkle, and Henningsen 2001; Wiech, Preissl, and Birbaumer 2000). Moreover, researchers have recently suggested that if phantoms are the *product* of reorganization, initiated by the loss of sensory input from the periphery, then one would expect the substitution or replacement of that sensory input to actually prevent reorganization, and hence pain. Herta Flor (2003:69) and her colleagues, at the forefront of this research, explain:

> The provision of correlated input into the amputation zone might be an effective method for influencing phantom pain. FMRI was used to investigate the effects of prosthesis use on phantom limb pain and cortical reorganization. Patients who systematically use a myoelectric prosthesis that provides sensory and visual as well as motor feedback to the brain showed much less phantom limb pain and cortical reorganization than patients who used either a cosmetic prosthesis or none at all.

In fact, Flor, Denke and Schaefer (2000a) suggested that cortical reorganization could even be reversed (see also Soros et al. 2001).[116] In other words, as researchers argued that phantom limb (or more specifically phantom pain) could effectively be prevented or undone vis-à-vis prosthetic sophistication, pain prevalence began to decline. The assertion that prostheses have the capacity to prevent and even reverse the reorganization of cortical topography corresponded with a decline in pain prevalence. Just as phantoms were characterized as amenable to prosthetic taming, pain reporting began to attenuate.

[116] With the discovery of pain memories, and as consequence of the supposition that phantom pain could be ameliorated or reversed by modulating input to the brain, curtailing or reversing cortical reorganization, some researchers began to speculate that assuring a pain-free interval prior to (Bach et al. 1988; Bloomquist 2001b; Fainsinger, de Gara, and Perez 2000; Flor 2002b; Halbert et al. 2002; Hazelgrove et al. 2002; Houghton et al. 1994; Hsu et al. 2004b; Jahangiri, Jayatunga, Bradley, and Dark 1994; Jensen et al. 2000; Katz 1992a; Katz 1997; Kooijman et al. 2000; Melzack et al. 2001; Middleton 2003; O'Neal et al. 1997; Ramachandran et al. 1998b; Stannard and Porter 1993; Wiech et al. 2004), during (Fisher et al. 1991; Flor 2002b; Jahangiri et al. 1994; Katz 1992a; Kooijman et al. 2000; O'Neal et al. 1997; Ramachandran et al. 1998b; Weinstein 1998), or following (Enneking et al. 1997; Fisher et al. 1991; Halbert et al. 2002; Hazelgrove et al. 2002; Jensen et al. 2000; Jensen et al. 1999; Katz 1997; Kiefer, Weich, Topfner, Haerle, Schaller, Unertl, and Birbaumer 2002; Kooijman et al. 2000; Melzack et al. 2001; Nikolajsen et al. 2001; Weiss et al. 1996; Wiech et al. 2004) surgery might be the most effective way of addressing the epidemic of phantom pain among amputees. Preemptive analgesia was even advocated for in cases of animal amputation (Coile 2001). However, other studies determined that preemptive analgesia was not effective in preventing phantom pain (Bone et al. 2002; Elizaga, Smith, Sharar, Edwards, and Hansen 1994; Flor 2003; Flor 2002b; Halbert et al. 2002; Hayes, Armstrong-Brown, and Burstal 2004; Lambert, Dashfield, Cosgrove, Wilkins, Walker, and Ashley 2001; Nikolajsen, Ilkjaer, Christensen, Kroner, and Jensen 1997a; Nikolajsen et al. 2001). As McQuay, Moore, and Kalso (1998:595) argue “underlying this is the pressing issue of knowing when the dodo is extinct.”

The Qualitative Peculiarities of Phantoms: *Treating Phantom Pain.*

Phantom manifestation prior to the late 1950s was predominantly attributed to psychic factors. Studies suggested that phantom limb qualified as: an hallucination (Feldman 1940; Hoffman 1954b; In Der Beeck 1953; Lunn 1955; Pontius 1964); a form of obsessional neurosis (Bailey et al. 1941); a fantasy (Weinstein et al. 1961:908); a psychosis (Pisetsky 1946); an infantile psychophysiological state (Pool et al. 1953:183); a regressive phenomenon (Zuk 1956); a form of denial (Noble et al. 1954; Simmel 1959b); "a kind of mourning for a part object" (Bressler 1956); imagined (Simmel 1958); a product of the unconscious (Zuk 1956); and/or an emotional disturbance (Weiss 1956). For example, Beller and Peyser (1951:432) wrote:

> PLP is usually not an organic pain, conducted through the spinothalamic tract, that bothers the patient; rather, his personality, his emotional tension and his psychic attitude toward his physical incapacity are the bases for the development of a painful phantom.

The assumption that phantom formation was symptomatic of psychosis essentially defined it as a second-order condition, which categorized patients as "crazy" (at least temporarily) and suggested a "natural" course of treatment that entailed addressing the psychosis. As *Appendix J: Treating Phantom Limb Pain* demonstrates, early treatment efforts for phantom limb (phantoms were rarely reported as painful before the late 1960s) included psychotherapy, electroshock therapy and prefrontal lobotomy.[117] In fact,

[117] Egas Moniz first performed the lobotomy in 1935, which was subsequently adapted for use in the case of phantom limb and phantom pain circa 1945 (Beller et al. 1951). During the 1940s, after the ice-pick technique was adopted, some 50,000 "cost-efficient" operations were performed in the US and elsewhere (Sargent 2005:267). Kolb (1950b) identifies one case in which a prefrontal lobotomy was requested by a patient after months of persistent pain. However, there was recognition, even at the time, that the procedure had its limitations and risks. Gutierrez-Mahoney (1944:447) argued that "unfortunately even this procedure does not truly abolish pain." Further, "in some instances, the substitution of severe personality disorder owing to damage to the frontal lobe [results. One lobotomy patient was described as] apathetic and relatively indifferent to his surroundings …he showed a moderate defect in his fund of general information. He was occasionally disoriented as to time and place and did not remember

between 1945 and 1950 these were the only treatments published in the American medical literature with the exception of neuroma injection, excision, or percussion[118], and nerve block or anesthesia. Further, lobotomy continued to be advocated until 1953, electroshock until 1968, and psychotherapy (as a sole or joint therapy) until the mid-1980s.

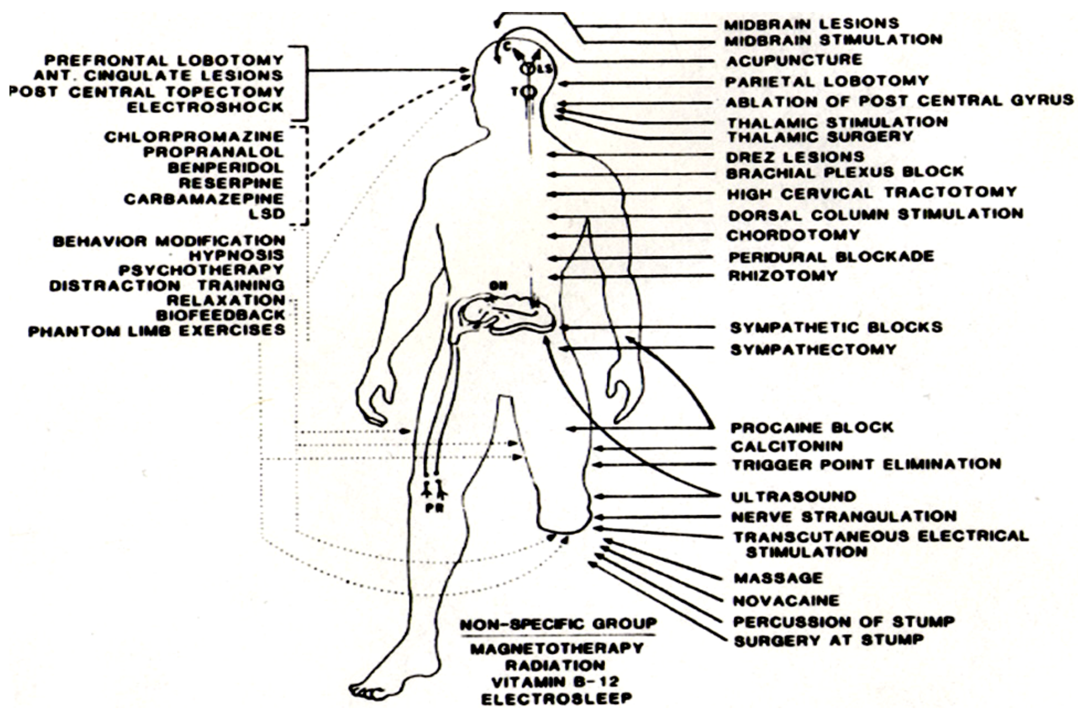

Figure 4: Phantom Limb Pain Treatments Attempts. Dr. Richard Sherman's illustration indicating the approximate location of treatments for phantom pain reported as being successful. The unbroken line indicates physical treatments; the dashed line indicates chemical treatments; and the dotted line indicates psychological treatment. C = cortex; LS = limbic system; T = thalamus; DH = dorsal horn; and PR = pain receptor. Taken with permission from Sherman's 1989 article *Stump and Phantom Limb Pain*.

By the mid-1950s, cordotomy,[119] sympathectomy,[120] and pharmacological interventions were introduced as therapeutic options for addressing the onset of phantom limb. These

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immediately past events…his wife remarked at length on his emotional lability, his casual indifference to everything but the stimulus at the moment, his new and strange lack of worry about himself and the future of the family…On one occasion while waiting for a bus she noticed that he was unconcernedly urinating. When she remonstrated against his inappropriate behavior he answered with the rhetorical question, "Whose pants are getting wet?" (Pisetsky 1946:471).

[118] Percussion: "A form of massage, consisting of repeated blows or taps of varying force" (Stedman 2000:1344).

[119] Cordotomy: "Any operation on the spinal chord" (Stedman 2000:410).

approaches surfaced as phantoms became medicalized. Phantoms arguably fell under the purview of medicine in the mid-1950s, through inclusion in the *Index Medicus*, and by the 1960s, overt critiques of psychological explanations began to pepper the literature (see "Chapter Five: Contested Territory").

As I argued in "Chapter Three: Contextualizing Phantoms," because of the postwar conflation of dismemberment and techno-liberation, dismemberment became dissociated from emasculation and mental instability. It is important to note that despite the fact that one would be labeled infantile, neurotic or regressive, despite the potential for invasive surgery of the brain or electric shock as means for ameliorating phantom sensations, despite what might be considered incentives for amputees to deny phantom experiences, the phenomena was considered universal until roughly 1980. Because amputees were thought to invariably develop phantoms, one could surmise that amputation, and hence war and the state, caused psychosis. The state could essentially be construed as responsible for physically compromising young men and with actualizing permanent psychosis. It was at this time that phantoms began to be re-conceptualized in physiological terms, rather than psychological, and medical treatment strategies for phantom limb began to multiply.

These new approaches to assuaging phantom pain were inspired by the predominance of specificity theory, which dominated medical understandings of pain until the introduction of gate control theory in 1965 (Baszanger 1998a; Baszanger 1998b; Williams et al.

[120] Sympathectomy: "Excision of a segment of a sympathetic nerve or one or more sympathetic ganglia" (Stedman 2000:1741).

1998).[121] Specificity theory assumes that pain travels along an ascending pathway from the skin to the pain center in the brain, that pain is felt and then responded to. Key to specificity theory are two assumptions; an external stimulus excites a specific specialized receptor and the extent of pain corresponds to the degree of injury (Melzack et al. 2001).[122] Conceptions of pain as a sensory projection system prompted attempts at pain reduction through neurosurgical lesioning. The successive introduction of gate-control theory was a move from the periphery to the center in terms of major causal explanations (Melzack 1993). Gate control theory, advanced by Melzack and Wall (1965) in the mid-1960s:

> basically, proposes that a gate-like mechanism exists in the somatic transmission system so that pain signals can be modulated before they evoke perception and response. The gate can be opened or closed by variable amounts, depending on factors such as the relative activity in large and small peripheral fibers, and various psychological processes such as attention and prior experiences. By proposing a variable gate, it became possible to attempt to close the gate by various manipulations (Melzack 1976:138).

Gate control offered a new heuristic for pain, one that stressed the modulation of pain perception within the nervous system (or psychologically), as opposed to pathway disruption (Baszanger 1998b). Cutting nerves or ablation of the cortex, for example, began to be used alongside modulation in the form of Transcutaneous Electrical Stimulation (1979), hypnosis (1978), relaxation (1979), biofeedback (1979), antidepressants (1979), acupuncture (1981), and numerous pharmaceuticals. I do not

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[121] For references to gate control theory in the phantom limb literature see: (Bartusch, Sanders, D'Alessio, and Jernigan 1996; Carabelli and Kellerman 1985; Connolly 1979; Davis 1993; Hill 1999; Kawamura, Ito, Yamamoto, Yamamoto, Ishida, Kawakami, Tani, and Kaho 1997; Lawrence 1980; Mackenzie 1983; Monga and Jaksic 1981; Naidu 1982; Riscalla 1977; Vichitrananda and Pausawasdi 2001).

[122] Baszenger (1998a) argues that pattern theory existed alongside specificity theory, which proposed that certain noxious inputs cumulate to produce pain. She writes, "particular patterns of nerve impulses generating pain are produced by summation of the skin sensory input at the dorsal horn cells. Pain results when the total output of the cells exceeds a critical level" (Baszanger 1998a:51). In addition, affect theory is identified as a "third protagonist…[which] follow[ed] the Aristotelian tradition, according to which pain was a property of the soul" (Baszanger 1998a:53).

mean to imply that these newly emerging treatment options replaced earlier approaches. In fact, a review of the literature on phantom pain treatment demonstrates clearly the instantiation of what Baszenger (1992: 182) refers to as the poles of *curing through techniques* and *healing through adaptation*. She argues that the treatment of chronic pain became organized around these two distinct impulses. Practitioners who embraced the approach of curing through techniques sought to cure pain through biophysical interventions including drugs and surgery. Conversely, those employing the healing through adaptation approach sought to control pain through behaviorally based interventions that were more global in scope. In the case of phantom pain, treatment options continue to include both approaches. In fact, some interventions persisted even in the face of evidence that they may essentially be exacerbating the problem. For example, although revision or re-amputation has long been thought to effectively multiply the number of phantoms (Chong-cheng 1986; Hoover 1964b; Kolb 1950b), what Ramachandran (1998a:33) called "and endless regression problem," the treatment continued to be either practiced (Hunter 1985) or identified as a potential therapeutic (Gillis 1964; Stannard 1993) in cases of pain even into the 1990s.[123] Jackson (2002:73) argues that:

> Some doctors have tried to treat phantom pain by…doing an additional amputation. Occasionally this helps, but each new amputation can also breed a new phantom, raising the specter of a hall-of-mirrors effect and an infinite number of phantoms-within-phantoms.

Appendix J: Treating Phantom Limb Pain, also clearly shows the proliferation of publications advancing treatment options for phantom pain during the 1980s. This

[123] Kolb (1950b) identifies one case study in which the patient was subjected to 27 different surgical procedures, including multiple re-amputations.

coincides with increases in both the frequency of publications reporting pain, and with reported pain prevalence rates. In other words, virtually mirroring the trend in increased pain reporting is the pattern of increased references to treatment options. By 1980, 68 different treatments were employed by VA hospitals, medical schools, pain clinics and pain specialists (Sherman, Sherman, and Gall 1980), all of which were reported by practitioners to be "somewhat successful" (Sherman 1994). By 1992, the number reached 86 (Katz 1992b), the majority of which have been found to be only temporarily effective in reducing pain in a minority of cases (Carabelli et al. 1985; Katz 1992b; Postone 1987; Sherman et al. 1980; Sherman 1997; Urban, France, Steinberger, Scott, and Maltbie 1986), or no more effective than placebo (Sherman et al. 1988; Sherman et al. 1980).[124] For example, Katz (1992b) reports that only seven percent of phantom pain sufferers received any long-term pain reduction from available treatment options. In fact, Mortimer et al. (2002) suggests that amputees are frequently told that nothing can be done about their phantom pain.

The Temporal Peculiarities of Phantoms: *Phantoms in Time.*

There has consistently been incredible variability in the literature in terms of the time of phantom *onset* (appearing immediately, days, months or years[125] after amputation),

[124] Sherman's 1997 survey of the literature, investigating the breadth and effectiveness of available treatment option for phantom pain, uncovered very little success. He found that six patients were reportedly cured by existing treatment modes: one was cured by drinking alcohol; two via increased use of their prosthetic; one through injection of an unspecified substance; and one through nerve strangulation. Of those who obtained a large permanent reduction in pain, two found relief with analgesics and electrical stimulation of the stump was effective for one. The following were also reported as alleviating pain in a single case: local anesthetics, massage of the stump end, unspecified nerve block, stump desensitization and ultrasound of the stump. Most advocated and practiced treatment options were no more effective than what would be expected from a placebo effect (Sherman 1980). In another study, 49 of 590 veterans were told by their physicians that there was no treatment available (Wartan, Hamann, Wedley, and McColl 1997).

[125] Murphy (1957) gave an example of phantom appearance after puberty, five years following amputation. Jensen and Nikolajsen (2000) reported a case of phantom onset 44 years after amputation.

development ("growing" gradually, fading in or out, suddenly appearing, or increasing in intensity), and *duration* (maintaining constancy or materializing intermittently, enduring over the live course, abruptly disappearing, or reappearing). The idiosyncratic manner in which phantoms have occupied time has consistently been one of the most considered and perplexing aspects of the etiological problem, particularly as cortical reorganization came to dominate as an explanatory frame.

As *Appendix K: Phantoms in Time* demonstrates, the 1950s consituted a period of disinterest in phantom onset largely because phantoms were considered universally experienced at the time. References to variability in onset emerge during the 1960s, including examples of both immediate and delayed onset. Yet, descriptions of phantom intensity and duration were rare. The "established" phantom prevalence rate during the 1960s dropped from 100% to approximately 80% (see *Appendix L: Phantom Prevalence*), and some researchers speculated that the incongruity with older reported rates might be attributable to delayed onset. As I indicated previously, denial was thought to be the cause of phantom formation. But let me be a bit more detailed at this point. I argue that denial was actually a binary concept. For some researchers denial was seen as desirable or at least a favorable sign, while for others denial was deleterious, a toxic state. Very briefly, denial was interpreted either as an indication that the sufferer was positively and authentically attached to or invested in their body (a mark of security), or denial was a response rooted in over-investment or pathological egotism (a mark of insecurity). Thus, the well-adjusted amputee was thought to immediately develop a phantom, while one might expect the onset to be delayed in those with problem-ed personalities. However, it was assumed that in time, all amputees would develop denial-based phantoms, whether they were egoistic or secure.

During the 1980s and 1990s, the research introduced by Drs. Timothy Pons and Michael Merznick began to be reproduced with increasing frequency. This line of investigation demonstrated that particular regions of the brain's architecture reorganized after deafferentation,[126] a universal biophysical response to the loss of sensory input from the periphery. Thus, phantom sensation should develop in amputees (notice phantom onset is rarely reported as appearing days, weeks, months or years after amputation during this period). If it did not, the cause was typically attributed to deficits in the individual's character. For example Shukla (1982:56) speculated in the case of delayed onset that "this difference may be because our patients, being educationally backward and rather unsophisticated, were slow to recognize its presence."

The debates concerning the permanency and extent of neuronal reorganization spawned increased interest in the duration of phantom sensation or pain which peeked in the 1980s, including references to phantoms appearing transiently, persisting, or even disappearing[127] and reappearing. Also evident are references to exceptionally intense phantoms or phantoms that grew, spread, faded or lengthened, which were also more frequent in the 1980s and 1990s than any other decade.[128] The increased interest in

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[126] Deafferentation: "A loss of the sensory input from a portion of the body, usually caused by interruption of the peripheral sensory fibers" (Stedman 2000:459).

[127] Patents are often told the phantom will disappear in time (Mortimer et al. 2002). However Fraser, Halligan, Robertson, and Kirker (2001) found only 7% of 76 phantoms had disappeared.

[128] Melzack, Israel, Lacroix, and Schultz (1997:1610) write that a young boy "initially responded to the sensation by asking his mother whether he was going to grow an arm." Melzack and Saadah (1994) also

phantoms in time corresponded with speculation about the extent of cortical reorganization in adult brains, as well as the proposed mechanisms. As we will see in the "Chapter Five: Contested Territory", some mechanisms imply temporary reorganization and others imply permanency.

It is also during the 1980s and into the 1990s when references to transient phantoms multiplied. Recall that this period corresponds with the peak of phantom pain, as well as with frequent claims that past research was methodologically flawed in a number of respects. One of the most common critiques is the failure to assess phantom pain (and phantom awareness/sensation) globally (across time and in a variety of circumstances), as opposed to in the present moment. Thus, it was at this time that references to intermittent phantom sensations literally double and claims were made that low prevalence rates could be attributable to a failure to historicize pain. Further, it may at first glance seem inexplicable why references to phantoms maintaining constancy tripled concurrently with increased references to transient phantoms. However, both have a relationship to pain prevalence. As pain became a common sequela of phantom manifestation, not only did intensity reports drastically change (as I demonstrated above), so too did duration.

Lastly, it was also during the 1980s and 1990s that reports of phantoms fading over time predominated. I argue that this is a consequence of two concurrent trends. The first is the sudden increase of treatment options available to amputees, many of which were asserted to have some type of success in reducing phantom limb pain. The other is the

reports the immediate growth of a full-length arm and fully formed hand, from the site of a congenitally absent limb, after falling from a horse.

emergence of a discourse of phantom potentiality that explicitly linked prosthetic use with the treatment of pain. One might expect a reduction in pain (and a fading of phantoms) as a direct consequence of clinical intervention, as well as by both compliance with prosthesis use and improved prosthetic technologies.

In the last decades of the twentieth century, onset became typified by extreme variability, and duration became typified by both disappearance and persistence. This trend coincides with emerging research demonstrating that cortical reorganization may be reversed and the functional relevance of cortical reorganization (and thus phantom formation) particularly for prosthetic use. As I will argue in a subsequent chapter these two tendencies, to view phantoms as both "reversible" and as central to prosthetic facility through animation currently exist in an uncomfortable tension. Future constructions of phantom phenomenon and prosthetic-phantom relations will be profoundly affected by how this tension is resolved.

The Morphologic Peculiarities of Phantoms: *Limb Facsimiles.*

After amputation it is not unusual for people to question the absence of a limb, prior to or even after the loss has been visually confirmed (Appenzeller et al. 1969; Blood 1956; Frederiks 1963; Gangale 1968a; Katz 1992b; Simmel 1956b; Simmel 1967). Some amputees even refuse to acknowledge that the surgery has been performed (Katz 1992b; Katz et al. 1990; Riding 1976). For example, Simmel (1956b:640) writes:

> In cases of amputation the patient often wakes up from the anesthesia and asks the nurse when he is going to be operated on. On being told that his arm or leg has already been removed he may not believe it until the covers are removed and he can see that the limb is indeed no longer there.

Phantoms have been thought to dissuade the immediate acknowledgement of surgical amputation because of the very "real" sensations that seemly originate in parts that are rationally understood as gone (Herman 1998), and because phantoms sometimes convincingly emulate the pre-amputated or intact limb, (Frazier and Kolb 1970; Spross et al. 1985). Lenor Madruga (1979:44 original emphasis) in her autobiography explains:

> The question I'm most frequently asked is, "what was your first reaction when you woke up and actually saw that your leg was gone?" My answer is always the same: When I finally regained full consciousness I did not, physically, feel that my leg was missing. My mind knew it, but my *nerve endings* did not…I could actually feel the full weight of my left leg. But it felt heavier than usual, almost like dead weight.

Historically, phantoms were imagined as replicas of real limbs in terms of size, shape, posture, and movement.[129] This is consonant with the organic-machine metaphor of the body that predominated within medicine and popular culture in the 1950s, and continues to be influential (Bowring 2003; Featherstone 1991; Gray 2002; Gray and Mentor 1995a; Gray et al. 1995c; Grenville 2001; Martin 1999; Synott 1992) whether in the form of the human-motor (Gleyse 1998; Kimbrell 1993; Rabinbach 1990), the human-computer (Gleyse 1998; Kay 2000; Keller 2002; Lynch and Collins 1998), or the cyborg (Gray et al. 1995a; Gray et al. 1995c; Grenville 2001; Tofts 2002). From this perspective, the body is essentially conceived as a complex machine (Shilling 2003), standardized/able, for example, in terms of forces, parts, and processes.[130]

> Modern life, with its essentially industrial momentum had processed our world and our bodies into dissociated, fetishized, ultimately empty and machinable elements…this was

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[129] There are many examples in the literature of phantoms retaining the shape, volume and length of the intact limb (see for example Bach et al. 1988), in addition to "mov[ing] in space and time" in a manner consistent with the pre-amputated limb (Grouios 1999; Hill 1999:127; Melzack et al. 1973). See also the discussion of pain memories.

[130] This metaphor continues to be influential today through an association with discourses of fragmentation, objectification and alienation. For example radical critics of sport have noted the predominance of the metaphor in the language of sporting (Shilling 2003).

> certainly congruent with a scientific worldview that has tended increasingly to treat human behavior as patterns of stimuli and responses, reducing mind to brain and brain to electrochemical impulses, and treating organs as interchangeable parts…the commanding image is now the machine: the well-oiled machine, the corrupt machine, the broken-down machine, the totalitarian juggernaut, the scrap heap. Our bodies themselves have been configured into machinehood (Schwartz 1992:105).[131]

Phantoms were hypothesized to be psychological in origin until circa 1960, the primary mechanism of which was denial. Because phantoms were literally wish-fulfilling manifestations, they were imagined as morphologically and kinesthetically mimetic of "normal" limbs, or more accurately "perfectly flawless" imitations of lost parts. For example, during a short-lived period in the late-19050s and the 1960s, phantoms were described as "possess[ing] *more awareness* than the real limb" (Frazier 1966; Frederiks 1963:76 original emphasis; Simmel 1956b; Simmel 1967; Weiss 1956),[132] as somehow *better* than the best fleshy limbs. Cook and Druckemiller (1952:509-510 emphasis added) write:

> As with many patients with this syndrome he was, at first, unable to reconcile the objective absence of his limb with the fact that it felt as if it were still present. This conflict must have been particularly disturbing since he said, "This one (left lower extremity) is here and dead, but this one (amputated extremity) is gone, yet it *feels alive*." From his description there was apparently a distinct sensation of *viability* in the phantom, and, subsequently, he explained that it felt as if he could kick someone with it.

Central theories, positing mechanisms rooted in the spinal chord or cortex, began to compete with psychological explanations circa 1960. The concept of the body scheme became one of the chief explanatory frames used to account for the onset of phantom sensations. Though the concept was proposed at the turn of the 20th century by Head and Holmes (1911), it was not until the 1960s that the body scheme began to morph from a

[131] However, Schwartz (1992) argues that centered rhythmic motion, indicative of the torque, was also a prevailing ideal.

[132] An exception is Melzack's (1989b:2) reference to phantoms sometimes feeling more real than the intact limb "because it has a tingling or 'pins-and-needles' quality that, initially at least, makes it highly salient."

psychological to a neuro-physiological structure, one which was hypothesized to be innate rather that developmentally secured. The body scheme maintained its primacy as a causal explanation until circa 1980 and phantoms continued to be conceptualized as replica or standardized copies of "real" limbs despite this etiological shift. However, the mechanism had certainly changed; phantom form was now emulative of phylogenic recapitulation, discussed below.

In fact, phantoms were frequently described as emulating the pre-amputated or intact limb in very precise ways. As *Appendix M: Phantom Posture* details, there are numerous references in the literature to phantoms that reportedly maintained the fixed,[133] relaxed, flexed or distorted/twisted position of the intact limb, particularly the positioning of the limb *just prior* to amputation. For instance, an amputee who had tried to protect himself from flying shrapnel permanently sensing his opened phantom hand in front of his face (Harber 1956). Phantom mimicry was routinely depicted as thoroughly authentic, and some amputees accordingly reported that their phantoms were disquieting impediments. Consider the following accounts:

> We observed a patient who felt his flexed and immovable phantom arm pressed upon his chest, just in the same way in which he had carried his arm in a sling for months…[or] the case of a patient who had to sleep on his belly because his phantom hand remained inconveniently situated on his back (Frederiks 1963:77).
>
> We have seen a patient whose arm was in a vertical wooden splint, flexed at the elbow, with the fingers hooked over the end of the splint, gripping it tightly. Two days later his arm was amputated, and when we saw him several weeks later, his phantom was in exactly the same position that his real arm had occupied, with the fingers hooked over an imaginary splint (Ramachandran et al. 1998b:1605-6).

[133] For example, Sacks (1987:66-7) presented the case of a sailor, whose rigid phantom appeared forty years after the amputation of his finger. He lived with the fear that he would poke his eye out while eating.

The Morphologic Peculiarities of Phantoms: ***Distorted/ing Phantoms.***

Despite the fact that phantoms were principally imagined as limb replicas until about 1980, a few early researchers wrestled with phantoms that seemingly were not like real limbs in very fundamental ways, the mongrels that were inherently out of bounds. I explore phantom distortion not because of its regularity or typicality, but because it is both more curious and more revealing than limb facsimile. The first references to distorted phantoms (Pool et al. 1953) emerged during the 1950s, as did references to incomplete phantoms or phantoms with "gaps" and "holes" (Bors 1951), and phantoms that telescoped or withdrew toward or into the body (Bors 1951; Kolb 1950a).

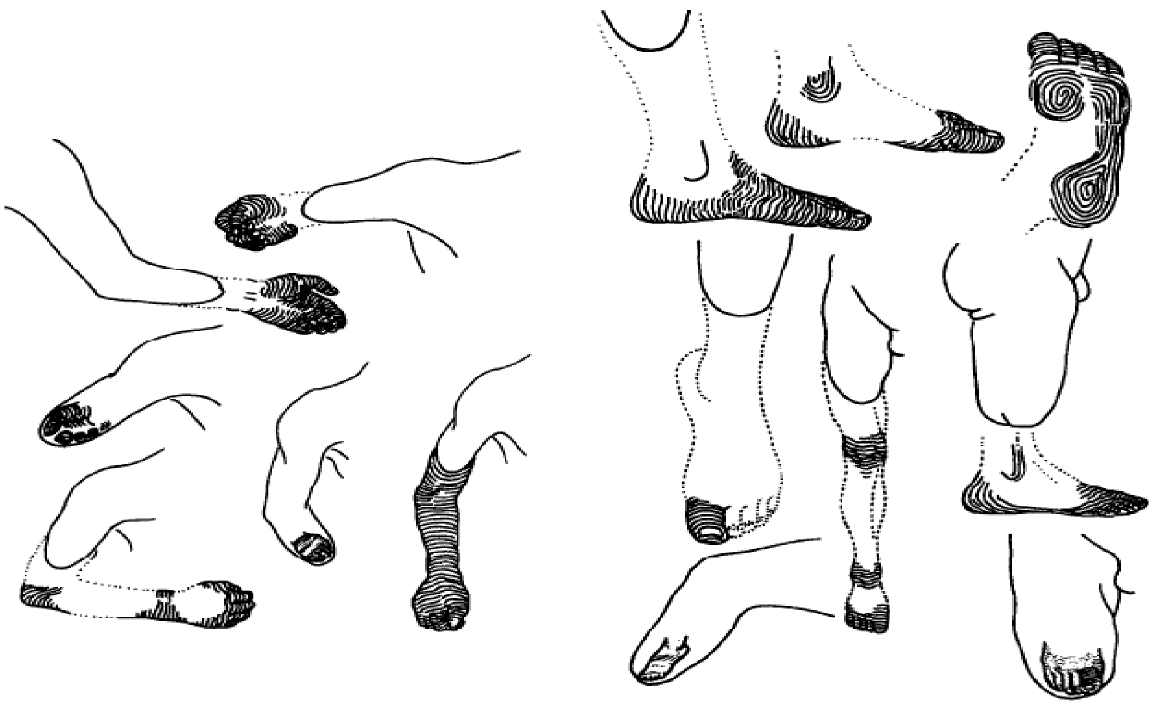

Figure 5: Phantom Illustrations. Based on patient's reports, these drawings depict phantom sensations; solid lines indicate the most vivid parts of the phantom while dotted lines illustrate areas where sensation is less vivid or not experienced. Phantoms that have telescoped into the residual limb are also indicated. Taken with permission from Melzack's 1990 article *Phantom Limbs and the Concept of a Neuromatrix*.

There are also a handful of early descriptions of phantom limbs as too short,[xxxv] too small,[xxxvi] too long,[xxxvii] too big[xxxviii] or too large. [134] For instance, in reference to a patient with spinal chord injury, Pollack (1957b:410) writes that "he felt as if both feet were extended out in a distance and that they were so long they were protruding through the wall of the hospital."

Unlike their historical equivalents, distorted phantoms today consist of instances of fundamental reorganization; reports include a phantom hand with only four fingers, a phantom foot with only three toes, a phantom foot with no toes (Melzack et al. 1997), a phantom foot with only the first and fifth toes (Brugger, Kollias, Muri, Crelier, Hepp-Reymond, and Regard 2000), a phantom leg with a knee located lower than normal at shin level (Melzack et al. 1997), or a phantom foot that is "on backwards" (DiMartino 2000). Distortions in the past were unintelligible, given the assumption that phantoms were mimetic of fleshy limbs in form and function, and thus when acknowledged were typically construed as incomplete (just not "filled in" or finish) or resized (simply a tiny or large version), while contemporary phantoms have sometimes been depicted as appreciably deviating from normal structure, reorganized in "unnatural" ways.[135]

As is demonstrated in *Appendix M: Phantom Posture*, the 1950s represented a notable period of interest in the posture of phantom limbs, which waned during the 1960s and

[134] Simmel (1956b:641) suggested that phantoms that are felt as "too large" correlate with lateral dominance, and those that are too small are found on the non-dominant side.

[135] Weinstein (1961:907) provides an early example of what I refer to as non-normal distortion. He writes: "he reported feeling neither fingers at the end of either phantom [double upper-limb congenital amputee] nor any bone within them. The phantoms could be described as very small 'blobs' or short nonskelatal stumps."

1970s, but reemerged as a prominent aspect of phantom manifestation throughout the 1980s and 1990s. Most appreciably, the proliferation of references to phantoms depicted as distorted or twisted, as *non-normal in form* occurred at this time. The reappearance of phantom posture as a consequential and evocative feature of phantom morphology, I argue, is attributable to the substantial rise in phantom pain and a profound shift in causal theorizing.

The 1980s marked the emergence of a "new imperative in Western Medicine," the detection and treatment of pain (Baszanger 1998a:1). In tandem with these developments, researchers and clinicians began to report an alarming increase in phantom pain. In fact, prevalence rates rose from approximately 5% to 80%, and as I detailed above, roughly 68 different treatments were developed primarily during the 1980s. Phantoms were becoming painful, sometimes excruciatingly so and, by end of that decade, *pain memories* would be "discovered." Melzack and his student, Joel Katz, proposed that under certain conditions, the revivification of pre-amputation pain could be experienced indefinitely (Katz et al. 1990). Examples of pain memories include terribly disfigured and reorganized phantom limbs; limbs that continued to sense the brutalism of combat, the devastation of disease or the ruin of industrial accidents. As a consequence of the rise in pain prevalence and the discovery of pain memories, the fundamentally re/disorganized phantom became both more common and more comprehensible.

Second, the work on phantom etiology, as I will detail in "Chapter Five: Contested Territory" has revealed that neuronal reorganization occurs within the motor and sensory homunculi of the brain after deafferentation. This processes is hypothesized to result in the *mis-location* of phantom sensations to other parts of the body. Mis-location refers to a kind of crossing-over of sensation. Very briefly, let me first illustrate using the case of an amputee who has lost his hand. Touching his face, for instance moving an index finger along his cheek, as one might expect, produces a sensation felt on the face. However, in some amputees the sensation is also felt on his missing hand. In the case of an amputated foot, to use another example, stimulation of the genitalia (might) produce an orgasm referred to the foot. Or, in the case of an amputated breast, a drop of water trickled down the ear may be felt as a wet phantom nipple. Mis-location was "discovered" circa 1990, as the research on neuronal reorganization flourished via, among other means, the sophistication of visualization technologies. Ironically, just as phantoms were being concretized through imaging, they also began to morph.

As van Loon (2002:111,112) argues, "modern technoscience is centrally concerned with 'presenting', that is the making visible of phenomena…by the same token, if technoscience is driven by a desire for the colonization of the unknown, it can only do so by creating another *remainder*: of that which defies visualization." It was not until the application of these new technologies to amputee brains that phantom visualization had been (partially and tentatively) realized, including Magnetic Resonance Imaging (MRI),[xxxix] including Functional Magnetic Resonance Imaging (fMRI)[xl] and Structural Magnetic Resonance Imaging (sMRI),[xli] Magnetoencephalographic (MEG)[xlii] recordings, Magnetic Source Imaging (MSI),[xliii] Positron Emission Tomography (PET) Scans,[xliv] Computed Tomography (CT) scan,[xlv] Neuroelectric Source Imaging (ESI) (Grusser et al.

2004; Karl, Muhlnickel, Kurth, and Flor 2004b), electromyograms (EMGs) (Sherman, Griffin, Evans, and Grana 1992), and Stereotactic mapping (SM).[xlvi] Yet, just as phantoms were being "captured by the camera," were being visibl-ized and causally accounted for, some literally shape-shifted and began to occupy new, or "wrong" body parts; they became remainders, hands superimposed on faces, and breasts situated on ears. And, I argue, as phantom parts became increasingly confused and "detached" from "normal" morphology, phantom distortion spread and became more intelligible.

The Morphologic Peculiarities of Phantoms: *A Nest of Hands in Her Bed or Supernumerary Phantoms.*

Supernumerary limbs[136] or surplus limbs have been documented in cases of paralysis,[xlvii] TBI,[xlviii] demyelination,[xlix] epilepsy,[l] stroke,[li] and in both congenital and surgical amputation.[137] Let me borrow from Bakheit and Roundhill's (2005:1) article to introduce this bizarre condition. They write about the case of a stroke victim:

> The patient repeatedly reported that he had a third leg protruding from his left knee. He consistently maintained that the phantom leg was attached to his knee with a 'bone plate' that 'had no flesh on it'…the phantom limb prevented him from turning over in bed, but did not adversely affect him otherwise…he believed that the phantom belonged to him, although he readily accepted that it was not 'normal' to have three legs…initially he reported that the 'leg' was growing from his own knee, but then reasoned that (given its size) he would have noticed it before the stroke. At other times he believed the leg was attached to him by the nursing staff, but could not explain why.

[136] Supernumerary limbs have also been referred to as doubled or surplus limbs (Hrbek 1976a), spare limbs (Canavero, Bonicalzi, Castellano, Perozzo, and Massa-Micon 1999), or reduplicative limbs (Mayeux et al. 1979; Simmel 1967; Vuilleumier, Reverdin, and Landis 1997).

[137] In the case of stroke, there are cases of patients not recognizing one entire side of their body. For example, Miller (1978:17) writes: "He may claim, for example, that the nurses have stuck someone else's arm on while he wasn't looking; he may be outraged by the presence of a foreign limb in his bed and ask to have it removed; he may insist that it beings to the doctor, or that prankish medical students have introduced it from the dissecting-room; one patient insisted that his twin brother was attached to his back" (Miller 1978:17).

In the following case *one* phantom developed in a paraplegic. Because he could see two limbs and feel another, he surmised that it was a spare:

> I concentrated myself on the arm that did not move in order to try to perceive even the smallest movement, I looked at the arm carefully; all of the sudden I started to have a strange sensation which can't be explained well with words: I had an extra arm, in addition to the one that I couldn't move, a sort of a spare arm; so at times I thought that I could unscrew the paralysed one and screw on the good one. Other times I had the sensation of having a good limb attached to my shoulder which I was able to move, a limb with which I could grasp something, but this limb couldn't feel either hot or cold sensations. It gave me self confidence…sometimes I even enjoyed moving it, and I liked the sensation of being able to control it…Sometimes I thought it didn't really matter if I had a paralysed arm, because I had a spare one (Grossi et al. 2002:477).

Surplus limbs have been documented as growing from an atypical site, for example from the middle of the chest (Sakagami, Murai, and Sugiyama 2002), or as replicating immoderately, as in the case of a woman who complained of having a 'nest of hands in her bed" (Halligan et al. 1993b:159).

Melzach and his colleges have been instrumental in chronicling spare limbs in the case of amputation. For example, Lacroix, Melzack, Smith and Mitchell (1992)[138] reported a case of a young girl who "grew" two feet and three sets of toes after the amputation of a congenitally defective limb. She reported a phantom foot and toes that replaced the amputated foot (a congenitally deformed phantom), which was felt 10cm higher than the normal foot (her "good" foot). Another set of "baby" toes extended from the end of the stump (a new set which protruded from/through her new residual limb), that she described as at times itchy and at other times constantly wiggling. Her third phantom was perceived as a shell of a leg composed of a calf, foot and toes, which was otherwise "normal" in size and position (a full length phantom of a limb that of course she never

[138] See also Saadah and Melzack (1994:480) for a discussion of the case.

had)! Melzack and his colleagues also detail a case in which a woman experienced a left phantom arm, hand and five fingers of normal size and shape. Her surplus arm however was attached, along with one of her other "real" arms, to the shoulder and was felt as always folded over her stomach" (Melzack et al. 1997:1612).

Supernumerary phantoms, I suggest contribute to a "thick perception" of the many ways in which the body has been subject to discursive and disciplinary transmutations (Feher 1987:159).[139] Phantoms are commonly found in pain clinics today, constituted through the new western imperative to detect and treat pain in all of its guises. On the other hand, because these phantoms defy symmetry, gravity, human morphology, kinesthetics, and logic, and because they are neither straightforward nor faithful replicas of normal human form and function, supernumerary limbs (as well as distorted phantoms in all of their incarnations) have pushed causal hypothesizing in new directions. Some phantom peculiarities and vagaries have forced reconsideration of suppositions about the neurophysiology of the brain. As I elaborate in the "Chapter Five: Contested Territory," phantom peculiarities have cast doubt on the conceptual viability of the birthed body scheme, on the hardwired assumptions of the physiology of the brain, and on the nature of the mind-body connection. I argue in the next section that, in tandem with these developments, there has been an expansion of the research agenda to address the implications of prosthetic replacement for neural reorganization.

[139] A language of utility and of ownership often undergirds accounts when patients are pressed to "explain" their odd state. In a case of two spare limbs one on each side of a paraplegia patient, the authors write: I feel that the 2 legs on each side are associated…not bound together but associated…they are distinct legs, each a full leg, but they must work together. I think this happens because I want them to be all right, so there are 2 legs on each side, maybe to help each other" (Vuilleumier et al. 1997:1544).

The Morphologic Peculiarities of Phantoms: *Phantom Telescoping*

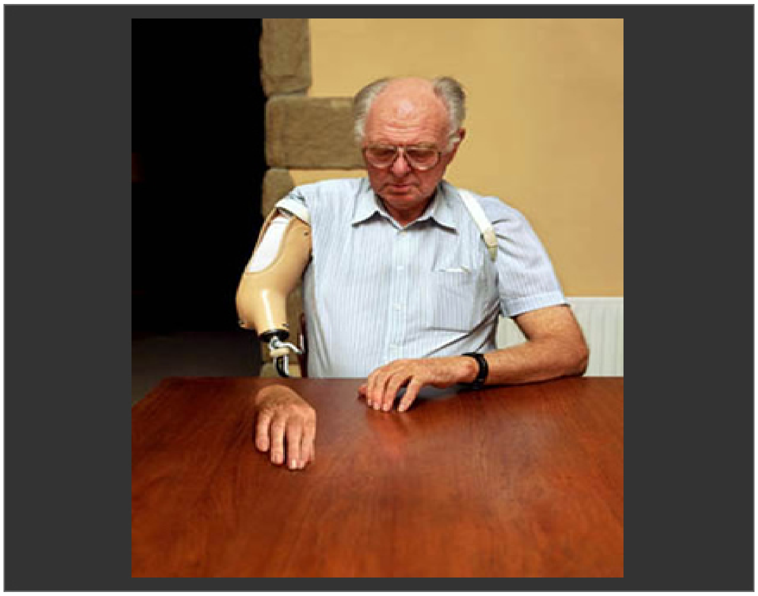

Figure 6: The Floating Phantom. During collaborative work with neurologist Dr. John Kew and neuropsychologist Dr. Peter Halligan, English visual artist Alexa Wright manipulated photographs to enable the "visualization" of phantoms described by amputees. RD's phantom hand and fingers are felt but the lower arm is absent. Taken with permission from Alexa Wright's 1997 *After Images*.

The most distal parts of the limb, the toes or fingers, hands or feet, are sites of strong and persistent phantoms.[lii] This may be the sole representation despite deafferentation of the entire limb, such that the hand or foot essentially floats or dangles in space.[liii] In Figure Six, the more distal parts of this man's phantom are present, but there is no sensory experience of the shin. If fact, he is consciously aware of this gap.

Parts of a phantom limb may "drop out" (Zuk 1956:511), sensed as missing (Fraser et al. 2001). For example, Buxton (1957:500) wrote: "He had always been aware of a phantom right foot, stating that the instep and big toes were most clear and resembled the real foot although the ankle was not part of the phantom." Other phantoms feel as if they are "not strongly attached," as if one might be able to pluck off the dangling bit (Melzack et al. 1997). These *disturbances of continuity* have been variably referred to in the literature as a phantom gap[liv] or hole,[lv] and are sometimes thought to be similar to (or synonymous with) what has been termed "telescoping."[140]

Figure 7: Phantom Gap. During collaborative work with neurologist Dr. John Kew and neuropsychologist Dr. Peter Halligan, English visual artist Alexa Wright manipulated photographs to enable the "visualization" of phantoms described by amputees. AM's phantom feels like his own leg, but it is sensed as a "dead piece of meat" with "bits missing." Taken with permission from Alexa Wright's 1997 *After Images*.

This curious event was originally introduced by Gueniot (1861) and is described as a process of the gradual decrease in the length[lvi] or size[lvii] of a phantom, such that it shrinks[lviii] and withdraws toward[lix] or into[lx] the stump. For example, Grusser et al. (Grusser et al. 2004:99) reported: "His phantom hand was localized in the residual limb

[140] Zuk (1956) suggested that the "dropping out of parts" is a sub-phenomena of telescoping. Other scholars have argued that diminution in size, disturbances of continuity and telescoping may be distinct phenomenon. Simmel (1956b:643) argued that disturbances of continuity produce telescoping. She proposed that when the upper thigh, knee, and calf begin to fade, a "whole or empty space" opens up between the body and the remaining vivid parts, the foot and toes, and because "phantoms and their owners seem to abhor a vacuum as much as nature is said to do…we find the separate parts moving together and approaching the stump."

and it was shrunk in size by about 60%. The fingertips of digits 1,2 and 3 were connected to one another and digits 4 and 5 were bent." Gueniot originally proposed that an amputee's phantom limb literally *regresses* to that of a child over time (Katz 1992a),[141] and indeed phantom hands have been described by amputees as child-sized (Spitzer et al. 1995), or as resembling "a 'baby's hand' curled up inside the stump" (Katz 1992a; Murphy 1957:474).[142]

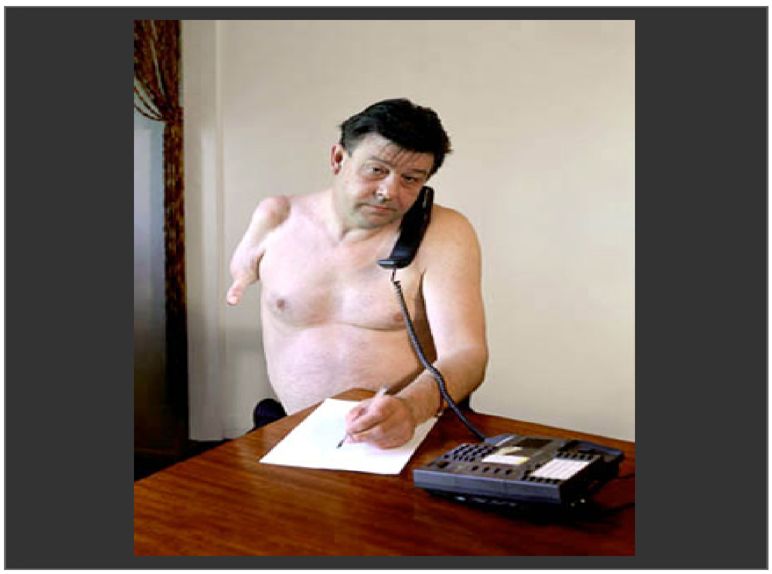

Figure 8: The Telescoped Phantom. During collaborative work with neurologist Dr. John Kew and neuropsychologist Dr. Peter Halligan, English visual artist Alexa Wright manipulated photographs to enable the "visualization" of phantoms described by amputees. GN's phantom has telescoped into his residual limb; only the phantom thumb remains. Taken with permission from Alexa Wright's 1997 *After Images*.

Sometimes the tiny hand is felt as if it is attached immediately to the stump's exterior,[lxi] or, as I mentioned above, as if it is barely dangling from tip of the residual limb.[lxii] In

[141] Gueniot's regression is not necessarily permanent; fully telescoped limbs can "zoom out" in an effort to reach for objects (Ramachandran et al. 1998a), or can regrow after doning a prosthetic (Kolb 1950b; Simmel 1956b). Melzack (1990:88) argues that "injury of the stump years or decades after fading or telescoping may suddenly produce a phantom as vivid and full-sized as that felt immediately after amputation.".

[142] Others have described their phantoms as the size of a silver dollar (Katz 1992a; Katz 1992b) or a postage stamp (Katz 1992a; Katz 1992b; Morgenstern 1964; Spitzer et al. 1995).

other cases, the shrunken fingers may be felt as if they protrude through the stump,[lxiii] or have been pushed completely inside.[lxiv] For instance, Simmel (1956b:643) stated:

> For some patients it seems that once the phantom foot had reached the stump it begins to fade, having after a while only the toes, and eventually these disappear too, temporarily at first and them for progressively longer time periods. But in some patients something else can be observed…The phantom foot may remain intact and gradually slip into the stump, with the toes sticking out longer than the heel. Gradually, the stump comes to enclose the whole foot, which may be felt within the stump for a long time before it disappears.

In Figure 7, the man's entire phantom arm has telescoped inside of the residual limb with the exception of his thumb, which pierces through to the outside. The sensation of one's amputated limb as embedded in the stump is often described as a kind of unsettling tension. For example, Scatena (1990:1230) relays an account of a congenital aplasitic who is quoted as saying "if the end of the stump was open, a hand would grow out of it, for I am sure there is something inside which wants to come out. It feels as though a lump inside is struggling to get out."

In aggregate, the literature reveals a great deal of ambiguity about the degree to which telescoping is a common sequela of phantom limb. Miller (1978:20) argues that telescoping is common:

> As time goes on, the phantom dwindles, but it does so in very peculiar ways. The arm part may go, leaving a maddening piece of hand waggling invisibly from the edge of the real shoulders; the hand may enlarge itself to engulf the rest of the limb.

Or for instance, Brown (1968) proposed that the process of telescoping was typical and typically "complete" within 12-30 months. As indicated in *Appendix N: Phantom Telescoping*, there is no consensus on the prevalence rate of telescoping among amputees and estimates have declined significantly over the last fifty years. Contemporary researchers speculate that the rate is approximately 30%, while in the early 1980s, the estimate was 66%, or 2/3 of all amputees, and in the 1970s telescoping was deemed almost as prevalent in amputees as phantoms were, roughly 80%. I argue that the striking decrease in telescoping prevalence rates, particularly the significant decline that occurred in the early 1980s, is a corollary of the neuroscientific reconstruction of phantoms as principally productive phenomenon at this time. Prior to this period, phantoms were thought to manifest as a consequence of denial and were imagined as a kind of phylogenic recapitulation; terms such as "growth," "maturation" or "regression" and "shrinkage" were commonly used to describe morphologic changes. As Pontius (1964) argues telescoping is demonstrative of the atavistic form of the phylogenic recapitulation of ontology (Ernst Tackle's biogenetic law); he states that during telescoping "limbs analogous to those of fish are experienced. Such limbs actually never occur after the earliest days of intrauterine life" (Pontius 1964:697).

From this perspective, an amputee's acceptance of his loss would necessarily render the phantom psychically useless and the specter would "naturally" disappear. But, would it decay or deteriorate? Would it deflate or wither? Researchers argued that the "natural" phantom[143] would shrink. It would regress. It would "un-grow" or "de-grow." It would telescope. And, one would expect this process to be highly prevalent among amputees. In other words, as amputees adjusted, they would no longer deny their amputations and their "wishful" phantoms would begin to shrink.

With the rejection of psychological explanations and the emergence of hypotheses involving central or cortical mechanisms, a number of suppositions surfaced, and the

[143] See section *Phantom Nosology* for references to the "natural phantom."

prevalence of telescoping declined. Although I will detail these events in "Chapter Five: Contested Territory", I want to briefly argue here that during the mid-1980s (and through the 1990s), the discourse on phantoms began to explicitly include what I call phantom-prosthetic relations, a discourse that emphasized the restorative role of prosthetic replacements, and underscored the utility of phantoms. Research began to introduce productive aspects of phantom formation, what is often referred to today as their "functional relevance," (Karl et al. 2001:3616), and scholars began to speculate on how these aspects might be harnessed to aid in prosthetic facility. In short, as phantoms morphed into productive phenomenon, the tendency for phantoms to regress or telescope dissipated. Further, research into the implications of prosthetic use on reorganization surfaced as an area of significant concern.

The Kinesthetic Peculiarities of Phantoms: *Phantom Movement.*

Hillel Schwartz (1992) argues that throughout the twentieth century, there was an elaboration of the human kinesthetic (see also Kristeva 1978 on post-war era kinesics), increasingly regarded as expressive, as evincing the soundness of body and soul. Character, it was thought, could be read through the body in motion (Grenville 2001; Kimbrell 1993). Yet, movement was also conceived as operative in that one's physical body and psychical character could be treated through proper rhythm.

> If one moved wisely, gesture would be a true reflection of the self…This, of course, was an essential pivot in the semantics of the new kinaesthetic, as it moved from the expressive to the operative, and from the operative to the transformative (Schwartz 1992:77,95).

The rationalization of natural and authentic movement in the case of amputees, particularly that which was willed, is evidenced by the increasing value placed on adequate prosthetic replacement options (Schwartz 1992), as well as an impulse to catalogue the kinesthetic features of phantom-ed bodies. Four types were of particular interest:[144] spontaneous,[lxv] automatic reflexive,[lxvi] conjunctive (in conjunction with movements of the intact limb),[lxvii] and voluntary.[lxviii] In some cases, “the phantom is felt to be a living, moving, ‘organic’ part of the body, broadly coordinated with the rest of the body’s movements. But at the same time, it behaves as if it were autonomous, with qualities and requirements of its own that impinge upon the subject and remain out of the subject’s volitional control” (Grosz 1994a:72). Katz and Melzack (1987:54) write of a patient whose phantom moved spontaneously:

> One of his primary complaints was that he had great trouble falling asleep at night, for if he lay on his right side he would experience a sharp increase in pain, and when he turned over, the phantom arm would rise upward like a helium-filled balloon until it was fully extended over his head. After several minutes in this posture, his arm would become heavy with fatigue, and an unbearable pain would ensue, forcing him to shift pos9ition once again.

In other cases, the phantom can at times be fixed and at other times move spontaneously.

> She thought the left hand was flexed at the wrist…she did not allow others to approach her from the left, and thought she might hit them with the phantom left arms. At times she reached out with their right hand ‘to calm’ the involuntary movement in the phantom arm. The perception of constant movement of the left are often awoke her from sleep, resulting in chronic insomnia (Jankovic et al. 1985:433).

[144] A typology was provided by Hrbek (1976b), but was identified earlier in paper by Jalavisto (1950). See also Cook and Druckemiller (1952) for early examples of both voluntary and involuntary phantom movement.

Both the import placed on highly functional prostheses[145] and on the kinesthetic features of phantoms were reflections of a desire to keep bodies in motion (Schwartz 1992:103), indicative of a body that has been essentially characterized vis-à-vis movement since the late 19th century (Grenville 2001). Purposive movement of one's phantom has always been advised; considered restorative and crucial to prosthetic animation, movement should be actively accomplished. For instance, Harber (1958b:625) advised that:

> Phantom sensations can be kept more 'natural' and more vivid if soon after amputation the patient takes daily exercises in 'willing' phantom movements; such exercises are said to make a patient better able to use a mobile (cineplastic) prosthesis.

Further, at various times, movement has been considered indispensable to the treatment of phantom pain and/or vital to its prevention. For this reason, voluntary movements, whether limited to *normal* ranges of motion or consisting of *impossible* amplitudes, (Price 1976) have consistently been considered desirable within the literature. For example, In Der Beeck (1953:225) detailed the case of an amputee whose volitional movement of his phantom toenails was key to the abolition of pain:

> Whenever the weather changes, I have the feeling as though the toe-nails are being pulled upwards…[and] the toes rise up of themselves, but do not go down again without my will. I always have to push them down again first. If I did not do that they would remain standing up. That gives a feeling of cramp and causes me trouble, and that is why I always have to push them down.

Involuntary movements, on the other hand, have been consistently represented as "out of control." Consider some of the descriptors used to convey involuntary movements: squirming (Falconer 1953), flapping (Harber 1958b), swaying (Melzack et al. 1997),

[145] "Torque, first used by electrical engineers, referred to the path and force of a twisting movement, such as torsion and rotation, around an axis. In prosthetics, the search for fluid movement sustained development of such innovations as cineplasty, popular in the 1950s, and the Seattle foot. In use since 1982, the Seattle foot employed an internal spring mechanism that gave the wearer added propulsion (Ott 2002a:20).

tensing (Harber 1958b), writhing (Ramachandran et al. 1996), trembling (Melzack et al. 1997), and as "stiffened and seem[ing] to fly in all directions"(Ament et al. 1964:2908).[146] One of the most frequently mentioned, most aberrant, and most "out of control" involuntary movements are varyingly referred to as *stump jumping*,[lxix] stump epilepsy,[lxx] phantom spasms,[lxxi] jactitation[147, lxxii] and more recently as phantom restless leg (Hanna, Kumar, and Walters 2004). This phenomenon is hypothesized to occur in about 10% of amputees (Bailey et al. 1992; Funakawa et al. 1987), and is described occasionally as a sensation originating the stump and other times as originating in the phantom. McGrath and Hiller (1992:50) write:

> She experienced an unusual sensation that she referred to as nerves jumping. She described it as: "you first get a weird tingling that starts in your toes and goes up to your stump and the nerves jump. The stump jumps up and down (1 or 2 inches) for a few seconds.

Phantom spasms, even in the absence of pain, are typically presented in conjunction with some means to treat the phenomenon, to silence the movement. Because movement, as Schwartz (1992) argues is a true reflection of the self, because it reveals the nature or disposition of one's character, involuntary action has been maligned, while willed movement has been celebrated.

The Kinesthetic Peculiarities of Phantoms: *Object Relations.*

Ramachandran and his colleagues have employed the phrase *learned paralysis* to describe a frozen or fixed phantom that imitates the paralysis of a limb prior to amputation (Hazelgrove et al. 2002; Ramachandran 1994; Ramachandran et al. 1998b;

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[146] Buxton (1957) reports of a case of phantom limb in a Parkinson's patient whose phantom trembles in concert with his intact limb.
[147] Jactitation: Extreme restlessness or tossing in bed (Costello 1997:725).

Ramachandran et al. 1996). As Grosz (1994a:72) describes it, the phantom is "experienced as thinglike, passive, inert, a mere object with no animating or receptive interiority." Feeling as if cast in cement or plaster (In Der Beeck 1953), as if imbedded in a block of ice, a fixed phantom may feel as if it pierces or penetrates an object (Harber 1956; Huckaby 2001; Zuk 1956). Phantoms often pass through solids (Frazier 1966; Hoffman 1954b; Jankovic et al. 1985; Omer 1981; Scatena 1990), sensing interior textures; for example feeling the inside of a mattress (Dernham 1986). They may also move through the person's own body (Grosz 1994a). However, phantoms may also telescope toward the stump (Jalavisto 1950; Scatena 1990), move to avoid the object (Scatena 1990) or may simply temporarily disappear (Jalavisto 1950; Scatena 1990).

Figure 9: Phantom Paralysis. During collaborative work with neurologist Dr. John Kew and neuropsychologist Dr. Peter Halligan, English visual artist Alexa Wright manipulated photographs to enable the "visualization" of phantoms described by amputees. LN's phantom is fixed at a right angle that will pass through his body when his stump is angled toward the back. Taken with permission from Alexa Wright's 1997 *After Images*.

In the most comprehensive study done on what she called obstacle shunning, Jalavisto (1954:175) suggested that *phantom shunning* (disappearing, moving within the stump, or "bending" to the side), as apposed to *phantom occupation* (moving inside of a wall or another person's body) is demonstrative of the degree to which a person's phantom limb is adaptive; shunning phantoms were regarded as "adaptable," while "rigid" phantoms were those that did not yield to "real" objects. One of her most interesting findings was that amputees between the ages of 17 and 24 described their phantoms as disappearing or moving when approaching a wall, while amputees over age 25 tended to depict their phantoms as entering the wall.[148]

The idea that phantoms either adapt to their environment or not communicates as much about the assumed "substance" of phantoms as it does about the author's preconceptions about amputees (particularly with regard to the age-related rigidity). Implicit in her dichotomy is an evaluative judgment about the appropriate ways in which bodies should relate to objects and others. Phantoms that bent or disappeared were constructed as essentially respecting the materiality of the world, while phantoms that "occupied" objects or persons disrespected the integrity of the real world, as well as the sacred subjectivity of others. In other words, frozen or fixed phantoms have consistently been problematized both because of their immobility (their failure to move expressively or curatively), and because of their irreverence for materiality.

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[148] That same year, Hoffman (1954b) proposed that when a phantom comes into contact with itself (such as a clenched fist) the result is typically pain. See also Frazier (1966) on this issue of object relations and pain. Others have suggested that pain results from all object relations that "should be" painful. For example, Spitzer, Bohler, Weisbrod, and Kischk (1995) demonstrated that when the air is struck in the place where the phantom should be, the resultant sensation is pain (Spitzer et al. 1995).

The Kinesthetic Peculiarities of Phantoms: *Phantom Potentiality.*

Phantom movement, whether purposive, conjunctive/reflective, or uncontrolled, has been ascribed to "forgetting" the amputation by both researchers (Price 1976:109; Simmel 1962) and amputees (Finneson et al. 1957). One man with an amputated digit explained:

> 'My hands feel normal to me when I'm woodcarving…when I'm working, like sewing or cooking, my hands feel normal…I feel the (right) index finger the most; it happens sometimes, no particular time. I catch myself starting to rub my eye, and then I know I don't have a finger' (Price 1976:112).

In his autobiography, Paul Martin succinctly writes of forgetting. He says, "there were times I got off the couch thinking I still had two feet: Face, meet Carpet" (Martin 2002:73). Price (1976:109) similarly writes "a leg amputee, when arising from bed quickly, tries to stand on his absent foot, having momentarily forgotten the amputation; often he falls to the floor." As show in *Appendix O: Using Phantoms*, the literature frequently describes the "use" of phantoms when walking or running,[lxxiii] crawling,[lxxiv] and stepping,[lxxv] or during the act of sitting,[lxxvi] getting up,[lxxvii] steadying,[lxxviii] or standing.[lxxix] Amputees also report a forgetful "use" of their phantoms to break a fall,[lxxx] catch an object,[lxxxi] or fend off a blow,[lxxxii] and to point,[lxxxiii] wave,[lxxxiv] grasp,[lxxxv] or reach.[lxxxvi] For instance Fairley's (2004:1) patient remarked "When I play tennis, my phantom will do what it's supposed to do…It'll want to throw the ball up when I serve or it will give me balance in hard shot. It's always trying to grab the phone. It even waves for the check in restaurants." Other amputees, however, relay something very unlike forgetting, a decisiveness about the use of their phantoms, rather like their purposive "exploitation." Scatena (1990:1230) provides an illustration:

> An 11-yr.-old girl with congenital absence of both forearms and hands…said that from the age of six she had felt two phantoms hands hanging below her stumps. She claimed to feel these hands clearly and to be able to move them at will…in her first years in school she had learned to solve simple arithmetic problems by counting her fingers…on these occasions she would place her phantoms on the table and count the outstretched fingers one by.

Although scholars and amputees have long described "forgetting", accounts of intentional use of phantoms began to emerge circa 1980, including general references to phantom utility (Connolly 1979), as well as specific reports of their use in counting,[lxxxvii] gesticulation,[lxxxviii] stretching,[lxxxix] writing,[xc] or shaking hands.[xci] These correlated with the surfacing of a discourse emphasizing phantom utility, a discourse that suggested that phantoms could be harnessed for the purposes of facile prosthetic use and pain reduction. And, as I will clearly detail in the next chapter, the emergence of a discourse of phantom potentiality coincided with the discovery of neuronal reorganization. As the logic goes, if brains are advantageously plastic and phantoms are the products of plasticity, then they must have a practical value. As it turns out, phantoms are exceedingly valuable, both to the amputee and to neuroscience.

Conclusion.

This chapter characterized phantom limb syndrome, detailing how the reported quality, temporality, morphology and kinesthesia of phantoms have changed from the 1930 to the present. I argue that phantoms are shape-shifters amenable to biomedical constructions and reconstructions; phantoms have been sensitive to medical rationalization and classification, to the institutionalization of pain medicine, to the elaboration of prosthetic science, and to efforts to revision and legitimate the field of phantom research throughout the twentieth century. By the turn of the twenty-first century, phantom limb syndrome had been re-cast in neuroscientific terms, a shift that eventuated in the emergence of a discourse emphasizing the productive aspects of phantoms limbs. In the next chapter, I historicize phantom theorizing, elaborating on the shift from the psychologization to the medicalization of phantom limb syndrome.

5 CONTESTED TERRITORY

Phantoms have been subject to highly contested/able territorialization (Deleuze and Guattari 1987), and consequently, through a strange politics of susceptibility and contagion, phantoms have multiplied, proliferated in kind and spread to vulnerable populations. As fickle copies, phantoms have always already been amenable to re-territorialization. It is because they have occupied the darkest recesses of minds as well as the deepest corners of brains, it is because they have inhabited the most peripheral as well as the most central regions of the nervous system, it is because in the geography of the human cortex they are both somewhere and nowhere in particular that they have always been difficult to protect against.

This chapter uncovers the processes and practices through which phantoms have come to in Young's (1995:6) terms "penetrate people's life worlds, acquire facticity, and shape the self-knowledge of patients, clinicians and researchers", how phantoms have been "made real." As spectral parts, embodied traces, illusionary ghosts, phantoms were, at the turn of the twentieth century, things with no essential thing-ness, but by mid-century, phantoms had achieved factuality, had acquired what Harre (2002:25) calls *social substance*. Phantoms have become substantive "not as an effect of the physical properties of the thing" but as a consequence of their social properties, their power-as-effect (Harre' 2002:25). Phantoms bridge corporeal biographies of the past with partial-ized physicalities of the present. Phantoms move effortlessly between the margins and the centers of bodies to both cause and ameliorate pain. Phantoms animate brains in order to be seen and animate prostheses in order to be felt. Phantoms remake the morphology of human bodies and remap the geography of human cortices. Phantoms are today profoundly socially substantive.

Etiological Tumult.

The history of phantom theorizing has again and again been described by researchers and clinicians as rife with controversy (Hoffman 1954b; Maroon et al. 1973; Melzack 1971b; Miles 1956a; Riscalla 1977; Stattel 1954). In the first half of the twentieth century, the "organicists" (proponents of the physiological origins of phantoms, whether attributable to peripheral or more central mechanisms) were depicted as engaged in a "long and bitter" controversy with the "psychopathologists" (advocates of the psychogenic origins of phantoms) (Hoffman 1954b:263; Riscalla 1977). Over the second half of the twentieth century, the "peripheralists" (champions of nerve irritation theory or the supposition that nerve and other tissue damage was causal) were engaged in impassioned debate with the "centralists" (exponents of the primary role of the central nervous system in phantom formation, including the spinal cord and/or cortex). Finally, since the turn of the twenty-first century, through the work of neuroscientists, phantom etiology has been situated squarely in the brains of amputees. Although remnants of the other debates remain, current dispute has primarily focused on exactly which structure/s are implicated (the localizationists versus the diffusionists) (Star 1989), as well as precisely how change in cortical cartography occurs (exponents of neural sprouting versus proponents of unmasking). I address each of these divisions in turn.

First, I present the major psychological approaches to phantom etiology detailing the various incarnations of the concept of the body scheme within the phantom literature, as well as introduce the concept of denial-based phantoms. This section begins the work of showing how phantom peculiarities have been read (and re-read) as proof of theory throughout their history, revealing how phantoms have been conceptually acclimatized to particular theoretical moments. In Casper's (1998a:24) terms, I uncover the "cultural filaments" that connect phantoms to theory or the processes by which (bio)medicine has "cultured" the phantom through theoretical abstraction. Over the last half of the twentieth century, the normalization of phantom paralysis or amputee "exposure," for instance, has fundamentally re-made phantom limb syndrome. The exceedingly private and exceptionally uncanny has become intensely public, of-the-social-body and quite "natural" indeed. However, I also show how phantoms have resisted attempts at domestication; they may have become increasingly rationalized but they certainly have never been acquiescent to solidity, to single origin stories, to certainty. In fact, I show how strategic emphasis on or attenuation of particular aspects of phantom phenomena actually caused their proliferation, an effect that resulted in the reinvention of body scheme theory.

Second, I argue that post-WWII renormalization efforts included the rehabilitation of the demobilized war wounded, the modernization of dismemberment through significant and unparalleled state investment in prosthetic technologies, and the strategic conflation of dismemberment with techno-liberation. Together these came to constitute a national program that was incommensurate with the earlier association of dismemberment with mental instability, with wish fulfilling psychosomatizations, or with egoistic denial. It was throughout the 1960s that phantoms became reconceptualized as fundamentally neurophysiologic phenomena. Although psychological accounts were still present until well into the 1970s, peripheral physiological theorizing increasingly gained prominence both because pain prevalence rates were rising and because nerve irritation theory presented phantom limb as a *doable* problem (Fujimura 1987) for practitioners.

Next, I follow phantoms into the brains of amputees. I argue that the brain became a viable prospect for locating the origins of phantom limb in part because of the emergence and proliferation of medical imaging technologies during the 1970s and 1980s. I demonstrate how the visualization of amputee brains encouraged the widespread acceptance of the malleability of the sensory and motor cortices (assertedly pivotal structures in the origin of phantom limb). This supposition was consonant with a larger trend in neuroscientific reach more broadly that began to challenge the relative stability (localizability) of neuronal connections in the adult human brain. Phantoms consequently became both the effect of cortical plasticity or reorganization (historically diffusionism), and the means of its prevention. Through the potential of phantom exercise to reverse cortical reorganization, and through the potential for prosthetic animation to prevent phantom pain, phantoms were transmogrified into conspicuously productive events. And it is via this discourse of *phantom potentiality* that phantoms have emerged as vital to the seamless coupling of amputees and prostheses.

Psychological Approaches: *The Body Scheme.*

In this section, I argue that the utilization of *body scheme* or *body image* theorizing to address the question of phantom etiology resulted in the emphasis or attenuation of particular facets of the "body of evidence" being compiled on phantom phenomena. These included: 1) the discovery of other amputated parts that were only sometimes associated with phantoms; 2) the correlation of phantom pain with prior exposure to an amputee; 3) the surfacing of phantom paralysis; 4) the detection of superadded features (a ring or watch for example); 5) the finding that amputees were often preoccupied with the continued care and proper disposal of detached parts; 6) and the revealment that amputee's dream in the whole. Each of these "truths" was engaged at various moments in ongoing arguments concerning the susceptibility of certain populations to phantom formation, including in congenital aplasia, leprotic absorption, and young children.

The term "body scheme"[149] has had a "long and illustrious history in western medicine," particularly within the work of psychologists and neurophysiologists (Grosz 1994a:62). Head and Holmes (1911), at the turn of the twentieth century, proposed this neuro-physiological substrate of the body, which was characterized as predominantly a *model* built up from kinesthetic, sensory and visual stimuli, the function of which was to register changes in the posture of the body and localize body parts in space (Harrington 1987). The body scheme was at once 1) a record of sensorial and kinesthetic histories; 2) the horizon against which corporeal futures could be considered; and 3) a standard from which both could be appraised (Grosz 1994a:66). Accordingly, the body scheme was foremost experientially fashioned, and as such, was always already intimately ecological.

[149] The terms body image and body scheme (also spelled schema) were often used interchangeably within the literature. Some authors used the term to denote a single structure, *the* body scheme, while others refer to a set of representations, *multiple* schemata. Further, the terms were often poorly defined (Van Wirdum 1965), making claims of synonymity quite problematic. This was true despite a few attempts to maintain conceptual specificity within the field. For example, Hoffman (1954a:147) advocated differentiating between 1) the body image or the sense of body position derived via proprioceptive senses; 2) the body scheme or the basic recognition of the body; and 3) the bodily ego or an amalgamation of the body image and scheme. Omer (1981:754) advocated differentiating between: 1) the body ideal or the idealized image of the body; 2) the body percept or the model of body movement and appearance; 3) the body concept or the thoughts, memories and attitudes about the body that are derived interpersonally, and 4) body ego or that aspect of the personality that concerns itself with the body image.

Bodily boundaries, it was argued, do not terminate at the skin's surface or the tips of fingers, but incorporate elements of the external/physical world, a process fundamental to its utility. In this sense, perceptual changes continually indicate postural, kinesthetic and functional alterations of the body that become traces and are actuated in:

> our recognition of posture, movement, and locality beyond the limits of our own bodies to the end of some instrument in the hand. Without them we could not probe with a stick, nor use a spoon unless our eyes were fixed upon the plate. Anything which participates in the conscious movement of our bodies is added to the model of ourselves and becomes part of these schemata (Head et al. 1911:118).

Although the body scheme, as a functional *model*, was thought to be constantly modulated through experience, the scheme *template* was conceived as innately acquired. From a Headian perspective, that one has a body scheme was universal, while the exact spirit or character of the postural model was idiosyncratic. Thus, it was estimated that the *birthed* material body was indelibly "inscribed" on the scheme template, constituting the model's foundational structure. For example, researchers argued that congenital aplastics developed body schemes that necessarily reflected their birthed partiality. By elaboration, one would not expect phantoms to materialize in cases of congenial amputation because the limb was never represented in the maturing or matured body scheme (Bressler 1956; Hoffman 1954b; Simmel 1961).

As *Appendix G: Phantom Populations*[150] demonstrates, whether or not phantoms *do* or *can* form in cases of congenital aplasia is one of the longest running and most

[150] *Appendix A: Phantom Populations* presents a table of references from the medical literature to populations discovered to or known to develop phantoms, or *not develop* phantoms by author, year, and number or percentage of cases. The table includes: 1) references to specific populations including congenital aplastics, paraplegics, children, etc.; 2) the authors' indication as to whether or not representatives of the population developed phantoms, including qualifiers such as sometimes, probably,

acrimonious debates within the phantom literature. Marianne Simmel, who published from the mid-1950s through the late-1960s, was a stanch defender of the position that phantoms did not develop in congenital aplastics (although even she published on a few "rare" cases). She was also one of the strongest proponents of the application of the Headian body scheme to the etiology of phantom limb. Simmel (1956b:645) wrote,

> Why do phantoms occur at all? The answer to this question must be given, I think, in terms of a schema which each person develops of his own body. Head's concept of the body schema based on postural, kinesthetic, and tactile learning from earliest infancy would appear more fruitful here than the concept of later authors in which visual and/or motivational elements are in the foreground….[F]or the normal painless phantom postural, kinesthetic, and tactile elements seem to be of a primary significance, not only in the genesis of the body scheme but also in the phantom experience proper.

Simmel employed as evidence of the body scheme's explanatory power both the absence of phantoms in cases of congenital amputation and the presence of phantoms in those who lost limbs/digits to leprosy. She argued that the body scheme was capable of amending itself to gradual change indicative of leprosy, but not the sudden change brought on by amputation (Simmel 1956a; Simmel 1956b; Simmel 1967).[151] Phantom formation in congenital aplasia reemerges throughout the history of phantom theorizing as one of the most persuasive ways of either buttressing claims or undermining them. And for that reason, Simmel was one of the literature's most significant interlocutors throughout the twentieth century.

Faithful representations of the body scheme as proposed by Head and Holmes (1911) can be found within the literature on phantom phenomena until the late-1960s (Bressler 1956;

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etc; 3) and sample size and the percentage of the sample who reported phantom sensations when the conclusion was based on a sample or case study (rather than sited from the literature).

[151] Whether phantoms *do* or *can* form in the cases of leprosy has been and remains contested (see Appendix *G: Phantom Populations).*

Frazier 1966; Gangale 1968b; Gillis 1964; Jalavisto 1950; Simmel 1962; Simmel 1956b; Simmel 1958). However, the body scheme was not a static concept or structure; in fact, the body scheme began to fissure and split as early as the late-1950s. I argue that a psychoanalytically-inspired rendering coexisted alongside its Headian double (which was actually increasingly invoked throughout the 1960s), and that a third version with a solely neurophysiologic undergirding infrastructure surfaced circa 1980. Let me first turn to what I call the *psychological organ* before elaborating on the body scheme as *engram or central representation*.

Psychological Approaches: *The Body Scheme as Psychological Organ.*

Juxtaposed to Headian elaborations of the body scheme within the phantom literature were references, chiefly throughout the 1950s and into the 1960s, to something quite different. This was kind of psychological substrate or organ that functioned to inform a person's mental/emotional relationship toward/with the body both in space (a moving, operative body in time and in three dimensional space) and place (an invested body situated within socio-cultural contexts). This conceptualization depicted the body scheme as a sensory-based developmental process and product with a learned genesis.

The degree to which the body scheme was amenable to modulation, the relative plasticity or openness of the body scheme, depended on the individual's experience (or more precisely age). The scheme's plasticity was greatest during its formation, becoming relatively stable by the age of six (see for example Hoffman 1954b).[152] The developmental quality of the body scheme, researchers argued, was support by the

[152] This was also true of the Headian version of the body scheme (Simmel 1956b).

curious phenomenon of telescoping. Mimicking the manner in which a child sequentially discovers his/her body parts (from the more peripheral to more central), the phantom was thought to "shrink away, perhaps in an order which is reverse of the impression of the body's image which was built up from infancy through childhood, adolescence and adulthood" (Kolb 1950a:469).

After full development, maturation or solidification, the body scheme was thought to operate as a barometer of sorts, from which all change was measured *prior to* entering into consciousness (Rosner 1952; Weiss 1958; Zuk 1956). Thus, the body scheme was considered a preconscious formation of the mind that influenced body *consciousness, attentiveness, and appraisal* throughout the life cycle. It incorporated all of a person's "exaggerations or diminutions, depending on the subject's particular sensitivities and feelings about his own body" (Esson 1961:111; Hirschenfang et al. 1966; Weiss 1958). To clarify, Esson (1961:619) gave the following description of a young boy and his large ears:

> He would imagine his 'self' running around inside his body. This self, vaguely but definitely masculine in shape and appearance, contained all his feelings, abilities, and drives; in his imagination this psychic self would wander up and down the inside of his skin, along his limbs, into his fingers and toes, it would slide around inside his skull and at times it would become almost lost in 'corridors' on the outer rims of his ears, which he felt to be rather large and prominent.

Consonant with Grosz's (1994a:67-70) elaboration of the psychologization of the concept with the work of Schilder during the 1920s and 1930s, references to the body scheme throughout the late-1950s and into the 1960s within the phantom literature became considerably more psychological in nature. Although the concept retained neurophysiological elements, researchers began to incorporate what might be referred to as versions of the self-concept. In other words, the body scheme developed into a composite of the neurophysiological body, the person's construal or assessment of their body and its parts, as well as the person's self-feelings about those judgments, all of which were mediated by socio-cultural contexts (Kyllonen 1964; Weiss 1956). For instance, Frazier (1966:445) employed the body scheme-as-*psychological organ* to hypothesize the relative scarcity of phantoms in (now commonly acknowledged) parts other than digits or limbs:

> The meaning of these percepts [phantom sensations] can be modulated by interpersonal and environmental values placed on body parts and body changes…phantoms are frequent in body parts emphasized by family and culture such as arms and legs, but are rare in body parts deemphasized, such as the genital organs. Certainly the emotional significance of body parts, which is determined early in life, may influence the phantom phenomenon. It may be more difficult to admit a phantom of the breast, penis, or nose because their loss is of greater significance to one's concept of the self.

Appendix C: Phantom Parts is a table of reports within the medical literature of body parts, other than limbs, feet, hands and digits, discovered to or known to be associated with phantom sensations or pain by date. During this period, from the late-1950s to the mid-1960s, there is a relative profusion of articles referencing phantom-ed parts other than limbs or digits (including the breast, penis, face, nose, eye, tongue, tooth, ear, rectum, and testicle).[153] Phantoms assertedly materialized in those parts that were considered valued/valuable (by the self, others, or both). Because the hand has historically been considered one the most emotive parts of body, a crucial instrument of expression (Jordanova 1994), and because the leg, as Frazier (1966:445) argued, was emphasized by family and culture, these parts acquired a level of import that was reflected in their tendency to persist as phantoms.

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[153] The phantom uterus (but never labia/clitoris) and the stomach were included in 1971 (Dorpat 1971), the appendix in 1998 (Ramachandran et al. 1998a), intestines by 2001 (Bloomquist 2001a), and the head two years later (Brugger 2003).

However and consequently, researchers had begun to anticipate that any body part was potentially vulnerable to phantom-ed mimicry circa 1955 and, in fact, researchers began to "find" exemplars. This era, from the mid-1950s through the mid-1960s, represents the first of two periods of what I call phantom proliferation. Phantoms literally multiplied in kind as a consequence of their normalization, effectuated by the active debate between body scheme theorists and peripheralists on the typicality and susceptibility of phantom limb syndrome. Very briefly, proponents of the peripheral genesis of phantoms suggested that one or more of the myriad changes in the residual limb (physical, chemical or structural) after amputation produced what the brain interpreted as noxious input originating from the periphery (the missing limb). Because phantom limb was a consequence of nerve injury, purportedly any innervated body part was susceptible. Alongside body scheme theorizing, peripheral accounts of phantom formation dotted the literature and were often referenced by scheme theorists as unpersuasive for various reasons. Peripheralists, on the other hand, argued that if one were guided by parsimony, one would conclude that the complexity of body scheme theory was simply unnecessary and undesirable. Both body scheme theory and nerve irritation theory conceptualized phantom limb as stemming from elemental processes of neurological or psycho-neurological function and were thus, basic to human physiology after amputation. It was the debate itself, with each side thinking through of the logic of the other, which shaped phantom typicality and susceptibility that I argue resulted in the proliferation of phantom parts.

During the second period of phantom proliferation circa 1990, "almost every external body part" (Dernham 1986:34) became vulnerable,[154] a trend I attribute to the biomedical rationalization of phantoms. Phantoms became inextricably coupled to technology vis-à-vis brain-imaging and prosthetic sophistication, a trend that prompted what I call the discourse of phantom potentiality (see below). Thus, it is was vis-à-vis the normalization and later biomedical rationalization of phantom limb syndrome that phantoms were able to proliferate, to spread to "susceptible" parts heretofore undocumented.

Although most body parts were apparently at risk for phantom-ed mimicry circa 1960, only those parts deemed worthy were reported as regularly disposed. Breasts,[155] for example, were considered only infrequently associated with phantoms until circa 1980, either because they were exceedingly significant aspects of the body scheme (Frazier 1966) or because they were fundamentally inconsequential (Kolb 1954); both arguments utilized the rarity of reports of phantom breast as support for the body scheme-as-*psychological organ*. Phantom breasts were as much "evidence" for the explanatory power of the body scheme, as they were "understood" through body scheme theorizing. As is indicated in *Appendix Q: Phantom Breast Prevalence,* despite an early reported prevalence rate of 64% of mastectomy patients, phantom breast remained an aberration until about 1980 (when rates were reported as "similar" to that of phantom limbs) (Hill 1999; Jamieson et al. 1979). Bressler (1956) argued that because the breast appeared late

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[154] "Theoretically, you can have a phantom of almost any part of the body, except of course, the brain" (Ramachandran 2001:Broadcast).

[155] Phantom breast was first acknowledged by Ambrose Pare circa 1550 (Bressler 1956:181). Mitchel (1872a) also mentioned phantom breast in a footnote in his *Injuries of Nerves and Their Consequences*. As is demonstrated in *Appendix C: Phantom Parts*, the most frequently cited phantom-ed parts other than limbs or digits are breasts (47), followed by penis/testicles/genitals (39), and noses/faces (18).

in phylogenic development and because the breast was un/underdeveloped during body scheme formation, the breast was rarely experienced as phantom-ed. Those women who did develop phantom breasts were thought to be both over-invested in their breasts (Ackerly, Lhamon, and Fitts 1955; Bressler 1956; Jamieson et al. 1979), attempting to use thier breasts as "aggressive weapons," and were thought to be expressing excessive shame or guilt over the loss of their breast (Bressler 1956).[156]

Appendix R: Predicting Phantom Pain shows that researchers also began a fascination with the impact of being "exposed" to amputation in the years following WWII,[157] particularly as it related to the onset, duration, and quality of phantom limb pain (Hoffman 1954b; Kolb 1952; Simmel 1956b; Weiss 1956). Researcher's anxieties were predicated on the assumption that seeing or having known another amputee (even past exposure prior to amputation) could profoundly influence an amputee's self-feelings and evaluative judgments about their own part-loss, particularly when either 1) the amputation was perceived as highly stigmatizing, or 2) the amputee was perceived as being excessively well cared for. In other words, phantom pain could result from the instantiation of an extreme body consciousness, attentiveness, and/or appraisal, stemming from the perception that amputation was a/the central concern of others. Kolb (1952) writes:

> Some amputees appear to be predisposed to the development of a painful phantom limb through an earlier association with another amputee. It is probable that such association with an amputee arouses fantasies of personal mutilation which are mastered by repression. These may be relighted by the threat of the surgical procedure.

[156] The finding that younger women tended to experience phantom breasts reportedly testified to their tendency to over-invest, over-sexualize and over-maternalize their breasts (Ackerly et al. 1955; Jamieson et al. 1979).
[157] There were approximately 50,000 major amputations performed on American soldiers during the Civil War, 2,610 during WWI, 14,912 during WWII, 1,477 during the Korean War, 5,283 during the Vietnam conflict, and 381 during the Global War on Terror (Potter and Scoville 2006).

Two years earlier, Kolb's (1950a:470) patient reportedly experienced impotence, depression and suicidal ideation all of which were prompted by amputee exposure, what he termed the "symptomatology of the war neurotic" even though the subject's amputation was not due to war-related injury. However, requisite to the process of translation from exposure to the psycho-somatization of pain was an unconscious, predisposed, (over) investment in a body part, typically derived through familial "conditioning."

> In the course of growth each person develops through his multiple sensory experiences a concept of his body and its parts which is commonly spoken of as the body image. In addition to the body image, the body and each portion has connected with it some emotional significance derived from early familial conditioning and the later cultural values placed on physical development. The attitude of the mother and father toward the body of the child leaves its indelible impression on that child as far as his later concept of himself as a person is concerned. According to earlier studies of patients with chronic painful phantom limb, the complaint of pain is often intermittent and represents an emotional response, an indication by the patient that he is suffering from the loss of an important part which has significance in terms of his relationship with others (Kolb 1950a:110).

Thus, not all exposure to amputees was thought translatable, through one's psychological organ, into phantom pain. Yet researchers remained anxious about the potential for exposure in the post-WWII years, due to the then palpable demobilization crisis. Professionals of all stripes feared that the demobilized war-wounded could consciously and effectively disrupt American post-war re-normalization efforts (see "Chapter Four: Contextualizing Relations" for a discussion of the demobilization crisis). Because of the risks associated with exposure, anxieties grew exponentially with increases in the amputee population.

Psychological Approaches: ***The Body Scheme, the Gestalt, and Denial*.**

At this point it is important to emphasize the literal web of ideas being brought together to think through phantom phenomena from the 1950s well into the 1970s. The body scheme had been assimilated into the psychological lexicon with the work of Schilder among others (Grosz 1994a:67-70) and, as I elaborated above, was key to understanding the etiology of phantoms. However two other significant conceptual influences were also increasingly evident. First, I argue that the concept of the gestalt (from gestalt psychology), which made its way to the US in the first half of the twentieth century, became a significant influence. It remained a part of the phantom literature far after "extensive theorizing of any kind [from this perspective] had become an unpopular commodity" (Green 2000:1), in part because the concept functioned as a much needed theoretical link or ideational bridge between the body scheme and phantom-ed mimicry.

Second, with the extension and elaboration of her father's work on defense mechanisms, Anna Freud popularized the concept of denial in psychology and beyond. I argue that this concept in the phantom literature functioned to buttress claims being made by proponents of the body scheme-as-*psychological organ*. Because the body scheme was theorized as a *preconscious* formation that influenced body consciousness, attentiveness, and appraisal, one could be wholly unaware the ramifications of significant perturbations in its structure. Alterations in the physical body could be compensated for, vigorously resisted, or even denied without the individual's conscious acknowledgment. Thus, the concept of denial allowed researchers to think through the relationship between: 1) a sudden mismatch of the physical body and the body scheme, and 2) the manifestation of unwelcomed phantoms ("hallucinatory," distorted, or pathologically painful phantoms). And, it was often the underlying *gestalt* of the body scheme, both the conscious and unconscious desire for wholeness, and the experiential "intactness" of the body's psychophysiological substrate, that was depicted as the impetus for amputee denial. For instance, Hoffman (1954a:147) argued:

> The meaning of the phantom can be understood as the attempt by the ego or the self at reorganization as to maintain the body image and scheme gestalt. There is a remarkable degree of inability to accept less than totality in his body configuration.

Let me first turn to the influence of Gestalt psychology before elaborating on denial. Gestalt psychology emerged in Germany during the early-1900s with the work of Max Wertheimer (1980-1943), Wolfgang Köhler (1987- 1967), and Kurt Koffka (1886-1941) (Green 2000). Koffka is attributed with introducing the concept of the gestalt to the US with the publication of a paper in 1922, and later, after settling at Smith College in Massachusetts, with the publication of *Principles of Gestalt Psychology* in 1935. Subsequently many of the leading proponents of the movement immigrated to the US to escape the Nazi regime, further solidifying the influence of gestalt psychology in the American context (Arnheim 1986). The Gestalt movement peaked in the US during mid-1940s, but continued to be influential particularly in the area of the psychology of perception until circa 1950. Arnheim (1986) argues that the movement's popularity had seriously waned by mid-century, after which only traces could be found in experimental psychology and in other more established theorizing. Despite the widespread abandonment of gestalt psychology by mainstream psychology and beyond, the concept continued to be influential for researchers thinking through the etiology of phantoms until the late-1970s (Ament et al. 1964; Hoffman 1954a; In Der Beeck 1953; Zuk 1956).

The concept of the gestalt remained alive and central to etiological theorizing, a trend that I argue was at least partially attributable to the efficacy of the concept as a conceptual bridge between the body scheme and phantom-ed mimicry. Essentially, the body scheme could only be understood as the underlying causal mechanism of phantom limb if the structure of the body per se were characterized by *intrinsic* wholeness or comprehensiveness. The assumption that lived partiality, living through/with an amputation (and hence, a disjuncture between the physicality of present and the schematic body of the past) would only "produce" a phantom (the continuation or perceptual copy of the postural, kinesthetic, functional, esthetic qualities of the part) if the scheme was not just experientially "historical" but also resolutely resistant to incompleteness.

A number of peculiar phantoms were enlisted during this period in an effort to reveal the explanatory robustness of the scheme gestalt, including the paralyzed phantom, the congenital phantom, and the phantom with superadded features. First, proponents exploited what has been termed phantom paralysis both as a means of elaborating on the phenomenology of part-loss and as a means of envisaging the significance of part-loss for the scheme gestalt (see "Chapter Four: Characterizing Phantoms" for a discussion of phantom paralysis). Hoffman (1954b:264-5) proposed that the fixed phantom was demonstrative of schematic preservation:

> One is accustomed to having a complete body. The phantom of an amputated person is, therefore, the reactivation of a given perceptive pattern by emotional forces…since the position of the phantom is often a rigid one and that in which the patient lost his limb, it

> is as if the person were trying to preserve the last moment in which the whole body image was present.

In the same vein, Zuk (1956:512) argued that the tendency for fixed, frozen, or paralyzed phantoms to penetrate objects (as opposed to disappearing or shrinking) was an indication that the body scheme inherently maintained both material integrity and temporal continuity, what was referred to as the gestalt of "good fit" between the material body and the felt body. Zuk (1956:512) wrote,

> When individuals report that the phantom has 'gone right through' a sold object, it would appear that they do so on purely logical grounds. How other than by a desire for intelligibility (or what the Gestaltists call 'good fit') could one explain why an amputee reports his phantom has penetrated a solid object?

However, Jalavisto's (1950) work in the tradition of *object relations* revealed that phantoms actually had multiple "strategies of adaptation" when dealing with solids/objects. Her work was wholly ignored by Zuk and Hoffman. She wrote:

> The conflict of the actual sensation of a (three dimensional) phantom limb, with the experience of objects sometimes occupying the same position in space as the phantom, without, however, eliciting any sensation of contact, is felt by most amputees to be very unpleasant. It may therefore be regarded as a distressing stimulus requiring adaptation. It can easily be seen that there are only three possible modifications of the phantom sensation capable of preventing this conceptual conflict between phantom sensation and physical objects, the disappearance of the phantom, the location of the phantom within the stump or the adoption of the behavior called obstacle shunning [bending to the side]. Each of these alterations of the phantom sensations forms a perfect solution of the conflict situation and may thus be considered as an equally good adaptation (1950:341).

In other words, Jalavisto (1950) showed that penetration was just one of many ways that phantoms adapted to object conflict. Nonetheless, a few years later in a 1954 article, Jalavisto had embraced body scheme theory, and argued (1954:167) that "the phantom is the most striking illustration of the existence of a 'body image'." In fact, she began referring to the experimental practice of pitting phantoms against walls as "constancy experiments," and attributing a phantom's low constancy ratings to insufficient adaptability. Phantoms that had employed one of the "perfect solutions" to object confrontation identified in her 1950 article had, a few years, later been *re-conceptualized* through the lens of the gestalt scheme as poorly adapted because they violated schematic constancy and intactness.

Second, proponents maintained that the absence of phantoms in congenital aplastics underscored the persuasiveness of body scheme theorizing. The reputed lack of phantoms in people with congenital amputation was thought congruous with the pre/unconscious egoistic need for wholeness, a need that necessarily accounted for the *precise* form of the birthed body (Bailey et al. 1941; Browder and Gallagher 1948; Frazier 1966:446; Gillis 1964). In other words, congenital amputees, it was proposed, had *intact* body schemes. Many researchers cited an early French article by Pick as the definitive statement on phantoms in congenital aplasia, but as Simmel (1966:83) argued: "If he had ever examined a group of individuals so affected, he kept it a secret." Weinstein and Sersen (1961) are often credited with the first published description in English of phantoms in children with congenital absences; five individual cases were included in this "largely ignored" paper (Saadah et al. 1994:479). Simmel (1962) responded with an article suggesting that children who undergo later amputation of congenitally malformed extremities experience phantoms only if sensory or motor function were present prior to surgery and only if the subject was older than four years of age. Two years later, Weinstein, Sersen and Vetter (1964) presented 13 new cases of phantoms in congenital amputees who had *not* undergone consequent surgical amputation. Poeck (1964) also reported that same year on a 11-year-old girl born without forearms and hands who counted with her phantom fingers. Despite these reports, researchers continued to claim that congenital aplastics did not experience phantoms (Frederiks 1963; Gillis 1964; Hoover 1964a), and as is indicated by *Appendix G: Phantom Populations*, the matter is far from settled.

Although the research community as a whole was not in agreement on the issue of susceptibility, the debate did lead ultimately to a serious revision of body scheme theory. I argue that by the mid-1970s, the body scheme had begun to morph into a *neurological engram or central representation*, and it was the congenital absence debate that proved to be a prescient indication of the future of body scheme theorizing. Foreshadowing was evident in Weinstein and colleagues (1961) confession that “at least the framework of the body schema might be ‘built-in’” and that phantoms, in cases of congenital aplasia, were likely representative of the scheme’s over-determined structure (a supposition that undermined the experiential quality of the body scheme). The purported absence of phantoms in child amputees (typically under the age of 5) was invoked by some researchers as means of adjudicating between these two positions (see for example Hoffman 1954a; Weiss 1956).[158] That children did not experience phantoms was assertedly demonstrative of the malleability of the body scheme, both *model* and *template*. If the child amputee did not develop phantom limb, then the maturing scheme in this instance could be envisioned as *itself* amputated, capable of tremendous revision during development, and hardly structurally fixed.

[158] Krane and Heller (1995:23) found that in children ages 5-19 who had experienced amputation, whether attributed to congenital absence, trauma/infection, or cancer, 100% experienced phantoms, and that pain was a symptom in the overwhelming majority. Still, reports given by children remain suspect because they are often deemed not credible (see for example Czerniecki 2005; Flor et al. 1998:210).

Psychological Approaches: *The Two Faces of Denial.*

The work of Anna Freud (1895-1982) on psychoanalytic defense mechanisms was enormously influential within American psychology particularly after the 1950s when she began to lecture regularly throughout the United States. Her *The Ego and the Mechanisms of Defense,* published in 1935, became the principal elaboration of the concept of denial for American psychoanalytic thought (Young-Bruehl 1988). Within the literature on phantom limbs, the concept was invoked (almost exclusively in tandem with the body scheme) from the early-1950s through the late-1970s. However, the concept was not a unitary one; rather there are two distinct renderings or applications that overlap temporally. For some researchers, denial was depicted as desirable, or at least as a favorable sign of the adaptation to part loss. But for others denial was deleterious, a toxic state, that had to be protected against. Denial was either an indication that one was positively attached to or invested in the body (a mark of security), or it was a reaction rooted in over-investment or pathological egotism (a mark of insecurity). I argue that the egoistically-denied phantom was an artifact of psychoanalytic theorizing that imagined the phenomenon as stemming from a fear of castration, while the securely-denied phantom emerged out of theorizing which foregrounded the body gestalt. Let me first turn to the securely-denied phantom before elaborating more fully on the egoistically-denied phantom.

I trace the introduction of the securely-denied phantom to the work of Kolb (1954) who argued that phantom materialization was a healthy response to the experience of amputation because it relayed a vital appreciation of, or regard for, the body. He proposed that phantoms were denial-based psychosomatizations of "the organized and continuing impressions of the patient's concept of his complete body" (Kolb 1952:110), manifestations illustrative of the scheme-based proclivity for perceptual, kinesthetic and postural congruity and integrity. If phantoms were the byproduct of the denial of part-loss, evidence of the need for psycho-physiological wholeness, then as Kolb (1954) surmised, the phantom exhibited of functional normality. This argument was actually a very early version of what I refer to as the discourse on *phantom functionality*, a discourse vitalized by the curiosity about what phantoms might accomplish if they were (re)conceived as productive phenomena. In other words, it was securely-based denial, which explicitly employed a body scheme-as-*psychological organ* framework to think through the origins of phantom limb, in conjunction with the increased functional value placed on pain and the rise in pain prevalence rates, which prompted researchers to inquiry about the purposiveness of phantoms.

Kolb was actually one of the few researchers writing against a version of Freudian wish-fulfillment theory (Dorpat 1971; Kolb 1954), a perspective that dominated psychological theorizing on the body scheme until the late-1960s. From the prevailing perspective, phantoms were more appropriately understood as egoistically-denied wish-fulfillments (see for example Frazier 1966). As Van Wirdum (1965:307) proposed, "the phantom is an old 'present' that has failed to become 'past.' But the phantom patient does not accept it; he destroys reality and in magic acts seeks to find a symbolic satisfaction." Egoistically-denied phantoms were characterized as narcissistic reactions to part-loss (Gangale 1968b; Hanowell and Kennedy 1979:437; Schilder 1935; Weiss 1956), a loss that was often considered tantamount to castration (Bressler 1956; Hoffman 1954b; Schwarz 1964). For example, Weiss (1958:25) stated, "the amputee experiences feelings of 'castration,' of being 'deprived' or 'half-a-man'." This discourse is quite reminiscent of the claims made by Mitchell in the nineteenth century that phantom manifestation was both symptomatic of irrational psychic resistance to loss, and emblematic of the forms of physical and mental weaknesses that feminize.

The painful or "pathological" phantom was considered an apt indicator of a particularly narcissistic personality, one whose adjustment problems were at times considered indicative of a serious personality disturbance (Gangale 1968b; Kyllonen 1964; Lundberg et al. 1986; White and Sweet 1952). As Gangale (1968b:426) notes:

> He refuses to accept reality or compromise with it. He is compelled to maintain his former image and, in the case of the painful phantom, serves the function of convincing him that he still has his limb. This denial is on the primitive, unconscious level for the individual would not consciously express the awareness of this form of denial. The painful phantom may also be a form of narcissism, making the amputee unable to accept the permanent loss.

In fact, as *Appendix R: Predicting Phantom Pain* shows, researchers continued to examine the psychological profiles of amputees for the next twenty years, focusing on personality attributes thought to be common among amputees who developed painful phantoms. At various times, amputees who reported painful phantoms were regarded as poorly adjusted (Almagor, Jaffe, and Lomranz 1978), depressive (Lindesay 1986; Parks 1973), rigid (Connolly 1979; Dernham 1986; Parks 1972; Parks 1973; Rounseville 1992; Sherman et al. 1979; Solomon and Schmidt 1978), compulsive (Dernham 1986; Lindesay 1986; Parks 1973; Rounseville 1992; Solomon et al. 1978), overly self-reliant (Connolly 1979; Dernham 1986; Parks 1972; Parks 1973; Solomon et al. 1978), psychopathic

(Lundberg et al. 1986; Miles 1956a; Miles 1956b), phobic (Catchlove 1983a:93), neurotic (Lundberg et al. 1986), unstable (Dawson and Arnold 1981) and/or passive-aggressive (Catchlove 1983a:93). Hoffman (1954b:265) writes,

> In a 'normal' individual a 'phantom grip' on the world can be relinquished to be compensated for by some other defense mechanism. If, however, this cannot be done, severe pain sets in and this, plus bizarre-positioned phantoms, indicates severe psychopathology. This may result in a severe obsessional neurosis, drug addiction, and/or suicide.

As phantom pain prevalence rates increased throughout the 1980s, these reports of poor adjustment became less frequent eventuating in their disappearance altogether.[159] Because painful phantoms were considered typical, work conducted in the 1980s sought to demonstrate that amputees with phantom pain were no more psychopathological than amputees without pain (Sherman et al. 1980), no more likely to have emotional problems than other amputees (Sherman and Bruno 1987a), no different psychologically than those in the general population (Sherman et al. 1987b) particularly those experiencing chronic pain (Sherman et al. 1988), and no more inclined toward personality disorders (Arena, Sherman, Bruno, and Smith 1990; Sherman et al. 1989).

What differentiated egoistically-denied phantoms from securely-denied equivalents was not only that the former were typically expressive of a more serious underlying personality issue, but also that they were predictably harmful. Egoistically denied phantoms were never functionally adaptive, never neutral, never to be lived with, but rather were materializations that must be eliminated once and for all. Hoover (1964a:47) presents an example of an adverse and consequential effect of egoistic denial;

[159] Pain memories, however, have recently been attributed to "mal-adjustment" (Mortimer et al. 2002).

> This is a psychological relation to deficiency or incompleteness…this reaction may be so strong as to interfere seriously with personal adjustment to the loss and with the preprosthetic preparation for fitting and the use of a prosthesis. An extreme example is an attractive, intelligent young woman who…refused prosthetic fitting because she was convinced that the arm would grow back.

At this time, as long as an amputee sensed a phantom, he was not cured of his egotism, and as long as he was not cured of his egotism, his phantom would present through troubling and injurious effects. Treatment, often described as difficult and lengthy, was considered successful when the phantom, painful or not, had entirely disappeared. Solomon (1978:186) offered the following case of a cured patient:

> She stated she would like to have had a funeral for her legs. She indicated that, were her legs buried somewhere, she would go and visit them. She indicated that, even though her legs are missing, she feels they are still with her and are an important part of her body…with reinforcement of the idea that the legs were with her in a spiritual sense…phantom pain and phantom sensations disappeared completely.

One of the most noteworthy effects of egoistic denial was the finding that amputees could become overly-invested in or preoccupied with the care and "proper" disposal of their amputated limbs (Blood 1956; Gangale 1968b; Parks 1972; Solomon et al. 1978). The amputee who sought to assure suitable treatment of the amputated limb or who found solace in knowing its fate had effectively denied the loss. After referencing his mothers' refrigerated arm (she intended to preserve until it could be buried with her), Schwarz's (1964:52) patient discussed the impending handling of his own amputated limb:

> Although he had initially said with false bravado that the physicians 'could feed it (amputated hand) to the chickens,' the patient's words dissolved into a pool of tears when he expressed the wish for his arm to be buried with him at death.

A particularly disruptive consequent of egoistic denial was the tendency for an amputee to associate the quality of his phantom pain with the handling of the amputated limb.

> When asked about disposal of the original amputated portion of the limb, he shook his head and denied that he had even wondered about it. Later, though, he thought that perhaps 'it was dissolved in acid.' He recalled then that, when he was 17 years old, a man in his neighborhood had had to have an arm amputated. Cramping phantom pain developed at the elbow. The arm was exhumed, the story went on, was found to be flexed, was straightened out and reburied, whereupon the phantom pain disappeared…then, after a week later, after a conversation with another amputee, he was upset, and a phantom 'aching' in the knee joint developed. The other patient had told him that cremation was the method of disposal of limbs at the hospital where the patient's first amputation had been performed. He questioned whether… [his current] surgeon had not also burned, rather than buried his limb (Blood 1956:114-5).

In other words, an amputee's preoccupation could be particularly disruptive if, like Blood's patient, he believed in a continued connection that could manifest in phantom pain. Egoistic denial was fundamentally maladaptive and phantom pain a possible sequela of poor adjustment to amputation.

If phantoms were truly egoistic wish-fulfillments then, as researchers suspected, one could confirm denial by exploring the nature of amputee dreams (Blood 1956; Chadderton 1978a; Murphy 1957; Ohry et al. 1989; Price 1976; Saadah et al. 1994; Shukla et al. 1982). Researchers assumed that the idealized body would inhabit the dream state and in fact, some reports indicated that amputees' bodies always appeared as intact in their dreams (Hrbek 1976b). This line of inquiry would, however, never produce definitive results, even though psychologists and neuro-psychologists pursued the implications of dream-morphology into the 1990s. The correlation been the body in dreams and the denial of part-loss was complicated by a number of reports that were difficult to resolve: 1) subsequent research demonstrated that about half of amputees dreamt of their bodies as intact (Chadderton 1978a; Shukla et al. 1982); 2) amputees who dreamt of their amputations experienced dream-phantoms as both similar and different from waking-phantoms (Frank and Lorenzoni 1989); and 3) in some cases, amputees dreamt of amputations they had never had, such as an upper limb amputee dreamt of himself as a lower limb amputee (Price 1998).

Psychological approaches: *The Central Representation or Engram.*

By the mid 1970s, Melzack and his colleagues began to argue against the applicability of the *psychological organ* to the etiology of phantoms. They attempted to resurrect a more Headian version of the body scheme as a neurological substrate. Like its Headian predecessor, the body scheme-as-*central representation or engram* functioned as a postural guide based on cutaneous, kinesthetic and visual input. However, they proposed that the engram was not experientially derived, rather they concluded that "the nature of the schema is fixed, archetypal and possibly inherited; rather than plastic and acquired" (Bromage and Melzack 1974:268). In other words, as opposed to the experientially-based, developmentally-secured, malleable structure envisioned by early proponents of body scheme theorizing, Melack proposed a much more static structure with a genetic basis that was relatively invariant from person to person. And, because the body scheme-*as-engram* was a built-in structure, Melzack (1973) and his colleagues envisioned that "our perceived limbs are, at least in part, images based on central neural activities and are not solely the result of feedback from our real limbs." Thus, unlike earlier versions of the body scheme, the engram was able to conceptually account for the materialization of phantoms in cases of congenital aplasia. Melzack and colleagues (1997:1618) wrote:

> It may be, then, that previous reports of phantom experience were rejected in part because there was no conceptual framework to make sense of the data. Simmel (1961) had espoused the concept that the phantom is produced by the body schema described by Head and Holmes (1911-1912) as the product of continuous proprioceptive and other somatic input. The idea of an innate structure for the neural basis of the phantom was, therefore, not considered. Yet, this is precisely where the data point.

Melzack's reinvention of the body scheme was primarily a corollary of the discovery of *experimental phantoms*, or phantoms that were induced in "normal" subjects, as well as paraplegics typically by anesthetic block (Dettmers et al. 2001; Gross and Melzack 1978; Hill 1999; Katz 1992a; Melzack et al. 1973; Paqueron, Leguen, Gentilli, Riou, Coriat, and Willer 2004).[160] In an early example, 77 patients being prepared for surgery were given an anesthetic block of the motor and sensory nerves of the arm and were subsequently asked to identify the position of the affected limb in space; patients reported a:

> sequence of experiences [that] was essentially the same for all subjects…the anesthetized arm felt normal in terms of its position in space; using his tracking arm, he generally showed it to be at the side of the body and bent at the elbow, or above the abdomen or lower chest. The real arm at this time lay flat beside the body. Sometimes the experimenter moved the anesthetized arm slowly until the lower arm and hand were beside the head. When the subject opened his eyes, he was astonished to find the discrepancy between the real anesthetized arm and the perceived arm. The reality of the phantom arm to the subjects was unequivocal. Most of them searched actively for their arm in the area where they felt it to be…some of them failed to recognize their real arm when it was raised above their head, and stared in disbelief at it and at the place where they perceived it to be" (Melzack et al. 1973:263).

The authors argued that patient reports of arm positioning both bore no relationship to the actual location and posture of the affected arm and, in aggregate, demonstrated remarkably constancy. Experimental phantoms assertedly revealed the stereotyped quality of the body scheme (Bromage et al. 1974), one associated with the body readied or poised for action. Bromage and Melzack (1974:273) wrote:

> The body schema is subservient to and waits upon objective reality. The nominal internal standard proposed by Head and Homes is set at its most efficient point, and is poised for phenomenal instruction…the final possibility for our phantom origins is one of inherited neural memory from postural patterns laid down and selected throughout the history of

[160] As is show in *Appendix S: Provoking Phantoms*, these experiments precipitated a fear among researchers that phantoms could actually be invoked or exacerbated in amputees by anesthesia, particularly in women. In fact, epidural anesthesia became contraindicated for lower limb amputees (Mackenzie 1983; Uncles, Glynn, and Carrie 1996), even though the reported incidence rate was only 5% (Tessler, Angle, and S. 1992).

> man. We have pointed out that the position-of-rest is also the position of alert for instant action. Indeed, the posture of repose adopted by the phantom homunculus is strikingly similar to the stance of a wrestler or knife fighter balanced and crouched to spring. Such an internal standard would have great functional value as an instrument for swift response in a dangerous environment, and it is tempting to see it as a kinesthetic legacy in our inherited repertoire for violent survival (Bromage et al. 1974:272,273).

By the 1990s, Melzack had seemingly abandoned the body scheme altogether, arguing that the theory was both too vague and that there was no cortical equivalent, no identified underlying neurological mechanism (Melzack 1989b). Other researchers have continued to employed the concept though typically as an abstraction, a conceptual corollary of the cortical regions of the brain known as the homunculi (discussed below) (Brunette 1980; Funk, Shiffrar, and Brugger 2005; Gallagher, Butterworth, Lew, and Cole 1998; Grouios 1999; Kew, Ridding, Rothwell, Passingham, Leigh, Sooriakumaran, Frackowiak, and Brooks 1994; McGonigle et al. 2002; Omer 1981; Ramachandran 1998; Ramachandran et al. 1998b; Shukla et al. 1982; Solomon et al. 1978; Weiss et al. 1999).

As an alternative to the body scheme, Melzack proposed what he terms the neuromatrix a "network of neurons that extends throughout widespread areas of the brain, composing the anatomical substrate of the physical self" (Melzack 1990:91), which produces both "overt action patterns" and "awareness of output" (Melzack 1995:78). He hypothesized the integration and parallel processing of three major neural circuits: 1) the sensory pathway through which information from the periphery travels via the thalamus to the somatosensory cortex (including the sensory homunculus); 2) the emotion pathway in which signals travel through the reticular formation to the limbic system; 3) and the "sential neural hub" through the parietal lobe, producing conscious awareness (Melzack

1989a; Melzack 1992; Melzack 1989b; Melzack 1990; Melzack 1995:76).[161] In many respects, the neuromatrix is equally as illusive as the body scheme, just without the conceptual "baggage." In fact, Davis (1993) interpreted the neuromatrix as a contemporized version of the central engram, and others use the term interchangeably with body scheme (Interview with Czerniecki July 21st 2005). Like the engram, the neuromatrix is genetically acquired and phylogenic (Davis 1993). But, unlike the central engram, the neuromatrix is capable of generating all the sensations felt by the body without sensory input (Davis 1993; Melzack 1993). As a:

> "template of the whole [the neuromatrix] …can generate every quality of experience which is normally triggered by sensory input…Phantom limbs are a mystery only if we assume the body sends sensory messages to a passively receiving brain. Phantoms become comprehensible once we recognize that the brain generates the experience of the body. Sensory inputs merely modulate that experience; they do not directly cause it (Melzack 1993:620, 629).

Today, the neuromatrix remains one of the most frequently referenced theories of phantom limb etiology.[xcii] That is not to say that the neuromatrix is without critics. In fact, the neuromatrix has been depicted as unable to account for: phantom limb pain, distorted phantoms, supernumerary phantoms, the absence of phantoms, delayed onset, the spontaneous cessation of pain, or the elimination of pain through cortical lesioning. Others have proposed that there is simply no substantial direct evidence to support the theory (Sherman et al. 1983). For instance, Taub argued that the neuromatrix is highly speculative:

[161] Melzack (Melzack 1990) theorizes that these three circuits simultaneously process information internal to the neuromatrix. The information is then distributed to other parts of the brain, producing an output termed the "neurosignature" and generating conscious awareness.

> There's not a great deal of evidence for it. I think that Ron Melzack, who's a good friend, is absolutely is convinced that he has found the answer. In fact, I wrote a laboratory analysis of it and the evidence for it is very weak. There was never any doubt in my mind that he was smart but smart people can get diverted by their pet hypotheses (Interview June 21, 2005).

Regardless of its speculative nature, the neuromatrix is representative of a new line of argumentation that surfaced circa 1990, which asserts that corporeality is epiphenomenal. As is elaborated in the "Chapter Four: Characterizing Phantoms", in the late or post-modern context, the body and embodiment is increasingly constructed as malleable, and the work being accomplished in this area of the neurophysiology of the brain is certainly contributory to and demonstrative of this inclination.

Phantoms in the Brain: *Denying Denial.*

As I argued in "Chapter Three: Contextualized Relations", post-WWII renormalization efforts included the rehabilitation of the demobilized war wounded, the modernization of dismemberment through significant and unparalleled state investment in prosthetic technologies, and the strategic conflation of dismemberment with techno-liberation. This was a national program that was incommensurate with the association of dismemberment with mental instability, with wish fulfilling psychosomatizations, or with egoistic denial, and throughout the 1960s, phantoms became reconceptualized as fundamentally neurophysiological phenomena.

The tension between neurology and psychology, which had heightened over the first half of the twentieth century as the disciplines jockeyed for position as the legitimate arbiters of the diagnosis and treatment of war-related injuries, began to give way as psychology itself became increasingly influenced by the growing authority of the neurosciences. Noteworthy critiques of the psychological origins of phantom sensations have, since the mid-1950s, coexisted alongside dominant theorizing. However, by the mid-1960s, these critiques became both more overt and more derisive (Appenzeller et al. 1969).

In an appraisal of the psychoanalytic theory of denial, Simmel (1959b) argued that what was known about phantoms was simply not congruous with the theory. She suggested that phantoms often persisted in amputees who had seemingly successfully adjusted to amputation and were thus not in need of a psychic defense. If fact, she argued that because phantoms were considered universally experienced after major amputation, so too would be denial, a supposition that is simply untenable. Further, phantoms often telescoped, a morphologic phenomenon incommensurate with a theory of denial. Simmel (1959b:605) wrote “if denial leads to such distortions, then, I would think, this turns out to be a very inefficient defense which does not even protect the individual at the level at which it is supposed to.” Finally, she surmised that because phantoms did not develop in cases of congenital aplasia, and “the individual with congenital absence of a limb, be he child or adult, has as much need to defend himself as the amputee”, denial was simply an unlikely etiology (Simmel 1959b:605).

Extending the critique of denial, Weinstein and colleagues (1961:908) argued that the tendency for more distal parts of the phantom to persist as vivid, while proximal parts faded, was also incongruous with the theory of denial. They wrote, “It is difficult to conceive that a fantasy or need should selectively concern, for example, the hallux more than other parts of the lower extremity” (Weinstein et al. 1961:908). They also argued that functionally or aesthetically unnaturally phantoms, telescoped or gapped phantoms for example, further challenge the psychological etiology of phantom limb. They wrote,

> In J.S., the existence of 2 'blobs' 4 and 6 in. in length does not seem to reflect a useful fantasy concerning the presence of the missing arms. In B.V., the subjective awareness of a calf and 2 toes with a gap between them can scarcely be considered a fantasy worth its salt (Weinstein et al. 1961:909).

Distortions such as gaps or telescoping were unintelligible if phantoms were denial-based copies of fleshy limbs in form and function. Though distorted phantoms were typically construed as incomplete (just not "filled in" or finished) or resized (simply a tiny or larger version), they were incomprehensible as manifestations of wishful denial.

Figure 10: The Cleaved Phantom. This image is an illustration of a cleaved phantom hand after Krukenburg's operation. Taken with permission from Melzack's 1990 article *Phantom Limbs and the Concept of a Neuromatrix.*

One of the most influential assaults came from Kallio's (1952:112) examination of amputees who had undergone kineplasic surgery to produce a forearm stump cleft, what is referred to as Krukenburg's operation;. The object of this operation is "to transform a forearm stump, by cleaving it, into a forcepslike gripping organ with sensation, a gripping organ to be used as such, without a prosthesis." Very crudely, during the surgery, the ulna and radius are essentially divided along with the accompanying muscular and tissue to produce a cleft between the two bones, a tong-like structure (Gangale 1968a:426), which resembles a "lobster claw" (Weiss 1956:670), capable with training of manipulation.

Interested in the nature of phantom limbs in the cases of cleft-ed arms, Kallio (1952:117) questioned dozens of amputees, revealing a curious trend; he noted:

> In the majority of cases the [phantom] hand was reported to have been cleft. In three cases there had been loss of fingers: in one the middle finger had disappeared, in another both the middle and the ring finger, and in the third case all that remained was the thumb and the little finger. Four patients reported that it felt to them that the ulnar fingers of the phantom hand were tied together.

In other words, the majority of amputees who had undergone Krukenburg's operation clefting the residual limb, consequently felt their phantom hands as cleft-ed, with fingers fused and palms split (Hill 1999; Kallio 1952; Spitzer et al. 1995; Wilson et al. 1978). Given his findings, Kallio (1952:117) described the denial-based wish-fulfillment of the intact body scheme as "downright impossible" and provided the following reasoning:

> The present writer emphasizes the fact that the Krukenberg (cleft) hand is in point of fact a new organ with no preexistent engrams or central representation. How could one imagine the presence of any sort of body scheme for straight, hinge-like movement between the radius and the ulna, which no human being has by nature?

Throughout the twentieth century, researchers continued to argue that the data were simply not consistent with the supposition that phantoms were a product of denial, wish fulfillment, mourning, psychopathology, psychosomatism, or neuroticism, pointing to reports that experimental phantoms could be induced in the non-amputee (Melzack 1973) or that some amputees "not only accept but are relieved by amputation" (Postone 1987). In my interview with Kelley Campbell, she argued:

> We have some folks who come in after living with a bad leg for some period of time – it usually between one and twenty years – and those people are eager to get rid of that leg. Generally they are pretty well adjusted after that. Sometimes it is a surprise to them; their anticipatory grieving didn't quite do the trick and now they are really freaked out. It is more difficult for people who are very into their bodily appearance. Some people develop the attitude that "I'm sad that my body has changed but I'm glad to be alive (Campbell July 19, 2005).

Most significantly, researchers and clinicians began to detail an alarming increase in reported phantom pain. As pain became a common sequela of phantom limb, the supposition that phantoms were denial-based wish-fulfillments, fantasies of the whole or complete body, became unreasonable. Bowser (1991:57,59) explains:

> Psychological explanations take a maladaptive approach in that phantom limb phenomena are seen to be the result of the amputee's inability to successfully adjust to the amputation. It is easy to see why this maladaptive approach might provide an acceptable explanation if the [pain] incidence figures are believed to be as low as 5-10% of all amputee populations as was previously thought. However, such explanations are less feasible given current [pain] incidence figures as high as 85%…the existence of studies supporting physiological mechanisms for phantom limb phenomena would dictate that psychological explanations be set aside when referring to phantom limb in general.

During the 1980s, references to psychological mechanisms appeared chiefly in terms of psychic contributions to the intensification or interpretation of phantom pain (see for example Abramson et al. 1981; Brunette 1980; Drachman 1967; Iacono et al. 1987; Naidu 1982; Prasad et al. 1982; Ribbers et al. 1989), or the psychic consequences of chronic pain (Fisher 1999; Sherman et al. 1988; Stein et al. 1982; Wall et al. 1999). By 1990, even amputees with phantom limb pain were thought to have measurably "normal" psychological profiles (Arena et al. 1990; Bartusch et al. 1996; Sherman 1989; Sherman et al. 1989; Sherman et al. 1987a; Sherman et al. 1987b; Sherman et al. 1980).[162]

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[162] Sherman (1989; 1987b; 1994), who wrote prolifically on the subject of the psychology of U.S. veterans, also argued against the use of psychoanalysis for the treatment for phantom limb or phantom pain.

Phantoms in the Brain: *Chasing the Phantom.*

Melzack (1971b) has described the history of phantom causation as a conceptual progression from the periphery to the center of bodies. Although accounts of the peripheral contributions to phantom etiology had existed alongside psychological explanations since the first half of the 20th century, it was not until the 1960s, when psychological theorizing had been increasingly criticized, that *Nerve Irritation Theory* came to dominate the literature (Bloomquist 2001a; Bowser 1991; Brunette 1980; Falconer 1953; Flor 2002a; Hrbek 1976a:82; Iacono et al. 1987; Jankovic et al. 1985; Jensen et al. 1983; Katz 1992b; Lundeberg 1985; Postone 1987; Prasad et al. 1982; Ribbers et al. 1989; Sellick 1985; Sherman et al. 1984; Siddle 2004; Sugarbaker et al. 1984; Wesolowski et al. 1993). Nerve irritation theorists asserted that nerve damage alone could account for the emergence, persistence and transmutation of phantoms. At the site of amputation, severed nerves are hypothesized to regenerate or heal through the formation of a neuroma, an "entwined mass of scar and nerve tissue" (American Academy of Orthopaedic Surgeons 1981:16). Unlike their parent fibers, these disturbed nerves typically express spontaneous and abnormal evoked activity, in addition to an increased sensitivity to a variety of stimuli (Jensen et al. 2000).[163] Nerve irritation theory continues as a popular explanation and guide to treatment for clinicians (Ramachandran

[163] After amputation, there are a number of changes that are proposed to occur both at the cellular level (Middleton 2003). Histamine, bradkykinin and phophilipases contribute to the sensitization of nociceptors: histamines contribute to swelling and stimulate nocicpetors which cause pain; bradykinin stimulates pain carrying nerve fibers increasing the nerve action potential rate and the onset of pain; phospholipases cause a reaction that sensitize nocicpetors. Various stimuli may subsequently produce increased action potentials, which are then interpreted by the CNS as an increase in the severity of pain. Further, through changes in the cell bodies of nociceptive neurons, neighboring nerve endings are activated. The end result is spontaneous firing of afferent neurons and "hyperalgesia (extreme sensitivity to pain) and allodynia (a painful response to a normally innocuous stimulus)" (Middleton 2003:31).

et al. 1998a; Wall 2000)[164], despite the fact that among researchers there is "virtually universal agreement that phantom limb phenomena cannot be explained in terms of peripheral mechanisms such as neuromas or other pathological activity of the stump" (Melzack 1989b:7). Nerve irritation theory gained prominence among researchers and clinicians because it was conceptually parsimonious, meaning that both research and therapeutic intervention were relatively straightforward. Thus, as phantom pain prevalence rates rose throughout the 1960s and 1970s, and amputees increasingly demanded efficacious management and treatment options, clinician concentrated their efforts on neuroma prevention and removal, treatments that were quite doable. In fact, I argue that it was the inherent *doability* (Fujimura 1986; Fujimura 1987) of the phantom problem from a peripheralist perspective that allowed nerve irritation theory to dominate.

Peripheral accounts existed alongside psychological explanations in an uncomfortable tension throughout the 1970s. By the 1980s,[165] as "centralists" became increasingly

[164] In my interview with nurse practitioner Kelly Campbell (July 19 2005) she argue that "phantom limb and phantom pain arise from a common source; I think it is just disrupted nerves." And, in my interview with Dr. Ronald Melzack (July 22 2005), he said, "I have actually found practitioners who still predominantly think that phantoms are a neuroma issue. Most of them – most physicians – do believe in it even though that should have gone out the window with the article that John Moser and I published in 1978."

[165] Circa 1980, researchers also began to hypothesis that spinal cord activity played a pivotal role in phantom etiology, including structural, physiological and neurochemical changes (Baron et al. 1995; Bartusch et al. 1996; Bloomquist 2001a; Bowser 1991; Brunette 1980; Carlen et al. 1978; Davis 1993; Enneking et al. 1997; Flor 2002b; Hanowell et al. 1979; Hill 1999; Hunter et al. 2005; Jacobson et al. 1989; Jankovic et al. 1985; Jensen et al. 1983; Jensen et al. 1984; Jensen et al. 2000; Khattab et al. 2000; Lundeberg 1985; Mayeux et al. 1979; Melzack et al. 2001; Nikolajsen, Hansen, Nielsen, Keller, Arendt-Nielsen, and Jensen 1996; Omer 1981; Postone 1987; Prasad et al. 1982; Ribbers et al. 1989; Rosen et al. 2001b; Sellick 1985; Sherman et al. 1989; Sherman et al. 1984; Siddle 2004; Wesolowski et al. 1993; Williams et al. 1997). However, the predominance of the role of the spinal cord was short lived at best because changes in the spinal cord did not explain: 1) the presence of superadded sensations (Postone 1987); 2) the disappearance of phantoms after stroke (Yarnitsky, Barron, and Bental 1988); 3) phantoms in cases of paraplegia and congenital absence (Dougherty 1980; Melzack 1978); 4) pain exacerbated by emotional disturbance (Dawson et al. 1981); 5) pain reduced by distraction, conditioning, hypnosis and psychotherapy (Dawson et al. 1981); 6) pain memories (Dawson et al. 1981); 7) pain after anesthesia (Melzack 1971a), and 8) most significantly, phantoms after complete transection of spinal cord (Carlen et

popular, explicit criticism of peripheralists grew more frequent. Researchers argued that nerve damage was an untenable explanation because: 1) phantom pain did not follow a known peripheral nerve supply (Brown 1968:301; Jensen et al. 1984; Postone 1987); 2) surgical revision of the residual limb or the proximal nerves did not alleviate pain (Brown 1968) or produce change in the painless phantom (Drachman 1967); 3) severing the nerves either in the spinal cord (Bromage et al. 1974; Catchlove 1983b; Melzack 1992; Melzack 1989b) or between the residual limb and the spinal cord was ineffective for pain reduction (Sherman et al. 1989); 4) neuromas developed gradually, while phantom limb often appeared immediately after surgery (Flor 2002b; Sherman et al. 1997); 5) phantom pain persisted long after adequate healing had occurred (Postone 1987); 6) phantoms were rarely reported in upper limb amputees; 7) local anesthetic did not produce pain relief (Bromage et al. 1974; Melzack 1992; Stannard 1993); and complex perceptual, kinesthetic and kinetic qualities could not be modified at the periphery (Jensen et al. 1984).

Despite the fact that nerve and/or tissue damage as a sole explanation of phantom materialization and persistence had been arguably debunked by researchers, the legacy of phantom peripheralism remains evident in the contemporary treatment of phantom

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al. 1978; Lawrence 1980; Melzack 1971b; Ramachandran et al. 1998a), the origins of phantom limb must lie elsewhere (Melzack 1989b). Researchers also argued that the sympathetic or/and autonomic nervous system were key to understanding the origins of phantom pain (Iacono et al. 1987; Lawrence 1980; Prasad et al. 1982; Ribbers et al. 1989; Sherman et al. 1989); and that other central (spinal cord, CNS, supra-spinal and cerebral) mechanisms were causative (Bloomquist 2001a; Bowser 1991; Dawson et al. 1981; Finnoff 2001; Flor 2002b; Hanowell et al. 1979; Hrbek 1976a:82; Iacono et al. 1987; Jankovic et al. 1985; Jensen et al. 1984; Katz 1992b; Lundeberg 1985; Postone 1987; Ribbers et al. 1989; Rosen et al. 2001b; Sellick 1985; Sherman et al. 1984; Sugarbaker et al. 1984; Wesolowski et al. 1993), which operated via central biasing (Dernham 1986; Fiddler and Hindman 1991; Iacono et al. 1987; Koyama, Watanabe, Tsuneto, Takahashi, and Naito 1988; Liaw et al. 1998; Melzack 1971b; Mihic and Pinkert 1981; Spross et al. 1985; Wilson et al. 1978), wind-up (Bloomquist 2001a; Davis 1993; Hazelgrove et al. 2002), reverberating circuits (Finnoff 2001; Hanowell et al. 1979), gate control (Melzack 1978; Postone 1987), or other pattern generating mechanisms (Melzack 1978).

pain.[166] As is shown in *Appendix J: Treating Phantom Limb Pain*, phantom pain treatments designed to mediate the effect of peripheral (especially nerve) damage, such as peripheral stimulation (TENs) or other local interventions, were still commonly employed even at the turn of the twenty-first century. This trend can be at least partly attributable to the popularization of the work of Dr. Richard Sherman, orthopedic surgeon at the Madigan Army Medial Center in Tacoma Washington (Bowser 1991; Dangel 1998). As I elaborated in "Chapter Four: Characterizing Phantoms", Sherman has been the strongest proponent of conceptualizing phantom pain as a *class of symptoms* (Sherman 1994). He proposed that one of the pains in his phantom triad, the burning phantom, results from reduced near-surface blood flow (Sherman et al. 1987a), a condition that is treatable using existing local interventions.

Phantoms in the Brain: *The Decade of the Brain.*

> The human brain, a 3-pound mass of interwoven nerve cells that controls our activity, is one of the most magnificent - and mysterious - wonders of creation. The seat of human intelligence, interpreter of senses, and controller of movement, this incredible organ continues to intrigue scientists and laymen alike. To enhance public awareness of the benefits to be derived from brain research…I, George Bush, President of the United States of America, do hereby proclaim the decade beginning January 1, 1990, as the Decade of the Brain. I call upon all public officials and the people of the United States to observe that decade with appropriate programs, ceremonies, and activities (Bush 1990).

By the early 1990s, phantom limb, like many disorders/syndromes/conditions, had been definitively located in the brain. No longer the psychsomatizations of denial, no longer the animations of damaged nerves and tissues, no longer the expressed hyperactivity of cells in the spinal cord, phantoms had been "chas[ed]…up into the brain itself" (Shreeve 1993:3). I argue that the brain had become a viable prospect for the origins of phantom

[166] Carlen et al. (1978:216) wrote in the late 1970s: "Alter aliis teneant" or "let others keep to the deep."

limb in part because of the emergence and proliferation of medical imaging technologies during the 1970s and 1980s (Dumit 1995; Dumit 2004; Joyce 2005; Joyce 2006; Kevles 1997; Pasveer 1989), technologies that procured very provocative and persuasive pictures. Joseph Dumit (2004:15), whose work details the emergence and popularization positron emission tomography (PET) scans, argues that what is unique about these technologies is that they "offer researchers the potential to ask a question about almost any aspect of human nature, human behavior, or human kinds and design an experiment to look for the answer in the brain." In fact, neurophysiologic research on phantom limb literally tripled during the 1980s and 1990s, with dozens of articles written every year on some aspect of the visualized/visualizable neurology of part-loss. As Dumit (2004:15) warns, these technologies have actually transformed how we think about our minds and in the case of phantoms, our bodies.

Medical imaging, Prasad (2005:292) insists, has radically altered the "mechanics and architecture of the medical gaze, shifting it to a visual regime that should be appropriately called cyborg visibility." Cyborg visibility had its origins in the U.S. military (Draper 2002; Petchesky 2000) becoming, by the turn of the twenty-first century, a highly routinized, intensely masculinized (Petchesky 2000), exceedingly privileged (Jenks 1995; Martin 1990) way of knowing. And, because these technologies simultaneously serve to observe and construct (Draper 2002:775; Keller 1996),[167] to "know" and to "do," they have been profoundly consequential. We can visualize, observe, isolate and intervene into brain-based phenomenon, and it is vis-à-vis imaging technologies that, as Casper (1995) proposes, "the representation becomes the phenomenon." The mind in western

[167] See also Thacker (1999:323) on the construction of "ocular evidence."

medicine has become the brain, what Beaulieu calls ‘the mind-in-the-brain’ (Beaulieu 2002), and the phantom (seen through the reorganized maps of the cerebral cortex) has emerged as proof that the body too is “all in the mind,” or more precisely that corporeality is all in the brain.

Phantoms in the Brain: The Exceedingly Minute Man.

> A neurologist might conclude that God is a cartographer. He must have an inordinate fondness for maps, for everywhere you look in the brain maps abound (Ramachandran et al. 1998a:39).

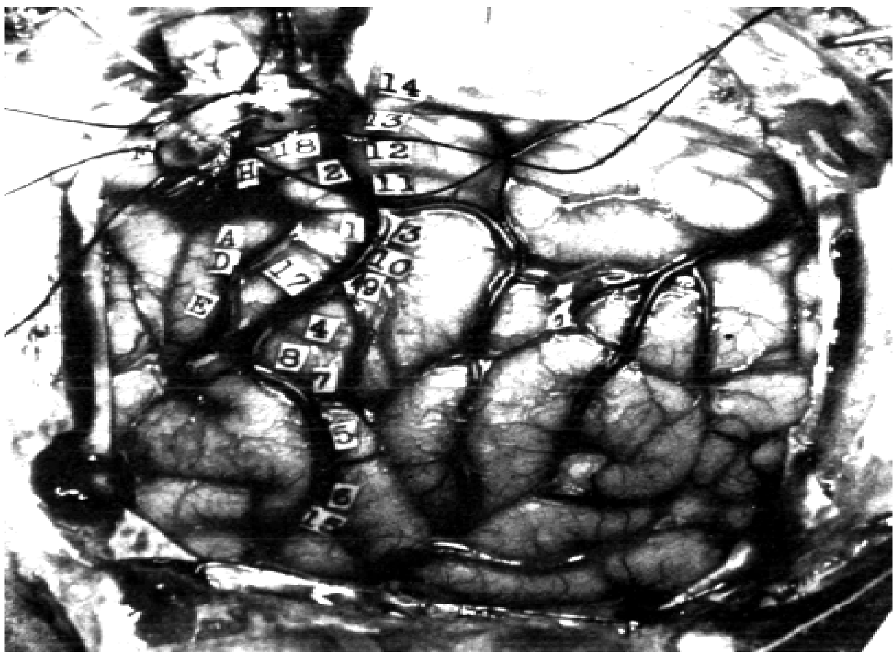

Figure 11: Penfield Map. The photograph shows Penfield’s mapping process. Tiny numbered tickets indicate the area of the cortex that produced a specific response (a sensation, memory, etc.) in his patients. Taken with permission form Penfield’s 1958 *The Excitable Cortex in Conscious Man*.

During the late-1930s and 1940s, the Canadian neurosurgeon Dr. Wilder Penfield (1891-1976)[168] worked to treat intractable epileptic seizures in his patients by inducing what is

[168] “When, in 1960, at the peak of his career, he retired as director of the Montréal Neurological Institute (MNI) he was widely recognized as one of the great neurosurgeons and neurologists of all times” (Feindel 1977:1365). For a comprehensive overview of the work of Wilder Penfield see the compilation of articles

termed the *aura stage* during neurosurgical operations (Finger 1994; Restak 1984). Using cortical stimulation, Penfield was able to pinpoint the section of “abnormal” brain matter that caused replication of the aura stage, typically felt by epileptics just prior to the onset of a seizure. This segment of brain matter, he speculated, could then be excised. Serendipitously, with conscious patients, a stenographer, photographer, electrodes and tiny numbered tickets dropped onto the brain, Penfield compiled masses of correspondence points from which maps of the human body within the somatosensory and motor cortices were compiled (Stevens 1971).

Equipped for exploration with his tiny territorializing flags, Penfield localized the “sensory and motor functions of the postcentral and precentral gyri, two convoluted ridges enclosing the brain’s central fissure” (Stevens 1971:260) typically referred to as the sensory and motor homunculi (Penfield and Boldrey 1937; Penfield and Rasmussen 1950).

In the below depictions of the homunculi,[169] a little man’s[170] distorted and reorganized body lies stretched across sections of each of the cerebral hemispheres, representing

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entitled “Wilder Penfield: His legacy to Neurology” in the *Canadian Medical Association Journal* June 1977.

169 Homunculus: “The figure of a human sometimes superimposed on pictures of the surface of the brain to represent the motor or sensory regions of the body represented there” (Stedman 2000:830).

170 The gross layout of each map is considered relatively invariant from person to person (Ramachandran et al. 1998a). You will notice that the homuncular body is anatomically male, which is consistent with Grosz’s (1994a:71) observation that “‘the’ body that is generally addressed by neuro- and psychophysiology is implicitly the male body,” as well as with Moore and Clarke’s (1995) detailed analysis of anatomical representations of genitalia. The penis as always present in anatomical representations, while the clitoris was only sometimes indicated, a tendency they call anatomical essentialism (see also Clarke 2003).

topographical maps of either sensory or motor function.[171] The maps are bilaterally reversed (the left side of the homunculus corresponds to the right side of the body), up-side down (the feet are at the "top" of the brain) and not continuous (from head to neck to shoulder, etc.). For example, in other more detailed depictions, the area corresponding to the genitalia in the sensory homunculus can be found located next to the feet, the breast adjacent to the ear, and the face bordering the hands.

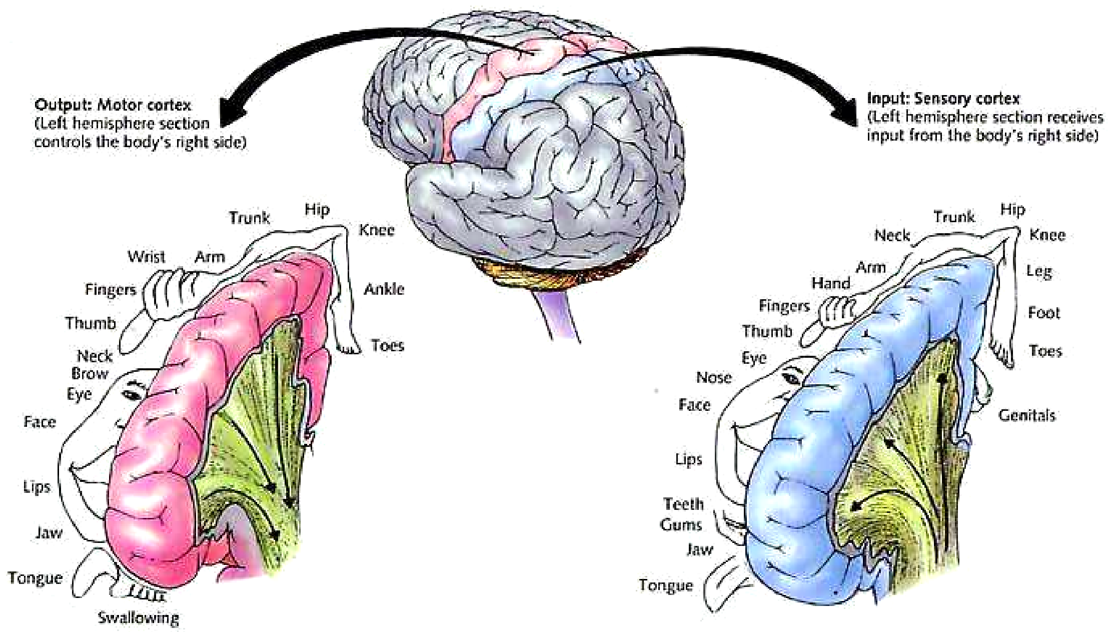

Figure 12: The Sensory and Motor Homunculi. Developed by Wilder Penfield, these maps or schematic representations of the sensory and motor homunculi indicate the proportion of cortical area devoted to each body part. This depiction is a popularly circulated example of the sensory and motor homuncular maps.

The sensory homunculus is considered to be a relay center that receives and processes sensorial information from the periphery, while the motor homunculus precipitates movement by sending signals directly to the muscles, and the two are hypothesized to

[171] "Corneluis Agrippa believed…that humans could be grown from mandrake roots. His contemporary, Paracelsus published instructions on the manufacture of a 'homunculus,' or miniature man. Human semen, Paracelsus suggested, should be put into an airtight jar and buried in horse manure for forty days. After this, it was to be 'magnetized', then preserved at the temperature of a mare's womb and fed human blood for forty weeks. A small, fully formed person was thought to emerge after this procedure" (Wood 2002:xv-xvi).

integrate in the parietal lobe, the site of body scheme/image formation (Metman, Bellevich, Jones, Barber, and Streletz 2005; Penfield et al. 1937; Penfield et al. 1950).

Penfield demonstrated that stimulation of the homuncular hand, through the use of an electrode placed on the surface of the brain, induced sensation felt as originating in subject's "real" hand (Almagor et al. 1978; Bolderly and Penfield 1937; Hess, Mills, and Murray 1986; Pascual-Leone et al. 1996; Woolsey, Erickson, and Gilson 1979).[172] Likewise, stimulation of a particular physical body part results in the activation of the corresponding regions of the primary somatosensory or motor cortex; when the hand, for instance, is introduced to heat, pressure or pain, the sensation is "registered" in/by the homuncular hand.

Some body parts are more densely innervated[173] than others and are, thus, associated with larger cortical areas; these parts are more sensitive to touch, temperature, pressure and pain, and are capable of finer degrees of discrimination (Ramachandran et al. 1998a; Ramachandran et al. 1998b). For example, the tongue and hands of the sensory homunculus, and the hands and lips of the motor homunculus, assertedly correspond to or occupy disproportionately larger cortical areas because of their sensitivity and import (Fraser et al. 2001; Omer 1981). Miller (1978:21) metaphorically explains:

> It is like an electoral map as opposed to a geographical one. Because of their functional importance, the hand and the mouth have more sense organs per square inch than the leg

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[172] Instructions can be found on the Woodrow Wilson Biology Institute website on mapping your homunculus. Complete with a materials list, procedure, and examples of analyses, the shape of your homunculus can be determined with the help of two assistants. It involves a blindfold and pricking yourself with toothpicks (http://www.woodrow.org/teachers/bi/1991/homunculus.html).

[173] Innervation: "The supply of nerve fibers functionally connected with a part" (Stedman 2000).

> or the trunk, and since all of the parts of the body are clamoring for attention, they have many more Members representing them in their Parliament, that is to say, in the brain.

The below image of the sensory homunculus illustrates the asserted proportional association between brain area and body surface. In other words, if the body were shaped in accordance with the brain's representation, we would look something like this.

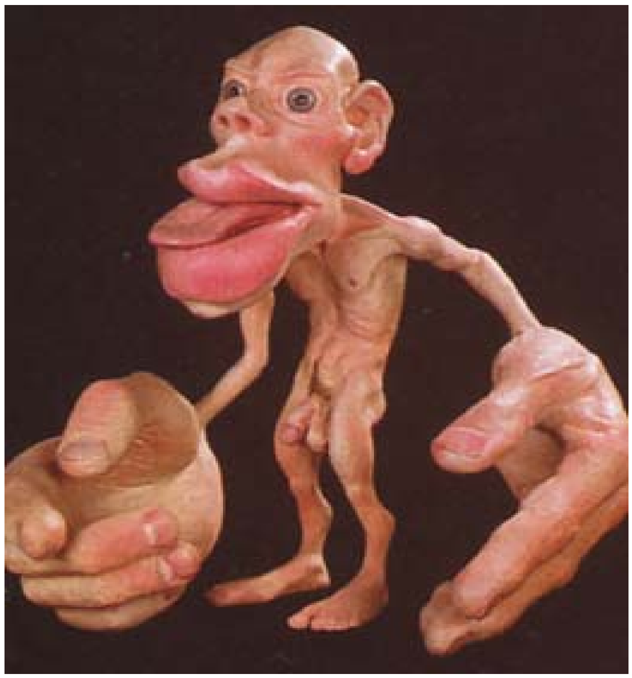

Figure 13: The Sensory Homunculus. This is a popularly circulated illustration of the somatosensory homunculus that shows the "size" of each of the sensory body parts in the brain. The proportions reflect the relative amount of cortical area devoted to each body part.

Penfield first published on the homunculi in 1937 (Penfield et al. 1937), but it was his *The Cerebral Cortex of Man* (Penfield and Rasmussen 1951) and *The Excitable Cortex in Conscious Man* (Penfield 1958) that were among his most significant contributions to modern neuroscience (McNaughton 1977). And, although there were correspondingly early references to Penfield's homuncular maps during the 1950s and 1960s within the phantom literature (Gangale 1968b; Hecaen, Penfield, Bertrand, and Malmo 1956; Lunn 1955; Simmel 1956b; Weinstein et al. 1961), it was not until the mid-1980s that the role of homunculi in phantom formation was widely acknowledged (Almagor et al. 1978:377).

In an application of the concept Lunn (1955:282) writes:

> The [phantom] perception corresponds to the patient's idea of 'a hand', 'a foot', etc., according to the distribution of the cortical representation. If we summarize the statements made by all the patients as to the part of the limb they perceive as present, or perceive with the greatest intensity, and if, on the basis of these statements, we draw an 'average phantom limb' this figure will display a striking likeness to the 'homunculus' illustrating the cortical motor and sensory representations.

In these initial references, the homunculi acted simply as a heuristic for detailing one aspect of phantom morphology, the dropping out of parts or phantom shrinking (phantom gapping and phantom telescoping were considered the same phenomenon at this time). The homunculus was not engaged as theory proper, as a means of explaining phantom phenomenon *in toto*, but rather as the structural correlate of the body image and a way of substantiating that body parts (homuncular, scheme-d, physical or phantom-ed) have differing degrees of import and vibrancy relative to one another. In other words, these early references read as affirmations of what researchers had already "known" about the structure and function of the body scheme. For instance, Simmel (1956b) argued that telescoping was the perceptual correlate of the differing degrees of significance of parts within the body scheme, as well as of the larger cortical areas devoted to more peripheral parts within Penfield's homunculi. Phantom-ed parts that had greater schematic and homuncular representation, the fingers and toes (the more distal parts), she argued were actually felt more vividly, and because of the resultant perceptual discrepancy between parts, the more proximal areas/parts necessarily "dropped out" over time. The more distal parts were thus sensed as disconnected or floating, a state that was both perceptually disturbing, and antithetical to the lived scheme gestalt. The "answer" to this type of embodied dissonance, floating fingers or detached toes, was in either the body stretching toward the hovering part or the part moving closer to reconnect with its body. Simmel (1956b) argued that because stretching would entail a change in body shape, parts would naturally telescope toward the body.

Because these early references to Penfield's somatosensory and motor maps were imbricated within body scheme theorizing, the homunculi were conceived as among the many places where the body schema could be found or more accurately among the many spaces of influence. The body scheme, even when conceptually well defined, was a quite illusive formation, and was often intimately intertwined with a number of other psychic structures, including the body ego, the body concept, and the body ideal --- other structures that were equally as amorphous. Accepted wisdom, then, was consonant with what Star (1989:176) termed *diffusionist localizationism,* an approach first advanced within the nascent field of neurophysiology by Charles Scott Sherrington at the turn of the twentieth century (1989:176). Sherrington asserted that the brain was not composed of discrete functional areas but rather was a complex of integrated functions and formations. Consonant with this logic, researchers investigating the vagaries of phantoms envisioned the body scheme to be a multifarious process/product with psychological, physiological, neurological, and experiential elements, and the homunculi to be an ancillary structures that were accordingly vulnerable to revision by way of psychosocial processes.

The work of Dr. Timothy Pons and others transformed the sensory homunculus into a purely neurophysiologic substrate and phantoms into evidence of the cartographic nature of the brain, a shift reflective of the rising predominance of *explicit localizationism*, an approach that "reached its apex" with the work of Penfield and others circa 1950 (Star 1989:179). Star (1989) argues that explicitly localizationist suppositions became entrenched in the institutions, practices and knowledges of modern neuroscience by mid-twentieth century; "the legacy of a successful scientific theory is not always found in the validity of its specific findings, but rather in the structure of its axioms and assumptions."

Phantoms in the Brain: Timothy Pons and his Implicated Actors.

In 1991, Dr. Timothy Pons (1956-2005),[174] a neuroscientist at the Laboratory of Neuro-phsychology at the National Institute of Mental Health, conducted a series of experiments with the now infamous 15 Silver Spring macaque monkeys (Holden 1989; Ramachandran et al. 1998a; Schwartz and Begley 2002; Sideris, McCarthy, and Smith 1999).[175] In the summer of 1982, in an unrelated rehabilitation experiment of Dr. Edward Taub's (Barinaga 1992; Elbert et al. 2004), the monkeys underwent rhizotomy, a procedure in which the nerves from the arm are completely severed from the spinal cord (Stedman

[174] Pons' work is often considered an elaboration of that begun by Dr. Michael Merzenich, a neuroscientist at the University of California San Francisco, in the mid-1980s (Kew et al. 1994; Knecht, Henningsen, Elbert, Flor, Hohling, Pantev, Birbaumer, and Taub 1995; 1995; Merzenich, Kaas, Wall, Nelson, Sur, and Felleman 1983; Merzenich, Nelson, Stryker, Cynader, Schoppmann, and Zook 1984). Merzenich conducted a series of experiments in which he amputated the middle fingers of several adult owl monkeys and subsequently stimulated the remaining fingers. Using neural imaging, Merzenich found that the area of the brain previously corresponding to the amputated finger subsequently responded to stimulation of the adjacent fingers. In *Discover* (Shreeve 1993:3), Meraenich is quoted as saying, "There had always been a countercurrent to the mainstream that suspected the brain could make such adjustments…We witnessed them happening."

[175] The details of the case of the Silver Springs monkeys vary by source according to the number of monkeys involved, the number of post-deafferentation years, and the number of monkeys euthanized. A very disturbing video detailing the specifics of the abuse, produced by People for the Ethical Treatment of Animals (PETA) can be found at http://www.petatv.com/tvpopup/Prefs.asp?video=silver-spring-monkeys.

2000:1568). Years later, the monkeys partnered with animal rights activists, whose zeal along with a court order, prompted a halt to the research and resulted in 6 charges of animal cruelty against Dr. Taub (Holden 1989; Sideris et al. 1999).[176] The monkeys were seized by police but languished in the custody of the NIH until the court demanded that three be humanly euthanized[177] (Shreeve 1993). In sardonic twist of fate, Pons was given permission to examine their brains before their euthanization and the monkeys spent their last days back in the laboratory (Pons, Garraghty, Ommaya, Kaas, Taub, and Mishkin 1991; Shreeve 1993).

During his examination, Pons found that in each of the monkeys the cortical area previously corresponding to the arm was not dormant or inactive, as one might assume after all those years of paralysis, but instead responded to stimulation of the *face* (Pons et al. 1991; Ramachandran et al. 1992; Shreeve 1993). Pons argued that because the homuncular face and the homuncular hand are adjacent to one another in the somatosensory cortex, and because the neural region belonging to the homuncular hand "sat unused," the homuncular face began to encroach upon or make use of the idle region. In fact, the deafferentated[178] area of the brain had purportedly been reorganized "at least an order of magnitude greater than that reported previously"[179] suggesting the growth of new connections between neurons, a phenomenon referred to as neuronal sprouting or

[176] Taub was eventually convicted of providing inadequate veterinary care but the Maryland appeals court overturned the conviction in 1984 (Green 2005).
[177] The monkeys had mutilated their own arms; a spokesperson at the NIH attributed their behavior to unrelenting phantom limb pain (Holden 1989).
[178] Deafferentation: "A loss of the sensory input from a portion of the body, usually caused by interruption of the peripheral sensory fibers" (Stedman 2000:459).
[179] Reorganization is now thought to occur over a greater distance, 10-14mm (Ramachandran et al. 1992), than the originally surmised maximum distance of 1-2 mm (Ramachandran et al. 1998b).

aborization (Flor 2002a; Florence and Kaas 1995; Kaas 1998; Moore et al. 2000; Pons et al. 1991; Roux et al. 2001). As Shreeve (1993:3 emphasis added) concluded:

> In effect, fully a third of the entire touch map – over half an inch of cortex – had switched its allegiance. With no orders coming in from the numbed limb, it had married its fortunes to those of the face instead. This is neural reorganization on a *massive scale, unimaginable in a hardwired brain.*

Pons' speculation that the cortex was amenable to reorganization through the growth of new connections contrasted with the "hard-wired" conception of cortical organization and development that then prevailed in the neuroscience.[180] Phantoms, visualized through the reorganized somatosensory cortices of macaque monkeys, had effectively shaken the foundation of modern neuroscience. Ramachandran (1998a:31) enthusiastically explained:

> The implications are staggering. First and foremost, they suggest that brain maps can change, sometimes with astonishing rapidity. This finding flatly contradicts one of the most widely accepted dogmas in neurology – the fixed nature of connections in the adult human brain.

The absence of neuronal activity within the sensory and motor homunculi, in the case of amputation, congenital aplasia, spinal cord injury[181] or stroke, is today commonly considered an impetus for cortical reorganization (Brugger et al. 2000; Cusick, Wall, Whiting, and Wiley 1990; Elbert et al. 2004; Kew et al. 1994; Knecht et al. 1996; Knecht et al. 1998a; Merzenich et al. 1983; Merzenich et al. 1984; Moore et al. 2000; Ojemann and Silbergeld 1995).

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[180] The "hardwired brain" is associated with the work of David Hubel and Torsten Wiesel at Harvard University. The two were awarded the Nobel Prize in 1981 (Barinaga 1992; Shreeve 1993).

[181] Amputation after spinal chord injury reportedly results in a phantom that can be differentiated from the paralysis phantom (Sherman et al. 1997).

Phantoms in the Brain: *Referred Sensations or Mislocation Phenomenon.*

Researchers have long documented what has been termed *mislocation phenomenon or referred sensation*[xciii] in cases of major amputation, describing the "projection" or mislocalization of sensation from a particular *trigger zone* (Aglioti, Bonazzi, and Cortese 1994a; Cronholm 1951; Doetsch 1997; Halligan et al. 1993a; Maroon et al. 1973; Ramachandran 1993; Ramachandran 1998; Ramachandran et al. 2000; Ramachandran et al. 1992)[182] located on the residual limb or stump, onto or into the phantom. In other words, sensation on the residual limb or stump (a light touch or painful pinch) is often "referred" to the phantom producing "separate sensations in the [phantom] foot and stump which appear to come from the same point" (Katz 1992b:286). Doetsch (1997:10) describes how, in one of his patients, sensation "retreated up the limb":

> When asked whether he could elicit sensations referred to his PH [phantom] by self-stimulation, he replied that he had always been able to do so–and proceeded to demonstrate the location and size of each of his TZs [trigger zones] by touching or lightly scratching his left forearm [stump] with his right index finger.

According to Penfield's map, the homuncular hand is adjacent to the homuncular upper arm/shoulder, and thus, a stimulus applied to the physical shoulder (the residual limb) would expectedly be referred to the phantom hand. These *dual percepts*, as they are sometimes called (Halligan, Marshall, and Wade 1994; Hunter et al. 2003; Hunter et al. 2005), remained a curious but relatively unexplored phenomenon until the documentation of trigger zones in parts of the body quite removed from the site of amputation. Following Pons' work in the early 1990s, researchers began to document faces (mouths

[182] These were later referred to as reference zones (RZ) (Moore et al. 2000), trigger points (Fraser et al. 2001), and misallocation points (Condes-Lara et al. 2000).

and lips)[xciv] referred to phantom hands, ears referred to phantom breasts,[xcv] and genitalia referred to phantom feet[xcvi] (and feet referred to phantom penises).[183,184,185]

Because most homuncular parts are flanked on either side,[186] researchers surmised that two separate referral zone existed, both of which would produce referral to the phantom. In other words, just as the implications of Pons' remapped somatosensory cortex were being thought through, amputees began to report multiple referral zones. For instance, researchers found in the case of amputation of the hand, that stimulation of the upper-arm/shoulder/trunk, as well as the face, produced sensation referred to the phantom hand (Dettmers et al. 2001; Fraser et al. 2001; Hunter et al. 2003; Kew, Halligan, Marshall,

[183] One of the first references to phantom penis is in a footnote in Weir Mitchell's (Mitchell 1872a) *Injuries of Nerves and their Consequences*. Price Heusner was a seventy-year-old man whose phantom penis intermittently became erect beginning two years after its amputation. Ironically, he had been impotent prior to his amputation and "tragically," a gunshot wound to the spine four years later left him paralyzed and impoverished of erections. One of the most illustrative articles written on the subject was a review by Fisher (1999:54) who presented 12 cases of penile amputation found prior to 1999. He "confirmed" that the phantom penis was similar to other parts in that they often accurately represented the size and position of the intact penis. He writes of one of the cases: "so real was the experience that even after 20 years, the subject was still periodically obliged to check on the situation, tactually and visually" (Fisher 1999:54). However, the phantom penis was dissimilar in a significant respect, it had the capacity to become erect. Other phantoms, Fisher (1999:55) contended "may be influenced by mental concentration, emotional states, surprise, pain, wearing a prosthesis, etc., but show no change comparable to that of the phantom erection."

[184] Kolb (1950a:470) gives one of the first accounts of the association of phantom sensations with sexual intercourse. He writes, "a married man 58 years of age came to the clinic complaining of pain in a phantom left hand. He declared that two years and nine months previously, while working alone on a neighbor's farm his left had was caught in a corn picker. He stated that he was unable to extricate himself and watched the hand and arm slowly being mangled over a period of ninety minutes. He was taken to the hospital immediately after being released where amputation was performed at the junction of the upper and middle third of the forearm. The patient felt well until after he returned home. He was aware of the existence of [sic] phantom extremity but it was not then painful. Later, after attempting sexual intercourse, the sensation of pain in the phantom hand was experienced for the first time. This pain recurred repeatedly when attempting the sexual act." The link between intercourse, orgasm and phantom limb continues to be documented even today. However, the sensation has become almost exclusively associated with amputation of the lower limb, and has been increasingly associated with referral. Thus, the phenomenon is no longer described as a phantom foot evoked during or after intercourse, but rather as an orgasm being referred to the phantom foot (Ray 2003) and thus felt as "bigger" (Ramachandran et al. 1998a).

[185] Ramachandran et al. (1998a) speculate that foot fetishes might result from the normal boundary crossing of neurons in adjacent cortical areas, the feet and genitalia.

[186] The two parts of the body found at the "end" of the map would only be adjacent to a single other homuncular body part.

Passingham, Rothwell, Ridding, Marsden, and Brooks 1997; Knecht et al. 1996; Melzack 2001; Moore et al. 2000; Ramachandran et al. 1998b; Ramachandran et al. 1992).[187]

> Because the hand area in the Penfield map is flanked on one side by the upper arm and the other side by the face, this is precisely the arrangement of points what one would expect if the afferents from the upper arm skin and face skin were to invade the hand territory from each side (Ramachandran 1998:1853).

For example, Ramachandran (1998a:29) reported the extraordinary discovery, using a common household Q-tip, of two distinct trigger zones; he found one "beautifully laid out 'map' of his missing hand" on D.M.'s upper arm and another on the side of his face.

> Neurologically speaking, at least, the hand was not missing at all – indeed, it was now a pair of left hands one meticulously laid out across his lower face, the other wiggling its digits just below his shoulder (Shreeve 1993:4)

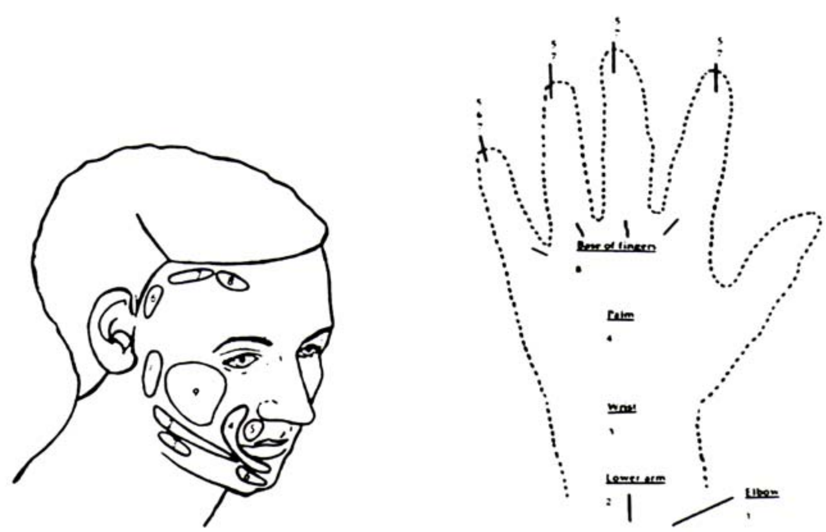

Figure 14: Mislocation Phenomena. The rendering shows the regions on the right side of the face of D.M. that elicited precisely localized, modality-specific, topographically organized sensation in the phantom. Taken with permission from Halligan, Marshall, and Wade's 1994 article *Sensory Disorganization and Perceptual Plasticity After Limb Amputation: A Follow-Up Study*.

[187] The first reports of amputees inadvertently discovering these referral sites while shaving (Ramachandran 2001), washing the face (Aglioti et al. 1994b) or applying makeup (Halligan et al. 1993a) began to surface in the mid-1990s.

Others too have found these topographically-precise maps,[xcvii] characterized by a one-to-one systematic correspondence between very precise points on a trigger zone and defined points on the phantom. Researchers have also reported that these referral maps are modality-specific;[xcviii] that temperature, pressure, vibration, as well as the sensation of metal, tickle, itch, massage, or a breeze can be transferred to or mislocalized to the phantom (Aglioti et al. 1994a; Katz 1992a; Ramachandran 1998:1853). Ramachadnran (1998b:1613) writes:

> On one occasion when the water accidentally trickled down his face, he exclaimed, with surprise, that he could actually feel the warm water trickling down the length of his phantom arm!…We tried applying a drop of warm (or cold) water on different parts of the face and found that the heat or cold was usually referred to individual fingers so that there was a sort of crude map of referred temperature that was roughly superimposed on the touch map.

What is so remarkable about these far-removed, modality specific, "trigger zones" is their complete absence from the literature until circa 1990. Incredibly, just as visualizing technologies began to be utilized regularly to investigate phantom phenomena and just as cortical remapping surfaced with the work of Pons and others, trigger zones spread to the very places that they were "supposed to be." They "should," theoretically, have been captured within the visualized maps of the sensory and motor function of bodies in ways that abided by Penfield's homuncular topography. And, if fact they were, phantom breasts lay across the ears of mastectomy patients, phantom feet spread their toes along genitalia, and phantom hands reached their fingers nimbly over jaws.

By the turn of the twenty-first century, researchers began to argue that these maps were actually quite rare; as quickly as they had come into view, they started to vanish. Though referral has remained a common phenomenon, topographically precise referral became exceptional, found in roughly 7% of amputees by 2000 (Flor et al. 2000b), and in only 3% of amputees today (see below). As researchers began to think through cortical reorganization, what they expected to find (or not find) shifted dramatically. Cortical reorganization became conceptualized as dynamic, as a product of activity (see below), and consequently, referred maps only made sense as short-lived phenomenon. If remapping occurs as a process over time, one would expect a referral map (superimposed on a face for instance) to move, to morph, to change size and shape as the cortex gradually (or rapidly) reorganizes, and thus the referred sensation would expectedly be sensed in the same way, as dynamic and thus ambiguous and amorphous. In fact, researchers in the late 1990s found those dynamic maps, multiple referred maps that appeared in the same individual, and maps that disappeared, expanded or shifted over time (Berlucchi and Aglioti 1997; Knecht et al. 1996). Knecht et al. (1998a:717) write of their "discovery":

> Contrary to our expectation, the topography of referred sensation had completely changed in every patient. These results suggest that while the overall extent of reorganization is a rather stable phenomenon, the concomitant changes in the pattern of sensory processing are not. This may be due to the fact that alterations of sensory processing are not hardwired, but are rather mediated by an extensive and interconnected neural network with fluctuating synaptic strengths. This mechanism may be of importance for neurological rehabilitation.

In an interview with Dr. Edward Taub, behavioral neuroscientist and professor of psychology at the University of Alabama Birmingham (Interview, July 26th 2005), he elaborates:

> In our research, we were able to show that after stroke the cortical representation of the affected hand shrinks by a half, and then through constraint induced movement therapy, it will expand back to normal size. What everyone typically points to, which is a

> fascinating phenomenon, is Mike Merzenich's invasion. But, I will be willing to lay ten-to-one odds that the cortical area shrinks but remains. Not all of the synaptic space has been taken up by the axonal sprouting and there is still representation of the limb there; it just hasn't been demonstrated. What happens in amputees is you get this referral to the phantom but the referral is not stable, which suggest a rapid alteration of the balance of excitatory/inhibitory factors in different parts of the body projecting to the area. And the area will keep shifting.

As precise referral was thought of as increasingly rare, the fact that it had at one time occupied such a prominent place in theorizing and had been depicted as a much more widespread phenomenon had to be explained. It is the very process of "finding" phantoms that researchers often advance as the source of substantial shifts in accepted knowledge. For instance, Taub (Interview July 26th 2005) argued that Ramachandran was mistaken about referred maps precisely because of how he acquired his "research material":

> The actual point-to-point facial remapping that Ramachandran found is very rare. In our research, we had one patient for whom there was facial remapping. But, we had four other patients with cortical reorganization and no facial remapping. It was a good hypothesis and actually, it was Ramachandran's hypothesis that inspired me to work on cortical reorganization. We had a public interchange at a meeting in 1993, where he said that his facial remapping phenomenon was the perceptual equivalent to Pons' physiological data. I pointed out that it was an excellent hypothesis, but it was still a hypothesis that required demonstration, to which he got very excited and he said, "It isn't a hypothesis, it's true, what else could it be?" To which I said, "I don't know what else it could be but there is no evidence that your assertion is correct."
>
> What actually happened with Ramachandran was interesting. There's no question in my mind that he was reporting accurately what he had observed; he wasn't falsifying anything. But he chose to emphasize the subjects who experienced facial remapping. He's a very personable individual and his friends in the San Diego area sent him the very patients he was interested in. At first he got a large number of patients with facial remapping and then as time went on, he began to recruit people from the general amputee population. In the last ten patients, there was not a single case of facial remapping and that's about what we got, maybe 3% of the population. Now, what is evident is that you cannot have a theory on the nature of phantom limb pain based on 3% of amputees. So I mean you put it all together and it's sort of an historical accident.

In her analysis of the developing field of reproductive science, Clarke (1995b:183, 187) argues, "in order to observe or produce the phenomena they study, all working scientists must obtain and manage research materials." She describes the "catch-as-catch-can ethos" that predominated materials acquisition at the turn of the twentieth century, an ethos typified by the establishment of creative networking (which eventuated in entrenched practices). In the neuroscientific study of phantoms, this catch-as-catch-can ethos gave way mid-century to a quality-catch ethos. Researchers were increasingly interested in finding, acquiring, or enlisting remarkable phantoms; phantoms that shrunk (telescoping), phantoms that remained fixed (paralysis), phantoms that penetrated objects, phantoms that retained the quality of the intact limb prior to amputation (pain memories), and, as Taub intimated, phantoms amenable to topographically-precise referral.

Phantoms in the Brain: *Cortical Plasticity.*

References to the causal role of cortical/cerebral plasticity in phantom formation after major amputation began to emerge during the mid-1980s (Aglioti et al. 1994a; Doetsch 1997; Halligan et al. 1994; Halligan et al. 1993a; Ramachandran 1993; Schady, Braune, Watson, Torebjork, and Schmidt 1994; Weiss et al. 1999). Sometimes termed neural remodeling (Aglioti et al. 1994a), neuronal rearrangement (Aglioti et al. 1994b), neural plasticity (Ramachandran et al. 1998b), cortical reorganization (Flor et al. 1998; Lotze et al. 1999), or cortical invasion (Knecht et al. 1998a; Weiss, Miltner, Huonker, R., Schmidt, and Taub 2000), reorganization of the cerebral cortex in neurophysiologic terms refers to changes in the cortical geography of the brain, especially[188] within the primary somatosensory cortex[xcix] and the primary motor cortex,[c] on a scale often described as

[188] Other areas that have been show to reorganize are the supplementary motor or sensory areas (Dettmers et al. 2001; Doetsch 1997; Moore et al. 2000; Ramachandran et al. 1998b; Willoch et al. 2000), the thalamus (Doetsch 1997; Gallagher et al. 1998; Karl et al. 2001), and other subcortical regions (Doetsch 1997; Nikolajsen et al. 2001)

massive or dramatic.[ci] Over the next 20 plus years, researchers began to detail both immediate (Calford et al. 1988; Cusick et al. 1990; Dostrovsky 1999; Elbert et al. 2004; Grusser et al. 2001; Moore et al. 2000; Ramachandran et al. 2000; Weiss et al. 2000)[189] and long-term (Cusick et al. 1990; Dostrovsky 1999; Elbert et al. 2004; Moore et al. 2000; Wiech et al. 2000) changes in cortical structure after deafferentation, and began to debate about the degree to which these changes were: 1) permanent/stable (Halligan et al. 1993a; Knecht et al. 1998a; Pons et al. 1991); 2) idiosyncratic/universal (Halligan et al. 1993a); 3) preventable (Halligan et al. 1993a); 4) and/or reversible (Calford et al. 1988; Wiech et al. 2004).

The widespread acceptance of the malleability of the sensory and motor homunculi was consonant with a larger trend in neuroscientific research more broadly that began to challenge the relative stability of neuronal connections in the adult human brain (Aglioti et al. 1994a; Aglioti et al. 1994b; Elizaga et al. 1994; Flor 2003; Halligan et al. 1994; Pons et al. 1991; Ramachandran 1998; Ramachandran et al. 1996). This trend necessitated the development of a new model of cerebral function. For instance, Ramachandran (1998:320; 2005) argued that the advances made in the area of cortical reorganization after deafferentation mandated the abandonment of earlier theories:

> The modular, hierarchical, 'bucket brigade' model of the brain popularized by computer engineers [that needs] to be replaced by a more dynamic view of the brain in which there is a tremendous amount of back-and-forth interaction between different levels of hierarchy and across different modules.

[189] Invasion from neighboring regions produces concomitant perceptual change in as little as four weeks (Ramachandran 1996; Ramachandran et al. 1992).

In the new millennium, assumptions about the functionality and organization of the human brain must be entirely rethought, and as researchers interested in and dedicated to the neurophysiology of phantoms have argued, the remapped brains of amputees may well provide some of the most fruitful insights. Perhaps most notably, researchers have begun to assert that cortical reorganization itself be re-conceptualized as a fundamental principle of human neural development and function. At the forefront of this research is Dr. Edward Taub. When I asked Dr. Taub why or how he became captivated by phantoms, he replied that he wasn't and that he never really had been. Rather, his research was animated by his intrigue with the processes and potentialities of cortical plasticity and phantoms, he admitted, were only a means for experimental investigation. Based on his work with both amputees and stroke victims, Dr. Taub asserted that the brain should be appreciated by neuroscientists as amenable to experientially-based reorganization, in fact "built for" restructuring, and that such ideation lead him to ask, if the brain is capable of remapping itself in response to the absence of input, how might the brain respond to "excessive" input (and by implication "different" input)?

Consequently, Taub and others have demonstrated that cortical remapping occurs under conditions of both reduced and enhanced peripheral input or stimulation (Buchner et al. 2000; Soros et al. 2001), what have since been termed injury-dependent (Elbert et al. 2004; Lotze et al. 1999) and use-dependent (Elbert et al. 2004; Lotze et al. 1999) reorganization.[190]

[190] Some researchers have suggested that telescoping may be dependent on use-dependent reorganization (extensive cortical reorganization) and thus is an adaptive phenomena associated with less phantom limb pain (Katz 1992b; Ramachandran et al. 1992).

Principles of Cortical Reorganization
Practice makes perfect: Enhanced stimulation of a body part enlarges its cortical representational zones and may change its topographic order. This cortical reorganization varies with functionally relevant changes in perceptual and behavioral activities in addition to those that produce them.
Use it or lose it: Lack of complete loss of afferent input leads to an invasion of representational zones located adjacent to the area deprived of its input. A permanent competition for cortical space enlarges those areas that are supplied by important information and leads to narrowing of others.
Fire together, wire together: Synchronous, behaviorally relevant stimulation of adjacent peripheral receptor sites results in the integration of representational zones.
You have to dream it to achieve it: Changes are seen only in behaviorally relevant tasks and in response to practice that is so intense and extended that the brain continues to process the task during sleep, suggesting that the first SWS and last REM stages during the night are of particular importance.

Table 1. **Principles of Cortical Reorganization**. A number of elemental principles were identified that underscored the import of both use-dependent and injury-dependent reorganization. Reproduced from Elbert' (2004:132) article *Reorganization of Human Cerebral Cortex*.

> You can adjust the organization of your system so it can operate more efficiently when the demand is put on a particular body part.' If you need a sensitive touch the brain expands the area focusing on that sensation (Barinaga 1992:218).

Taub explained:

> There are two kinds of reorganization, afferent increase and afferent decrease; one might say injury-related and use-dependent cortical reorganization. For a few years noone recognized that these were behaviorally different causations. But, in 1994 I starting thinking "wait a second, there are two separate things going on." The mechanisms may be similar; you have injury-related cortical reorganization where the lip invades the formaer hand area, and now presumably the other extremity has to do the work of both, so you get an increase in the size of the cortical representation of the intact hand. You have to kinds of cortical reorganization in a single brain.

In fact, it was the experimental investigation into and conceptual exploration of the commonalities between use and injury dependent reorganization that prompted researchers to conceive of phantom limb as a product of neuronal activity rather than of inactivity. This proposition that has significant implications for both the treatment of phantom pain and prosthetic use (Buchner et al. 2000; Elbert et al. 2004; Lotze et al. 2001; Ramachandran et al. 1998b; Weiss et al. 1999). Let me elaborate on the relationship between cortical reorganization and pain before discussing the implications for prosthetic use in more detail.

Phantoms in the Brain: ***We are smarter than our brains***

> We know that the source of phantom limb is in the brain itself, he says [Ramachandran]. Far from being deadweight in the brain, the cortex associated with the lost limb is alive and well, passing messages further on up into the system. The messages may not be originating in the limb anymore, but the rest of the brain doesn't know that (Shreeve 1993:5).

Researchers disagree about the process by which neighboring or adjacent areas of homunculi (and other cortical regions) begin to utilize the "fallow" regions left silent by deafferentation. Dr. Vilayanur Ramachandran, professor of psychology, biology, and neuroscience at the University of California, San Diego, published the widely read popular science text *Phantoms in the Brain* with Sandra Blakeslee in 1998. Here he details his hypothesis on neural remapping.[191] In contrast to the theory of neural sprouting or aborization proposed by Timothy Pons and others, Ramachandran advanced what has been termed the unmasking hypotheses emphasizing the role of hidden circuitry (see also Aglioti et al. 1994b; Borsook et al. 1998; Condes-Lara et al. 2000; Dhillon, Kruger, Sandhu, and Horch 2005; Flor 2002a; Gallagher et al. 1998; Halligan et al. 1993a; Knecht et al. 1998a; Merzenich and Kass 1982; Pascual-Leone et al. 1996; Ramachandran et al. 1998a; Ramachandran et al. 1996; Ramachandran et al. 2000; Ramachandran et al. 1992; Roux et al. 2001; Wiech et al. 2004).[192] On the other hand, Timothy Pons, in an interview Shreeve (1993:5), insisted that:

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[191] *Phantoms in the Brain* has been translated into eight languages. It has also has been the subject of a PBS special and featured on the BBC. In *Newsweek's* annually published *The Century Club*, Ramachandran was named "one of the hundred most prominent people to watch in the next century" http://psy.ucsd.edu/chip/ramabio.html.

[192] Others have hypothesized that both sprouting and unmasking are at work (Aglioti et al. 1994a; Darian-Smith and Gilbert 1994; Das and Gilbert 1995; Doetsch 1997; Elbert, Sterr, Flor, Rockstroh, Knecht, Pantev, Wienbruch, and Taub 1997; Flor et al. 1995; Florence et al. 1995; Merzenich et al. 1982). In my interview with Taub (July 26 2005), he suggests that "There are demonstrations that this or that mechanism operates at some times but as to what is going on at any one specific time, one doesn't know. What was generally believed to be the case was – that is after the Pons, et al study – was that there was a combination of axonal sprouting from neurons that are intact in the vicinity of the debris of the neurons that have died.

> there is no evidence for latent circuits capable of invading whole cortical regions, waiting to be unmasked. It's like saying that when your electricity blacks out, your backup generator will kick in, he says. Only in this case, there isn't any backup generator.

Because cortical remapping can occur within weeks of deafferentation, he speculated that the reactivation of dormant circuits, rather than the laying down of new circuits, is likely occurring in the brains of amputees (Ramachandran et al. 1996).

The adult human brain, he proposes, is predominantly characterized by redundancy, by latent neuronal connectivity that is typically inhibited and hence nonfunctional (Ramachandran 2005). As a consequence of neuronal competition, stronger synapses dominate weaker adjacent synapses effectively "masking" their activity. However, in the brains of amputees, the activity of weaker neurons is unmasked becoming functionally significant. Ramachandran argues that far from stagnant, "each neuron in the map is in a state of dynamic equilibrium with other adjacent neurons; its significance depends strongly on what other neurons in the vicinity are doing (or not doing)" (Ramachandran et al. 1998a:35). In other words, neuronal *activity*, he asserts, is the primary source of phantom sensations, not neuronal *inactivity*. Ramachandran (1998a:33) writes in the case of his patient Tom:

> To put it crudely, the phantom emerges not from the stump but from the face and jaw, because every time Tom smiles or moves his face and lips, the impulses activate the 'hand' area of his cortex, creating the illusion that his hand is still there. Stimulated by all these spurious signals, Tom's brain literally hallucinates his arm.

There was also the consideration of unmasking of previously silent neurons. Those are both not only excellent hypotheses but you can demonstrate that they occur. And, an increase in the excitability of the remaining neurons possibly associated with something called deafferentation supersensitivity…There is a disinhibition of the small diameter fibers in the thalamus which would give rise, obviously, to an increase in excitability of the areas that they project to. What I really believe is that there are a number of mechanisms that no one has thought of that may be more important than anything that anyone has been talking about recently."

Because the brain can be stimulated by "spurious" signals, it can literally be outwitted, a tendency that Ramachandran has assertedly exploited in his effort to treat phantom limb pain. For example, in cases of phantom paralysis or painful flexion (a tightly clenched phantom hand for instance), Ramachandran began placing amputees' hands (the intact hand and the phantom hand) in a mirror box. The mirror box is a simply cardboard square with a mirror inserted down the middle, allowing the intact hand to be projected onto the phantoms.

> The reflection of his [intact] hand is optically superimposed on the…phantom limb so that he has the distinct visual illusion that the phantom limb had been resurrected. If he now made…movements while looking in the mirror, he received visual feedback that the phantom limb was obeying his command (Ramachandran et al. 2000:319).

According to Ramachandran and others, this crude device has been quite effective in producing change in phantom morphology; it has caused telescoping and reversed telescoping, led to impossible posturing or the normalization of posture, prompted feelings of movement and enhanced awareness, produced other morphologic distortions, and caused phantoms to disappear (Barnett-Cowan and Peters 2004; Hunter et al. 2003; Ramachandran et al. 1998a; Ramachandran et al. 1996; Sathian, Greenspan, and Wolf 2000). In terms of the latter, Ramachandran exclaimed: "What we had achieved, therefore, may be the first known case of an 'amputation' of a phantom limb!" (Ramachandran et al. 1996:382). Because "the brain doesn't 'know' that the hand is missing" (Ramachandran et al. 1996:379) it can easily be tricked with mirrors. Remarkably, by the end of the 1990s, we had truly become smarter than out brains.

Phantoms in the Brain: ***The Functional Significance of Phantoms and The Plasticity of Plasticity.***

In the early 1990s, researchers characterized cortical reorganization as a dysfunctional process, one that was beneficial to the organism during early development but that, in cases of deafferentation, was quite maladaptive (Doetsch 1997; Schady et al. 1994). It was a capacity never "intended" for the adult human brain. In an interview for *Discover* Kaas clarified this:

> I doubt that it does anybody any good to have their missing arm mapped out across their face, or to suffer from extreme pain, says Kaas. But these things demonstrate that the adult brain has far greater flexibility than we thought. They are a result of brain plasticity that works against the person (Shreeve 1993:6).

By 2000, cortical remapping was decidedly functional (Flor 2003; Flor 2000; Soros et al. 2001; Weiss et al. 2000), in fact beneficial (Mercier et al. 2006), and fundamentally adaptive (Elbert et al. 2004). What had previously been described as "dramatic" reorganization or reorganization on a "massive" scale (Aglioti et al. 1994a; Barinaga 1992; Calford et al. 1988; Flor 2003; Garraghty et al. 1991; Halligan et al. 1994; Larbig et al. 1996; Merzenich et al. 1984; Pons et al. 1991; Ramachandran et al. 1996), became cortical "modification" (Reilly, Mercier, Schieber, and Sirigu 2006). What had once been characterized as an "invasion" became "recruitment." This shift in perspective, I argue, is at least partially attributable to the discovery that cortical reorganization was correlated with phantom limb pain,[cii] pain memories (Flor 2003; Flor 2002a; Flor 2002b), and not phantom sensations (Flor et al. 2000b).[193] Dr. Taub (Interview, July 26 2005) elaborates on the significance of the shift:

> The idea was that there was a functional correlate of cortical reorganization. Up until that time people had worked primarily with animals who can't talk. And that is one of the reasons that there was no strong evidence of the functional significance of cortical reorganization. Phantom pain had previously been considered adverse, but if we thought of it as functional we could imagine advantageous consequence.

Cortical reorganization became a correlate of, a consequence of phantom limb pain, and by implication, the most effective means of treating phantom limb pain became the prevention of reorganization (of the somatosensory and motor cortices and related cortical structures or regions) (Huse et al. 2001; Wiech et al. 2000). That reorganization resulted in pain would seem to connote dysfunction; so why was this finding the impetus for re-conceptualizing cortical remapping as an adaptive or functional process? The link between phantom pain and cortical reorganization, from a "productive" perspective seems at first glance to be quite tenuously had until the legacy of localizationism is taken into consideration. Even if the brain could be tricked, even if parts of the cortex could/did switch its functional or structural allegiance, researchers did not abandon the presupposition that place was equated with purpose, that function could be localized. In the early 1990s, researchers had begun to recognize what were described as "electrically 'silent' zones, or islands…found within the reorganized region of cortex" (Katz 1992a:286). At the time, these islands of inactivity were thought to be simply too far

[193] Two exceptions are the work of Condes-Lara et al. (2000) and Schwenkreis et al. (2001). Condes-Lara et al. (2000) argued that non-painful sensations were positively correlated with reorganization of the thalamic and the somatosensory and motor regions, while Schwenkreis et al. (2001) showed that phantom pain intensity was not correlated with reorganization. Others have found different activation patterns in the same structures for phantom limb and phantom pain (Willoch et al. 2000). For example, when imagining (willed phantom) painful finger movements and non-painful finger movements, different parts of the cortex were activated (Rosen et al. 2001a).

from the neighboring areas of neuronal activity to be recruited by other homuncular parts, by other cortical regions; they were for all purposes dead zones. By 2000, these zones were and recharacterized as pockets of allegiance, neuronal clusters that retained some of their original sensory and motor function (Dhillon et al. 2005; Roux et al. 2001). Doetsch (1997:13, 15 emphasis added) explains:

> Although physiological reorganization takes place – in the sense that previously ineffective sensory inputs gain excitatory access to a set of cortical neurons – this physiological remapping apparently is not accompanied by significant functional remapping. Activation of a set of cortical neurons appears to retain its *original meaning*! …The trick is to identify the positive and negative features of brain plasticity, and to develop ways (physiological, pharmacological, behavioral, etc.) to enhance the former and diminish the later.

Because these islands retained the capacity to receive input from the periphery, because they remain at least somewhat allied to the lost part, researchers speculated that phantom movement or sensation would reactivate the neurons, return input to these silent cortical islands and consequently, prevent phantom pain (Buchner et al. 2000; Mackert, Sappok, Grusser, Flor, and Curio 2003). This was, of course, not a new idea. In fact, purposive movement of one's phantom has always been advised. It is considered restorative and crucial to prosthetic animation, but also indispensable to the treatment of phantom pain and/or vital to its prevention (however rare). Because phantoms animate prostheses, keeping one's phantom fit was historically thought of as essential to facile prosthetic use and adequate investment in or coupling with one's prosthetic. Today, keeping the phantom fit allows the neural connectivity between the periphery and the somatosensory and motor cortices to remain active and thus "healthy," in Doestch's (1997:15) terms, a positive feature of brain plasticity.

Over the last few years, researchers have been increasingly interested in the role of phantom-use in stimulating or "reawakening" deafferentated areas of the cortex (Mackert et al. 2003; Reilly et al. 2006; Roux et al. 2003). Brain imaging studies have demonstrated that movement of the residual limb or stump produces a pattern of cortical activity that is dissimilar to what is termed virtual movement or the willed movement of the phantom, and that phantom movement more closely approximates the pattern of activity produced by the intact limb than it does the residual limb. In other words, moving the phantom looks (in the brain) more like moving the intact hand (on the other side) than it does like moving the stump. This suggests that the deafferentated brain responds differently to stump activity than it does to phantom activity, a supposition with significant implications for the treatment and prevention of phantom pain. For example, training that required an amputee to match voluntary movements of the phantom with pre-recorded movements of a hand, purportedly resulted in both reversed cortical reorganization and pain reduction (Bergmans et al. 2002). Employing the concept of the mirror box, others have created "augmented" or virtual reality environments that allow amputees to both view and control the motion of their phantoms to reverse cortical reorganization and alleviate pain (Brodie, Whyte, and Waller 2003; Giraux et al. 2003; O'Neill, dePaor, and Mac Lachlan 1997). The deafferentated area is thought to remain functional (or functionally allied) for years or decades after amputation. Thus, the potential for phantoms to be utilized for pain prevention or amelioration, even long after amputation, was increasingly recognized. This line of argumentation was the first move toward the instantiation of what I call the discourse of *phantom potentiality*. Phantoms, because they produce a unique neurophysiologic signature (different from use/movement/sensation of the residual limb) became (potentially) exceedingly productive phenomenon, with astonishing potential ready for harnessing. However, it was via prosthetic animation that phantom potentiality could be fully realized and it was this relationship with and to prostheses that solidified the phantom's indispensability.

If the sensory and motor cortices remained amenable to the reestablishment of a connection with the periphery, then the truncated nerves of the residual limb should retain access to the deafferentated somatosensory cortex, the "dormant" area of the brain (Mackert et al. 2003). Researchers speculated that sufficient stimulation of residual nerves and tissues would provide cortical input, prevent reorganization, and avert the onset of phantom pain (Fraser et al. 2001). In other words, both phantom movement and stump/nerve stimulation, were thought to have some capacity to prevent and even reverse cortical reorganization (Mercier et al. 2006). Although prosthetic use has long been correlated with the reduction of phantom limb pain (Abramson et al. 1981; Bartusch et al. 1996; Brodie et al. 2003; Dawson et al. 1981; Finnoff 2001; Flor 2003; Iacono et al. 1987; Kooijman et al. 2000; Lotze et al. 1999; Middleton 2003; Postone 1987; Ribbers et al. 1989; Weiss et al. 1999; Whyte et al. 2002),[194] researchers demonstrated that prosthetic use (prosthetic-induced increased use of an amputation stump) decreased cortical reorganization (Weiss et al. 1999), and that decreased/reversed reorganization was correlative with pain reduction/elimination (Birbaumer et al. 1997; Fisher 1999; Flor 2003; Flor 2002a; Hill 1999; Pleger et al. 2004; Weiss et al. 1999). In fact, researchers

[194] Kegel et al. (1977) found that 10% of amputees who wore their prostheses required medication for pain control, compared to 42% of amputees who did not wear a prosthesis.

found that the extent of cortical reorganization was directly related to daily prosthesis use (2004b) and with the frequency of phantom pain (Fraser et al. 2001).

Dhillon (2005) and his colleagues surmised that functional connections between the periphery and the cortex could be strengthened with training and suggested that prosthetics could potentially interface directly with residual nerves to allow an amputee to have closed-looped control of a prosthesis with, of course, significant implications for prosthetic facility but also for pain prevention.

> Our study implies that if a neuroprosthetic arm were to be interfaced to the residual nerve stumps, amputees might be able to improve control over its movements and incorporate it into their body image through the effects of training, learning and central plasticity (Dhillon et al. 2005:2631).

In fact, the use of upper limb myoelectric prostheses, rather than purely cosmetic alternatives, was found to permit more extensive use of the residual limb, reduce phantom pain and correlate with less cortical reorganization (Lotze et al. 1999; Weiss et al. 1999), or what Elbert (2004) terms the "normalization of homuncular organization."

> In case the provision of correlated input into the amputation zone might be an effective method for influencing phantom pain. FMRI was used to investigate the effects of prosthesis use on phantom limb pain and cortical reorganization. Patients who systematically use a myoelectric prosthesis that provides sensory and visual as well as motor feedback to the brain showed much less phantom limb pain and cortical reorganization than patients who used wither a cosmetic prosthesis or none at all (Flor 2003:69).

Even long after amputation, the use of functional prostheses leads to decreased pain (Dettmers et al. 2001). In other words, functional prostheses provide peripheral stimulus, producing use-dependent (afferent-increase) reorganization that functions to countervail injury-related (afferent-decrease) reorganization (Elbert et al. 2004:138; Weiss et al. 1999).

Today, prosthesis use (particularly sophisticated prosthetics that provide a greater degree of sensory feedback) is commonly thought to effectively ameliorate phantom pain through the prevention or reversal of cortical reorganization (Lotze et al. 2001; Topfner, Wiech, Kiefer, Unertl, and Birbaumer 2001). And, because phantoms are considered vital to prosthetic animation, they have become a necessary (or at least desirable) precondition for exploiting the pain prevention possibilities of prosthesis use. Although I discuss the implications of phantom-prosthetic relations in detail in the next chapter, I do want to point out here the significance of this connection. This is the second facet of what I call the discourse of *phantom potentiality*. Both alone and through prosthetic animation, phantoms have surfaced as central to taping into the functional, the beneficial, and the adaptive aspects of cortical plasticity. In neuroscience today, through theoretical contestation and through biomedical rationalization, phantoms have become theoretically coupled to prosthetics with the same intimacy to which they have always been materially coupled. I argue in the next chapter that this may in fact be a lethal joining, as phantoms have become increasingly vulnerable to being theorized into extinction.

6 PHANTOM-PROSTHETIC RELATIONS

Phantom limb syndrome is a disease of time; phantoms are conflations of past bodies and present embodiments, at once temporal contradictions and convergences. And still, phantom limb syndrome is a disease of space. Phantoms inhabit metals, plastics and rubbers, and move through objects and others, disrespecting material integrity and sacred subjectivity.

This chapter traces shifts in what I call phantom-prosthetic relations, highlighting the dynamic and processual nature of this techno-corporeal coupling. I will show how phantom-prosthetic relations are based on what actor-network theorists call *relational materiality* (Law 1999). Here, the very substance of phantoms and prostheses have emerged out of the interplay of the social interestedness of each. The negotiation or *translation* of these social interests have, over the last half of the twentieth century and into the present, have given rise to shift from what I call the "phantomization of prostheses" to the "prosthetization of phantoms."

I begin by arguing that in the post-WWII years, phantoms were thought to have the capacity to animate prostheses, a process vital to successful rehabilitation. Phantoms had the natural power to vivify, and it was at this time that phantoms sensations were most commonly found to be *exacerbated by* prosthetic use. Over the last half of the twentieth century and into the twenty-first, phantom-prosthetic relations changed significantly. The vital phantom that had animated the passive prosthesis itself became dependent on the prosthesis to provide the kind of structure necessary for phantom refinement; the phantom needed taming if it's animating possibilities were to be realized. This shift in phantom-prosthetic relations, I argue, is attributable to three concurrent trends, the increased collaboration of amputation surgery and prosthetic science (see "Chapter Two: Part Loss), the rise in phantom limb pain prevalence rates, and the elaboration of prosthetic technologies.

By the 1980s, as pain prevalence rates became epidemic, researchers began to attribute the emergence of the pathological phantom to a failure to properly domesticate or civilize the phantom. Phantoms that were not tamed were at risk of becoming either pathological or of disappearing altogether. By the turn of the twentieth century, researchers demonstrated that prosthetic use decreased cortical reorganization and that decreased/reversed reorganization was correlative with pain reduction/elimination. However, it was not just prosthetic use that researchers considered to be most efficacious for ameliorating or even preventing phantom pain, but the use of functional prostheses. In other words, the curative power of prostheses was correlated with both extensive use and the sophistication of prostheses. And, it was at this time that researchers' reports of phantom disappearance and phantom fading were interpreted as demonstrative of both the curative properties of prosthesis and the potential for prostheses to cause "absolute synchronicity" or the experiential fusion of phantom and prosthesis.

In the next section, I elaborate on what I call the discourse of *phantom potentiality*, introduced in "Chapter Five: Contested Territory." Through the possibility of phantom exercise to reverse cortical reorganization and through the potential for prosthetic animation to prevent phantom pain, phantoms became potentially productive phenomena. It is via this discourse of phantom potentiality that phantoms emerged as vital to the rehabilitation of the prosthetized amputee. Phantoms surfaced as central to taping into the functional, the beneficial, and the adaptive aspects of cortical plasticity.

Finally, by the turn of the twenty-first century, researchers began to argue that cortical reorganization could be prevented or reversed through prosthetic use. Because phantom formation is hypothesized to be a consequent of cortical reorganization and because prosthesis use is thought to prevent or reverse cortical reorganization, phantom manifestation can hypothetically be impacted by innovations in prosthetic science. The sophistication of prosthetic technologies, in conjunction with increased use, has been associated with the decline of phantom prevalence rates. In other words, I argue contemporary biomedical constructions of phantom-prosthetic relations predict phantom extinction.

Phantom- Prosthetic Relations: *Vitalizing Prostheses*.

Since the turn of the twentieth century, researchers and practitioners advocated the use of prosthetics in order to prevent or minimize social stigma, and suggested that adequate investment in one's prosthesis could be determined by the degree to which an amputee integrated his new limb into his self-concept or body scheme. Integration, in turn, could be determined by the degree to which his phantom and his prosthetic "coincided."

> Phantom feeling is a retention of physical wholeness which remains with us when the anatomical substratum is removed. When the phantom limb is trained the individual retains the totality of their physical experience…if a healthy phantom feeling exists or is regained by training then it is *brought into line* with the artificial arm (Stattel 1954 :156 emphasis added).

Although consistently lauded since the turn of the century, the importance of coinciding intensified in the post-WWII years because it was vital for both amputees and the state to invest in the rehabilitative process. Investment was symbolic of the state's capacity to restore productivity to the war-wounded and transform a pained nation. Phantoms became key to "reading" an amputee's commitment to the rehabilitative process, in addition to being essential to prosthetic animation. Because prosthetic animation was eminently desirable, the healthy phantom was thought to "naturally" coincide with the prosthesis and those who reported coinciding were considered effectively rehabilitated.

Concomitantly, researchers found that prostheses were often capable of provoking phantoms. That is, donning a prosthesis was reportedly associated with the return of a previously disappeared/faded phantom, with the exacerbation of phantom sensations (Harber 1958b; Hoffman 1954b; Kolb 1950b; Parks 1973; Weinstein et al. 1961), as well as with reverse telescoping (a phantom "reverting" to full size) (Simmel 1956b).[195] In fact, some researchers reported that phantoms were always present when a prosthetic was donned (Weinstein et al. 1961). Because phantoms have the power to animate, researchers expected phantoms to routinely materialize when a prosthetic was donned.

Phantoms have been thought since the post-WWII period to animate prostheses, inhabiting the woods, rubbers, metals and plastics that constitute their structure; phantoms literally "occupy" prostheses, vitalizing their materiality. In my observations at the O&P Clinic, the prosthetists spoke of the animation process and its utility in

[195] Two exceptions in the literature were Cronholm (1951) and Harber (1958b) who reported no relationship between prosthesis use and phantom sensations.

allowing an amputee to become facile with a prosthesis quickly, to develop a more "natural" looking gait in the case of lower limb loss, and to aid in the rehabilitation process generally-speaking. But more interestingly, I was actually able to observe the process of animation that prosthetists and amputees seemed to negotiate during manufacture and fitting. In the clinic and in the shop, I found that although components (parts of prostheses) or the residues of construction (molds and impressions) were discarded or reemployed as tools, a person's artificial limb was treated with care; it was a body part. Check sockets (a clear impression of the stump), plaster models of stumps, and other components or phase-residues of the prosthetization process were not limbs or body parts, but things divested of life. For example, my first experience in the shop revealed.

> tools, unidentifiable equipment and body parts, lathes and legs, feet and baby powder, nails, glue, torsos of plaster, saws and Velcro; a remarkably cacophony. A shapely leg juts from a large tub of plaster and the impression of a thigh sits ready to be used as a scoop in a vat of sand. Feet are employed as weights and torsos are used to hold feet… (Field Notes 10-11-2001).

The value and vitality imputed to a prosthesis was based on the degree of completion, and more importantly the extent of embodiment. It was during the final phases of manufacture and fitting that the prosthetic became animated for both the amputee and the prosthetist. This was in part because the phantom was (sometimes) elicited, called forth, when the prosthesis was donned.

As Steven Kurzman (2003) suggests in his dissertation entitled *Performing Able-Bodiedness: Amputees and Prosthetics in America*, both the amputee and prosthetists have a desire to attain embodiment, to attain "incorporation", although of course for very different reasons. Prosthetists "tend to consider bodies as biomechanical systems in conjunction with prostheses, and are generally more interested in the interface between bodies and prostheses as a system, rather than in the body itself" (Kurzman 2002:231). The prosthetist, like the orthopedic surgeon, is concerned with creating a new interface between the body and the world (see "Chapter Two: Part Loss"). The amputee, on the other hand, wants transparency, wants seamlessness, wants what Drew Leder (1990:84) has described as absence. Such absence is preferred over what is commonly experienced during pain, discomfort, tension, etc. as the "absence of an absence." Kurzman (2003:74) argues that "we can view amputation and the process of fitting, aligning, and learning to use a prosthesis as a 'dys-appearance' of the body." When the body *dys-appears,* it is brought fully into our awareness; the body, normally absent, becomes present (Leder 1990). It is partly through animation that the prosthesis begins to approximate the embodied limb, to fade into what Olesen (1992) has referred to as *taken-for-grantedness*.

Phantom-Prosthetic Relations: *Phantomization and Prosthetization*.

The phantom and the prosthesis have always been thought to have a "natural predilection" for each other, but the precise nature of their affiliation has shifted considerably over the last half century. I argue that the relationship between prostheses and phantoms was, at mid-century, characterized as the active phantom animating the passive prosthetic, what I call the "phantomization of prostheses." Simmel (1956b), for example, highlights the capacity for phantoms to give life to prostheses such that the prosthesis became "of-the-body". The phantomed-prosthetic was a "living member," embodied because phantoms were vital and because they had the power to vivify.[196] "Phantoms of the lower extremities often coincide with the prosthesis; that is, the patient comes to experience the prosthesis as a living member, much as he experiences his leg on the other side, and is literally walking on the phantom" (Simmel 1956b:644).

Although this natural proclivity has persisted, other aspects of phantom-prosthetic relations have changed dramatically.[197] Researchers and practitioners began to argue that prostheses were fundamental to phantom "taming." Because phantoms were "wild" and unruly, they needed to be practiced and exercise; they needed structure. With the rapid rise in phantom pain prevalence rates circa 1980, the phantom became potentially quite dangerous, capable of pathologization. Yet, phantoms were also considered a potentially productive force, capable of "fleshing out" prostheses. Prostheses were thought to provide the kind of structure necessary for the phantom refinement. The phantom needed taming if its animating properties were to be realized. For example, Melzack (1990:89 emphasis added) described the renormalization of a distorted phantom through prosthetic use:

> The most astonishing feature of the phantom limb is its 'reality' to the amputee, which is *enhanced by wearing an artificial arm or leg*; the prosthesis feels real, 'fleshed'. Amputees in whom the phantom leg has begun to 'telescope' into the stump, so that the foot is felt to be above floor level, report that the phantom fills the artificial leg when it is strapped on and the phantom foot occupies the space of the artificial foot in its shoe.

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[196] Because phantoms were understood as both "body-based traces" (Hocky and Draper 2005:47) and embodied ghosts, they retained the signification of both dead and living parts. They were simultaneously of the dead and of the living.

[197] A symbiotic relationship between the phantom and prosthesis was ideal, though phantoms and prostheses did not always associated un-problematically. "One could, for example, imagine the awkward situation in which the phantom limb has another shape or length than the prosthesis. Then one would expect a decrease in prosthesis use if phantom sensations are present. On the other hand, it is also possible that the presence of a prosthesis makes the experience of phantom pain or a phantom limb less bothering or strange" (Kooijman et al. 2000:34).

Not only is the prosthesis attributed to have the power to reverse telescoping, but it also has the capacity to enhance the very reality of the phantom; the phantom is somehow made more real through prosthetization. A few years earlier, Melzack (1997:1609 emphasis added) wrote of one of his patients "He likens his prosthesis to a glove, which *envelops* his life-like PH [phantom] hand." What once was active language used to describe the animation process became passive. This change is particularly evident when comparing Melzack's (1989b:2 emphasis added) description of this <u>same</u> phenomenon almost a decade earlier: "The amputee with a painless phantom, however, may find that the reality of the phantom is enhanced by wearing an artificial arm or leg; the phantom usually *fills* the prosthesis 'like a hand fits into a glove'; the prosthesis feels real, 'fleshed out.'" Rather than being "enveloped by," the phantom was described as "filling" the prosthesis. This shift in phantom-prosthetic relations from the *phantomization of prostheses* to the *prosthetization of phantoms*, I argue, is attributable to three concurrent trends, the increased collaboration of prosthetic science and amputation surgery (see "Chapter Two: Part Loss"), the rise in phantom limb pain prevalence rates, and the elaboration and sophistication of prostheses.

The Prosthetization of Phantoms. *Pain Prevention*.

Prior to the 1970s, the phantom pain prevalence rate was typically reported as between 1% and 15% (see *Appendix I: Phantom Pain Prevalence*). Pain prevalence began to rise circa 1970, to between 35% and 50%, and was correlative with an intensifying culture of pain in the US. Circa 1985, prevalence rates were reported as between 66% and 85%, what I have referred to as the peak of pain. Contemporaneously, researchers began to attribute the emergence of the pathological phantom, the painful phantom, to a failure to properly domesticate or civilize the phantom; this was assertedly evidenced by the correlation of prosthetic use with the reduction of phantom limb pain (Abramson et al. 1981; Finnoff 2001; Flor 2003; Iacono et al. 1987; Kooijman et al. 2000; Lotze et al. 1999; Postone 1987; Ribbers et al. 1989; Weiss et al. 1999; Whyte et al. 2002). Phantoms that were not tamed, were not provided such structure, were at risk of becoming either pathological or of disappearing altogether, neither of which were considered desirable fates.

By 1980, phantom pain was beginning to reach epidemic rates and prevention, as evidenced by burgeoning treatment options, became a central concern. In 1980, 68 different treatments were employed by VA hospitals, medical schools, pain clinics and pain specialists (Sherman et al. 1980:91). Throughout the 1980s and the 1990s, researchers and practitioners increasingly argued that consistent and extensive prosthetic use was one of the most effective means of both preventing and treating phantom limb pain. Further, the curative properties of prostheses, as I argued in "Chapter Five: Contested Territory" were most pronounced when prostheses were functional rather than cosmetic.

By the turn of the twenty-first century, researchers had demonstrated that prosthetic use decreased cortical reorganization (Weiss et al. 1999), and that decreased/reversed reorganization correlated with pain reduction/elimination (Birbaumer et al. 1997; Fisher 1999; Flor 2003; Flor 2002a; Hill 1999; Pleger et al. 2004; Weiss et al. 1999). In fact, researchers found that the extent of cortical reorganization was directly related to daily prosthesis use (2004b) and to the occurrence of phantom pain (Fraser et al. 2001). However, it was not just prosthetic use that researchers considered to be most efficacious for ameliorating or even preventing phantom pain, but specifically with the use of functional prostheses. For example, the use of upper limb myoelectric prostheses, rather than purely cosmetic alternatives, was found to permit more extensive use of the residual limb, to reduce phantom pain and to correlate with less cortical reorganization (Lotze et al. 1999; Weiss et al. 1999). In other words, the curative power of prostheses was correlated with both extensive use and with prosthetic sophistication.

Indeed, the state of prosthetic science today seems like the stuff of science fiction. Let me briefly give a few examples, with one caveat. I am not arguing that these technologies are commonly employed, are available to the average amputee[198] or are intrinsically transformative. Rather, I am arguing that researchers and practitioners alike characterize the current situation as one in which significant advances have occurred, particularly over the last fifteen years. The state of the science is, in fact, commonly

[198] The majority of prostheses are paid for through Medicare, Medicaid or the VA (Wilson 1998). Kurzman (2003:44) reports that a "moderately sophisticated" below knee prosthesis costs about $5,000 and an equivalent above knee prosthesis approximately $10,000. However, because Medicare employs a typology of five functional levels, ranging from minimal to active, to assign a reimbursement rate, not all amputees have the same prosthetic choices (Kurzman 2003). The Amputee Resource Center (www://amputeeresource.org) estimated the full retail cost of the advanced C-leg at $62,185. Because of financial, regulatory and other restrictions, most amputees feel that they do not have much input when choosing a prosthesis. Nicholas et al. (1993) found that 84% of amputees perceived that they had no choice in their prosthetic prescription and 24% were dissatisfied their current prosthesis. Of their sample, 74% wore the prostheses eight hours or more per day. The rejection rate is typically higher with upper limb amputees (Chadderton 1978b), and lower limb amputees tend to use more prosthetic adaptations. Kegel, Carpenter, and Burgess (1977:46, 49) found that of 156 respondents, 91% wore a prosthetic and that 5% used recreational prosthetic adaptations, such as a swim fins or outriggers for snow skiing.

considered quite advanced. Prosthetiz-ed bodies have already or will soon pioneer the following:[199]

- At MIT's Leg Lab, Hugh Herr and Gill Pratt have produced legs with microprocessors which allow detection of speed, force, and torque (Geary 2002).[200] These *intelligent legs* can determine via sensors if a person is, for example, walking up stairs or on flat terrain and can detect how fast the person is ambulating (Brooks 2002).
- Myo-pneumatic hands[201] attach directly to truncated tendons and residual musculature and have sensors that control actuators in the prosthetic (Gray 2002; Savage 2001).
- "Bionic arms" are in development at the Rehabilitation Institute of Chicago funded by the Defense Advanced Research Projects Agency. These arms are attached directly to severed nerves[202] and operate by "moving" the amputated limb/phantom (making the same kind of effort) (Brown 2006:A5).
- Prostheses with sensory feedback use the capacity of rerouted nerves to provide sensation felt as if originated in the missing limb; severed nerves are rerouted to an area on the chest. "The person…ends up with a patch of skin the width of a baseball that, when stroked, warmed or pricked, feels like a hand rather than part of the chest…In the future, electrodes in the hand will send touch signals up the arm to the chest skin, which will send them on to the brain where they will be perceived as sensation" (Brown 2006:A5).
- Prostheses that are pressure sensitive were developed by Thomas Sinkjaer at the Centre for Sensory-Motor Interaction at Aalborg University (Geary 2002). NovaCare

[199] Some of the advances have been more low-tech but no less profound, for example tissue salvage to preserve stump length (Thomas, Altman, Lubahn, and Hood 1996), limb lengthening in short stumps (Bowen, Struble, Setoguchi, and Watts 2005), and tissue engineering including bone, skin, and blood vessels (Fairley 2002; Langer and Vacanti 1995; Williams 1997).

[200] Herr lost both legs after a rock-climbing fall and was dissatisfied with the available prosthetic options (Geary 2002). Amputees have often been the industry's innovators.

[201] Myo-Pneumatic technology is also used to enhance lower limb prostheses (Misuraca and Mavroidis 2001).

[202] In order to prepare the residual nerves for interfacing with the prosthesis "they cut the nerves to two chest muscles, the pectoralis and serratus, at a point where those nerves have branched to go to different parts of the muscles, but far 'upstream' from the point where the nerves divide into tiny fibers that attach to individual bundles of muscles fiber. They then sew the stumps of the large nerves that once went to the arm and hand to the cut ends of the chest-muscle nerves. In the same operation, the nerves carrying sensation from the skin over the pectoral muscle are also sewn into the arm nerves. Over several months, the arm nerves grow down the sheaths of the motor fibers and attach to the muscles. (The amputee assists this process by mentally 'exercising' the missing hand, which helps promote a firm nerve-muscle connection)…if all goes well, a person is left with chest muscles that twitch in different places in response to such thoughts as 'bend the wrist back,' 'move the thumb' and 'clench the fingers.'…The prosthesis is strapped onto the shoulder stump and torso in a way that positions electrodes over the regions of the chest muscles that are responding to different 'hand instructions'…when the amputee tells the fingers to close, the designated part of the pectoral or serratus muscle twitches and the electrode over it detects the signal, activating the appropriate motor" (Brown 2006:A5).

Sabolich also developed "Sense of Feel and Sense of Hot/Cold systems" in the mid-1990s (Kurzman 2003).[203]

- Biomechatronic prosthetics, developed by MIT's Leg Lab, use animal derived muscle tissue that burns glucose as a power source for upper and lower limb prosthetics (Geary 2002; Savage 2001).
- Osseointegrated prostheses attach directly to remaining bone (Myers 2002). The technique involves inserting a titanium threaded implant into the femur (in the case of above-knee lower limb amputation) so that when it has fully osseointegrated, the implant operates as a direct attachment site for an external prosthesis.
- One of the most "futuristic" directions being pursued is direct neural interfacing which involves harnessing "naturally occurring" neuronal activity to prostheses via computer chips implanted in the brain (Andersen, Burdick, Musallam, Pesaran, and Cham 2004; de Peralta Menendez, Andino, Perez, Ferrez, and del R Millan 2005; Musallam, Corneil, Greger, Scherberger, and Andersen 2004). Hypothetically, this technology would allow amputees to control their prostheses simply by thinking about movement (Nicolelis and Chapin 2002).[204] At the forefront of this research is neurobiologist Dr. Miguel Nicolelis from Duke University. In collaboration with MIT's Laboratory for Human and Machine Haptics, Nicolelis has linked the neuronal signals from the brain of Belle the tiny owl monkey to a robotic arm called "phantom" (Geary 2002); when Belle moved her arms, the neuronal activity in the motor cortex was read by an external computer and sent to "phantom," which mimicked Belle's movement in real time (O'Mahony 2002). "Nicolelis sees the effort as part of an impending revolution that could eventually make HBMIs as commonplace as Palm Pilots and spawn a whole new industry-centered around the brain" (Regalado 2001:1).

The Prosthetization of Phantoms: *Phantom Disappearance*.

It was both the real advances made in prosthetic science and the thinking through of the implications of the sophistication of prostheses for phantom-prosthetic relations that gave rise to the discourse of the prosthetization of phantoms. Prostheses have been attributed a power that has, in some respects, supplanted that of the phantom. Phantoms, however,

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[203] It is believed that these systems never reached a mass market (Kurzman 2003).

[204] In a human subject named Ray, electrodes were implanted into the motor cortex that registered movement (or imagined movement) of his left hand. Ray was trained to pair these willed movements with cursor movement. "As he imagined moving his hand, the electrode in his brain picked up the signals of the few neurons near it and broadcast those to a nearby computer…gaining control over it [the pointer] was like learning to move his hand all over again, an exhausting trial-and-error process. Yet little by little, Ray got the hang of it…What's more, by Ray's reports, he had stopped thinking about moving his hand…He willed the cursor to move without any kind of intermediary. In some sense, the computer had become a part of him" (Naam 2005:174).

have not become superfluous; in fact they are now considered an indispensable means through which all of the curative, restorative, transformative properties of the prosthesis are enabled.

By the mid-1980s, researchers commonly argued that phantom pain could be curtailed or ameliorated through the use of functional prostheses. The healthy phantom, vital to prosthetic animation, it was asserted, could be called forth through prosthetic use. Although the phantom could be unpredictable, could even pathologize, the painless phantom was consistently lauded because of its animating properties. In fact, by the mid 1980s, phantom loss was overtly maligned. Sacks (1987:67) for example, writes “the disappearance of a phantom may be disastrous, and its recovery, its re-animation, a matter of urgency.”

Because prostheses were thought to have the power to call forth, to provoke the phantom, one would expect references to phantom disappearance to be relatively rare. However, as demonstrated by *Appendix K: Phantoms in Time*, in fact, they were not. Phantom fading and phantom disappearance were commonly reported throughout the 1980s, the peak of interest in the phenomenon. I argue that this period of relative interest is itself a product of researchers’ and practitioners’ anxiety about phantom loss, as well as the need to explain why some phantoms were not persuasively provoked by prostheses. Both references to prostheses causing phantoms to disappear or gradually fade, as well as later references to the amplification of phantom vividness after a prosthesis is removed (Morse 1985; Saadah et al. 1994; Wilkins et al. 1998) did not undermine the purported power of prostheses; phantom disappearance was in fact *constructed as evidence* of the curative properties of prostheses (in cases of pain) and more importantly, was also demonstrative of the taming power of prostheses. In some cases, the phantom was brought into a kind of "absolute synchronicity" with the prosthesis, the experiential merging of phantom and prosthesis. This absolute synchronicity argument had emerged during the post-WWII period, but was resurrected during the 1980s and throughout the 1990s.

In the post-WWII period, reports of phantoms fading or disappearing when a prosthetic was worn (Appenzeller et al. 1969; Harber 1958b; Henderson et al. 1948; Herrmann and Gibbs 1945; Hoffman 1954b; Parks 1973; Weinstein et al. 1961) were interpreted as instances of profound coinciding; the phantom had "become one" with the prosthesis, such that neither was experienced independently of the other. In other words, it was because prostheses were thought to cause the disappearance of phantom pain (some phantoms are only painful phantoms) and because absolute synchronicity could be achieved, that phantoms could be experienced as disappearing when a prosthesis was donned rather than doffed. In a contemporary example, Andre and colleagues (2001:195) referred to this event as phantom-prosthetic "fusion":

> Prosthetic devices could be incorporated or even fused with the phantoms. Prosthetic devices and normal phantom limbs are confounded in use…phantoms tend to disappear in amputees who wear their prosthesis regularly, being replaced by the illusion of a normal body. Thus amputees may confound their prosthetic limbs with their normal primary limb as long as the prosthesis meets the mechanical and kinetic expectations of the lost limb and remains under control like a real limb.

Cortical Reorganization and Phantom Potentiality.

As I argued in the "Chapter Five: Contested Territory", the proliferation of medical imaging technologies during the 1970s and 1980s allowed new modes of visualization of amputee brains and encouraged the widespread acceptance of the malleability of the sensory and motor cortices among the researchers investigating phantom phenomena. Consequently, phantoms became both the effect of cortical plasticity or reorganization, and the means of its prevention. Through the possibility of phantom exercise to reverse cortical reorganization, and through the potential for prosthetic animation to prevent phantom pain, phantoms became potentially productive phenomenon. It is via this discourse of *phantom potentiality* that phantoms emerged as vital to the rehabilitation of the prosthetized amputee. Researchers and practitioners alike have begun to argue that at least theoretically, phantom pain could become a problem of the past. For example, Dr. Mark Jensen (Interview, July 20th, 2005) stated, "my personal belief is that phantom limb pain is relatively easy to treat if your intervention produces cortical reorganization." And in fact, reported pain prevalence rates have begun to decline from their historic high during the late-1980s and 1990s.

One of Melzack's students Dr. Joel Katz, a professor in the Department of Psychology and in the School of Kinesiology and Health Science at York University in Toronto, "recognized" the potential for prostheses to effectively ameliorate pain more than a decade ago. He states:

> "I predicted in a paper in 1992 that extensive use of the stump - and I think that is essentially what these new prostheses do is they generate use dependent change – would cause reoccupation phenomenon that leads to decreased pain. I think old prostheses just weren't adequate. Flor and others have shown the relationship between phantom pain

> and type of prosthesis; cosmetic prostheses did not result in a reduction in pain whereas the more modern ones that involve a use of the stump did" (Interview, July 29th, 2005).

The discourse of phantom potentiality emerged after the turn of the twenty-first century, a trend that I attribute to researchers thinking through the relationship between cortical reorganization and increased prosthetic sophistication. Although it was possible to effect cortical reorganization or remapping through phantom training or exercise, amputees who wore functionally effective prostheses were thought to be theoretically accomplishing this end without the need for artificial reality (see "Chapter Five: Contested Territory").

To effectively reverse or prevent the reorganization of cortical geography, prostheses had to restore input from the periphery. Functional prosthetic use is commonly thought to effectively ameliorate phantom pain through the prevention or reversal of cortical reorganization (Flor et al. 2000b; Flor 2002a; Lotze et al. 2001; Topfner et al. 2001). Functional prostheses are those that engage the residual nerves and musculature (sending peripheral input to the homunculi), producing use-dependent afferent-increase cortical reorganization (see "Chapter Five: Contested Territory" for elaboration). For example, the Sauerbruch prosthesis:

> is a mechanical device connected to one of the muscles of the arm by cables that operate a rod terminating at its proximal end in a surgically created tunnel in the muscle that operates it. Movement of the prostheses is produced by contraction and relaxation of that muscle (Weiss et al. 1999:132).

These kinds of deeply integrated or embodied prostheses are thought to have greater intimacy with the cerebral cortex. And, the phantom has become the model along which this kind of interfacing is envisioned.

> The brain knows that it has an arm and a hand because it is connected to these things and gets feedback from them. The same could be true for robotic or virtual appendages. If you control a remote hand that senses objects and sends tactile sensations back to your brain, it behaves as if it's your own hand. It becomes part of you. Your body becomes extended beyond the surface of your skin. Hybrid brain-machine interfaces have the potential to enhance our perceptual, motor and cognitive capabilities by revolutionizing the way we use computers and interact with remote environments. What Nicolelis is describing is a kind of reverse phantom limb syndrome…new appendages…could be added to the body and that the brain would eventually come to regard these as its own. In other words, the prosthetic limb would become a sensory add-on rather than an indication that something was missing…Nicolelis explains, 'studies of brain plasticity show that neural maps of the body are dynamic, continuously changing and adapting. If we created a brain-machine interface, a virtual or robotic object could become part of the brain's body map…in the future bodies may no longer be limited to two arms, two legs, two eyes, and two ears (Geary 2002:112-113).

Because phantoms are considered vital to prosthetic animation, they have become a necessary (or at least desirable) precondition for exploiting the pain prevention possibilities of prosthetic-use. Further, phantoms have surfaced as central to taping into the functional, the beneficial, and the adaptive aspects of cortical plasticity.

> Simulation of a nerve once connected to the thumb of the amputated hand evoked a sensation that seemed to emanate from the missing thumb. In other words, the nerve stimulation brought a phantom thumb to life. Prosthetic limbs could become much more efficient and realistic if signals from a phantom thumb, for example, could be matched to an artificial thumb (Geary 2002:107).

Cortical Reorganization and Phantom Potentiality: *Phantom Extinction*.

By the turn of the twenty-first century, researchers began to argue that cortical reorganization could be prevented through the "replacement" of lost stimuli from the periphery. Prostheses that provided an adequate degree of sensory information (interpreted by the brain as originating in the now absent limb) could prevent changes in the geography of the cortex brought on by the absence of cortical activity.

Deafferentated[205] areas of the cortex, it was purported, retained at least some degree of responsive to the periphery (in terms of both sensory an motor function) and if this connection were exercised, cortical reorganization could be reverse. Consonant with this argument, Flor, Denke and Schaefer (2000a) have demonstrated the reversibility of cortical remapping (Birbaumer et al. 1997; Calford et al. 1988; Lotze et al. 1999). Let me be very clear about the implications of this line of thinking: phantoms can essentially be either prohibited or undone by prostheses. Because phantom formation is hypothesized to be a consequence of cortical reorganization and because the use of (sophisticated) prostheses can prevent or reverse cortical reorganization, phantom manifestation can hypothetically be curtailed (see for example Flor et al. 1995; Katz 1992b) or reversed (see for example Flor et al. 2000a). Dr. Edward Taub explains:

> You can manipulate the amount of cortical reorganization by increasing or decreasing the use of a body part. Functional prostheses expand the cortical representation into the dormant area. Now there is a flaw in the logic, but I'm not willing to say that it is wrong. What you are really doing is increasing the input in the stump, not increasing the input to the hand that is not there. Nevertheless, the phantom pain over long periods of time decreases dramatically, down to zero in most people (Interview, July 26th 2005).

The sophistication of prosthetic technologies (e.g. temperature or pressure sensitivity), further physiologic incorporation (e.g., osseointegrated prostheses that attach directly to the bone provide proprioceptive stimulation, pressure, torque, etc. at the skeletal and deep tissue level), in conjunction with increased use (e.g., immediate post-operative fitting and fitting for both the elderly and children), greater adaptability (e.g., prosthetic attachments like swimming fins, golf spikes, or climbing feet that are length adjustable), and biomechanical elaboration (e.g., the use of animal and mechanic models like the cheetah

[205] Deafferentation: "A loss of the sensory input from a portion of the body, usually caused by interruption of the peripheral sensory fibers" (Stedman 2000:459).

leg or the hydraulic knee) are today implicated in phantom decline of phantom prevalence rates. As is indicated in *Appendix L: Phantom Prevalence*, since the turn of the twenty-first century, prevalence rates have been reported as low as 70%. What once was considered a universal phenomenon is now described as "relatively common" (Webster's 2003). In other words, phantoms are being theorized into extinction.

Conclusion.

Phantom-prosthetic relations are today characterized by an uncomfortable tension. Phantoms animate prostheses and are, thus, key to harnessing the pain-preventing properties of prostheses, as well as to the successful embodiment of an artificial limb. Phantoms have also surfaced as central to taping into the functional, the beneficial, and the adaptive aspects of cortical plasticity. As prosthetic technologies have become increasingly sophisticated, the discourse on phantom-prosthetic has shifted to highlight the transformative power of prosthesis. Taming the phantom became a means of hastening synchronic and productive phantom-prosthetic relations. Phantoms consequently became both the effect of cortical plasticity or reorganization, and the means of its prevention. Through the potential of phantom exercise to reverse cortical reorganization and through the potential for prosthetic animation to prevent phantom pain, phantoms were transmogrified into conspicuously productive events. And, it is via this discourse of *phantom potentiality* that phantoms have emerged as vital to the seamless coupling of amputees and prostheses. Nevertheless, phantoms are "disappearing" and prostheses are theoretically accountable for phantom disappearance and fading, as well as for the prevention of phantom formation. By extension, phantom prevalence rates are expected to continue to decline as innovations in prosthetic science lead to greater levels of functional and sensory recovery.

As Clarke and Olesen (1999) argue, not all tensions can or need to be resolved; rather some tensions should be diffracted. The authors write, "such tensions may instead be paradoxes and contradictions within which we must dwell. Such tensions are especially common around the difficult powers of bodies and embodiment…most importantly diffractions are intended to provoke actions" (Clarke et al. 1999:5). Whether this uncomfortable tension is resolved or refracted will have profound implications for the future of phantom-prosthetic relations.

7 CONCLUSION

Prostheses, like phantoms, are objects that have what Lucy Suchman (2005) calls *affiliative powers*: she writes "by affiliative powers I mean the ways in which objects are not innocent but fraught with significance for the relations that they materialize." Her work contributes to a perspective that re-conceptualizes objects not as instruments or commodities, but rather as core to *object-centered socialities* (Knorr-Cetina 1997). It is through object-centered socialities that people come to establish and renew social relations, identities and selves. Knorr-Cetina (1997:2) suggests, "a strong thesis of 'objectification' would imply that objects displace human beings as relationship partners and embedding environments, or that they increasingly mediate human relationships, making the later dependent on the former."

Throughout the dissertation, I show how amputees, prosthetists, orthopedic surgeons, neuroscientists, as well as other individuals and collectivities, have developed prosthetic-centered and phantom-centered socialities of various kinds. However, and following Suchman (2005:381), I would like to highlight not just the "trajectories" or functions that these socialities promote, but also the forms that they assume. Objects that "present themselves to us as self evident" (Suchman 2005:381), as or "black-boxed" (Latour 1987), are in fact far from singular or fixed, but rather are made to appear as such. As Suchman (2005) argues, within our *culture of the copy* (Schwartz 1998a), affiliative objects are often both replica and original, both the new and the old, object forms that ultimately have significant relational implications.

Using the affiliative object as a heuristic, the next three sections of this chapter synthesize the major contributions of my work. First, I discuss the biomedicalization of phantoms, arguing that contestation within the field has always been about the struggle to find "the real McCoy." Next, I detail how the study of prostheses has contributed to the user-designer debate within technology studies, showing how prosthetic-centered socialities have been mediated by phantom authenticity. Third, I elaborate on how an analysis of embodied part-loss and part-replacement has contributed to the growing literature on the sociology of the body, arguing that as phantoms became proof of the epiphenomenal nature of the human body, they were transformed into pure simulacra. In the final section of the chapter, I briefly describe some possible future directions of my work.

The Biomedicalization of Phantoms: *Poor Copies.*

In many ways my dissertation reads like a model project in medical sociology: I tell a story of legitimation, of quantification, of susceptibility, of contagion, of categorization, of therapeutic intervention, of causal accounting, of prevention, and ultimately of the socio-cultural and temporal specificity of a syndrome. But here I would like to foreground here the ways in which my dissertation is also a story of how an amorphous, spectral, ghostly object acquires affiliative power, how and in what ways the always already mimetic becomes *socially substantive* (Harre' 2002:25) or becomes material vis-à-vis affiliative effects.

Phantoms, today, are asserted to be a consequent of the reorganization of the human cortex; the geography of the brain quite literally remaps in response to the loss of sensory input, in response to cortical silence. Researchers and clinicians have begun to use phantom exercise, improved prosthetic sensory "input," and even virtual reality in an attempt to "control" cortical reorganization by supporting established connections, preventing new ones and/or upsetting others. According to contemporary biomedical discourse, phantoms, like all things corporeal, are brain-based. Past psychological and medical accounts of phantom limb syndrome as rooted in psychosis, denial, wish fulfillment, peripheral nerve irritation, spinal chord reverberation, etc., have been recast as merely fanciful stories.

Past accounts of phantom phenomena had material acquisition, measurement, operationalization, discrimination, detection, ego, and truth-telling problems, while brain-based phantoms are today considered analytically pure. In other words, past phantoms have been reworked as problematic, as poor copies of the genuine thing, because they had not been suitably (analytically) uncoupled from selves, poor science, stories, and most importantly bodies. Present phantoms, by contrast, are more "real" because they are analytically clear and because they are now properly situated in brains. In effect, past phantoms have been measured against present phantoms in an effort to sort the authentic from the chimerical, to rationalize phantoms, and to distance contemporary scientific work in the field from its "fanciful" history.

The dissertation, then, contributes to a long line of research that seeks to demystify scientific and medical knowledges, revealing the socially constructed nature of such knowledge systems, and uncloaking the implications of those constructions. I show how many peculiarities of phantoms emerged as intelligible over time as a consequence of medical legitimation, and I situate the etiology, nosology and epidemiology of phantom limb within its broader social-cultural and epistemological conditions. I detail how phantom "symptoms" came to be defined as such, giving meaning to the emerging syndrome, but more importantly, I reveal how this was always a site struggle over uncovering the "real thing."

Techno-Corporeal Coupling: *Authenticity.*

My project also contributes to the vast scholarship in technology studies interested in the socio-cultural and historical contextualization of the development, elaboration and use of technologies of all kinds. Specifically, my work engages with what has been referred to as the user-designer debate (see for example Oudshoorn and Pinch 2005). I argue that in sharp contrast to their historical predecessors, prosthetics today are not simply facsimiles or approximations of limbs. Rather they are objects designed with intent, and with *user representatives* (Akrich 1994; Akrich et al. 1994; Woolgar 1991) in mind, which has significant implications for the kinds of possible *object-centered socialities* (Knorr-Cetina 1997) and *technosocialities* (Oudshoorn 2003). For example, I have shown how by/through war-driven state-sponsored investment in prosthetic science, dismemberment and phantom limb syndrome were transformed. Here prosthetized amputees, envisioned as technologically liberated citizens, became icons of postmodern malleability.

However, I also acknowledge the inherent negotiability of technologies in use. Technologies are never simply self-evident (Suchman et al. 1999), often not even user-friendly (Suchman 2005), and are frequently used for unintended purposes or in unintended ways. I argue that those technologies of the body that are *deeply embodied*, those that are successfully *incorporated* (Kurzman 2002) or have a *taken-for-granted-ness* (Olesen 1992), are those that are highly negotiable because they involve relations with recalcitrant bodies. Bodies may wittingly or unwittingly join political projects of all kinds, and may transgress in unplanned or unimaginable ways. Throughout the dissertation, I have elaborated on how phantoms have resisted biomedical rationalization. In fact, they have functioned as *actants* (Callon 1986b; Callon 1999; Latour 1987; Latour 1991; Law 1992; Law 1997), engendering major shifts in phantom-prosthetic relations and prosthetic-centered socialities. Just as phantoms were being causally accounted for, captured by the camera or tamed by the (re)structuring of prostheses, they began to morph, to "distort", to occupy new body parts. The poor copies of the past, those that were mimetic of fleshy limbs, were recast as distortions, while distorted phantoms, shrunken phantoms, phantoms with gaps and holes, or fused phantoms became "authentic."

Corporeal Futures: *Facsimiles and Other Representations.*

Finally, contributing to the growing body of literature on the sociology of the body, my work explores the implications of biomedical constructions of amputation and prosthetization for embodiment, for how part-loss is to be "done" and how techno-corporeal coupling is to be lived. In other words, I uncover the "cultural filaments"

(Casper 1998a:24) that connect prostheses to phantoms, elaborating on the implications of these connections for embodied dismemberment and prosthetization.

In this work, I quite intentionally reattached phantoms to ambulating bodies and located phantom-ed bodies within aesthetics and economies of embodiment. I showed how historically, phantoms purportedly upset the overall economy of the male body and were conceived as emblematic of the physical and mental weaknesses that feminize, how phantoms *fractioned* (O'Connor 2000) the body and the self. In other words, phantoms were evidence that the body, that corporeality, could be persuasively fraudulent. In the decades since WWII, with the modernization of dismemberment, the (bio)medicalization of phantoms, and the visualization of amputee brains, phantoms were re-conceptualized as productive phenomena, with properties capable of exploitation in the pursuit of elaborating bodies with technologies. Contemporary phantoms were transformed; no longer "evidence" of the fraudulent quality of bodies, phantoms became neuroscientific proof of the epiphenomenal nature of the human body. According to neuroscientific discourse, the postmodern body per se is illusion and the phantom, thus, a copy of a copy, pure simulacra.

I further demonstrate how the modernization, medicalization and militarization of dismemberment profoundly impacted what amputees came to represent in the US. Prosthetized amputees have become icons of the liberatory promise of science/medicine/technology. I argued that it was through the very embodiment of militarized prostheses by demobilized veterans that dismemberment became associated with techno-liberation, implicating amputees in imagined corporeal futures of bodily enhanced transformations. In other words, I propose that prosthetic-centered socialities do not simply entangle amputees, but rather have significance for the practical, moral, aesthetic, and neuroscientific sensibilities of bodies more broadly.

Future Directions.

This project has functioned as point of departure rather than a destination or end point. Many of the ideas I have for future projects are the spawn of both theoretical entanglements, thinking through prosthetization or how embodiment is "done" vis-à-vis absence for example. Others are the products of pure curiosity, with all of the associative excitement about where a research object might take me if I set out to follow it with passionately wide eyes.

I propose further examination of embodied part-loss and part-replacement, including hand/arm transplantation, replantation, and cross-transfer. Replantation procedures involve reattaching amputated parts, while transplantation involves the use of a donor part, and cross-transfer procedures replace an irreparably damaged limb with an a limb from the opposite side. Price (1998:385), who interviewed both cross-transfer and reattachment patients, writes about the cross-transfer patient's experience of phantom limb:

> He felt the presence of a phantom left [amputated] arm primarily by its weight; the phantom lying inert at the side of his body…everything he feels on his right [left are cross-transferred to his right side] he feels in his left phantom hand.

Both transplantation and replantation involve forms of embodied part-replacement that may further contribute to an understanding of how new body parts "materialize" in biomedical contexts, how these parts operate as technologies of the body, and how they are purportedly lived.

Second, I propose a study of amputee athletes training and participating in the Paralympic games. The history of prosthetic innovation is one in which amputees themselves have played a significant part (Northwestern 2002) and those amputees who demand the most from their prostheses and their prosthetists are extreme athletes. A study of this kind would allow an examination of the conditions under which innovations are realized, including how innovations are negotiated by amputees, prosthetists, Olympic regulatory bodies, and others. It would also enable an investigation into the impetus for such innovations and the particular forms that prosthetic advances, developed especially for extreme athletes, take.

Lastly, I propose a study of one of the US laboratories investigating the neural interfacing of prostheses. Neural interfacing involves harnessing "naturally occurring" neuronal activity to prostheses via computer chips implanted in the brain (Andersen et al. 2004; de Peralta Menendez et al. 2005; Musallam et al. 2004). This technology is purportedly the most significant breakthrough in prosthetic technologies to date, one that has implications far beyond limb replacement. "Nicolelis sees the effort as part of an impending revolution that could eventually make HBMIs as commonplace as Palm Pilots and spawn a whole new industry-centered around the brain" (Regalado 2001:1). This project would continue to trace the connections between dismemberment and neuroscience, as well as detail how phantom limb syndrome has been translated into a new model for brain-body interfacing within various contexts, of which war is assuredly one.

Lastly, I propose a cross-cultural study of osseointegrated prostheses. Such prostheses attach directly to remaining bone (Myers 2002). The technique involves inserting a titanium threaded implant into the femur (in the case of above-knee lower limb amputation) so that when it has fully osseointegrated, the implant operates as a direct attachment site for an external prosthesis (Branemark, Branemark, Rydevik, and Myers 2001). Osseointegrated prostheses are under development in the UK, Sweden, Australia, and other countries, but not in the U.S. A project of this kind would contribute further to an understanding of *deeply embodied* technologies.

ENDNOTES

[i] On phantom vibration see: Harber (1956), and Weinstein (1998).
[ii] On phantom itch see: Carlen et al. (1978), Davis (1993), Flor (2002b), Finnoff (2001), Grusser et al. (2004), Hill (1999), Hsu et al. (2004b), Hunter et al. (2003), Hunter et al. (2005), Kolb (1950a), Lacroix et al. (1992), McGrath et al. (1992), Melzack (1989b), Melzack (1990), Melzack et al. (1997), Sherman et al. (1979), Sherman et al. (1989), Sugarbaker et al. (1984), Varma et al. (1972), Weinstein (1998), and Wilkins et al. (1998).
[iii] On tickly phantoms see: Carlen et al. (1978), Davis (1993), Finnoff (2001), Lacroix et al. (1992), Melzack (1989b), Melzack (1990), and Spross et al. (1985).
[iv] On sweaty or damp phantoms see: Appenzeller et al. (1969), Davis (1993), Finnoff (2001), Melzack (1989b), Melzack (1990), Melzack et al. (1997), Murphy et al. (1984), Postone (1987), and Williams et al. (1997).
[v] On numb phantoms see: Grusser et al. (2004), Harber (1956), Hsu et al. (2004b), Katz et al. (1991), Sugarbaker et al. (1984), Lacroix et al. (1992), Melzack et al. (1997)**,** Varma et al. (1972), Wilkins et al. (1998), and Spross et al. (1985).
[vi] On fatigued phantoms see: Davis (1993), Doughtery (1980), Hunter et al. (2003), Melzack (1990), and O'Neal et al. (1997).
[vii] On phantoms wearing bandages see: Friedmann (1978), Katz (1992b), and Weiss et al. (1996).
[viii] On phantoms feeling bound by a tourniquet see: Ament et al. (1964).
[ix] On phantoms feeling bound by a cast see: Danke et al. (1981), Katz et al. (1990).
[x] On phantoms wearing a ring or watch see: Andre et al. (2001), Frazier (1966), Frederiks (1963), Friedmann (1978), Halligan et al. (1993a), Harber (1958b), Hazelgrove et al. (2002), Katz et al. (1990), Katz (1992b), Melzack (1989b), Melzack (1990), Omer (1981), Ramachandran (1998a), Ramachandran et a. (1998b), Varma et al. (1972), and Wesolowski et al. (1993).
[xi] On phantoms wearing a shoe see: Andre et al. (2001), Fisher (1999), and In Der Beeck (1953), Katz et al. (1990).
[xii] On phantoms holding a cane see: Katz et al. (1990), Wesolowski et al. (1993).
[xiii] On the sensation of blood in a boot see: Hazelgrove et al. (2002), Katz et al. (1990), Katz (1992b), Wesolowski et al. (1993).
[xiv] On phantoms as unusually vivid or vague see**:** Andre et al. (2001), Brown (1968), Chong-cheng (1986), Davis (1993), Dernham (1986), Fisher et al. (1991), Grusser et al. (2004), Halligan, et al. (1993a), Harber (1958b), Hunter et al. (2003), Jensen et al. (1983), Jensen et al (1984), Lacroix et al. (1992), Livingston (1938), Morgenstern (1964), Ovesen (1991), Postone (1987), Rounseville (1992), Scatena (1990), Spross et al. (1985), and Stannard (1993).
[xv] On phantoms as unusually hot or warm see: Brown (1968), Finnoff (2001), Halligan et al. (1993b), Hrbek (1976b), Hunter et al. (2003), Jensen et al. (1983), Katz et al. (1987), Katz et al. (1991), Melzack et al (1973), Melzack (1989b), Melzack et al. (1997), Melzack (1990), Montoya et al (1997), Morgenstern (1964), Murphy (Murphy 1957), Postone (1987), Rounseville (1992), Sherman et al. (1979), Sherman et al. (Sherman et al. 1985), Spross et al. (1985), Sugarbaker et al. (1984), and Williams et al. (1997).
[xvi] On phantoms as unusually cool or cold see: Appenzeller et al. (1969), Bergmans et al. (2002), Finnoff (2001), Frederiks (1963), Grusser et al. (2004), Halligan, et al. (1993a), Harber (1958b), Hrbek (1976b), Hunter et al. (2003), Jensen et al. (1983), Katz et al. (1991), Melzack et al (1973), Melzack et al. (1997), Melzack (1990), Morgenstern (1964), Murphy (1957), Nashold et al. (1969), Postone (1987), Riscalla (1977), Spross et al. (1985), Sugarbaker et al. (1984), and Williams et al. (1997).
[xvii] On phantoms as unusually heavy or light see: Carlen et al. (1978), Fraser et al. (2001), Hrbek (1976b), Melzack et al. (1973), Melzack (1989b), Montoya et al. (1997), Pool et al. (1953), Spross et al. (1985), and Sugarbaker et al. (1984).
[xviii] On phantoms as unusually dense or hallow see: Hrbek (1976b).
[xix] On phantoms described as pleasurable see: Herman (1998), and Weiss and Lindell (1996).
[xx] On phantoms described as pleasant see: Andre et al. (2001), Brown (1968), Gangale (1968b), Harber (1956), Melzack and Bromage (1973), Rounseville (1992), Simmel (1956b), Simmel (1962), Simmel (1967), Stein and Warfield (1982), and Weiss (1956).
[xxi] On phantoms described as welcome see: Saadah and Melzack (1994).

[xxii] On phantoms described as not unpleasant see: Blankenbaker (1977), Brown (1968), Naidu (1982), and Weiss (1956).
[xxiii] For other references to fingers tearing the palm see: Brown (1968), Davis (Davis 1993), Doetsch (1997), Humphrey (1992), Maroon et al. (1973), Postone (1987), Ramachandran (1998), Ramachandran and Rogers-Ramachandran (1996), Ramachandran et al. (1998b), Ramachandran and Rogers-Ramachandran (2000), Shukla et al. (1982), and Wilson et al. (1978).
[xxiv] For pre-1990 references to pain memories see: Appenzeller et al. (1969), Bach et al. (1988), Iacono, Linford, and Sandyk (1987), Jensen et al. (1983), Katz et al. (1987), Melzack (1989b), Morgenstern (1970), Parks (1973), Sherman and Sherman (1985), Stein et al. (1982), Weiss (1956), and Wilson et al. (1978).
[xxv] For post-1990 references to pain memories see: Andre et al. (2001), Baron and Maier (1995), Flor (2002b), Flor (2002a), Flor (2003), Fisher (1999), Grusser et al. (2001), Halligan et al. (1993a), Hill (1999), Hill et al. (1996), Houghton et al. (1994), Jensen et al. (2000), Katz et al. (1991), Katz (1992a), Katz (1992b), Larbig et al. (1996), Melzack et al. (2001), Mortimer et al. (2002), Nikolajsen et al. (2000), Nikolajsen et al. (2001), Oakley et al. (2002), O'Neal et al. (1997), Pucher et al. (1999), Ramachandran et al. (1998b), Rosen et al. (Rosen et al. 2001b), Weinstein (1998), Wiech et al. (2004), Wilkins et al. (1998), and Woodhouse (2005)
[xxvi] On phantoms with slivers under the nail see: Bailey et al. (1941), Prasad et al. (1982), Scatena (1990), and Weiss (1996).
[xxvii] On phantoms with bunions see: Halligan et al. (1993a), Melzack (1989b), and Weiss (1996).
[xxviii] On phantoms with corns see: Katz (1992b), Finneson et al. (1957), Katz et al. (1990), Kessel et al. (1987), Melzack (1989b), and Melzack et al. (2001).
[xxix] On phantoms with blisters see: Katz et al. (1990), Katz (1992b), Melzack et al. (2001), and Weiss (1996).
[xxx] On phantoms with an ingrown toenail see: Katz (1992b), Rouneville (1992), Melzack et al. (2001), Jensen et al. (2000), Katz et al. (1990), and Scatena (1990).
[xxxi] On phantoms with carpel tunnel syndrome see: Andre et al. (2001).
[xxxii] On phantom ulcers see: Katz et al. (1990), Katz (1992b), Melzack (2001), and Jensen et al. (2000).
[xxxiii] On phantom gangrene see: Katz et al. (1990), Katz (1992b), Melzack (2001).
[xxxiv] On phantom cuts see: Katz et al. (1990), Katz (1992b), Melzack (2001).
[xxxv] On phantoms described as too short see: Andre et al. (2001), Grusser et al. (2004), Hazelgrove et al. (2002), Katz (1992b), Kegel et al. (1977), Melzack (1990), Melzack et al. (1997), Morgenstern (1964), O'Neal et al. (1997), Postone (1987), Ramachandran et al. (1998b), Roux et al. (2003), Weinstein et al. (1961), and Wilkins et al. (1998).
[xxxvi] On phantoms described as too small see: Bach et al. (1988), Katz (1992b), Melzack et al. (1997), Morgenstern (1964), Murphy (1957), and Roux et al. (2003).
[xxxvii] On phantoms described as too long see: Andre et al. (2001), Melzack et al. (1997), Pollock (1957b), and Weinstein et al. (1961).
[xxxviii] On phantoms as too big see: Andre et al. (2001)
[xxxix] On the use of MRI see: Bitter et al. (2005), Karl et al. (2001), Knecht et al. (1996), Knecht et al. (1998a), and Miyazawa et al. (2004).
[xl] On the use of fMRI see: Brugger et al. (2000), Condes-Lara et al. (2000), Dettmers et al. (2001), Elbert et al. (2004), Ersland et al. (1996), Farne et al. (2002), Giraux et al. (2003), Lotze et al. (2001), Lotze et al. (1999), McGonigle et al. (2002), Moore et al. (2000), Ramachandran et al. (1998b), Rosen et al. (2001a), Roux et al. (2001), and Roux et al. (2003).
[xli] On the use of sMRI see: Elber et al. (1994), and Yang et al. (1994).
[xlii] On the use of MEG see: Elbert et al. (1994), Elbert et al. (2004), Pleger et al. (2004), Ramachandran et al. (1998b), Ramachandran et al. (1996), Soros et al. (2001), Wiech et al. (2000), Wiech et al. (2004) and Yang et al. (1994).
[xliii] On the use of MSI see: Elbert et al. (2004), Flor et al. (1998), Flor et al. (2000b), Huse et al. (Huse, Larbig, Flor, and Birbaumer 2001), Karl et al. (2001), and Wiech et al. (2004).
[xliv] On the use of PET see: Elbert et al. (2004), Pascual-Leone et al. (1996), Rosen et al. (2001b), Roux et al. (2003), and Willoch et al. (2000).
[xlv] On the use of CT see: Bitter et al. (2005), Grossi et al. (2002), Lu (1998), and Miyazawa et al. (2004).
[xlvi] On the use of SM see: Davis et al. (1998).

[xlvii] For a report of supernumerary phantom in the case of lesions of the spinal cord injury see Frederiks (1963), and Grossi, Di Cesare, and Tamburro (2002). For a report of supernumerary phantom in the case of paraplegia see Simmel (1956b). For a reference to supernumerary phantoms in the case of brachial plexus avulsion see Ramachandran and Hirstein (1998b). Finally, for a report on the growth of supernumerary pair of upper and lower limbs in a quadriplegic penitent after petit mal seizure see Ohry, Gur, and Zeilig (1989).

[xlviii] For a examination of supernumerary phantom in the case of bilateral parietal lobe damage see Vuilleumier, Reverdin, and Landis (1997).

[xlix] For a reference to supernumerary phantom in the case of demyelination see: Brugger (2003).

[l] For a reference to supernumerary phantom in the case of epilepsy see: Brugger (2003).

[li] For an examination of supernumerary phantom in the case of stroke see Miyazawa, Hayashi, Komiya, and Akiyama (2004). They suggest that there have been 20 documented cases in the past 70 years. Also see Canavero, Bonicalzi, Castellano, Perozzo, and Massa-Micon (1999) and Halligan et al. (1993b).

[lii] On distal parts as strong sites see: Cook et al. (1952), Davis (1993), Dernham (1986), Finnoff (2001), Fisher (1999), Gangale (1968b), Hill (1999), In Der Beeck (1953), Jensen et al. (1983), Jensen et al. (1984), Jensen et al. (2000), Postone (1987), and Stein et al. (1982).

[liii] On phantoms floating or dangling see: Dernham (1986), Hill (1999), Katz et al. (1990), Liaw, You, Cheng, Kao, and Wong (1998), Melzack (1990) O'Neal et al. (1997), Rounseville (1992), and Williams et al. 1997 (1997).

[liv] On phantom gaps in the literature see: Harber (1958b), Katz et al. (1987), Katz (1992a), Katz (1992b), Melzack et al. (1997), Morgenstern (1964), Roux et al. (2003), Scatena 1990, and Weinstein et al. (1961).

[lv] On phantom holes in the literature see: Price (1976), and Zuk (1956).

[lvi] On the gradual decrease in length see: Spitzer, Bohler, Weisbrod, and Kischka (1995).

[lvii] On the gradual decrease in size see: Blankenbaker (1977), Brunette (1980), Kallio (1952), Morgenstern (1964), and Spitzer et al. (1995).

[lviii] On phantom shrinking see: Flor (2002b), Fraser et al. (2001), Harber (1958b), Kolb (1950a), Katz et al. (1990), Kyllonen (1964), Middleton (2003), and Zuk (1956).

[lix] On phantoms shrinking toward the stump see: Brunette (1980), Connolly (1979), Dernham (1986), Fisher (1999), Flor (2002b), Iacono et al. (1987), Katz (1992a), Melzack (1990), Morgenstern (1964), Patterson (1988), Postone (1987), Woodhouse (2005), and Zuk (1956).

[lx] On phantoms shrinking into the stump see: Bach et al. (1988), Brunette (1980), Fisher (1999), Flor (2002b), Harber (1958b), Hill (1999), Hirschenfang and Benton (1966), Iacono et al. (1987), Kolb (1950a), Katz (1992a), Kyllonen (1964), Mayeux et al. (1979), Melzack (1990), Morse (1985), Nikolajsen et al. (2001), Rounseville (1992), Sellick (1985), Spitzer et al. (1995), and Zuk (1956).

[lxi] On phantoms attached immediately to the stump see: Grouios (1999), Hill (1999), Hrbek (1976b), Middleton (2003), O'Neal et al. (1997), Omer (1981), and Wesolowski et al. (1993).

[lxii] On phantoms dangling see: Melzack (1989b), Ramachandran et al. (1998b), and Ramachandran et al. (1996).

[lxiii] On phantoms protruding through the stump see: Fisher (1999), Haber (1958b), Katz et al. (1990), Pontius (1964), and Weiss et al. (1996).

[lxiv] On phantoms that feel as it they have been pushed inside see: Haber (1958b), Katz (1992b), Katz et al. (1990), and Melzack et al. (1997).

[lxv] On spontaneous or involuntary phantom movement see: Blankenbaker (1977), Carlen et al. (1978), Chong-cheng (1986), Davis (1993), Halligan et al. (1993a), Harber (1958b), Hrbek (1976b), Jankovic and Glass (1985), Jensen et al. (1983), Kallio (1952), Melzack et al (1973), Melzack et al. (1997), Murphy (1957), O'Neal et al. (1997), Ramachandran et al. (1998b), Roux et al. (2001), Roux et al. (2003), Weinstein (1998), and Weinstein et al. (1961).

[lxvi] On reflexive phantom movement see: Hrbek (1976b), Kallio (1952), Melzack et al. (1997), Melzack (1990), and Ramachandran et al. (1998b).

[lxvii] On conjunctive or synkinetic phantom movement see: Andre et al. (2001), Fraser et al. (2001), Halligan et al. (1993a), Hrbek (1976b), Kallio (1952), Katz et al. (1987), Melzack (1989b), Melzack et al. (1997), Melzack (1990), and Ramachandran et al. (1998b).

[lxviii] On voluntary phantom movement see: Carlen et al. (1978), Davis (1993), Doetsch (1997), Fisher (1999), Fraser et al. (2001), Giraux et al. (2003), Halligan et al. (1993a), Harber (1958b), Hazelgrove et al. (2002), Hoffman (1954b), Hrbek (1976a), Jensen et al. (1983), Kallio (1952), Katz et al. (1987), McGrath

and Hillier (1992), Melzack et al (1973), Melzack et al. (1997), Murphy (1957), O'Neal et al. (1997), Postone (1987), Price (1976), Ramachandran (1998), Ramachandran et al. (1998b), Roux et al. (2001), Roux et al. (2003), Simmel (1962), Simmel (1967), and Weinstein (1998).

[lxix] On stump jumping see: Bailey et al. (1992), Hrbek (1976a), Katz et al. (1987), Liaw et al. (1998), McGrath et al. (1992), Mortimer et al. (2002), and Spross et al (1985) Steiner et al. (Steiner, DeJesus, and Mancall 1974).

[lxx] On stump epilepsy see: Beller et al (1951).

[lxxi] On phantom spasms see: Esson (1961), Frazier (1966), Hrbek (1976a), Katz et al. (1991), Roux et al. (2001), Roux et al. (2003), and Sherman et al. (1979).

[lxxii] On jactitation see: Carlen et al. (1978), Falconer (1953), Funakawa, Mano, and Takayanagi (1987), Grouios (1999), Jankovic et al. (1985), Morgenstern (1964), and Shukla et al. (1982).

[lxxiii] On using phantoms during walking or running see: Blankenbaker (1977), Davis (1993), Grouios (1999), Halligan et al. (1993a), Krane et al. (1995), Melzack (1990), Melzack et al. (1997), and Prasad and Das (1982).

[lxxiv] On using phantoms when crawling see: Esson (1961).

[lxxv] On using phantoms when stepping see: Hrbek (1976a), Melzack (1989b), Melzack (1990), Postone (1987), Rounseville (1992), Simmel (1959a), Simmel (1962), Simmel (1967), and Stein et al. (1982).

[lxxvi] On using phantoms during sitting see: Grouios (1999), Melzack (1989b), and Prasad and Das (1982).

[lxxvii] On using phantoms while getting up see: Scatena (1990).

[lxxviii] On using phantoms for steadying or balancing see: Fairley's (2004), Melzack et al. (1997), Simmel (1962), and Simmel (1967).

[lxxix] On using phantoms for standing see: Krane et al. (1995), Melzack (1989b), and Mortimer et al. (2002).

[lxxx] On using phantoms to break a fall see: Ramachandran et al. (1996), and Ramachandran et al. (1998b).

[lxxxi] On using phantoms during catching see: Harber (1958b).

[lxxxii] On using phantoms while fending off a blow see: Ramachandran et al. (1996), and Ramachandran et al. (1998b).

[lxxxiii] On using phantoms for pointing see: Melzack et al. (1997), and Harber (1958b).

[lxxxiv] On using phantoms for waving see: Ramachandran et al. (1996) Ramchandran et al. (1998b), and Fairley's (2004:1).

[lxxxv] On using phantoms for grasping or grabbing see: Esson (1961), Melzack (1989b), Simmel (1962), Simmel (1967), Fraser et al. (2001), and Fairley (2004)

[lxxxvi] On using phantoms when reaching see: Dernham (1986), Harber (1958b), Melzack (1990), Melzack et al. (1997), Ramchandran et al. (1998b), Scatena (1990), and Stein et al. (1982).

[lxxxvii] On using phantoms for counting see: Saadah et al. (1994), and Scatena (1990).

[lxxxviii] On using phantoms during gesticulation see: Price (1976), and Ramachandran et al. (1998a).

[lxxxix] On using phantoms when stretching see: Grouios (1999), Melzack (1990), and Prasad et al. (1982:30).

[xc] On using phantoms during writing see: Hrbek (1976a).

[xci] On using phantoms to shake hands see: Ramachandran et al. (1996) and Ramchandran et al. (1998b).

[xcii] See: (Andre et al. 2001; Bittar et al. 2005; Dominguez 2001; Ersland et al. 1996; Finnoff 2001; Flor et al. 1998; Flor 2002a; Flor 2002b; Hazelgrove et al. 2002; Hill 1999; Hill et al. 1995; Hill et al. 1996; Jensen et al. 2000; Khattab, Terebelo, and Dabas 2000; Larbig et al. 1996; Le Chapelain, Beis, and Andre 2001; Lee and Donovan 1995; Liaw et al. 1998; Melzack 1992; Melzack et al. 2001; Melzack et al. 1997; Middleton 2003; Montoya et al. 1997; Montoya, Ritter, Huse, Larbig, Braun, Topfner, Lutzenberger, Grodd, Flor, and Birbaumer 1998; Pucher et al. 1999; Ramachandran, Stewart, and Rogers-Ramachandran 1992; Roux et al. 2001; Saadah et al. 1994; Scatena 1990; Siddle 2004; Smith and Thompson 1995; Wesolowski et al. 1993; Williams et al. 1997; Woodhouse 2005).

[xciii] See for example: (Elbert et al. 1994; Flor et al. 1998; Flor et al. 2000b; Grusser et al. 2004; Hunter et al. 2003; Hunter et al. 2005; Knecht et al. 1998a; Knecht, Soros, Gurtler, Imai, Ringelstein, and Henningsen 1998b).

[xciv] See: (Aglioti et al. 1994a; Aglioti, Cortese, and Franchini 1994b; Barinaga 1992; Bergmans et al. 2002; Dettmers et al. 2001; Elbert et al. 2004; Farne et al. 2002; Flor 2003; Flor et al. 2000b; Flor 2002a; Fraser et al. 2001; Gallagher et al. 1998; Grusser et al. 2001; Halligan et al. 1994; Halligan et al. 1993a; Hunter et al. 2003; Karl et al. 2001; Knecht et al. 1996; Knecht et al. 1998b; Lotze et al. 2001; Moore et al. 2000; Pascual-Leone et al. 1996; Ramachandran 1996; Ramachandran 1998; Ramachandran 2005; Ramachandran

et al. 1998b; Ramachandran et al. 1996; Ramachandran et al. 2000; Ramachandran et al. 1992; Roux et al. 2003; Spitzer et al. 1995; Wiech et al. 2004).

[xcv] See: (Aglioti et al. 1994a; Aglioti et al. 1994b; Halligan, Zeman, and Berger 1999; Ramachandran et al. 1998a).

[xcvi] See for example: (Aglioti et al. 1994a; Blegvad, Byatt, Cleary, Hill, Kunzru, and Wood 2003; Ramachandran 1996; Ramachandran et al. 1998b; Ray 2003).

[xcvii] See for example: (Borsook, Becerra, Fishman, Edwards, Jennings, Stojanovic, Papinicolas, Ramachandran, Gonzalez, and Breiter 1998; Halligan et al. 1994; Halligan et al. 1993a; Hunter et al. 2003).

[xcviii] See for example: (Aglioti et al. 1994a; Borsook et al. 1998; Flor 2003; Flor 2002a; Gallagher et al. 1998; Grusser et al. 2004; Knecht et al. 1996; Ramachandran 1998; Ramachandran et al. 1998b; Ramachandran et al. 2000).

[xcix] See for example: (Aglioti et al. 1994a; Borsook et al. 1998; Buchner, Richrath, Grunholz, Noppeney, Waberski, Gobbele, Willmes, and Treede 2000; Dettmers et al. 2001; Doetsch 1997; Farne et al. 2002; Flor 2003; Flor et al. 1998; Flor et al. 2000b; Flor 2002a; Grusser et al. 2001; Hunter et al. 2003; Karl et al. 2001; Kew et al. 1994; Knecht et al. 1998b; Lotze et al. 1999; Lotze et al. 2001; Nikolajsen et al. 2001; Schwenkreis, Witscher, Janssen, Pleger, Dertwinkel, Zenz, Malin, and Tegenthoff 2001; Weiss et al. 1999; Weiss et al. 2000; Wiech et al. 2000; Wiech et al. 2004; Willoch et al. 2000).

[c] See for example: (Dettmers et al. 2001; Flor 2003; Karl et al. 2001; Kew et al. 1994; Lotze et al. 1999; Mercier, Reilly, Vargas, Aballea, and Sirqu 2006; Ojemann et al. 1995; Schwenkreis et al. 2001).

[ci] See (Aglioti et al. 1994a; Barinaga 1992; Bergmans et al. 2002; Calford and Tweedale 1988; Dettmers et al. 2001; Doetsch 1997; Flor 2003; Flor et al. 1998; Garraghty and Kaas 1991; Halligan et al. 1994; Larbig et al. 1996; Merzenich et al. 1984; Pons et al. 1991; Ramachandran et al. 1996).

[cii] See for example: (Birbaumer, Lutzenberger, Montoya, Larbig, Unertl, Topfner, Grodd, Taub, and Flor 1997; Buchner et al. 2000; Condes-Lara et al. 2000; Dettmers et al. 2001; Elbert et al. 2004; Flor 2003; Flor et al. 1998; Flor et al. 1995; Flor et al. 2000b; Flor 2002a; Grusser et al. 2004; Grusser et al. 2001; Jensen et al. 2000; Karl et al. 2001; Karl, Diers, and Flor 2004a; Karl et al. 2004b; Knecht et al. 1996; Knecht et al. 1998a; Lotze et al. 2001; Montoya et al. 1997; Nikolajsen et al. 2000; Pleger et al. 2004; Ramachandran et al. 1998b; Roux et al. 2003; Soros et al. 2001; Wiech et al. 2000; Wiech et al. 2004; Woodhouse 2005).

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APPENDIX A: SITUATIONAL MAP

INDIVIDUAL HUMAN ELEMENTS/ACTORS

Living

Dr. Ronald Melzack
Dr. Joel Katz
Dr. Richard Sherman
Dr. Edward Taub
Dr. Vilayanur S. Ramachandran
Dr. Dawn Edhe
Dr. Herta Flor
Dr. Mark Jensen
Dr.

Historical

Dr. Ambrose Paré
Dr. Timothy Pons
Dr. Wilder Penfield
Dr. Silas Weir Mitchell
Jimmy Wilson
US Surgeon General Norman T. Kirk
Dr. Ernest Burgess

Fictional

George Deadlow

COLLECTIVE HUMAN ELEMENTS/ACTORS

Amputees
Male veterans
Orthopedic surgeons
Prosthetists
Congenital aplastics
Children
Paraplegics

DISCURSIVE CONSTRUCTIONS OF INDIVIDUAL AND/OR COLLECTIVE HUMAN ACTORS

The feminized amputee
The emasculated amputee
Amputee as superior disabled category
Militarized amputee
Cyborg Warrior

POLITICAL/ECONOMIC ELEMENTS

Technologies-of-mutilation indicative of warfare
The Office of War Information (OWI)
Chamber of horrors
National Research Council
The Committee on Prosthetic Devices (CPD)
Veterans Administration
Advisory Committee on Artificial Limbs
Artificial Limb Program (ALP)
Amputee Coalition of America

TEMPORAL ELEMENTS

Coining the phrase *phantom limb*
Inclusion in the *Index Medicus*
The interwar new masculinity
Psychotherapy, electroshock therapy and prefrontal lobotomy
Postwar America prosperity
Peak of prosthetic innovation
Establishment of the American Orthotic and Prosthetic Association (AOPA)
Modernization of dismemberment
Visualization technologies
Invention of pain
Culture of pain

MAJOR ISSUES/DEBATES (USAULLY CONTESTED)

Etiology of Phantoms
Phantoms as a symptom class
Amputation is a reconstructive procedure
Pain memories
Productive potential of phantoms
Functional significance of cortical reorganization
Susceptible populations
Prevalence
Phantom Mislocation

NONHUMAN ELEMENTS AND ACTANTS

Phantom limbs
Prosthetics
Homunculus
McGill Pain Questionnaire

IMPLICATED/SILENT ACTORS/ACTANTS

The Female hysteric
Mentally disabled
Silver Spring monkeys

DISCURSIVE CONSTRUCTION OF NONHUMAN ACTANTS

The misbehavior ghost
Phantom-object relations
Phantom gaps/holes or distorted phantoms

SOCIOCULTURAL/SYMBOLIC ELEMENTS

Militarized male
Cyborg

RELATED DISCOURSES

Postbellum corporeal ideology
The veteran problem
Patriotism

APPENDIX B: MEDICAL LITERATURE CODING SCHEME

			Notes
Identifying information	Date		
	Authors		
	Journal title		
	Journal type		
Review of previous literature	Report of phantom prevalence		
	Report of phantom quality		
	Report of phantom pain prevalence		
	Report of phantom pain quality		
	Report of phantom population		
	Treatment attempts		
	Causal mechanism referenced (theory)		
Study sample	Sample number		
	Amputation level		
	Amputated part		
	Time since amputation		
	Population characteristic		
Phantom characteristics	Phantom prevalence (from sample)		
	Phantom part		
	Onset		
	Duration and frequency		
	Quality		
Phantom pain	Pain prevalence (from sample)		
	Phantom part		
	Onset		
	Duration and frequency		
	Quality		
	Treatment		

APPENDIX C: PHANTOM PARTS

Phantom Parts. Reports within the medical literature of body parts, other than limbs, feet, hands and digits, discovered to or known to be associated with phantom sensations or pain by date.

PHANTOM PARTS

Body Parts Associated with Phantom Sensation or Phantom Pain

Date	Author	Organ	Date Cont	Author Continued	Organ Continued
(1872)	Mitchell	Breast, penis	(1989)	Melzack	Breast, genitals, bladder, rectum
(1941)	Bailey et al.	Teeth	(1990)	Katz et al.	Breast, teeth, internal and special sense organs, rectum, stomach, eye, uterus
(1941)	Riddoch	Nose, penis	(1990)	Melzack	Breast, penis, bladder, rectum, uterus
(1954)	Hoffman	Face	(1991)	Ovesen et al.	Rectum
(1950)	Heusner	Penis	(1992b)	Katz	Bladder
(1950)	Kolb	Breast, ear, nose, penis	(1992a)	Katz	Rectum, bladder
(1951)	Bors	Bladder, rectum, penis	(1992)	Bailey et al.	Breast, penis, tooth
(1955)	Ackerly et al.	Breast	(1992)	Melzack	Breast, genitals and other body areas
(1955)	Bressler et al.	Breast	(1993)	Scholz	Breast
(1956)	Blood	Nose, breast, ear, penis, teeth	(1993)	Davis	Genitalia, teeth, tongue, ladder, rectum, breast
(1956)	Bressler	Breast	(1993)	Wesolowski et al.	Tongue, breast, teeth, penis, bladder
(1956)	Zuk	Face, Breast, Penis	(1994)	Aglioti et al.	Breast, penis
(1957)	Murphy	Testicle	(1996)	Bartusch et al.	Breast, genitals, tooth
(1959)	Simmel	Nose, eyes, genitals	(1996)	Battrum et al.	Tooth
(1963)	Frederiks	Breast, penis, testis, teeth, eyeball, face, rectum	(1997)	Williams et al.	Breast, rectum, penis bladder
(1964)	Gills	Nose, breast	(1997)	Doetsch	Breast, penis
(1966)	Simmel	Breast	(1998a)	Ramachandran et al.	Appendix
(1966)	Maloney et al.	Breast, penis	(1998)	Weinstein	Digit, eye, nose, teeth, tongue, breast, bladder, anus, and genital organs
(1967)	Simmel	Breast, genitals	(1998b)	Ramachandran et al.	Breast, face, rectum, stomach, penis, reproductive organs, appendix
(1967)	Simmel	Breast, genitals	(1998a)	Ramachandran et al.	Reproductive organs
(1968)	Gangale	Nose, breast, penis	(1999)	Fisher	Penis
(1971)	Dorpat	Uterus, stomach, penis, bladder, rectum	(1999)	Grouios	Anus, ear, eyes, female breast, nipples, nose, penis, teeth, tongue, bladder, rectum, stomach, uterus
(1976)	Hrbek	Breast, genitalia, tooth, eye, face	(2001)	Melzack et al.	Hysterectomy, breast, teeth, internal organs, stomach, rectum, bladder, eye
(1979)	Hanowell et al.	Tongue, nose, breast, penis	(2001)	Bloomquist	Teeth, intestines, breast, penis
(1979)	Brena et al.	Urinary Bladder	(2001)	Roux et al.	Face, breast
(1979)	Jamieson et al.	Breast	(2002)	Oakley et al.	Breast
(1979)	Connolly	Breast, penis, nose	(2002)	Flor	Breast, rectum, penis, testicles, eye, tongue, teeth
(1979)	Mayeux et al.	Genitals, breast	(2002)	Abraham et al.	Breast
(1981)	Pollman	Teeth	(2003)	Middleton	Breast
(1986)	Dernham	Eyes and "almost every external body part" (34)	(2003)	Brugger	Head, nose, chin, ear
(1987)	Iacono et al.	Breast	(2003)	Chavez et al.	Uterus
(1989)	Frank et al.	Eyes, penis, breast, tooth, rectum	(2003)	Chavez et al.	Uterus

(1989)	Ribbers et al.	Eyeball, nose, tongue, penis, scrotum, teeth, breast	(2005)	Bakheit et al.	Breast, penis, tooth
(1989)	Kroner et al.	Breast	(2005)	Woodhouse	Tongue, teeth, genitals, bladder, breast

Methodological Note: The formation of phantoms after the removal of an internal organ can be distinguished from phantom formation after loss of limbs and other external organs/tissues in that they are felt in terms of *function*. For example, after removal of the uterus, menstrual cramps (Dorpat 1971; Melzack 2001; Ramachandran et al. 1998a), swelling (Scholz 1993), and labor pains (Dorpat 1971; Melzack 2001) have been reported. After removal of the stomach, hunger (Dorpat 1971) and ulcer pains (Dorpat 1971; Melzack 2001) have been reported. After removal of the bladder, distention or full bladder (Brena et al. 1979; Dorpat 1971; Katz 1992b), and sensations of urination (Davis 1993; Dorpat 1971; Katz 1992b; Melzack 2001) have been reported. After removal of the rectum, sensations of defecation (Aglioti et al. 1994; Davis 1993; Dorpat 1971), hard stool (Ovesen et al. 1991), and flatulence (Davis 1993; Dorpat 1971; Ovesen et al. 1991), as well as hemorrhoid pains (Melzack 2001; Ovesen et al. 1991) have been reported. After removal of the appendix, spasmodic pain (Ramachandran et al. 1998a) has been reported.

APPENDIX D: LIST OF RESPONDENTS

UNIVERSITY OF WASHINGTON

Kellye M. Campbell, MN, ARNP	Department of Rehabilitation Medicine
Dr. Joseph M. Czernieki	Department of Rehabilitation Medicine and VA Rehabilitation Research and Development Center
Dr. Dawn Ehde	Department of Rehabilitation Medicine
Dr. Mark Jensen	Department of Rehabilitation Medicine

MADIGAN ARMY MEDICAL CENTER

Dr. Richard Sherman	Department of Orthopedic Surgery

THE UNIVERSITY OF ALABAMA

Dr. Edward Taub	Department of Psychology

YORK UNIVERSITÉ UNIVERSITY
redefine THE POSSIBLE.

Dr. Joel Katz	Department of Psychology and School of Kinesiology and Health Science

McGill

Dr. Ronald Melzack	Department of Psychology

APPENDIX E: GENERAL INTERVIEW PROTOCOL

BIOGRAPHY

1. Background
   - How did you become involved in your field?
   - How did you become interested in phantom limb syndrome?
   - Can you talk specifically about your interest in _____?

WORK

2. Major concerns
   - What would you consider to be the major concerns of your work?
   - How would you relate these concerns to the field more broadly?
   - Over your career, have there been any major shifts in your work in terms of interest of focus?
3. Influences
   - Who do you consider to be the major contributors to the field?
   - Is there anyone in particular who has informed your work in a significant way?
4. Collaboration
   - How do you collaborate with your colleagues?
   - Outside of publications, are there other, possibly informal, means of collaborating?
   - How would you situate the U.S./Canada relative to work being done elsewhere?

KNOWLEDGE

5. Etiology
   - In terms of etiology, what are the major debates?
   - How has your work contributed to these debates in particular?
   - How have these debates informed your work?

6. Pain
   - The literature has noted an increase in phantom limb pain (PLP) prevalence amongst amputees. Why do you think reports of PLP have increased?
   - Why do you think PLP treatments have been so ineffective?
   - How do you conceptualize the relationship between PLS and PLP?
   - How has your work contributed to differentiating and/or elaborating on this relationship?
7. Models
   - Which models inform your work (pain memories, phantom complex, preemptive analgesia, immediate post-operative prosthetic fitting, biopsychosocial perspective, multi-sited pain, pain thresholds, neuromatrix)?

TRAJECTORY

8. Future
   - What do you think are the important questions/problems that your field must address in the future?
   - Do you anticipate any obstacles?

APPENDIX F: INTERVIEW PROTOCOL WITH EDWARD TAUB

BIBLIOGRAHY

1. I'd like to start with your background.
   - Specifically, how did you become interested in phantom limb?
   - Would you consider the study of phantom limb a primary area of interest?

WORK

2. Major concerns
   - What would you consider to be the major concerns of your work?
   - How would you relate these concerns to the field more broadly?
   - Over your career, have there been any major shifts in your work in terms of interest of focus?
3. Influences
   - Who do you consider to be the major contributors to the field?
   - Is there anyone in particular who has informed your work in a significant way?
4. Collaboration
   - How do you collaborate with your colleagues?
   - Outside of publications, are there other, possibly informal, means of collaborating?
   - How would you situate the U.S./Canada relative to work being done elsewhere?

KNOWLEDGE

5. Etiology, Pain and Models

In 1991 you published "Massive cortical reorganization after sensory deafferentation in adult macaques." In this article, you suggested that the results showed a need to reevaluation the upper limit of cortical reorganization.

- Did you suspect at this time that reorganization was still determined by the projection Zones of individual axons?

In 1994 you published "Extensive reorganization of the somatosensory cortex in adult humans after nervous system injury." In this article, you demonstrate that the topographic representation of the face in the SSC had shifted, suggesting the possibility for extensive plastic reorganization in the human cortex. However, you propose that this is not a sufficient cause of phantom facial remapping.

- Why not?

In 1995a you published "Phantom-limb pain as a perceptual correlate of cortical reorganization following arm amputation." Your research tackles the supposition that cortical reorganization could both account for non-painful phantom-limb and have an adaptive function (pain preventing function). You predicted, based on back pain research, that cortical reorganization and phantom pain would be positively correlated, but not non-painful phantoms.

- Why not pain-less phantoms?

In 1995 you published "Cortical reorganization in human amputees and mislocalization of painful stimuli to the phantom limb." You argue that because mislocation was evoked from both sides of the body, using painful stimuli, this suggests involvement of bilateral pathways.

- Mislocation was only produced with painful stimuli?
- Stimulating the R/L face and R/L shoulder produced equally strong sense of the hand?

In 1996 you published "Reorganizational and perceptional changes after amputation." You argue that the extent of reorganization correlates with the number of sites (ipsi and contra lateral) from which painful stimuli evoked sensation. Thus, reorganization is related to painful stimuli and bilateral pathways suggest perceptual changes go beyond what can be explained by shifts in neighboring cortical representational zones.

- Is reorganization related to nociceptive inputs. From the stump, from the referred sites?
- If shifts in cortical representational zones do not produce perceptual changes, what mechanism did you hypothesize to be responsible?

In 1997 you published "Effects of regional anesthesia on phantom limb pain are mirrored in changes in cortical reorganization." You document the use of anesthesia on residual limbs, which produced the elimination of pain and cortical reorganization in 3 of 6 patients. The three subjects whose pain was not reduced experienced no change in the SSC and the pain-free sample experience no change in the SSC.

- Was the extent of reorganization prior to anesthesia less in the pain free sample?
- What do you think about pre-operative preventative analgesia?

In 1997 you published "The relationship of phantom limb pain to other phantom limb phenomena in upper extremity amputees." You demonstrate a correlation between stump pain and phantom pain, and suggest that the incidence of non-painful phantom limb sensations was higher in patients with PLP.

- Do you get the sense that individuals have difficulty discriminating between phantom and stump pain?
- Why do you think phantoms do not develop?
- Why do you think pain can resemble the pain prior to amputation (an ulcer or contorted limb)?

In 1997 you published "Input-increase and input-decrease types of cortical reorganization after upper extremity amputation in humans." You document a case of invasion of the lip, after amputation of the hand, and also an increase in the representation of digits of the intact hand.

- In this case, the reorganization was not bilateral?

In 1998 you published "Cortical reorganization and phantom phenomena in congenital and traumatic upper-extremity amputees." The study demonstrated that both congenital aplastics and amputees without pain had minimal reorganization, while amputees with pain had massive reorganization.

- Those with congenital absence had an inactive area?
- Had any of the subjects had corrective amputations?
- None of your subjects with congenital absence had phantoms; did you consider sampling from those who do?
- Why do you think some people with congenital absence experience phantoms?

- Why do you think people develop supernumerary phantoms?
- Why do you think people develop superadded sensations?

In 1998 in "Plasticity of plasticity? Changes in the pattern of perceptual correlates of reorganization after amputation" you did a follow-up study and found the correlation remained between the amount of reorganization and the number of sites from where pain evoked referred PL. However, topography of the referred sensation had completely changed.

- Can you explain what you mean by changed and suggest why?

In 1999 in "Decrease in phantom limb pain associated with prosthesis-induced increased use of an amputation stump in humans" you compared cosmetic versus functional prosthetic use and found that those with functional prostheses have large decreases in pain but no reduction in phantom sensations or telescoping.

- Was the pain reduction both phantom and stump pain?
- You suggest a countervailing use-dependent afferent-increase. Would you suspect that with increased sophistication of prosthetics, pain could be eliminated?
- The literature on PLP shows an increase from .5% to ~80% today, suggesting the opposite trend. Why do you think that is the case?
- The literature also suggests a decline in PL sensations from a universal phenomenon to ~70% today. How do you explain the trend?

In 1999 in "Constraint-Induced Movement Therapy: a new family of techniques with broad application to physical rehabilitation--a clinical review" you suggest that constraint-induced movement therapy could be helpful for PLP.

- Can you explain how?

In 2000 in "Progressive transneuronal changes in the brainstem and thalamus after long-term dorsal rhizotomies in adult macaque monkeys" you demonstrate that non-painful referred sensations were not associated with a shift in cortical representation of the mouth into the hand. However, in 2000 in "A neural substrate for non-painful phantom limb phenomena" you argue that amputated fingers in the SSC became reorganized and invaded by other fingers of the same hand.

- Does SSC reorganization occur when pain is not present?

FUTURE

6. What direction will your future research take?

APPENDIX G: PHANTOM POPULATIONS

Phantom Populations. References within the medical literature to populations discovered to or known to develop phantoms or NOT develop phantoms by author, year, and number or percentage of cases.

PHANTOM POPULATIONS

Populations Recognized as Potentially Vulnerable to the Manifestation of Phantom Limb

Date	Author	Population	Reported or NOT	Cases
(1941)	Riddoch	Spinal chord injury (SCI)	Reported	
(1941)	Bailey et al.	Congenital Aplasia (CA) *	NOT	
(1944)	Pisetsky	CA	NOT	
(1948)	Browder et al.	Children (CH) under 5	NOT	
(1950)	Kolb	SCI	Reported	
(1951)	Bors	SCI[*]**	Reported	50/50
(1951)	Li	Paralysis (PA)	Reported	1
(1952)	Cook et al.	PA	Reported	2
(1954b)	Hoffman	CA, CH under 5 Leprosy (LY)	NOT	
(1954a)	Hoffman	CA CH under 6	Probably NOT	
(1956)	Weiss	CA CH under 5	NOT	
(1956)	Zuk	CH under 3-5	NOT	
(1956)	Miles	CA CH under 6	NOT	
(1956)	Simmel	LY CH under 5 “feebleminded”	NOT	
(1957)	Pollock	SCI	Reported	Majority/ 213
(1957)	Murphy	CA CH under 6-7	NOT	
(1957)	Murphy	LY CH under 15	Uncommon	
(1958)	Harber	CA	NOT	
(1958)	Woosley	CA	NOT	
(1959a)	Simmel	“Mental defectives”	Reported	8/12
(1959b)	Simmel	Brachial plexus lesions or avulsion (BPL) SCI	Reported	
(1959b)	Simmel	CA, CH under 4-5	NOT	
(1961)	Weinstein et al.	CA	Reported	5/30
(1961)	Simmel	CA	NOT	
(1961)	Esson	CH age 3	Reported	1
(1962)	Simmel	CA without amputation	NOT	
(1962)	Simmel	CH under 10	Reported	68 cases ***
(1962)	Simmel	CH under 4	Rare	
(1962)	Weinstein	SCI	Reported	150/150
(1963)	Frederiks	SCI Cerebral lesions (CL)	Reported	
(1963)	Frederiks[*]****	CA “Gross mental defect” CH young LY	NOT	
(1964)	Weinstein et al.	CA	Reported	13
(1964)	Poeck	CA	Reported	1
(1964)	Pontius	CA	Reported	
(1964)	Gillis	CA CH	NOT	
(1964)	Hoover	CA	NOT	
(1964)	Hoover	CH	Seldom	
(1965)	Van Wirdum	CH	NOT	
(1966)	Maloney et al.	SCI CA	Reported	

(1967)	Simmel	PA BPL CL	Reported	
(1967)	Simmel	CA LY	NOT	CA 20 cases
(1967)	Simmel	CH under 4	Small portion	
(1967)	Vetter et al.	CA	Reported	27
(1969)	Appenzeller et al.	CA	Reported	
(1968)	Gangale	PA, BPL	Reported	
(1968)	Gangale	CA, CH under 5	NOT	
(1978)	Gross et al.	PA	Reported	
(1976)	Price	LY	Reported	90% of 42
(1976)	Hrbek	LY Gangrene (GN) SCI BPL	Reported	
(1976)	Hrbek	CH	Rare	
(1977)	Riscalla	CA	Reported	
(1978)	Melzack	PA	Reported	5
(1978)	Melzack et al.	PA	Reported	
(1978)	Wilson et al.	PA with complete transection	NOT	
(1978)	Wilson et al.	LY	Reported	
(1979)	Connolly	PA	Reported	
(1979)	Mayeux et al.	Multiple Sclerosis (MS), CA	Reported	1
(1980)	Dougherty	PA, CA	Reported	
(1981)	Mihic et al.	SCI	Reported	
(1981)	Abramson et al.	CA	Reported	18/101 children
(1983)	Catchlove	PA	Reported	1
(1983)	Catchlove	CA	NOT	
(1984)	Jensen et al.	PA	Reported	
(1985)	Janovic et al.	CA, CH	NOT	
(1986)	Chong-cheng	CH, CA	Reported	
(1986)	Dernham	CA	NOT	
(1987)	Postone	CA, MS, PA, LY	Reported	
(1987)	Iacono et al.	CA	Reported	
(1989)	Ohry et al.	PA	Reported	
(1989)	Ribbers et al.	SCI, BPL, CA	Reported	
(1989)	Frank et al.	BPL	Reported	
(1989)	Melzack	SCI, BPL, CA, CH under 5	Reported	18% in CA
(1990)	Melzack	CA, BPL, SCI, CH under 6	Reported	
(1990)	Skoyles	CA	NOT	
(1997)	Melzack	CA	Reported	41/125
(1992)	Bailey et al.	CA, CH early	NOT	
(1992)	Lacroix et al.	CH, CA	Reported	1 of CH
(1992)	McGrath et al.	CH	Rare	
(1992)	Melzack	BPL, SCI	Reported	
(1992a)	Katz	BPL, SCI	Reported	
(1992b)	Katz	BPL, SCI	Reported	
(1992b)	Katz	LY	NOT	
(1993)	Halligan et al.	Stroke	Reported	1 surplus
(1993)	Davis	CA, PA	Reported	
(1993)	Stannard	BPL, SCI	Reported	
(1993)	Wesolowski et al.	CA	Reported	
(1994)	Saadah et al.	CA	Reported	4/65
(1994)	Aglioti et al.	BPL, SCI	Reported	
(1994)	Kew et al.	CA	Rare	
(1995)	Lee et al.	LY	NOT	
(1995)	Spitzer et al.	PA	Reported	
(1995)	Spitzer et al.	Low intelligence Senile dementia	NOT	
(1995)	Krane et al.	CH	Reported	24/24
(1996)	Hill et al.	CA	Reported	
(1997)	Williamset al.	SCI, BPL	Reported	
(1997)	Doetsch	BPL, SCI	Reported	
(1997)	Melzack et al.	CA, CH under 6	Reported	41 of 125, 12% of CA, 21% of CH
(1997)	Sherman et al.	SCI	Reported	

(1998)	Dangel	Pediatric Amputees (PED)	Reported	98%
(1998)	Wilkins et al.	CH, CA	Reported	67% of 60, 7.4% of 60
(1998)	Ramachandran et al.	CA	Reported	
(1999)	Hill	SCI, CA	Reported	
(1999)	Wall et al.	PA, SCI, BPL	Reported	
(1998)	Montoya et al.	CA	NOT	
(1998)	Flor	CA	NOT	
(1999)	Grouios	BPL, SCI, CA, CH	Reported	
(2000)	Brugger et al.	CA, SCI	Reported	1 CA
(2000)	Moore et al.	SCI	Reported	9/12
(2000)	Khattab et al.	CA	Reported	
(2001)	Roux	CA	Reported	
(2001)	Rosen et al.	SCI	Reported	
(2001)	Finnoff	CA	Reported	
(2001)	Andre et al.	CA, CH	Reported	
(2001)	Melzack et al.	BPL, SCI	Reported	
(2001)	Le Chapelain et al.	PA	Reported	
(2002)	Oakley et al.	BPL, stroke	Reported	
(2002)	Techanivate et al.	BPL, SCI	Reported	
(2003)	Thomas et al.	PED	Reported	42% of 60
(2003)	Roux et al.	CA	Rare	
(2003)	Giraux et al.	BPL, PA	Reported	
(2003)	Middleton	CA	Reported	
(2005)	Funk et al.	CA	Reported	1
(2005)	Bittar et al.	SCI, CA	Reported	
(2005)	Woodhouse	CA	Reported	

* Congenital aplasia includes both phocomelia (a congential deformity in which the limbs are extremely shortened) and peromelia (congenital malformation).
** Seven patients were identified who were paraplegics with amputation. In some of these patients, the amputation phantom and the paraplegia phantom were perceptually distinct. (Bors 1951:618-9).
*** Of the 68 cases, 20% of children under 2 reported phantoms, 25% between 2-4, 61% between 4-6, 75% between 6-8, and 100% of children between 8-12 (Simmel 1962).
****Fredricks (1963) also claimed that phantoms do not occur under extreme psychological conditions, with the loss of an internal organ, in cases compounded by denial, and in cases of disappearance of memory.

APPENDIX H: PHANTOM QUALITIES

Phantom Qualities. References in the medical literature to the quality of phantom sensations by descriptor and year, organized by consonance with the terminology advanced in the McGill Pain Questionnaire.

PHANTOM QUALITIES

Descriptors Used to Express the Quality of Phantom Sensations

Overlap With MPQ				***No Overlap*** ***With MPQ***	
Descriptor	**Author**	*Descriptor*	**Author**	**Descriptor**	**Author**
Aching	Katz et al. (1991) Marshall et al. (2002) Hsu et al. (2004)	***Pounding***	Montoya et al. (1997)	***Ants Crawling /Crawling /Formicating***	Beller et al. (1951) Varma et al. (1972) Price (1976) Melzack (1989) Lacroix et al. (1992) Davis (1993) Flor (2002) Grusser et al. (2004)
Annoying	Katz et al. (1991) Katz (1992a) Montoya et al. (1997)	***Pressing/ Pressure***	Carlen et al. (1978) Sherman et al. (1979) Spross et al. (1985) Melzack (1989) Melzack (1990) Davis (1993) Weinstein (1998) Hunter et al. (2003) Grusser et al. (2004) Hsu et al. (2004)	***Bruised***	Melzack et al. (1997)
Beating	Katz et al. (1991) Montoya et al. (1997)	***Pricking***	Varma et al. (1972) Carlen et al. (1978) Spross et al. (1985) Katz et al. (1991) McGrath et al. (1992) Katz (1992a) Grusser et al. (2004)	***Clenching Contracting***	Harber (1956) Carlen et al. (1978)
Boring	Wilson et al. (1978)	***Pulling***	Kolb (1950)	***Clutching***	Harber (1956)
Burning	Kolb (1950) Gillis (1964) Brown (1968) Varma et al. (1972) Melzack (1978) Carlen et al. (1978) Sherman et al. (1979) Sherman et al. (1980) Sherman (1980) Shukla et al. (1982) Spross et al. (1985) Sherman et al. (1987) Sherman et al. (1989) Melzack (1989) Katz et al. (1991) Rousenville (1992) Sherman et al. (1992) Katz (1992b) Sherman (1994) Montoya et al. (1997) Hill (1999) Bloomquist (2001) Rusy et al. (2001) Andre et al. (2001) Flor (2002) Hazelgrove et al. (2002) Marshall et al. (2002) Middleton (2003) Hsu et al. (2004) Mortimer et al. (2004)	***Pulsing/ Pulsating***	Harber (1956) Spross et al. (1985) Katz et al. (1991) Hunter et al. (2005)	***Electric current/ shock***	Beller et al. (1951) Harber (1956) Brown (1968) Varma et al. (1972) Carlen et al. (1978) Shukla et al. (1982) Spross et al. (1985) Sherman et al. (1985) Kessel and Worz (1987) Sherman et al. (1989) Katz et al. (1991) Sherman et al. (1992) Sherman (1994) Andre et al. (2001) Flor (2002) Hunter et al. (2005)

	Grusser et al. (2004) Bittar et al. (2005) Harden et al. (2005) Hunter et al. (2005)				
Cramping	Gillis (1964) Brown (1968) Melzack et al (1973) Carlen et al. (1978) Melzack (1978) Sherman et al. (1979) Sherman et al. (1980) Shukla et al. (1982) Sherman et al. (1983) Spross et al. (1985) Sherman et al. (1985) Sherman et al. (1989) Melzack (1989) Katz et al. (1991) Sherman et al. (1992) Rousenville (1992) Katz (1992b) Sherman (1994) Hill (1999) Bloomquist (2001) Rusy et al. (2001) Flor (2002) Hazelgrove et al. (2002) Bergmans et al. (2002) Middleton (2003) Iida et al. (2004) Grusser et al. (2004) Hunter et al. (2005)	***Punishing***	Katz et al. (1991) Katz (1992a)	***Fluttering***	McGrath et al. (1992)
Cruel	Montoya et al. (1997)	***Searing***	Montoya et al. (1997)	***Full***	Katz et al. (1991)
Crushing	Melzack (1978) Carlen et al. (1978) Shukla et al. (1982) Spross et al. (1985) Rousenville (1992) Bloomquist (2001) Andre et al. (2001) Middleton (2003) Hsu et al. (2004) Mortimer et al. (2004)	***Sharp***	Varma et al. (1972) Sherman et al. (1979) Sherman et al. (1983) Katz (1992a) Hsu et al. (2004)	***Furry***	In Der Beek (1953)
Cutting	Shukla et al. (1982) Montoya et al. (1997) Grusser et al. (2004)	***Shooting***	Gillis (1964) Brown (1968) Varma et al. (1972) Sherman et al. (1979) Sherman et al. (1985) Sherman et al. (1989) Melzack (1989) Sherman et al. (1992) Sherman (1994) Rusy et al. (2001) Middleton (2003) Hsu et al. (2004) Mortimer et al. (2004)	***Glowing***	Brugger et al. (2000)
Discomfort-ing	Katz et al. (1991)	***Sickening***	Katz et al. (1991) Katz (1992a)	***Gritty***	Sugarbaker et al. (1984)
Distressing	Katz et al. (1991)	***Smarting***	Blankenbaker (1977)	***Grinding***	Bailey et al. (1992)
Drawing	Bailey et al. (1992)	***Sore***	Katz et al. (1991)	***Gripping***	Harber (1956)
Dreadful	Montoya et al. (1997)	***Squeezing***	Gillis (1964) Brown (1968) Carlen et al. (1978) Sherman et al. (1979) Sherman et al. (1983) Sherman et al. (1985) Katz et al. (1991) Sherman (1994) Rusy et al. (2001)	***Jabs*** ***Knocking***	Carlen et al. (1978) Grusser et al. (2004)

			Hanna et al. (2004) Flor (2002) Harden et al. (2005) Hunter et al. (2005)		
Exhausting	Montoya et al. (1997)	***Stabbing***	Sherman et al. (1979) Shukla et al. (1982) Sherman et al. (1992) Montoya et al. (1997) Bloomquist (2001) Rusy et al. (2001) Flor (2002) Hazelgrove et al. (2002) Hsu et al. (2004) Bittar et al. (2005) Hunter et al. (2005)	***Petrified***	Montoya et al. (1997)
Freezing	Katz et al. (1991)	***Stinging***	Varma et al. (1972) Spross et al. (1985) Marshall et al. (2002)	***Pins and Needles***	Harber (1956) Gillis (1964) Melzack et al (1973) Spross et al. (1985) Melzack (1989) Katz et al. (1991) Wilkins et al. (1998) Hazelgrove et al. (2002) Hunter et al. (2003)
Grueling	Doughtery (1980) Montoya et al. (1997)	***Tearing***	Shukla et al. (1982) Montoya et al. (1997)	***Raw***	Nashold et al. (1969)
Horrible	Montoya et al. (1997)	***Tender***	Melzack et al. (1997)	***Steaming***	Katz et al. (1991)
Hot	Carlen et al. (1978) Sherman et al. (1983) Kessel and Worz (1987) Katz (1992a) Montoya et al. (1997)	***Throbbing***	Harber (1956) Melzack et al (1973) Shukla et al. (1982) Katz et al. (1987) Sherman et al. (1987) Sherman et al. (1989) Katz et al. (1991) Sherman (1994) Montoya et al. (1997) Bloomquist (2001) Flor (2002) Hazelgrove et al. (2002) Middleton (2003) Grusser et al. (2004) Bittar et al. (2005) Harden et al. (2005) Hunter et al. (2005)	***Sticking***	Sherman et al. (1979)
Intense	Montoya et al. (1997)	***Tight/ Tightening***	Spross et al. (1985) Rusy et al. (2001)	***Swollen***	Bors (1951) Simmel (1956) Katz et al. (1991)
Killing	Montoya et al. (1997)	***Tingling***	Gillis (1964) Varma et al. (1972) Melzack et al (1973) Sherman et al. (1979) Sherman et al. (1983) Sherman et al. (1985) Sherman et al. (1987) Sherman et al. (1989) Melzack (1989) Katz et al (1990) Katz et al. (1991) McGrath et al. (1992) Sherman et al. (1992) Katz (1992a) Sherman (1994) Montoya et al. (1997) Wilkins et al. (1998) Flor (2002) Hazelgrove et al.	*Terrible*	Montoya et al. (1997)

			(2002) Hunter et al. (2003) Hsu et al. (2004) Grusser et al. (2004)		
Knifing	Carlen et al. (1978) Spross et al. (1985) Harden et al. (2005)	***Tiring***	Katz et al. (1991) Katz (1992a)	***Twitching***	Kolb (1950)
		Torturing	Doughtery (1980) Montoya et al. (1997)	***Wrinkled***	Weinstein (1961)
Lancinat-ing	Gangale (1968) Brown (1968) Sherman et al. (1980) Kessel and Worz (1987) Rousenville (1992) Bartusch et al. (1996) Hazelgrove et al. (2002) Hsu et al. (2004)	***Twisting***	Kolb (1950) Sherman et al. (1989) Bailey et al. (1992) Bloomquist (2001)		
Nagging	Katz et al. (1991) Katz (1992a)	***Unbearable***	Montoya et al. (1997)		
Penetrating	Montoya et al. (1997)	***Wrenching***	Montoya et al. (1997) Andre et al. (2001)		
Piercing	Grusser et al. (2004)	***Wretched***	Katz et al. (1991) Katz (1992a) Montoya et al. (1997)		

APPENDIX I: PHANTOM PAIN PREVALENCE

Phantom Pain Prevalence. Reports of phantom limb pain prevalence in amputees by author, date and population characteristics when specified.

PHANTOM PAIN PREVALENCE

Reports of Phantom Pain Prevalence Rates

Date	Author	Prevalence	Date Cont	Author Continued	Prevalence Continued
(1947)	Ewalt et al.	8 of 2,284 army hospital amputees	(1993)	Halligan et al.	95%
(1948)	Henderson et al.	1%	(1993)	Davis	85%
(1950)	Kolb	"In only a few cases" (pg 467)	(1993)	Power-Smith et al.	63% severe pain, 30% chronic pain
(1952)	White et al.	"Occurs only in the most unstable of the amputees, those with severe psychoneurotic potentialities" (pg 113)	(1993)	Stannard et al.	2-98%
(1952)	Cook et al.	30%	(1993)	Hill	85%
(1953)	Falconer	1% of amputees the pain is "intense and intractable" (pg 299)	(1993)	Stannard	2-97%
(1954)	Kolb	5% of amputees reported pain when asked.	(1994)	Houghton et al.	78%
(1956)	Simmel	1-2%	(1994)	Martin et al.	1-85%
(1956)	Zuk	2-10%	(1995)	Smith et al.	48% in cancer-related patients between 5-17 years, 12% in trauma
(1956)	Miles	An "abnormal experience" occurring in a "small percentage of amputees" {365)	(1995)	Krane et al.	80%
(1956)	Weiss	97-98% some pain and 1% disabling pain	(1995)	Knox et al.	70%
(1957)	Feinstein	35%	(1995)	Hill et al.	54-85%
(1959)	Simmel	"Probably less than 1%" of amputees (pg 609)	(1996)	Bartusch et al.	2-88%
(1964)	Ament et al.	5-15%	(1996)	Weiss et al.	63-85%
(1964)	Gillis	13%	(1997)	Nikolajsen et al.	70%
(1964)	Kyllonen	1% of cases (traumatic and congenital amputees)	(1997)	Montoya et al.	60-85%
(1966)	Frazier	8-13%	(1997)	Wartan et al.	55% of 590 veterans
(1968)	Brown	5-10%	(1997)	Williams et al.	90%
(1968)	Gangale	1-50%, typical occurrence is 2%	(1997)	Birbaumer et al.	50-80%
(1969)	Appenzeller et al.	19 of 34 (56%) of male amputees	(1997)	Enneking et al.	83%
(1972)	Varma et al.	8 of 20 (40%)	(1997b)	Katz	70%
(1973)	Parks	4-50%	(1997a)	Katz	60% continue
(1973)	Maroon et al.	"Severe pain in the stump and/or phantom limb persists in from 2% to 10% of amputees" (pg25)	(1998)	Jeffries	60-70%
(1976)	Hrbek	5%	(1998)	Flor et al.	50-80%
(1977)	Blankenbaker	35% some pain, 2-10% severe pain	(1998)	Liaw et al.	70%
(1978)	Carlen et al.	33% of 73 traumatic amputees	(1998)	Machin et al.	2-97%
(1978)	Wilson et al.	5-35% stump and phantom pain	(1998)	Ramachandran et al.	70% remain painful
(1978)	Miles et al.	2-50%	(1999)	Hill	0.5-85%
(1979)	Hanowell et al.	2-10% "develop pathologic limb pain" (pg 436)	(1999)	Jenson et al.	70% of amputees irrespective of cause
(1979)	Connolly	"The unlucky lot of a tiny percentage of amputees" (pg	(1999)	Smith et al.	63% of 92

		13)			
(1980)	Brunette	5-10% severe pain	(1999)	Weiss et al.	60-85%
(1980)	Berger	2-5%	(1999)	Pucher et al.	85%
(1980)	Sherman	.4-50% chronic	(1999)	Wall et al.	80%
(1980)	Sherman et al.	.4-50% chronic	(1999)	Grouios	70%
(1980)	Dougherty	35%, 5-10% persisting	(2000)	Willoch et al.	2/3
(1981)	Deuchar	"True phantom pain is a most rare variant" (pg 116)	(2000)	Ehde et al.	0.5-100%
(1981)	Abramson et al.	2% of 2000 amputees over a ten year period	(2000)	Kooijman et al.	76% of 124 upper limb amputees
(1981)	Monga et al.	35% some pain, 5-10% severe pain	(2000)	Condes-Lara et al.	50-80% of traumatic amputees
(1981)	Dawson et al.	"Small number of amputees" (pg 135)	(2000)	Jenson et al.	60-80%
(1981)	Nystrom et al.	5%	(2000)	Ehde et al.	72% of 255
(1981)	Mihic et al.	5-10% severe pain	(2000)	Flor et al.	50-80%
(1982)	Stein et al.	5-10%	(2000)	Leskowitz	50-70%
(1982)	Sternbach et al.	66% of 73, follow-up 73% of 42	(2000)	Rasmussen et al.	50%
(1982)	Shukla et al.	Over 2/3 of 72 amputees	(2001)	Rosen et al.	70-80%
(1983)	Logan	5-10% persistent	(2001)	Finnoff	72-80% postoperatively, 3-10% after several years
(1983)	Sherman et al.	85% of 1200 military veterans	(2001)	Bloomquist	50-70%
(1983)	Jensen et al.	72% of 58 eight days after surgery, 67% six months after	(2001)	Rusy et al.	At least 80%
(1984)	Sugarbaker et al.	70% of 63 hemipelvectomy amputees	(2001)	Topfner et al.	55-80%
(1984)	Sherman et al,	78% veterans			
(1985)	Jankovic et al.	5-10% persistent and disabling pain (pg 433)	(2001)	Lambert et al.	60-70%
(1985)	Krebs	52% of 86	(2001)	Nikolajsen et al.	60-80%
(1985)	Saris et al.	6-60%	(2001)	Lotze et al.	50-80%
(1985)	Jensen et al.	72% of 58 eight days after surgery, and 67% six months after (sample = 1984)	(2001)	Huse et al.	50-80%
(1985)	Sellick	5-80%	(2002)	Whyte et al.	85%
(1985)	Carabelli et al.	90% of 6,300 US veterans	(2002)	Oakley et al.	85%
(1986)	Urban et al.	5-85%	(2002)	Marshall et al.	72% of 478 lower limb amputees
(1986)	Lundberg et al.	2- 48%	(2002)	Van der Schans et al.	49-78%
(1986)	Dernham	67%	(2002)	Dijkstra et al.	72% of 536
(1986)	Carrie et al.	0.4-50%	(2002)	Flor	2-85%
(1986)	Helm et al.	2/3 of 107	(2002)	Halbert et al.	
(1986)	Carrie et al.	0.4-50%	(2002)	Bone et al.	50-67% difficult to treat
(1986)	Dernham	Up to 67%	(2002)	Kiefer et al.	67-87%
(1986)	Lundberg et al.	2-48%	(2002)	Hazelgrove et al.	51% of 124
(1987)	Iacono et al.	85%	(2002)	Miller	As high as 85%
(1987)	Kessel et al.	50-85%	(2002)	Ide et al.	55-59%
(1987)	Postone	2-88%	(2002)	Bergmans et al.	59-85%
(1988)	Saris et al.	6-67% stump and/or phantom pain	(2002)	Jensen et al.	As many as 85%
(1988)	Bach et al.	5-85%	(2003)	Middleton	65-85%
(1988)	Sherman et al.	80% of 11,000 veterans	(2003)	Maier et al.	60-70%
(1989)	Ribbers et al.	1-97%	(2003)	Brodie et al.	85%
(1989)	Sherman et al.	80%	(2004)	Hanna et al.	70% and 50% continued
(1990)	Scatena	59% of 93	(2004)	Karl et al	50-80%
(1990)	Arena et al.	85%	(2004)	Borsje et al	49-82%
(1990)	Melzack	70% within the first few weeks, 50% continued	(2004)	Hanley et al.	60-85%
(1989)	Sherman	80% stump or phantom pain	(2004)	Bradbrook	5-10% chronic
(1990)	Katz et al.	60-72%	(2004)	Hayes et al.	49-88%
(1991)	Bowser	5-85%	(2004)	Siddle	60-80%
(1991)	Fisher et al.	85%	(2004)	Paqueron et al.	Up to 80%
(1991)	Ovesen et al.	50-85%	(2004)	Whyte et al.	60-80%
(1992)	Melzack	60-72%	(2004)	Hsu et al.	Up to 85%
(1992)	McGrath et al.	80%	(2004)	Robinson et al.	72%
(1992a)	Katz	70% continued	(2005)	Bittar et al.	55-85%
(1992b)	Katz	70% continued	(2005)	Harden et al.	50 to 85%

(1992)	Rounseville	80%	(2005)	Woodhouse	60-80%
(1992)	Yuh et al.	35%	(2005)	Stremmel et al.	78% of 39
(1993)	Wesolowski et al.	50%			

Methodological Note: When an article presented a prevalence rate or range based on past reports, I indicated this by simple percentage. When an article presented a prevalence rate based on the study sample I indicated this by percentage followed by the sample size. When an article presented both a prevalence rate based on past reports and a prevalence rate for the study sample, the sample rate was used.

APPENDIX J: TREATING PHANTOM LIMB PAIN

Treating Phantom Limb Pain. References in the medical literature to surgical, pharmacological, psychological, and other treatments for phantom limb pain by efficacy.

TREATING PHANTOM LIMB PAIN

Surgical, Pharmacological, Psychological, and Other Attempted Treatments for Phantom Limb and Phantom Limb Pain

Date	Authors	Treatment	Effectiveness
(1941)	Bailey et al.	**Surgical** Neuroma excision	
(1941)	Riddoch	**Surgical** Neuroma excision	
(1944)	Gutierrez-Mahoney	**Surgical** Cortical ablation	Good in 19, fair in 4, poor in 5
(1946)	Lhermitte et al.	**Surgical** Prefrontal lobotomy	
(1946)	Horraz	**Surgical** Prefrontal lobotomy	
(1946)	Pisetcsky	**Psychological** Electroshock	
(1949)	Russell	**Other** Peripheral stimulation	
(1950)	Stone	**Surgical** Cortical ablation	
(1950)	Scarff	**Surgical** Prefrontal lobotomy	
(1950)	Winston	**Pharmacological** Nerve Block	1 case free of any symptoms
(1950b)	Kolb	**Surgical** Prefrontal lobotomy **Psychological** Psychotherapy, electroshock	Successful
(1950a)	Kolb	**Psychological** Psychotherapy	
(1951)	Li	**Pharmacological** Anesthesia	Some relief
(1951)	Beller et al.	**Surgical** Prefrontal lobotomy	The patients troubles disappeared
(1951; 1952)	White et al.	**Surgical** Cordotomy	11/14 abolished
(1953)	Pool et al.	**Surgical** Prefrontal lobotomy, Cordotomy, Sympathectomy, Neuroma excision **Pharmacological** Neuroma injection **Other** Peripheral stimulation	1 case of highly satisfactory results
(1953)	Falconer	**Surgical** Cordotomy	9/12 greatly benefited
(1954)	Stattel	**Psychological** Psychotherapy	
(1956)	Zuk	**Psychological** Psychotherapy	
(1956)	Miles	**Pharmacological** Chlorpromzine	
(1956)	Blood	**Psychological** Psychotherapy	Benefit
(1958)	Anderson	**Other** Ultrasound	4 cases of some benefit
(1964)	Morgenstern	**Psychological** Sensory deconditioning	3 cases of profound change
(1964)	Gillis	**Surgical** Neuroma excision, Reamputation, Rhizotomy, Cordotomy, Tractotomy, Cortical Ablation **Pharmacologica**l Neuroma injection **Psychological** Psychotherapy, Electroshock **Other** Peripheral stimulation, Muscle exercises	
(1964)	Schwarz	**Psychological** Psychotherapy	
(1965)	Jamieson	**Surgical** Thalamotomy	1 case completely pain free
(1967)	Kuromaru et al.	**Pharmacological** LSD	Significant effects in PL 7/8 and PLP disappeared in 7/8
(1968)	Brown	**Surgical** Neuroma excision, Sympathectomy, Rhizotomy, Cordotomy, Thalamotomy, Cortical ablation, Prefrontal lobotomy **Pharmacologic**al Neuroma injection **Psychological** Psychotherapy, Electroshock **Other** Peripheral stimulation	
(1969)	Nashold et al.	**Surgical** Midbrain Lesions	4/6 cases of successfully reduction
(1969)	Appenzeller et al.	**Surgical** Spinal cord lesions	alter phantom sensations and in some cases may abolish them completely
(1972)	Sugita et al.	**Surgical** Thalamotomy	
(1977)	Blankenbaker	**Surgical** Neuroma excision	

		Pharmacological Neuroma injection **Other** Peripheral stimulation	
(1978)	Almagor et al.	**Psychological** Psychotherapy	
(1978)	Solomon et al.	**Psychological** Hypnosis	PLP and Pl disappeared completely
(1978)	Miles et al.	**Other** Peripheral stimulation	20 cases of excellent to partial relief
(1979)	Brena et al.	**Psychological** Relaxation training, Assertiveness training **Other** TENS	75% reduction
(1979)	Connolly	**Surgical** Rhizotomy, Thalamotomy, Cortical ablation **Psychological** Psychotherapy	All have been tried without much success
(1979)	Hanowell et al.	**Surgical** Rhizotomy, Cordotomy, Cortical ablation, Thalamotomy **Pharmacological** Neuroma injection, Nerve block, Anesthesics, Antidepressants **Psychological** Hypnosis, Distraction, Psychotherapy	
(1979)	Siegel	**Psychological** Hypnosis, Relaxation, Biofeedback	1 case of control
(1979)	Sherman et al.	**Other** Relaxation training	
(1978)	Solomon et al.	**Psychological** Hypnosis	PL and PLP disappeared completely
(1980)	Berger	**Surgical** Neuroma excision, Thalamotomy, Reamputation, Rhizotomy **Other** Peripheral stimulation	8 cases of relief
(1980)	Dougherty	**Psychological** Relaxation, Biofeedback	Reduction in frequency and intensity
(1981)	Monga et al.	**Other** Acupuncture	Quite impressive
(1981)	Omer	**Overview** of Surgical, Pharmacological and Other	
(1982)	Marsland et al.	**Pharmacological** Beta blockers	3 cases very impressed
(1982)	Gross	**Pharmacological** Anesthetics	PLP reduced or abolished
(1982)	Naidu	**Other** TENS	5 cases of alleviation
(1983)	Logan	**Pharmacological** Chlorpromazine	
(1984)	Levine	**Pharmacological** Nerve block **Psychological** Hypnosis, Psychotherapy **Other** TENS, Message	1 case responded strikingly
(1985)	Hunter	**Surgical** Reamputation	Not successful
(1985)	Lundeberg	**Other** Peripheral stimulation	75% of 24 cases of reduction
(1985)	Morse	**Pharmacological** Antidepressants	Improvement
(1985)	Saris et al.	**Surgical** DREZ	Good results in some
(1985)	Spross et al.	**Surgical** Neuroma excision, Sympathectomy, Rhizotomy, Cordotomy, Thalamotomy, Cortical Ablations **Pharmacological** Analgesics, Anticonvulsants **Psychological** Behavioral therapy, Hypnosis, Electroshock **Other** Physical therapy, Peripheral stimulation, Ultrasound	
(1985)	Carabelli et al.	**Other** TENS	3 cases responded
(1986)	Urban et al.	**Pharmacological** narcotics and antidepressants	5 cases of successful management
(1987)	Iacono et al.	**Overview** of Surgical, pharmacological, Other	
(1987)	Postone	**Overview** of Surgical, Pharmacological, Psychological, Other	
(1987)	Kessel et al.	**Pharmacological** Calcitonin	9/10 cases of Immediate relief
(1988)	Patterson	**Pharmacological** Carbamazepine	1 case of successful treatment
(1988)	Saris et al.	**Surgical** DREZ	67% of 22 cases of good relief
(1989)	Rogers	**Pharmacological** Antidepressants	Adequate relief of PLP in young children
(1989)	Jacobson et al.	**Pharmacological** Analgesics	2 cases of favorable response
(1989)	Jacobson et al.	**Pharmacological** Analgesics	1 case of extinguishing pain for 8 hours
(1989)	Katz et al.	**Other** TENS	

(1991)	Fiddler et al.	**Pharmacological** Calcitonin	1 case of PLP alleviation
(1991)	Katz et al.	**Other** TENS	28 cases of decrease
(1992)	Jaeger et al.	**Pharmacological** Calcitonin	90% of 21 cases of significant reduction
(1993)	Stannard	**Surgical** Sympathectomy, Reamputation, Cordotomy, Nerve Block **Pharmacological** Analgesics **Other** Peripheral stimulation	
(1993)	Power-Smith et al.	**Pharmacological** Antidepressant	
(1993)	Wesolowski et al.	**Overview** of Surgical, Pharmacological, Other	
(1995)	Krane et al.	**Surgical** Deep brain stimulation, Spinal Cord stimulation **Pharmacological** Anticonvulsants, Antidepressants, Beta blockers, Nerve block, Anesthetics **Other** Peripheral stimulation, acupuncture, DREZ	
(1995)		**Other** Mirror Box	4/5 cases of relief
(1995)	Omote et al.	**Pharmacological** Analgesics	2 cases of complete long-lasting relief
(1995)	Knox et al.	**Pharmacological** Anesthetics	1 case of pain control
(1996)	Nikolajsen et al.	**Pharmacological** Ketamine	11 patients responded
(1996)	Bartusch et al.	**Pharmacological** Clonazepam	2 cases of effective relief
(1996)	Bartusch et al.	**Overview** of Surgical, Pharmacological, Other	
(1996)	Muraoka et al.	**Other** Hypnosis	1 case of relief
(1997)	Kawamura et al.	**Other** TENS	10 cases of significant relief
(1997)	Williams et al.	**Overview** of Surgical, Pharmacological, Other	
(1998)	Lu	**Other** Acupuncture	1 case of successful reduction
(1998)	Lierz et al.	**Pharmacological** Nerve Block	
(1998)	Ramachandran	**Other** Mirror Box	4/5 cases of relief of pain and telescoping
(1998)	Weinstein	**Overview** of Pharmacological, Psychological, Other	
(1999)	Wall et al.	**Pharmacological** Calcitonin	May be effective
(2000)	Leskowitz	**Other** Therapeutic touch	1 case of successful treatment
(2000)	Ramachandran et al.	**Other** Mirror Box	4/5 cases of relief
(2000)	Rasmussen et al.	**Psychological** Electroshock	2 cases of substantial relief
(2001)	Vichitrananda et al.	**Pharmacological** Midazolam	2 cases of complete relief
(2001)	Finnoff	**Overview** of Surgical, Pharmacological, Psychological Other	
(2001)	Katayama et al.	**Surgical** Deep brain stimulation	19 cases of satisfactory pain control
(2001)	Andre et al.	**Other** Vestibular caloric stimulation	12/12 cases of relief
(2001)	Rosen et al.	**Other** Hypnosis	2 cases of modification and control
(2001)	Bloomquist	**Overview** of Pharmacological, Psychological, Other	
(2001)	Belleggia et al.	**Other** Biofeedback	1 case of complete elimination
(2001)	Huse et al.	**Pharmacological** MST	42% significant reduction
(2001)	Rusy et al.	**Pharmacological** Gabapentin	6/7 cases of resolution
(2001)	Nikolajsen et al.	**Overview** of Surgical, Pharmacological, Other	
(2002)	Oakley et al.	**Other** Hypnosis	2 cases of hypnosis as a useful adjunct to other treatments
(2002)	Abraham et al.	**Pharmacological** Dextromethorphan	3 cases of reduction
(2002)	Bone et al.	**Pharmacological** Gabapentin	14 better than placebo
(2002)	Flor	**Overview** of Surgical, Pharmacological, Other	
(2002)	Hazelgrove et al.	**Overview** of Surgical, Pharmacological,	

		Other	
(2002)	Bergmans et al.	**Pharmacological** Methadone	4 cases of adequate relief
(2003)	Maier et al.	**Pharmacological** Memantine	36 cases no benefit
(2003)	Middleton	**Overview** of Surgical, Pharmacological Other	
(2003)	Giraux et al.	**Other** Matching voluntary movement to illusory	2 cases significant reduction
(2004)	Robinson et al.	**Pharmacological** Amitriptyline	39 cases no benefit
(2004)	Siddle	**Overview** of Pharmacological, Psychological and Other	
(2004)	Hsu et al.	**Overview** of Pharmacological	
(2004)	MacLachlan et al.	**Other** Mirror Box	
(2004)	Robinson et al.	**Pharmacological** Antidepressants	39 cases of no benefit
(2004)	Wiech et al.	**Pharmacological** N-methyl–D-aspartic	8 cases of no effect
(2005)	Bittar et al.	**Surgical** Deep brain stimulation	3 cases of relief
(2005)	Harden et al.	**Other** Biofeedback	5/9 cases of reduction

APPENDIX K: PHANTOMS IN TIME

Phantoms in Time. References in the medical literature detailing the onset, intensity, and/or duration of phantom limb sensation and phantom limb pain, by author and year.

PHANTOMS IN TIME

Phantom Limb Onset, Intensity and Duration

Onset	Author		Onset	Author
Appearing Immediately After Amputation	Esson (1961)	McGrath et al. (1992)	**Appearing Days/Weeks After Amputation**	Gillis (1964)
	Gillis (1964)	Dureja et al. (1992)		Brown (1968)
	Brown (1968)	Wilkins et al. (1998)		Gangale (1968)
	Varma et al. (1972)	Ramachandran et al. (1998)		Skula et al. (1982)
	Hrbek (1976)	Jensen et al. (2000)		Jensen et al. (1983)
	Carlen et al. (1978)	Finnoff (2001)		Postone (1987)
	Wilson et al. (1978)	Dettmers et al. (2001)		Krane et al. (1995)
	Mayeux et al. (1979)	Nikolajsen et al. (2001)		Montoya et al. (1997)
	Sherman et al. (1980)	Roux et al. (2001)		Ramachandran et al. (1998)
	Berger (1980)	Roux et al. (2003)		Wilkins et al. (1998)
	Monga et al. (1981)	Paqueron et al. (2004)		Finnoff (2001)
	Prasad et al. (1982)	Whyte et al. (2004)		Nikolajsen et al. (2001)
	Jensen et al. (1983)	Hsu et al. (2004)		Middleton (2003)
	Spross et al. (1985)	Woodhouse (2005)		Whyte et al. (2004)
	Chong-cheng (1986)			Hsu et al. (2004)
	Dernham (1986)			Hayes et al. (2004)
	Postone (1987)			Harden et al. (2005)
	Bailey et al. (1992)			
Onset	**Author**		**Onset**	**Author**
Appearing Years After Amputation	Simmel (1956)	Montoya et al. (1997)	**Appearing Months After Amputation**	Gillis (1964)
	Murphy (1957)	Wilkins et al. (1998)		Brown (1968)
	Maroon et al. (1973)	Jensen et al. (2000)		Carlen et al. (1978)
	Hrbek (1976)	Finnoff (2001)		Sherman et al. (1980)
	Wilson et al. (1978)	Nikolajsen et al. (2001)		Bailey et al. (1992)
	Berger (1980)	Dettmers et al. (2001)		Dureja et al. (1992)
	Chong-cheng (1986)	Miller (2002)		McGrath et al. (1992)
	Bailey et al. (1992)	Roux et al. (2003)		Wilkins et al. (1998)
	Dureja et al. (1992)	Middleton (2003)		Finnoff (2001)
	Krane et al. (1995)	Whyte et al. (2004)		Nikolajsen et al. (2001)
		Paqueron et al. (2004)		Middleton (2003)
				Roux et al. (2003)
Intensity	**Author**		**Intensity**	**Author**
Increasing in Intensity	Hrbek (1976)	Sherman et al. (1985)	**Growing Spreading Or Lengthening**	Prasad et al. (1982)
	Skula et al. (1982)	Bowser (1991)		Chong-cheng (1986)
	Jensen et al. (1983)	Krane et al. (1995)		McGrath et al. (1992)
	Sherman et al. (1984)	Nikolajsen et al. (2001)		Satchithananda et al. (1998)
Duration	**Author**		**Duration**	**Author**
Appearing Intermittently Periodically or Transiently	Harber (1958)	Frank et al. (1989)	**Enduring or Persisting**	Fredricks (1963)
	Weinstein et al. (1961)	Sherman (1989)		Maroon et al. (1973)
	Price (1972)	Fisher et al (1991)		Hrbek (1976)
	Varma et al. (1972)	Bailey et al. (1992)		Price (1976)
	Carlen et al. (1978)	Bartusch et al. (1996)		Wilson et al. (1978)
	Wilson et al. (1978)	Melzack et al. (1997)		Sherman et al. (1980)
	Berger (1980)	Williams (1997)		Brunette (1980)
	Monga et al. (1981)	Wilkins et al.(1998)		Omer (1981)
	Omer (1981)	Nikolajsen et al. (2001)		Sugarbaker et al. (1984)
	Jensen et al. (1983)	Mortimer et al. (2002)		Janovic et al. (1985)
	Sherman et al. (1983)	Hazelgrove et al. (2002)		Spross et al. (1985)
	Jensen et al. (1984)	Marshall et al. (2002)		Roux et al. (2001)
	Sellick (1985)	Whyte et al. (2001)		Mortimer et al. (2002)
	Spross et al. (1985)	Middleton (2003)		Marshall et al. (2002)
	Chong-cheng (1986)	Hsu et al. (2004)		Roux et al. (2003)
	Postone (1987)	Bittar et al. (2005)		Bittar et al. (2005)
	Patterson (1988)	Woodhouse (2005)		Woodhouse (2005)
Intensity	**Author**		**Duration**	**Author**

Maintaining Constancy	Esson (1961) Gillis (1964) Price (1972) Wilson et al. (1978) Berger (1980) Monga et al. (1981) Jensen et al. (1983) Sherman et al. (1983) Jensen et al. (1984) Morse (1985)	Sellick (1985) Postone (1987) Patterson (1988) Sherman (1989) Frank et al. (1989) Melzack (1997) Williams (1997) Wilkins et al.(1998) Nikolajsen et al. (2001) Mortimer et al. (2002) Hazelgrove et al. (2002) Middleton (2003) Hsu et al. (2004) Hayes et al. (2004)	**Disappearing**	Maroon et al. (1973) Hrbek (1976) Carlen et al. (1978) Sherman et al. (1980) Skula et al. (1982) Janovic et al. (1985) Spross et al. (1985) Carrie (1986) Chong-cheng (1986) Dernham (1986) Postone (1987) Patterson (1988) Bowser (1991) Jensen et al. (2000) Fraser et al. (2001) Roux et al. (2001) Nikolajsen et al. (2001) Roux et al. (2003)
Duration		**Author**	**Duration**	**Author**
Fading	Harber (1958) Hrbek (1976) Price (1976) Blankenbaker (1977) Wilson et al. (1978) Jensen et al. (1984) Janovic et al. (1985) Sellick (1985) Spross et al. (1985)	Dernham (1986) Postone (1987) Patterson (1988) Sherman et al. (1989) Katz et al. (1989) Melzack (1990) Katz et al. (1990) Bowser (1991) Halligan et al. (1993) Ramachandran et al. (1998) Weinstein (1998) Andre et al. (2001) Middleton (2003)	**Reappearing/ Reawakening**	Jankovic et al (1985) Morse (1985) Chong-cheng (1986) Katz et al. (1989) Dureja et al. (1992) Ramachandran et al. (1996) Ramachandran et al. (1998)

APPENDIX L: PHANTOM PREVALENCE

Phantom Prevalence. Reports within the medical literature of phantom limb prevalence in amputees by date and population characteristics when specified**.**

PHANTOM PREVALENCE

The Prevalence Rate of Phantom Limb Among Amputees

Date	Authors	Incidence	Date Cont	Author Continued	Incidence Continued
(1945)	Thomas et al.	100%	(1990)	Scatena	Virtually all acquired amputees
(1946)	Guy et al.	95%	(1990)	Melzack	95-100%
(1950)	Winston	"Usual for the patient" (pg 299)	(1991)	Bowser	84-98%
(1950a)	Kolb	98%	(1991)	Ovesen et al.	80-100%
(1950b)	Kolb	95%	(1992)	McGrath et al.	80%
(1951)	Beller et al.	80-90%	(1992)	Melzack	Universal
(1952)	Cook et al.	90%	(1992)	Bailey et al.	43 of 55 (78%)
(1953)	In Der Beeck	Nearly everyone	(1992a)	Katz	90%
(1955)	Lunn	90% of 235	(1992b)	Katz	80-100%
(1956)	Simmel	98%	(1993)	Wesolowski et al.	Virtually all
(1968)	Gangale	85-98%	(1993)	Stannard	Most amputees
(1964)	Gillis	67% had persistent states and all at one time	(1994)	Martin et al.	1-85%
(1965)	Jamieson	"Probably an almost universal occurrence" (pg 688)	(1994)	Houghton et al.	82%
(1968)	Brown	80-69%	(1994)	Sherman	Virtually all adult amputees
(1969)	Appenzeller et al.	100% of 34 male amputees	(1995)	Baron et al.	Nearly all
(1972)	Varma et al.	19 of 20 (95%)	(1995)	Hill et al.	90-100%
(1976)	Riding	90%	(1995)	Krane and Heller	100%
(1976)	Hrbek	95-100%	(1995)	Spitzer et al.	80-100%
(1976)	Price	Universal	(1996)	Bartusch et al.	100%
(1977)	Blankenbaker	Nearly every amputee	(1997)	Montoya et al.	70-100%
(1978)	Carlen et al.	100%	(1997)	Wartan et al.	Virtually all
(1977)	Kegel et al.	80% of 156	(1997)	Chang et al.	72-97%
(1979)	Hanowell et al.	90-100%	(1998)	Flor et al.	80-100%
(1979)	Connolly	Almost always	(1998)	Ramachandran et al.	90-98%
(1979)	Mayeux et al.	Almost universal	(1998)	Weinstein	Universal
(1980)	Sherman	Virtually all	(1999)	Hill	Virtually everyone
(1980)	Sherman at al.	Virtually all	(1999)	Smith et al.	80% of 92
(1981)	Abramson et al.	"Universally" experienced by "all patients who could understand the question" (pg 108)	(1999)	Grouios	5-100%
(1981)	Wall	100% Israeli soldiers	(2000)	Kooijman et al.	76% of 124 upper limb amputees
(1982)	Stein et al.	Almost universal	(2000)	Ehde et al.	71% of 255
(1982)	Shukla et al.	86% of 72	(2000)	Condes-Lara et al.	80-100% of traumatic amputees
(1982)	Sternbach et al.	100% of 73, follow-up 86% of 42	(2000)	Willoch et al.	Nearly all
(1983)	Jensen et al.	84% of 58 8 days after, 90% 6 months after	(2001)	Finnoff	Nearly universal
(1984)	Sugarbaker et al.	98% of 64	(2001)	Roux et al.	90-100%
(1984)	Levine	Nearly all	(2001)	Fraser et al.	96% of 76 upper-limb amputees
(1984)	Jensen et al.	71% 2 years later, 84% 8 days post-operatively	(2001)	Dettmers et al.	Up to 80%
(1985)	Jankovic et al.	All amputees	(2001)	Dominguez	Universal
(1985)	Krebs	77% of 86	(2001)	Lotze et al.	Virtually all
(1985)	Sellick	Most amputees	(2001)	Rosen et al.	70-80%
(1986)	Buchanan et al.	84%	(2002)	Abraham et al.	2/3
(1986)	Chong-cheng	100% of 25 congenital and	(2004)	Karl et al.	Nearly All

		acquired			
(1986)	Dernham	Nearly universal	(2004)	Paqueron et al.	Up to 80%
(1987)	Iacono et al.	Almost universal	(2004)	Bradbrook	70%
(1987)	Postone	Virtually all amputees	(2004)	Miyazawa et al.	90-100%
(1988)	Patterson	Virtually all amputees	(2004)	Robinson et al.	79%
(1988)	Bach et al.	Almost all amputees	(2005)	Bittar et al.	Almost invariable
(1989)	Ribbers et al.	80-100%	(2005)	Harden et al.	90%
(1989)	Sherman et al.	Virtually all amputees	(2005)	Woodhouse	80-100%
(1989)	Melzack	Universal			

Methodological Note: When an article presented a prevalence rate or range based on past reports, I indicated this by simple percentage. When an article presented a prevalence rate based on the study sample I indicated this by percentage followed by the sample size. When an article presented both a prevalence rate based on past reports and a prevalence rate for the study sample, the sample rate was used.

APPENDIX M: PHANTOM POSTURE

Phantom Posture. References in the medical literature to phantoms described as fixed, relaxed, flexed, or distorted, twisted, or contorted by author and year.

PHANTOM POSTURE

Reports of Fixed, Relaxed, Flexed or Distorted Phantoms

Position	Author		
Fixed	Kolb (1950)	Harber (1958)	Melzack et al. (1997)
	In Der Beeck (1953)	Carlen et al. (1978)	Ramachandran (1998)
	Falconer (1953)	Jankovic et al. (1985)	Ramachandran et al. (1998)
	Zuk (1956)	Iacono et al. (1987)	Hill (1999)
	Harber (1956)	Lacroix et al. (1992)	Fraser et al. (2001)
Relaxed	Kallio (1952)	Jensen (1994)	Melzack et al. (1997)
	Riscalla (1977)	Doetsch (1997)	Hill (1999)
	Ribbers et al. (1989)		Hunter et al. (2005)
Flexed	Kallio (1952)	Stein et al. (1982)	Iacono et al. (1987)
	In Der Beeck (1953)	Lundeberg (1985)	Doetsch (1997)
	Zuk (1956)	Jankovic et al. (1985)	Melzack et al. (1997)
	Bromage et al. (1974)	Postone (1987)	Hunter et al. (2005)
Distorted/ Twisted	Pool et al. (1953)	Mayeux et al. (1979)	Davis (1993)
	Morgenstern (1964)	Spross et al. (1985)	O'Neal et al. (1997)
	Frazier (1966)	Jankovic et al. (1985)	Williams et al. (1997)
	Price (1976)	Iacono et al. (1987)	Weinstein (1998)
	Wilson et al. (1978)	Patterson (1988)	Hill (1999)
		McGrath et al. (1992)	Bradbrook (2004)

APPENDIX N: PHANTOM TELESCOPING

Phantom Telescoping. References in the medical literature to phantom telescoping prevalence rates by author and year.

PHANTOM TELESCOPING

Reports of Telescoping Prevalence Rates

Date	Author	Prevalence
(1951)	Bors	Common
(1972)	Varma et al.	80% of 20
(1978)	Carlen et al.	45% of 50 LL and 62% of 15 upper limb amputees
(1982)	Shukla et al.	2/3 of 72
(1983)	Jensen et al.	30% of 58
(1985)	Krebs	30% of 86
(1992)	Katz	1/3
(1993)	Wesolowski et al.	25-75%
(1997)	Montoya et al.	1/3
(1995)	Spitzer et al.	1/3
(1998)	Ramachandran et al.	~50%
(1999)	Hill	1/3
(2001)	Finnoff	30%
(2002)	Flor	30%
(2003)	Middleton	1/3
(2004)	Bradbrook	1/3

APPENDIX O: USING PHANTOMS

Using Phantoms. References in the medical literature to phantoms being used during various activities or actions by author and year.

USING PHANTOMS

Reports of Phantom Use

Action	Author	
Grasping/Grabbing	Esson (1961) Simmel (1962)	Simmel (1967) Katz et al. (1987) Fraser et al. (2001)
Catching	Harber (1958)	
Counting	Scatena (1990)	Saadah et al. (1994)
Gesticulating	Price (1976)	
Steadying	Simmel (1962) Simmel (1967)	Melzack et al. (1997)
Breaking a fall	Ramachandran et al. (1996)	Ramachandran et al. (1998)
Stepping	Simmel (1962) Simmel (1959) Simmel (1967) Hrbek (1976)	Stein et al. (1982) Postone (1987) Katz et al. (1990) Melzack (1990) Rounseville (1992)
Crawling	(Esson 1961)	
Walking/Running	Blankenbaker (1977) Melzack (1990) Davis (1993) Halligan et al.(1993)	Krane et al. (1995) Melzack et al. (1997) Grouios (1999)
Stretching	Melzack (1990)	Grouios (1999)
Reaching	Harber (1958) Stein et al. (1982) Dernham (1986) Melzack (1990)	Scatena (1990) Katz et al. (1990) Melzack et al. (1997) Ramchandran et al. (1998)
Sitting	Grouios (1999)	
Getting up	Scatena (1990)	
Writing	Hrbek (1976)	
Pointing	Harber (1958)	Melzack et al. (1997)
Waving	Ramachandran et al. (1996)	Ramchandran et al. (1998)
Shaking hands	Ramachandran et al. (1996)	Ramchandran et al. (1998)
Standing	Krane et al. (1995)	Mortimer et al. (2002)
Fending off a blow	Ramachandran et al. (1996)	Ramachandran et al. (1998)

APPENDIX P: PHANTOM NOSOLOGY

Phantom Nosology. References in the medical literature to phantom limb syndrome, phantom limb phenomenon, phantom limb experience or phantom limb sensation by author and year.

PHANTOM NOSOLOGY

Categorizing Phantoms in the Literature

Terminology	Author	
Phantom limb syndrome*	Cook et al. (1952)	Jamison et al. (1979)
	Pool et al. (1953)	Funakawa et al. (1987)
	Hoffman (1954b)	Kroner et al. (1989)
	Miles (1956)	Ailey et al. (1992)
	Finneson et al. (1957)	Martin et al. (1994)
	Hrbek (1976)	Kwekkeboom (1996)
Phantom limb phenomenon**	Jalavisto (1950)	Dorpat (1971)
	Bors (1951)	Price and Twombly (1972)
	Kallio (1952)	Riding (1976)
	Hoffman (1954a)	Price (1976)
	Jalavisto (1954)	Almagor (1978)
	Haber (1956)	Wilson et al. (1978)
	Zuk (1956)	Brena et al. (1979)
	Murphy (1957)	Brunette (1980)
	Pollock (1957b)	Abramson et al. (1981)
	Esson (1961)	Shukla et al. (1982)
	Frederiks (1963)	Doetsch (1997)
	Gillis 1 (1964)	O'Neal et al. (1997)
	Ament et al. (1964)	Price (1998)
	Kuromaru et al. (1967)	Miyazawa et al. (2004)
Phantom limb experience	Lunn (1955)	Appenzeller et al. (1969)
	Simmel (1959)	Rosen et al. (2001)
	Pontius (1964)	
Phantom limb sensation***	Stattel (1954)	Wesolowski et al. (1993)
	Bressler et al. (1955)	Bartusch et al. (1996)
	Weiss (1958)	Weiss et al. (1996)
	Christopher et al. (1963)	Braverman (1997)
	Hirschenfang et al. (1966)	Fommff (2001)
	Maloney et al. (1966)	Rosen et al. (2001)
	Brown (1968)	Techanivate et al. (2002)
	Postone (1987)	Hunter et al. (2003)
	Davis (1993)	Thomas et al. (2003)

Methodological Note: Phantom limb has also been referred to as spectral limb (Pollock 1957a), post amputation limb phantom (Morgenstern 1964), phantom symptoms (Van Wirdum 1965), phantom sensation phenomenon (Gangale 1968), phantom limb consequent (Weinstein, Vetter, Shapiro, and Sersen 1969), and as the "natural" phantom (in contrast to the painful phantom, the phantom that is morphologically non-normal, and the phantom that moves spontaneously) (Harber 1956; Henderson and Smyth 1948; Weiss 1956). Others use phenomenon, sensation, experience and/or syndrome interchangeably (Dureja and Sandhya 1992; Krane and Heller 1995; O'Neill, dePaor, and Mac Lachlan 1997; Paqueron, Leguen, Gentilli, Riou, Coriat, and Willer 2004; Varma, Lal, and Mukherjee 1972).

*Syndrome: The aggregate of symptoms and signs associated with any morbid process, and constituting together the picture of the disease (Stedman 2000:1746). Stedman's Medical Dictionary list hundreds of syndromes but do not include phantom limb syndrome.

**I am distinguishing between the phantom limb phenomenon as a synonym for phantom limb and references to phenomena associated with phantom limb.

***I am distinguishing between the phantom limb sensation as a synonym for phantom limb and references to sensations associated with phantom limb.

APPENDIX Q: PHANTOM BREAST PREVALENCE

Phantom Breast Prevalence. References in the medical literature to phantom breast or Phantom Breast Syndrome prevalence rates by author and year.

PHANTOM BREAST PREVALENCE

Reports of Phantom Breast Prevalence Rates

Date	Author	Prevalence
(1955)	Ackerly et al.	11/55 or 20%
(1956)	Bessler	16/25 or 64%, 5 painful
(1979)	Jamieson et al.	54% of 41, 80% of 54% painful
(1979)	Jameson et al.	10-64%, 18-54% painful review of 6 studies
(1989)	Kroner et al.	26% of 120, one year later 25% of 110
(1990)	Melzack	25%, 13% painful
(1994)	Aglioti et al.	11/15 or 73% spontaneously reported
(1996)	Kwekkeboom	12.7% to 55% review of four studies
(1998)	Weinstein	10%
(1999)	Hill	As high as phantom limb
(2003)	Chavez et al.	50%
(2004a)	Hsu et al.	12-55%
(2004b)	Hsu et al.	12-55%

APPENDIX R: PREDICTING PHANTOM LIMB PAIN

Predicting Phantom Limb Pain. References in the medical literature to factors that either did or did not correlate with the onset of post-operative phantom limb pain

PREDICTING PHANTOM LIMB PAIN

Factors Contributing to the Manifestation of Post-Operative Phantom Limb Pain

Factor	Correlation	No correlation	Notes
Cause of Amputation	Weinstein (1998) Flor (2002b)*	Sherman et al. (1983) Jensen et al. (1984) Sherman et al. (1984) Postone (1987) Davis (1993) Ramchandran et al. (1998) Hsu et al. (2004b)	*Not in cases of congenital absence
Trauma	Brown (1968) Maroon et al. (1973) Sherman et al. (1983) Spross et al. (1985) Spitzer (1995) Ramchandran et al. (1998)		
Surgery	Wilson et al. (1978) Wilkins et al. (1998)		
Blood Clot	Weiss et al. (1996)		
Gangrene	Weiss et al. (1996) Nikolajsen et al. (2001)		
Disease		Pucher et al. (1999)	
War-related	Morgenstern (1970)		
Amputation Factors			
Level of amputation	Stein et al. (1982) Sugarbaker et al. (1984)* Rousenville (1992) Weiss et al. (1996) Bartusch et al. (1996) Finnoff (2001) Fraser et al. (2001) Borsje et al. (2004) Bitters et al. (2005)	Sherman et al. (1984) Jensen et al. (1985) Spross et al. (1985) Postone (1987) Ramchandran et al. (1998) Kooijman et al. (2000) Nikolajsen et al. (2001) Fraser et al. (2001) Hazelgrove et al. (2002)	* 0% BK, 19% AK, 40% hip disarticulation, 68% hemipelvectomy
Extremity	Brown (1968)* Omer (1981)** Dijkstra et al. (2002)*** Borsje et al. (2004) Bitters et al. (2005)****	Spross et al. (1985) Nikolajsen et al. (2001)	* More common in upper-limb **Upper-limb pain is stronger and longer lasting *** More common in lower limb **** More common in lower limb
Pre-amputation chemotherapy	Smith et al. (1995)	Hsu et al. (2004a)	
Pre-amputation surgeries	Morgenstern (1970) Dernham (1986) Postone (1987) Rousenville (1992) Finnoff (2001)		
Pre-amputation pain	Maroon et al. (1973) Sunderland (1978) Wilson et al. (1978) Jensen et al. (1983) Dernham (1986) Postone (1987) Bailey et al. (1992) Dureja et al. (1992) Rousenville (1992) Krane et al. (1995) Kwekkeboom (1996) Ramchandran et al. (1998) Nikolajsen et al. (2000) Finnoff (2001)	Sherman et al. (1984) Wall et al. (1985) Fraser et al. (2001) Middleton (2003)	

	Bloomquist (2001) Melzack et al. (2001) Flor (2002b) Halbert et al. (2002) Bone et al. (2002) Flor (2002a) Middleton (2003) Borsje et al. (2004)		
Pre-amputation lasting illness	Dernham (1986) Finnoff (2001) Hsu et al. (2004a)*		*Pre-amputation breast pain
Poor wound healing	Rousenville (1992) Finnoff (2001)		
Past Illnesses	Parks (1973)* Rousenville (1992)		*Pain persisting more than a year
Limb dominance	Fraser et al. (2001)	Jensen et al. (1985) Kooijman et al. (2000) Hazelgrove et al. (2002) Hsu et al. (2004a)*	*Correlates with side of mastectomy
Bilateral amputation	Dijkstra et al. (2002) Bitters et al. (2005)		
Temporal Factors			
Time since amputation		Sherman et al. (1983) Sherman et al. (1984) Pucher et al. (1999)	
Age at time of amputation	Flor (2002b)*	Sherman et al. (1983) Sherman et al. (1984) Davis (1993) Pucher et al. (1999) Kooijman et al. (2000) Mortimer et al. (2002)	*Less likely in the very young
Time to rehabilitation	Rousenville (1992)	Hazelgrove et al. (2002)	
Time to prosthetic fitting	Rousenville (1992)		
Prosthetic use	Fraser et al. (2001)*	Sherman et al. (1983)	*Prosthetic wearers experienced pain more frequently
Demographics			
Age	Morgenstern (1970) Maroon et al. (1973)* Riding (1976)** Kegel et al. (1977) Wilson et al. (1978) Hanowell et al. (1979) Brunette (1980) Weiss et al. (1996)*** Fraser et al. (2001)**** Roux et al. (2003) Hsu et al. (2004a)*****	Parks (1973) Sherman et al. (1983) Jensen et al. (1984) Sherman et al. (1984) Postone (1987) Ramchandran et al. (1998) Nikolajsen et al. (2001) Hazelgrove et al. (2002)	* More common in older amputees ** Youth protects against PLP ***Older amputees had higher thresholds ****Younger amputees had more pain ***** Phantom breast pain is higher in younger women
Gender/Sex	Connolly (1979)* Weiss et al. (1996)** Hill (1999)*** Gallagher et al. (2001)**** Borsje et al. (2004)*****	Parks (1973) Jensen et al. (1985) Postone (1987) Davis (1993) Ramchandran et al. (1998) Kooijman et al. (2000) Nikolajsen et al. (2001) Hazelgrove et al. (2002)	*Women complain more and were given stronger analgesics **Women report higher intensity and men had a higher thresholds ***Incidence is greater in men ****Women more often report pain and at higher intensities *****Women reported higher frequency
Ethnicity/Race	Weiss et al. (1996)*	Davis (1993)	*Caucasians report higher levels of pain and had higher thresholds
Culture	Hanowell et al. (1979)*		*Most frequently in elder, skilled workers without higher education
Social class/SES	Riding (1976) Hanowell et al. (1979)*	Parks (1973) Ramchandran et al. (1998)	*Pain declines with increase in class status

	Postone (1987)		
Occupation/ Occupational Status	Parks (1973)* Riding (1976) Hanowell et al. (1979)* Brunette (1980)		*Unemployment was correlated with pain **Pain declines with occupational level
Education	Riding (1976) Hanowell et al. (1979)*		*Pain declines with increased education
Intelligence	Brunette (1980)		
Marital status		Postone (1987) Ramchandran et al. (1998)	
Military status		Carlen et al. (1978) Sherman (1985) Sherman et al. (1987) Postone (1987) Davis (1993) Nikolajsen et al. (2001)	
Psychological Factors			
Attitude toward medical facility		Sherman et al. (1984)	
Insecurity	Parks (1973)		
Rigid	Parks (1973)		
Rigid	Parks (1973) (1979)		
Self-Reliant Personality	Parks (1973)		
Perfectionism		Parks (1973)	
Knowing/seeing an amputee	Hoffman (1954) Kolb (1952) Simmel (1956) Weiss (1956) Varma et al. (1972) Solomon and Schmidt (1978)	Sherman et al. (1983)	
Depression/Recurrent depression	Parks (1973) Morgenstern (1970)		
Anxious/Worried		Parks (1973)	
Neuroticism	Morgenstern (1970)		
Discussing PLP w/family	Fraser et al. (2001)		
Discussing PLP w/providers		Fraser et al. (2001)	
Personal problems	Dawson et al. (1981)		
Pain sensitivity		Parks (1973) Sherman et al. (1983)	
Preparedness for operation		Parks (1973)	
Physiological factors			
Health status		Nikolajsen et al. (2001)	
Phantom limb	Carlen et al. (1978)* Montoya et al. (1997) Borsje et al. (2004)	Weinstein (1998) Fraser et al. (2001)	*Pain follows rather than proceeds PL
Phantom telescoping	Finnoff (2001)		
Stump pain	Morgenstern (1970) Parks (1973) Carlen et al. (1978) Wilson et al. (1978) Jensen et al. (1983) Sherman et al. (1983) Sherman et al. (1984) Jensen et al. (1985) Sherman et al. (1989) Montoya et al. (1997) Nikolajsen et al. (1997) Ramchandran et al. (1998) Kooijman et al. (2000) Nikolajsen et al. (2001) Hazelgrove et al. (2002) Middleton (2003) Borsje et al. (2004) Whyte et al. (2004) Mortimer et al. (2004)	Fraser et al. (2001)	
Presence of trigger points	Fraser et al. (2001)		
Neuroma	Morgenstern (1970) Postone (1987)		

APPENDIX S: PROVOKING PHANTOM LIMB

Provoking Phantoms. References in the medial literature to the onset or reappearance of phantom limb or phantom limb pain by precipitant and date.

PROVOKING PHANTOM LIMB

Factors Contributing to Onset or Reappearance of Phantom Limb or Phantom Limb Pain

Date	Author	Precipitant
(1950)	Kolb	PL evoked by illness, stump stimulation or prosthetic fitting, sexual intercourse
(1951)	Toker	PLP evoked by spinal analgesia
(1951)	Harrison	PLP evoked by spinal anesthesia
(1954)	Hoffman	Lower PL evoked by urination in 90% of cases
(1956)	King	Phantom sciatica evoked by back injury
(1956)	Miles	PLP evoked by spinal anesthesia
(1957)	Finneson et al.	PLP evoked by herniated disc
(1957)	Buxton	PL induced by fracture of femur of the stump
(1958)	Harber	PL recurred with urination, defecation and smoking
(1961)	Weinstein et al.	PL evoked by writing, playing ball, frightened, physically exerted or falling asleep
(1963)	Frederiks	PL evoked by angina
(1964)	Dejong	PL evoked nerve block
(1964)	Gills	PLP evoked by angina, carcinoma of the prostate, ulcer, colitis
(1966)	Maloney et al.	PL evoked by palpitating an inflamed prostate
(1966)	Frazier	PL exacerbated by fatigue, pain, emotion, urination, defecation, sexual intercourse, smoking, seeing another amputee, injury, weather
(1969)	Weinstein et al.	PL evoked by epileptic attack
(1969)	Appenzeller et al.	PL induced by sexual intercourse, urination, bumping the stump and defecating
(1972)	Varma et al.	PLP exacerbated by seeing another amputee
(1971)	Maloney	PL induced urinary flow
(1973)	Melzack	PL induced by full bladder or anger
(1973)	Maroon et al.	PLP evoked by movement, anxiety, intercourse, micturition, defecation and temperature change
(1976)	Hrbek	PLP exacerbated by sleepiness, sudden waking, warmth, alcohol, emotion, prosthetic use
(1976)	Riding	PLP induced by anger or orgasm
(1978)	Wilson	PLP evoked by herpes zoster
(1977)	Riscalla	PL evoked by seeing another amputee
(1978)	Miles et al.	PLP induced by urination, organism
(1978)	Carlen et al.	PL/PLP induced/exacerbated by ejaculation, urination and defecation, falling asleep or hitting the stump
(1979)	Mayeux et al.	Supernumerary PL evoked MS
(1979)	Connolly	PLP induced/exacerbated by knocking the stump, full bladder, pain in the opposite limb, and strong emotions like anger.
(1981)	Mihic et al.	PL/PLP evoked epidural anesthesia
(1982)	Stein et al.	PLP evoked/induced by urination, defecation, ejaculation, cold, herpes zoster, stump pathology, prosthesis, disc hernia
(1983)	Mackenzie	PLP evoked by spinal anesthesia
(1983)	Sherman et al.	PLP evoked or exacerbated by weather, nerves, stump spasm, prosthesis, fatigue, stump problems, elimination, hemorrhoids, chronic back pain
(1984)	Sherman et al.	PLP evoked by weather, prosthesis, stress, fatigue, intestinal and back problems, stump problems
(1984)	Sugarbaker et al.	PLP evoked by cancer recurrence
(1984)	Murphy et al.	PLP evoked by spinal anesthesia
(1985)	Sellick	PLP evoked by spinal anesthesia
(1985)	Spross et al.	PLP induced by ejaculation, defecation, urination, coughing or yawning
(1985)	Janovic et al.	PL reoccurred after tardive dyskinesia
(1985)	Sherman et al.	PLP exacerbated by weather, prosthesis, stress, fatigue, intestinal and back problems, stump problems
(1986)	Chong-cheng	PL evoked by acupuncture and labor
(1986)	Dernham	PLP induced/exacerbated by urination, catheterization, defecation, prostate exam, smoking, organism, cold weather, stress
(1987)	Sherman et al	PLP evoked by stress, fear, anxiety
(1988)	Koyama et al.	PLP evoked by spinal analgesia
(1989)	Sherman et al.	PLP evoked by fatigue, stress, weather
(1990)	Scatena	PLP evoked by menstruation
(1988)	Tourian et al.	PL movement induced by TENS
(1988)	Patterson	PL induced by stress, cold, local irritants

(1988)	Koyama et al.	PLP evoked by spinal anesthesia
(1992)	Yuh et al.	PL evoked by MRI
(1992)	Tessler et al.	PLP evoked by spinal anesthesia
(1992)	Lacroix et al.	Supernumerary PL evoked after amputation of a congenitally defective limb
(1992)	Dureja et al.	PLP evoked during labor
(1992)	Bailey et al.	PLP evoked by blow to the stump 25 years after amputation
(1992)	Rounseville	PLP induced by urination, defecation, ejaculation, pressure, cold, angina and herpes zoster
(1993)	Davis	PLP induced/exacerbated by emotional stress, exposure to cold, local irritation to the stump
(1994)	Martin et al.	PLP evoked by angina
(1994)	Saadah et al.	PL evoked by falling off a horse, cyst removal, and removal of toenails
(1995)	Lee et al.	PLP reoccurred after nerve block and anesthesia
(1995)	Knox et al.	PLP provoked by chemotherapy
(1996)	Uncles et al.	PLP reoccurred after epidural anesthesia for caesarean section
(1997)	Melzack et al.	PL induced by thinking or talking about the phantom, removing or donning a prosthetic, irritating the stump, stress, cool weather, activity, and anything resembling a snake
(1997)	Williams et al.	PLP induced back scratching, weather, irritants
(1997)	Braverman	PLP evoked by carpel tunnel syndrome
(1997)	O'Neal et al.	PL growth after amputation of congenital limb
(1997)	Chang et al.	PLP exacerbated by spinal metastasis
(1998)	Satchithananda et al.	PL lengthening subsequent to heart transplant
(1998)	Ramachandran	PL reoccurred with mirror box
(1999)	Grouios	PL evoked by spinal anesthesia
(2000)	Khattab et al.	PLP evoked by paclitaxel therapy
(2001)	Dominguez	PLP reoccurred during anesthesia
(2001)	Vichitrananda et al.	PLP evoked by spinal anesthesia
(2001)	Rosen et al.	PLP exacerbated by cold weather and stress
(2001)	Finnoff	PLP exacerbated by stress, cold, irritants, organism, catheterization, defecation, urination, smoking
(2001)	Melzack et al.	PLP reoccurred after injection into the stump
(2001)	Nikolajsen et al.	PL exacerbated by stress, attention, urination, stump message, weather, prosthetic
(2001)	Belleggia et al.	PLP exacerbated by cold environments
(2002)	Flor	PLP exacerbated by weather, pressure, stress
(2002)	Abraham et al.	PLP reoccurred by stress, urination, defication
(2002)	Miller	PLP evoked after aneurysm
(2002)	Hazelgrove et al.	PLP exacerbated by weather, prosthesis use, emotion, attention
(2004)	Iida et al.	PLP reoccurred after cervical spinal decompression
(2004)	Hsu et al.	PLP exacerbated by distress, exercise and touch
(2004)	Paqueron et al	PLP evoked by regional anesthesia

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