1. CHAPTER ONE:

INTRODUCTION

"All perception of truth is the detection of an analogy."
Henry David Thoreau

> 'Biotechnology' has become the overarching term for a wide variety of new technologies, of which genetic engineering and the cloning of animals are only two of the best-known examples. What all these technologies have in common is the simulation and manipulation, whether in the laboratory or industrial setting, of fundamental life processes at the cellular and molecular levels (Tokar, 2001: 3).

Biotechnology, argues Tokar, "has come to represent the fullest realization of technological power for human benefit" (ibid: 2). Just a few of the benefits that such technologies are said to usher in for the future include: agriculture that is less damaging to the environment; medical treatments that are more personalised and efficacious; "cures for intractable genetic diseases and, ultimately, an epochal transcendence of human limitations such as infertility and ageing" (ibid). Biotechnology may also present "the only possible solution to persistent problems of hunger, disease, population growth and environmental pollution" (ibid).

> Today, at the start of a new millennium, questions about biotechnology and genetic engineering have come to occupy a central place in shaping public debates about the future. With profound implications for our health, the environment … [these] genetic technologies have aroused worldwide attention. … Not since the dawn of the nuclear age has a technology come to represent such diametrically opposite views of the future. … Indeed, commentators well across the spectrum of opinion often appear to agree that the twenty-first century will be the Age of Biotechnology (ibid: 1-2).

I hope that this introduction excites the reader as to the possibilities for the future (and even the present) that such technologies seem to hold. However, when considering the power that biotechnology seems to be wielding with regard to society,[1] one should not forget the

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[1] Various theorists have explored the way in which science has been granted a privileged status as a means of understanding the 'truth' about complex subjects, and is afforded respect from the general public and mass

potential dire consequences that could emanate as a result of an incomplete understanding of all the interrelated functions of the body, or even the food sources required for the body.[2] How much more perilous would the consequences be, if the fundamental understanding of DNA (which composes genes) were based on a heterogeneous combination of cultural, social, scientific, political, economic and metaphorical considerations?

Well, this is already the case for DNA and concomitantly for the discipline of genetics. With genetics' influence in all the above described areas I feel that it is important to examine how the present conceptualisations of DNA and genetics developed, as well as the effects of these conceptualisations.

Due to the increasing import of genetics in our lives, not only are scientific conceptualisations of the subject important but popular representations are also significant, since how the general public perceives genetically modified foods will affect food trends and farming practices. But how would one go about examining the way in which genetics is understood in scientific as well as popular sectors of society? I have decided to achieve this by using metaphor as my lynchpin with which to straddle scientific and popular representations of molecular biology. I have chosen metaphor because of its overwhelming usage in the formalisation of concepts, and its ability for portraying (scientific) information and making ideas more comprehensible to scientists and the general public. Thus, in order to explore how areas of molecular biology are conceptualised I will be examining the use of metaphor in representations. My focus will be on scientific and popular representations[3]

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media. My research draws on and assumes the work of numerous cultural and gender theorists who have addressed the legitimacy and authority that is bestowed on science in Western influenced society. For instance, Hacking, (1983), and Green, (1981), discuss the repercussions of scientific ideology within society, while Kuhn, (1970), explores how scientific paradigms arise. Haraway, (1992), and Keller, (1983b), examine the links between science, power and society. Whereas, Martin, (1989), and Stepan, (1990), present specific examples that illustrate how scientific ascendancy has affected perceptions of gender.

[2] I am referring here to concerns surrounding the possible ramifications stemming from the (mis)use of genetically modified crops, otherwise known as 'Frankenstein foods', as well as human cloning.

[3] I have used the term 'popular representations' for the purposes of this research as a designation to encompass the wide body of representations available to the public at large, which synergistically aid in determining cultural, social and political perceptions of scientific endeavors and their influences (in this case, with respect to the scientific disciplines of genetics and immunology). My examples are mainly textually derived, and I realize that "texts are social spaces in which two fundamental social processes simultaneously occur: cognition and representation of the world, and social interaction" (Fairclough, 1995: 6). It is this "cognition," "representation" and "social interaction" that I have investigated through the utilization of metaphors. In the Foucaultian sense "texts in their ideational functioning constitute systems of knowledge and belief," and "any part of any text can fruitfully be examined in terms of the co-presence and interaction of these constitutive processes" (ibid). Since the "interplay between cognition and interaction … is a crucial feature of textual practice" I have (in the subsequent chapters) analyzed the "implicit content" of a wide-

that are presented to the public, through newspapers, magazines and educational pamphlets.[4] Thereby, I will not be limiting myself to purely scientific texts but rather take into account a broader audience (beyond that of the small scientific community, and peer reviewed journals). However, I will also consider texts aimed at scientists, such as textbooks and journals, as well as texts intended for interested laymen and women (as in the journal *National Geographic*). By analysing both scientific and popular representations, through the utilisation of metaphor, the interconnectivity of the relay of complex scientific ideas between science and the mass media, and their respective target audiences can be more inclusively ascertained.

The foremost reason that I will be focusing specifically on the use of metaphors in science is because of my background knowledge in this field. I am a recently graduated scientist with a BSc in genetics and biochemistry, and a BSc Honours (with distinction) in microbial genetics. As part of my tuition I have also completed undergraduate courses that dealt with immunology, microbiology and virology. This, I feel, has indelibly given me a perspective into scientific thinking and experimental methodology procedures. Yet, as someone trained in science, I was unaware of the philosophical and discursive issues that are pertinent to it. During my studies, the use of analogy in facilitating the comprehension of scientific ideas and, consequently, scientifically 'true' concepts, literally 'went without saying'. Hence, (because nothing was said) I took for granted the role of the metaphoric in structuring scientific 'fact'. Subsequently, after reading the works of people such as Nancy Leys Stepan, (1990), it was a revelation and a shock to realise how I had been taking figurative explanations literally. It also led to my interest into how certain metaphors define scientific facts, through their predominance in both scientific and popular representations.

My further realisation (and incentive to pursue this research) was that if metaphor was just a means of facilitating understanding and yet, I was using it to construct my fundamental conceptual knowledge of science, what would the implications of that be? Additionally,

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ranging number of texts in order to obtain "valuable insights into what is taken as given, as common sense … implicit assumptions" of scientific 'fact', which (as will become apparent) are based on concept metaphors (ibid).

[4] Due to the restrictions on the length of this research report I have had to limit my discussion to the printed media, thus elements of film and animation representations could not be included. The printed media was specifically chosen, since scientists do not generally produce films aimed at other scientists regarding their latest research. Instead, scientists mainly publish scientific articles. Thus, I felt that the printed media serves as an excellent format, throughout this research, to track how the representation of scientific concepts interrelate between anything from scientific journals to, even, books aimed at children.

what could the ramifications be when applied to the biotechnological sciences? After all, such technology has import for disease control, and even human cloning. In other words, metaphors used to conceptualise scientific concepts were affecting scientists' perceptions of what was occurring at a molecular level in organisms. Therefore, these perceptions were ultimately influencing decisions over life and death. These considerations finally led me to question if it would be possible to reconcile the use of metaphor in explaining scientific concepts, without becoming reliant on its usage in predicating the understanding of certain concepts? However, before these intriguing questions can be answered, the basics of metaphor must first be addressed.

To begin to understand how metaphors operate within science it should be realised that such "analogies are fundamental to science" (Stepan, 1990: 39). In fact, Nancy Leys Stepan quotes Richard Boyd who explains that metaphors "are 'irreplaceable parts of the linguistic machinery of scientific theory', since cases exist in which there are metaphors used by scientists to express theoretical claims 'for which no adequate literal paraphrase is known' " (ibid). Indeed, "some philosophers of science are now prepared to assert that metaphors and analogies are not just psychological aids to scientific discovery, or heuristic devices, but constituent elements of scientific theory" (ibid).[5]

There is nothing 'wrong' with the use of metaphor in science, rather, metaphors "through their capacity to construct similarities" are useful, and even required, in order to "create new knowledge" (Stepan, 1990: 48). Nevertheless, it is should be realised that "the full range of similarities brought into play by a metaphor or analogy is not immediately known or necessarily immediately predictable" (ibid). This is a valuable characteristic of metaphor in that "the metaphor, therefore, allows for 'discovery' and can yield new information through empirical research" (ibid). The problem emerges when "metaphor has become so woven into our culture and linguistic system as to have lost its obviously metaphorical quality and to seem a part of 'nature' " (ibid). When the metaphor becomes so entrenched as to be unrecognisable, then "it is the metaphor" that is allowing "us to see similarities that the metaphor itself helps to constitute" (ibid). The repercussion is that

> because metaphor or analogy does not directly present a preexisting nature but instead helps 'construct' that nature, the metaphor generates data that conform to it,

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[5] These aspects of metaphor and its relation to science will be discussed more substantially in the next chapter.

> and accommodates data that are in apparent contradiction to it, so that nature is seen through the metaphor and the metaphor becomes part of the logic of science itself (ibid: 51).

When the metaphors become part of the logic of science in the locale of molecular biology, which informs our comprehensions of self, then their presence should be monitored even more carefully. Nevertheless, the metaphors applied to genetics and immunology are so omnipresent that they largely go unrecognised or at least generally unacknowledged, especially in popular representations. Since such biotechnological applications hold so much power for the future, it is important to determine the predominant metaphors that are helping to 'construct' the 'reality' of these disciplines.

Biotechnology encompasses many recent technologies, however, they are all fundamentally based on genetics and areas of immunity. Therefore, I have chosen the indispensable, yet, topical and highly influential scientific subjects of genetics and immunology with which to study the implications of metaphor in science, and science translated into educational and popular arenas. Besides my training, the prime reason that such scientific fields were selected to highlight my discussion is that both disciplines have a profound effect on our understanding of ourselves and our world.[6] These scientific subjects also interlink, as both deal with disease. For instance, the immune system is the obvious area that maintains health

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[6] I would like to point out that this sense of the world and ourselves is influenced by many factors, in terms of work, discipline, development, power and knowledge. Or, to put it another way, these disciplines (such as genetics and immunology) are caught up in a power knowledge nexus, which Foucault refers to (through Jones) as the "social and cultural influences on the body" which "define its universal, natural features in different ways" (2003: 124). Jones describes it as "Foucault's sociology of the body" which "concentrates on the way in which cultural definitions of normal and abnormal behaviour regulate people's ideas about their bodies and what they should and should not do with them" (ibid). Thus, what we claim to know about the world, our knowledge of it and our bodies, is affected by "the discourses that dominate a time in history and a place in the world," and this allows people to obtain "their mind-set, or world-view" (ibid: 125). (I discuss Foucault's notion of "discourse" in footnote 8). This also means that "we are only able to know truth and falsehood, right and wrong, as a result of the influence of discourses of some kind or other" and therefore, "we are clearly hamstrung and restricted by the particular discourses we encounter" (ibid).
Foucault also felt that "the most important discourses ... are those which regulate both *the social body and the individual body*" (my emphasis, ibid: 126). While, "Western medicine provides us with the best example of a modern form of knowledge that exercises both considerable bio-power and anatomo-power" because,

> to understand life … you only need to realize the huge extent to which we … humans have become subject to the power of medical definitions of normality and deviance – that is the extent to which we have become so preoccupied with our bodily health (ibid).

To Foucault this is "a form of *surveillance* to ensure the conformity of a population to particular notions of truth and falsehood, good and bad" (original emphasis, ibid). This "medicalization of ... life … refers to the way in which universally experienced features and functions of human existence are ... appropriated and commandeered by medicine" and then "defined in terms of essential categories of health and illness and managed accordingly" (ibid: 129).

in humans. However, genetic engineering is also being used to alter the levels of immunity in people; especially those with autoimmune disorders.

In my dissertation I shall argue that genetics and immunology are popularly represented through the broad concept metaphors of information coding and militarization, respectively, and that these concept metaphors arise from the influence of society in science. My exploration surrounding these concept metaphors will not be quantitative with regard to the number of examples, but rather, a qualitative investigation of examples based on their persistent usage in popular culture. These concept metaphors are essentially Western in origin and, yet, are widely dispersed in South African popular media.

To frame my research I utilise the work of Nancy Leys Stepan, and Lakoff and Johnson for their insights into the use of metaphor in science and the workings of conceptual metaphors. Also useful in understanding metaphor and its implication in biology is Susan Oyama. In my subsequent chapters I will be employing feminist and cultural discussions along the lines of Donna Haraway, Katherine Hayles, Evelyn Fox Keller, Emily Martin and Ona Nierenberg. I will offer a brief explanation as to why each of these theorists has been chosen.

Haraway is important due to her analysis of "the potent and polymorphous object of belief, knowledge, and practice called the immune system," where she explores the binary between 'self' and 'other' in immunological discussions (1991: 204). She also examines how:

> the immune system is a map drawn to guide recognition and misrecognition of self and other in the dialectics of Western biopolitics. That is, the immune system is a plan for meaningful action to construct and maintain the boundaries for what may count as self and other in the crucial realms of the normal and the pathological (1991: 204).[7]

Donna Haraway and Emily Martin both discuss the impact that the portrayal of molecular biology has on society and vice versa. Thus, their work forms a useful basis for my examination of the representations of molecular biology. Martin, for instance, gives an overview of the metaphorical nature of molecular biology:

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[7] Besides Haraway's figurative discussion of 'self' and 'other' in terms of immunity, it was also these concerns that on a broader scale became politically skewed in apartheid South Africa. Therefore, in a South African context, she will serve as an important literary reference source.

> Development of the new molecular biology brought additional metaphors based on information science, management, and control. In this model, flow in information between DNA and RNA leads to the production of protein. Molecular biologists conceive of the cell as 'an assembly line factory in which the DNA blueprints are interpreted and raw materials fabricated to produce the protein end products in response to a series of regulated requirements' (1989: 37).

Hayles offers insights into how information theory and cybernetics have affected genetics, one example being how, "much of the discourse of molecular biology treats information as the essential code the body expresses" (1999: 1).

Keller examines questions related to the production of science, as well as to what science works at producing. Besides her examinations of the relations between society and science, she is useful to frame questions of how physics as a discipline has significantly influenced molecular biology.

Many physicists' utilised information theory. Ona Nierenberg deals with the "institutionalized … deployment of information theory terminology into the domain of biology" (1999: 218). Whereby,

> information theory became the interdisciplinary schema which equated cells, molecules, animals, humans and machines, as psychologists, neuropsychologists, biologists, and engineers employed a common vocabulary of messages, communication, information, codes, control and feedback to describe their respective domains in terms of data input/output devices and processes (ibid: 229).

Cybernetics is a branch of information theory. With regards to cybernetics, Nierenberg examines how "cybernetics proved communication *is* control as its vocabulary soon gained hegemony in molecular biology, and the control of the flow of information became the 'reality' of the gene" (original emphasis, ibid: 235). In relation to metaphors and genetics Nierenberg delves into "how textual metaphors derived from information theory have enabled the discourse of DNA to veil its own exclusions, limitations and contradictions" (ibid: 238). Therefore, these observations into how conceptualisations of genetics have been impelled by information theory and cybernetics serve as a significant reference when exploring how the metaphors in genetics developed, as well the lasting implications of these metaphors.

Utilising the arguments set forth by these theorists, I will examine the predominant concept metaphors concerning genetics and immunology. My examination of these concepts will only deal with these Western influenced ideas, but will do so largely in a South African context. Although there are many competing discourses[8] concerning disease and inheritance in South Africa, the dominating Western ideas, as analysed by, for example, the above theorists, are so ubiquitous that they have permeated South African popular culture.[9]

To contextualise the importance of metaphor in terms of South Africa: The way the body, self and non-self are portrayed in popular culture can also impinge upon larger social understandings of self and other, and has the potential for reinforcing dominant social ideas of difference. Such effects and metaphorical interpretations must be carefully observed in a country such as South Africa, with its past history of reaction to difference. Although this specific aspect will not be the focus of my research report, it serves as an example of the use and power of metaphor to affect science and popular understanding, and why metaphor should not be taken for granted. This is validated by Stepan in her discussion on how differences in race and gender were perceived in the nineteenth and twentieth centuries:

> Human variation and difference were not experiences 'as they really are, out there in nature,' but by and through a metaphorical system that structured the experience and understanding of difference and that in essence created the objects of difference. The metaphorical system provided the 'lenses' through which people experienced and 'saw' the differences between classes, races, and sexes, between civilized man and the savage, between rich and poor, between the child and the adult. … Not surprisingly, the social groups represented metaphorically as 'other' and 'inferior' in Western culture were socially 'disenfranchised' in a variety of ways (1990: 41-42).

This research is also beneficial for South Africa at this current stage with respect to issues such as HIV (Human Immunodeficiency Virus) and AIDS (Acquired Immune Deficiency Syndrome), since it is these issues that are fundamentally based on our current perception of the virus and syndrome's pathology which, in turn, are based on our metaphorical

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[8] I realise that the use of the word discourse brings with it a body of arguments and that "discourse is a difficult concept, largely because there are so many conflicting and overlapping definitions formulated from various theoretical and disciplinary standpoints" (Mann and Thompson, 1992: 3). For example, Michel Foucault's "contribution to a social theory of discourse in such areas as … the discursive construction of … knowledge" (Fairclough, 1992: 37-38). However, for the purposes of this research report I will be utilising the term 'discourse' in a broad sense to encompass discussions of ideas, in conversations and texts, including the use of specific words with which to convey and conceptualise these ideas. My use of the term discourse also accommodates its description as "a depiction of reality and a set of prescriptions for behaviour based on a particular form of knowledge, as in medical discourse" (Jones, 2003: 198).

[9] When perusing through the articles of representations of both immunology and genetics, I have been fully aware that other concept metaphors are available for these subjects. I have also been prepared to discuss and explore them further. However, from my collected representations, I found no such examples that even remotely compared with the preponderance of the concept metaphors of militarization and information coding.

constructions in order to conceptualise them.[10] Also, as part of this research, a large number of examples have been obtained from South African media resources. These examples serve to offer insight into the pervasiveness of these essentially Western ideas in a South African context.[11]

The methodology employed for my research, involved discourse analysis[12] following that of central theorists, as well as data gathering and qualitative analysis. This was accomplished by obtaining newspaper and magazine articles. I also utilised biology textbooks, literature and educational pamphlets. Newspaper articles relating to immunology and genetics were sourced from the independent newspapers. Textbooks and literature were also available at *University of the Witwatersrand's* libraries. The *LoveLife* organisation and the *Planned Parenthood Associate of South Africa (PPASA)* provided many such educational pamphlets, which they update and produce continually for the general population.

1.1. SCIENCE SERVING SOCIETY AND SOCIETY SERVING SCIENCE

In this final section of the introduction I would like to present some pertinent insights into how science and society are unavoidably linked, and how culture, science and metaphor synergise to create our popular perceptions of 'scientific truths'. I feel this is necessary in

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[10] Metaphors surrounding HIV and AIDS are addressed in subsequent chapters. AIDS serves as one area of discussion within the context of immunity, but it also serves to link immunology and genetics due to the nature of the causative agent of the syndrome (a virus), which is thought to perpetuate its genetic material in the immune system's cells. In fact, the medicines currently available on the market to try and inhibit the virus, for example AZT, are chiefly structural analogues of the chemical groups of DNA called bases. Thus AIDS, although not the focus of my research, is relevant in a South African context as well as fitting into my discussion as one of the main areas of exploration of immunology and genetics. However, it will not be examined from a medical viewpoint; but rather, analyzed in terms of its representations.

[11] With regard to HIV and AIDS, South Africa has been an interesting case in point, since the South African government has been principally resistant to the wide-spread usage of Western medicine to treat AIDS in South Africa. The President, Thabo Mbeki, has previously been vocal in his search for other possible reasons for, and curing of, the pandemic.

[12] By "discourse analysis" I signify the "analysis of how texts work within sociocultural practice" (Fairclough, 1995: 7). However, it should be noted that by "texts" I include "other symbolic forms such as visual images" (in print format) "and texts which are combinations of words and images" (Mann and Thompson, 1992: 4).

order to understand why science seems to have attracted such power in society (as introduced in footnote 1).

One of the key reasons that science has proven so successful in Western culture is due to its ability to assist us in interacting, manipulating and dominating our surroundings. It has done so in a number of ways by primarily offering hope of control over our future, for example, hope that we may one day be able to stop disease. This is just one component, however, and for science to succeed it must fulfil certain requirements, as explained by Evelyn Fox Keller:

> A certain amount … of the work that a successful theory or research program must do can be described in strictly human (psychosocial, political, and economic) terms. It must be able to generate jobs and doable problems; it must offer explanations that provide aesthetic and emotional satisfaction; it must work rhetorically to recruit students, 'win allies,' get grants. … But the promises held out – must be made good. For a research program to work, it must satisfy the desires that motivate it, at least well enough to keep it going. … By scientists' own internal ethic, explanations must provide at least some predictive success to remain satisfying; and by the social and political ethic justifying their support, this predictive success must enable the production of at least some of the technological 'goods' the public thinks it is paying for (1992: 90-91).

Thus, for science to be successful it must satisfy what are essentially social, cultural and political agendas. These conditions have obviously been fulfilled by science programs and research, and, therefore, both the popularity and persistence of the scientific method in society has been maintained. Another, and I think most vital reason that scientific research has continued in a similar manner up until the present time, is because of its ability to formulate explanations that help make sense of the environment around us, in ways that either already do (for instance, genetically manipulated bacteria that produce insulin for diabetics), or hold the future promise (such as stem cells improving our immunity) of bettering our lives. This is especially the case with molecular biology:

> The truly remarkable thing about … molecular biology … is that it has been able to realise so many of these needs and desires,[13] that it has produced a body of theory that matches the world well enough to satisfy this network of overlapping interests, that has given us stories good enough (or true enough) to enable us to change the world in ways that we seem to want (ibid: 91).

Keller points out that, ultimately, science has continued successfully due to its scientists' accomplishments in "producing tools that appear to dissolve nature's resistance to our own

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[13] The needs and desires referred to are those stated in the previous quote.

needs," as a result of "their interactions with each other, with the public at large, with their own heritage, and with a judiciously culled set of facets of the inanimate world" (ibid).

Bearing this in mind, the idea of science as a 'disembodied, detached, objective' practice must surely be contested by the realisation that science is inexorably influenced by the subjective, societal, and cultural considerations already mentioned by Keller.

Just how science and society are correlated is easily answered through an excerpt from a South African science article trying to argue for increased incorporation of philosophical thinking in scientific research procedure. Although the article has noble intentions, it still has blatantly apparent presuppositions.

> Since scientific achievement is almost invariably tied up with social goals, no analysis of scientific enterprise can be completed without the perspective of sociology. Only by looking at specific features of the growth of science in society and its relations with the ethical and political issues of the day, can scientists evaluate with detachment the necessity and desirability of pursuing one kind of science rather than another, when funds are insufficient to support both (Austin, 1987: 16).

You will notice that this excerpt contains a paradox. While trying to maintain that scientists are detached when pursuing research, the passage also indicates that scientists are swayed by political, ethical and economic factors, and the goals of the society. In the face of its own opposing assertions, the concept of the 'disembodied, detached, objective' scientist still prevails.[14] However, the objective reality that scientists aim to compose is governed by societal, cultural and subjective considerations and thus "so-called objective reality … leaves out human aspects of reality, in particular the real perceptions, conceptualizations, motivations, and actions that constitute most of what we experience" (Lakoff and Johnson, 1981:146).

To explore how these motivations have impacted on areas of molecular biology I will be utilising metaphor as a means to investigate the "complex cultural, social and representational issues tied up with conceptual shifts and technological innovations" in science, since both science and society generate metaphors that influence each other (Hayles, 1999: 24). In the production of scientific research and theories, metaphors are

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[14] This is in and of itself a result of the pervasive analogy of science acting as a disembodied view of the body of nature.

deployed and utilised in order to conceptualise and describe observed results. These theories (containing metaphors) are subsequently printed in scientific journals and disseminated in the media (especially when the science deals with the possible resolution of issues such as genetic diseases). In the media additional enhancements and/or simplifications may occur (depending on the target audience). However, it is generally the metaphors derived from the initial science that are employed in popular media descriptions. These popular descriptions may be modified through media interpretations, thereby allowing for an altered conception of the metaphor which may feed back into science. Thus, it is through both science and the media that these metaphors continue to be relied upon to convey scientific concepts. However, metaphoric descriptions of science are not necessarily, nor usually, misconstrued in the media, since these metaphors are rooted within science (as shall become apparent in the subsequent chapters). Furthermore, it is in this recursive cycling between science and the media that the metaphorically comprehended concept is continually reiterated and finally reified as a ‘scientific truth’, while the role of metaphor in this cognition is usually overlooked.

To demonstrate how scientific metaphors can be affected by society and altered or reapplied to other sectors of society, I will utilise Susan Sontag’s explanation of how the conceptualisations of the disease of cancer can be affected by economic representations, and how economic portrayals can, in turn, affect understandings of cancer. Sontag first describes that “cancer is … thought to be a pathology of energy” in other words, “a disease of the will … the … idea of cancer as a disease of unexpected energy” (1978: 65-66).Concurrently, in

> our own era of destructive over-production by the economy and of increasing bureaucratic restraints on the individual, there is both a fear of having too much energy and an anxiety about energy not being allowed to be expressed (ibid: 66).

When societal and medical understandings and metaphors merge, “the language used to describe cancer evokes a[n] … economic catastrophe: that of unregulated, abnormal, incoherent growth” where “the tumour has energy, not the patient; ‘it’ is out of control” (ibid: 67). “Cancer cells, according to the textbook account, are cells that have shed the mechanism which ‘restrains’ growth” (ibid). This means that “cancer cells will continue to grow and extend over each other in a ‘chaotic’ fashion, destroying the body’s normal cells, architecture, and functions” (ibid). Sontag compares this to “advanced capitalism” which “requires expansion, speculation, the creation of new needs (the problem of satisfaction and dissatisfaction); buying on credit; mobility" that is to say "an economy that depends on the irrational indulgence of desire" (ibid). The economics and medical disease converge in the representations where "cancer is described in images that sum up the negative behaviour of twentieth-century *homo economicus*: abnormal growth; repression of energy, that is, refusal to consume or spend" (ibid). In other words, the metaphors used to represent these diverse areas of science and socio-economics interrelate and feed into and off each other in order to constitute augmented conceptualisation of each subject. This serves as an illustration of the recursive cycling that occurs between science and society and how their metaphors and conceptualisations intermingle, thereby influencing the understanding of each subject.

2. CHAPTER TWO:

MIND YOUR METAPHORS

"The metaphor is perhaps one of man's most fruitful potentialities. Its efficacy verges on magic, and it seems a tool for creation which God forgot inside one of His creatures when He made him."
José Ortegay Gasset

Since so much of my research is reliant on metaphor and its influence in conceptual configuration, I will first establish the technical definition of a metaphor. "A metaphor is a figure of speech in which a name or descriptive term is transferred to some object that is different from, but analogous to, that to which it is properly applicable" (Stepan, 1990: 54). Metaphor is thus useful for "understanding and experiencing one kind of thing in terms of another" (Lakoff and Johnson, 1981: 5). This is because metaphor essentially serves as cross-domain mapping between two things that are actually dissimilar, but are joined together through the metaphor, to "bring into cognitive and emotional relation with each other two different things, or systems of things, not normally so joined" (Stepan, 1990: 44). Due to this interactive nature of metaphor this is known as the "interaction" theory and it opposes the "substitution" theory of metaphor.[15] Many people misconstrue the "substitution" theory as correct, when they presume "that the metaphor is telling us indirectly something factual about the two subjects – that the metaphor is a *literal comparison*, or is capable of a literal translation in prose" (original emphasis, ibid). Although this "substitution" theory has been applied to DNA, (for instance when DNA is viewed as an information code, as will become evident in the next chapter) "the metaphor cannot be simply reduced to literal comparisons or 'like' statements without loss of meaning or cognitive content, because meaning is a product of the interaction between the

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[15] A number of other theories on metaphor exist, however, Max Black's interaction theory (despite certain criticisms) "has been the most widely accepted and influential view of metaphor" (Way, 1991: 50). Black's analysis of metaphor "as more than literary style or mere comparison between words" has resulted "in a more dynamic and flexible view of language itself" (ibid).

two parts of a metaphor" (ibid). In this way, metaphors create similarities rather than only describe them, and through interactions and associations "both parts of a metaphor are changed," with "each part" being viewed "as more like the other in some characteristic way" (ibid: 45).

Now that I have defined metaphor I would like to elucidate the role of concepts in relation to metaphor. To do so, I would first like to explain that concepts, as mental representations, exist "whenever two or more distinguishable objects or events have been grouped or classified together and set apart from other objects on the basis of some common feature or property characteristic of each" (Bourne, 1966: 1). This allows for the generation of *conceptual systems*, since "no individual concept can be understood without some understanding of how it relates to other concepts" (Keil, 1989: 1). Thus, concepts "can be considered to embody systematic sets of beliefs" which, in turn, are "beliefs that may be largely causal in nature" (ibid).[16]

Lakoff and Johnson summarise the relationship between conceptual systems and metaphors by asserting that "our ordinary *conceptual system*, in terms of which we both *think and act*, is fundamentally *metaphorical* in nature" (my emphasis, 1981: 3). This means that metaphor extends beyond language and "mere words," since "human *thought processes* are largely metaphorical" (original emphasis, ibid: 6). This is an important realisation, because, "metaphors as linguistic expressions are possible precisely because there are *metaphors* in a person's *conceptual system"* and thus can influence our thoughts and actions (my emphasis, ibid). Furthermore, the "concepts that govern our thoughts are not just matters of the intellect" but "also govern our everyday functioning," in terms of structuring our perceptions, "how we get around in the world" and how we interact with others (ibid: 3). Therefore, "our conceptual system ... plays a central role in defining our everyday realities" and since "our *conceptual system* is largely *metaphorical,*" our thinking, our experiences and our everyday actions are "very much a matter of metaphor" (my emphasis, ibid). However, "our conceptual system is not something we are normally aware of" and thus the prevalence of metaphor in our everyday life goes largely undetected (ibid).

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[16] This "notion of concepts as containing systematic sets of causal beliefs is closely linked to … notions of concepts as being embedded in theories and mental models" (Kiel, 1989: 2).

To demonstrate just how metaphors structure our conceptual systems as well as how we can be oblivious to it, I will make use of Lakoff and Johnson's example. This is an everyday example: "the concept ARGUMENT and the conceptual metaphor ARGUMENT IS WAR. This metaphor is reflected in our everyday language by a wide variety of expressions" (original emphasis, ibid: 4). Lakoff and Johnson provide examples of such expressions, for example, "he *attacked every weak point* in my argument. His criticisms were *right on target*. … I've never *won* an argument with him" (original emphasis, ibid). They offer other various expressions exemplifying the same point and then explain (or argue):

> It is important to see that we don't just *talk* about arguments in terms of war. We can actually win or lose arguments. We see the person we are arguing with as an opponent. We attack his positions and we defend our own. … We plan and use strategies. … Many of the things we *do* in arguing are partially structured by the concept of war … there is a verbal battle, and the structure of an argument … reflects this. It is in this sense that the ARGUMENT IS WAR metaphor is one that we live by in this culture; it structures the actions we perform in arguing (original emphasis, ibid).[17]

I have used this example to illustrate how even the procedure of an argument is structured along culturally perceived, yet, unquestioned metaphorically framed concepts. Therefore, this serves as a specific "example of what it means for a *metaphorical concept*, namely ARGUMENT IS WAR, to structure (at least in part) what we do and how we understand what we are doing when we argue" (my emphasis, ibid: 5). This example also illustrates how

> our conventional ways of talking about arguments presuppose a metaphor we are hardly ever conscious of. The metaphor is not merely in the words we use – it is in our very concept of an argument. The language of argument is not poetic, fanciful, or rhetorical; it is literal. We talk about arguments that way because we conceive of them that way – and we act according to the way we conceive of things (ibid).

As a result, "the ARGUMENT IS WAR metaphor is one that we *live* by in this culture; it structures the *actions we perform* in arguing" (my emphasis, ibid: 4). Thus, this serves as an apposite example to demonstrate how our metaphors not only affect our concepts but also our actions.

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[17] One may dispute this and say that this is the most convenient and appropriate way in order to structure such discussions. The authors contest this statement by using examples where argument is viewed in terms of a dance between two people working for a mutual goal.

2.1. THE CONCEPT METAPHOR

The association between concept and metaphor, that I have been explaining, has been described by Lakoff and Johnson as the "*metaphorical concept.*"[18] They utilise this term when referring to the *thought processes*, that are influenced by "human *conceptual systems"* being "*metaphorically structured* and defined" (original emphasis, ibid: 6). This leads me to discuss what I have termed the '*concept metaphor*'. My designation of 'concept metaphor' is based on Lakoff and Johnson's "metaphorical concept." I have used the expression 'concept metaphor' to encompass the predominant metaphors that configure concepts which are integral in understanding or conceptualising the fundamental knowledge of a subject. In other words, 'concept metaphors' are the central concepts, structured in terms of pivotal metaphors, that facilitate the comprehension of significant aspects of a subject. After all, in order to understand something new, we generally have to relate it to something we already know, and metaphor is a useful means of allowing us to do this in order to form a concept of the new information. However, when we refer back to this information, or utilise it to grasp additional information, we rely on the same concepts and accordingly the same metaphors to cognitively ideate on a certain subject. Thus, due to the centrality of the concept metaphor, entanglements arise from it and can affect other areas and understandings of the topic at hand. To give an example, the contemporary study of genetics is largely predicated on conceptualising DNA metaphorically, as an information code. Since DNA forms the fundamental basis of the study of genetics, the conceptualisation of DNA as an information code will have repercussions for how genes are comprehended as well as genetics as a whole. Thus, the predominant concept metaphor of information coding, which is applied to DNA, has entanglements that affect how the rest of the subject of genetics is understood, as well as scientific research that is consequently undertaken.[19] As for immunology, its predominant concept metaphor is militarization, in

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[18] The causal effects arising from the relationship between concept and metaphor have also been described by Susan Oyama, where she has used the term "cognitive-causal metaphor" (1985: 46).

[19] As with Lakoff and Johnson's "metaphorical concept" the 'concept metaphor' is implicated not only in our use of language (and choice of words) but also our thoughts and subsequent actions. (The extent of the actions being carried out as a result of these concept metaphors, regarding DNA and immunology, becomes evident in the following chapters). However, while Lakoff and Johnson's "metaphorical concept" can be applied to more general metaphors, throughout this research I have focused on concept metaphors as being more fundamental in influencing perceptions as well as grounding genetics and immunology.

other words, the concept of our immune system is based on it being a type of battleground where we wage wars against foreign attackers. This concept metaphor of militarization has obvious wider implications and entanglements that have an impact on our impressions of health and disease.

The effects of these concept metaphors are considerable, though they are not always considered. As Lakoff and Johnson demonstrated, we are not usually cognizant of the metaphors utilised in constituting concepts. Neither are we always mindful of our concept metaphors. This is especially because they are pervasive and they generally form the core of presuppositions and assumptions that underlie subjects. Lakoff and Johnson describe an insidious consequence of their metaphorical concepts, which also pertains to my term of concept metaphors: "The very systematicity that allows us to comprehend one aspect of a concept in terms of another" (as with the example of conceptualising an argument in terms of war), means that "other aspects of the concept" will unavoidably be hidden (1981: 10). Thus, "in allowing us to focus on one aspect of a concept" a concept metaphor "can keep us from focusing on other aspects of the concept that are inconsistent with that metaphor" (ibid). Therefore, although a concept metaphor prevails in highlighting or bringing certain features to the fore, other components remain veiled by the concept metaphor being employed. So, if one assumes DNA to be an information code, this forms the groundwork for ensuing research into its ability to be '*deciphered*' or '*solved*', as well as its functioning in '*reading*' and '*writing*' the information contained in its code. However, other aspects of DNA must inevitably be obscured by the concept metaphor. Whereas, immunology's concept metaphor of militarization has considerable ramifications when it comes to understanding how our body is conceptualised. For instance, keeping our bodies healthy is viewed as being reliant on our bodies being '*protected*' and able to '*fight* off flu', while other possible conceptualisations of the body remain concealed by the pervading concept metaphor.

In summary, when particular concept metaphors are utilised persistently in popular, educational and scientific representations, the metaphorical nature of the metaphor becomes taken for granted and they are seen as 'true', literal, non-mediated accounts of nature. When that occurs, metaphors are no longer devices used to enhance understanding; rather they become part of our conceptual system, and frame how we understand the world. Thus, these concept metaphors can become entrenched and may establish paradigmatic,[20] uncontested, conceptualisations of sections of science. Additionally, since concept metaphors "have entailments through which they highlight and make coherent certain aspects of our experience," these concept metaphors may also hide other (usually contradictory) facets (Lakoff and Johnson, 1981: 156). Of course, "a given metaphor may be the only way to highlight and coherently organize exactly those aspects of our experience" (ibid). However, when the metaphor is reinforced by its repetitive usage, and legitimised by the authority of science it can begin to dominate reasoning rather than act as an aid. Hence, metaphors can become reflexive in their effects:

> metaphors may create realities for us, especially social realities. A metaphor may thus be a guide for future action. Such actions will, of course, fit the metaphor. This will, in turn, reinforce the power of the metaphor to make experience coherent. In this sense metaphors can be self-fulfilling prophecies (ibid).

When applied to areas of science, the effects of concept metaphors are further reinforced by the credibility and legitimacy conferred by the authority of science. Therefore, analysis of the major metaphors in the areas of genetics and immunology is important. Since, by doing so, new conceptualisations, observations, explanations and theories can be determined and consequently, scientific progress in these fields can be expedited. With this in mind, let's return to the discussion of metaphor and its involvement in science, using Keller's insight, that "what we know or claim to know about the natural world comes to us in our own constructions – constructions that are inevitably shaped by our cultural and linguistic frames" (1992:3).

2.2. MADE UP MINDS: THE MEETING OF METAPHOR, SCIENCE AND CULTURE

To elaborate on why it is so important that metaphor be revealed in science I will use Nancy Leys Stephan's explanation:

> Detection is necessary because as metaphors in science become familiar or commonplace, they tend to lose their metaphorical nature and to be taken literally.

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[20] Kuhn, (1970 and 1977), offers significant insights into the creation, maintenance and effects of paradigms in science.

> … The tendency for metaphors to become dogmatic and to be seen as literally true and non-metaphoric is particularly strong in science because of the identification of the language of science with the language of objectivity and reality (1990: 52).

Since science is largely perceived, in Western society, as technical, logical and composed of theories which are unambiguously detailed through specifically chosen jargon that is free of poetic fancy and subjective figurations, the use of metaphor in science is not always acknowledged. (As I have already explained, and will become abundantly more obvious in the ensuing chapters, metaphors are readily utilised in science).

> The confusion of metaphor for reality in science would be less important if metaphors did not have social and moral consequences in addition to intellectual ones. This aspect of metaphoric and analogic science is often overlooked in discussions of paradigms, models and analogies in science, in which the main focus tends to be on the metaphor as an intellectual construct with intellectual consequences for the doing of science. But metaphors do more than this. Metaphors shape our perceptions and in turn our actions, which tend to be in accordance with the metaphor (ibid).

When such "analogies … [become] 'naturalized' in the language of science, and their metaphorical nature disguised" the effect is more significant precisely because they are presumed as accurate fact, within the contexts of science (ibid: 42). Furthermore, "the analogies now" have the "weight of empirical reality and scientific theory" to prove and perpetuate them (ibid: 43). And when "conceptual issues" become so all-pervading that they "are not detachable from empirical ones" the result is that "they are there whenever one decides what to count as data, interprets them, draws theoretical or practical inferences from them and frames the next research question in terms of a particular method" (Oyama, 1985: 2).

Of course, since metaphors and models are so necessary for the production of knowledge and serve crucial roles in aiding understanding and conveying complex notions, they are indispensable for advancing and progressing enhanced comprehension (in this case with respect to science). In fact, metaphors are prevalent in science because of their capacity to evoke "more specially constructed systems of implications" and "scientists are in the business of constructing exactly such systems of implications, through their empirical investigations into nature and through their introduction into discourse of specialized vocabularies and technologies" (ibid). Actually, what seems to make "an analogy suitable for scientific purposes" is precisely "its ability to be suggestive of new systems of implications, new hypotheses, and therefore new observations" (ibid). The problem, however, comes when "the very systematicity that allows us to comprehend one aspect of a concept in terms of another" also conceals "other aspects of the concept" (Lakoff and Johnson, 1981: 10). This is because "in allowing us to focus on one aspect of a concept," a concept metaphor "can keep us from focusing on other aspects of the concept that are inconsistent with that metaphor" (ibid). In effect, the metaphor "directs attention away from those aspects of reality that challenge" the expectations that the metaphor establishes (Stepan, 1990: 51).

This key ability of metaphor, to steer cognizance away from that which it impugns, applies not only to the lay person, but also to scientists. Since scientists obtain their knowledge through textbooks which use these conceptual metaphors that may shape their thinking regarding science, their perceptions of it and possibly their subsequent research.

By focusing my attention on genetics and immunology I intend to use these subjects as a means to reveal certain predominant, but little recognised, characteristics of the use of metaphoric representation for the production of scientific knowledge, and its popular translation. Firstly, metaphoric utilisation for explanation may become reliant on a few select concept metaphors. Secondly, prevailing concept metaphors are so ubiquitous within science and, accordingly, the mass media that they have a tendency to be taken for granted and assumed as 'scientific truths', and literalized for public consumption. In doing so, these metaphors are appropriated in order to perform the task of socio-political work.[21] Finally, the most deceptively pernicious repercussion is the sustained utilisation of these metaphors even when they no longer serve as adequate explanatory accounts for new information surfacing through scientific endeavours (as is occurring presently, with regard to genetics and immunology). The result is that these conceptual metaphors which are viewed as explaining 'scientific truths' are in fact (in certain cases) delaying and contributing to halting the progression of scientific research, by averting the investigation of areas of molecular biology that are precluded by the established concept metaphors.[22]

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[21] This aspect of metaphor has already been extensively discussed by theorists such as Haraway, Harding, Keller, and Martin. I have drawn on their arguments to ground my discussion of this trait of metaphor utilisation.

[22] This is demonstrated in my conclusion.

As a solution to this outlook that science defines and discovers 'truths', Lakoff and Johnson offer the "experientialist account of understanding and truth" as an alternative to objectivism[23] (that is so widely aimed for in science) and subjectivism[24] (1981: 192). They "reject the objectivist view that there is absolute and unconditional truth without adopting the subjectivist alternative of truth as obtainable only through the imagination, unconstrained by external circumstances" (ibid).[25] Rather, Lakoff and Johnson propose that metaphor serves to connect "reason and imagination" (ibid: 193). Since reason "involves categorization, entailment, and inference," while "imagination, in one of its many aspects, involves seeing one kind of thing in terms of another kind of thing" through the use of the metaphor (ibid). Thus, Lakoff and Johnson draw the conclusion that metaphor is "imaginative rationality" as a consequence of "categories of our everyday thought" being "largely metaphorical" as well as "our everyday reasoning" involving "metaphorical entailments and inferences," hence, "ordinary rationality" due to its innate characteristics is imaginative (ibid).

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[23] I have supplied a brief overview of objectivism, which is delineated by the view that: "The world is made up of objects" whose properties are independent of the researcher, researching them (Lakoff and Johnson, 1981: 186). We attain our knowledge of the world by determining the objects in it and their intrinsic characteristics and relationships to other objects. These objects are understood in terms of concepts as well as categories that "correspond to properties the objects have in themselves (inherently)" (ibid: 187). In science objectivity is viewed as rationality, and subjectivity as being emotional and irrational. Hence, objectivity is perceived as being

> a good thing. Only objective knowledge is really knowledge. Only from an objective, unconditional point of view can we really understand ourselves, others, and the external world. Objectivity allows us to rise about personal prejudice and bias, to be fair, and to take an unbiased view of the world (ibid: 188).

[24] Subjectivism is based on the tenets that we should trust our senses and intuitions to lead us towards the correct actions to take. Furthermore, imagination is regarded as significant in the production of knowledge. Also, in subjectivism the

> language of the imagination, especially metaphor, is necessary for expressing the unique and most personally significant aspects of our experience. In matters of personal understanding the ordinary agreed-upon meanings that words have will not do (Lakoff and Johnson, 1981: 188).

For information on subjectivism and objectivism as well as other philosophical insights into theories and science; Green, (1981), Hacking, (1983), Kuhn, (1970), and Waddington, (1948), may be consulted.

[25] Lakoff and Johnson's "experientialist" alternative attempts to utilize (what the authors view as) the positive elements from both the objectivist and subjectivist's theories. Thus:

> From the experientialist perspective, truth depends on understanding, which emerges from functioning in the world. It is through such understanding that the experientialist alternative meets the objectivist's need for an account of truth. It is through the coherent structuring of experience that the experientialist alternative satisfies the subjectivist's need for personal meaning and significance (1981:230).

The “experientialist” point of view still allows for scientific knowledge,[26] but involves “giving up the claim to absolute truth” (inherent in objectivism) in order to “make scientific practice more responsible” (ibid: 227). “Since there would be a general awareness that a scientific theory may hide as much as it highlights” due to the metaphors that it uses to structure understanding of what is occurring at, for example, the molecular level of the cell (ibid). In recognition of this theory I have utilised its major observations in order to come up with a new approach that can be applied to genetics. I discuss this in my concluding chapter. While, in chapter three I offer explanations regarding how the predominant concept metaphor of information coding has developed (through less than the high ideals of objectivism), and in the fourth chapter, I discuss the implications of this in connection with immunology and its prevailing concept metaphor of militarization. Now that I have clarified the importance of metaphor in science, I can turn my attention to elucidating its impact with regard to molecular biology in scientific, educational and popular representations.

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[26] Besides the “experientialist” point of view, there are other theories to account for knowledge, and the question of objectivity. For example, Donna Haraway’s account of objectivity, in a feminist context, “calls for a doctrine of *embodied objectivity* whereby omniscient scientists do not escape representation and formerly conquered objects (*marked subjects*) may be appreciated for their *situated knowledges* and *partial perspectives*” (original emphasis, Terry, 2002: 2). These “situated knowledges” or “partial perspectives” refer to each person’s distinctive outlook that results from their location within society. To Haraway it is this “situated knowledge” which “promises objective vision” (1991: 583). In the biological sciences (such as genetics and immunology) the production of bodies (through representations) are what Haraway refers to as “material-semiotic generative nodes” whose boundaries are reified through social interactions. Also along feminist lines, is Nancy Hartsock’s “standpoint theory” which maintains that based on circumstances and experiences everyone has a unique standpoint with which they view the world. Thus, a person in a position of power as opposed to a subjugated person would have dissimilar perspectives. The standpoint theory also explains that the subjugated person can understand both their view and the one imposed on them by the person in authority. This theory has been criticised by other theorists, such as Sandra Harding who has developed a theory of “feminist empiricism,” while Evelyn Fox Keller has produced a “psychoanalytic/object relations theory” (Terry, 2002: 2).

3. CHAPTER THREE:

INFORMING GENETICS

"DNA is no longer just a scientific entity. It's erupted as this huge cultural phenomenon, as a metaphor for our natures. It's in our daily conversation, in art. When you were working on the double helix, did you foresee DNA ever becoming this well known?"

John Rennie[27]

Genetics has become implicated in so much more than Mendel, or even James Watson and Francis Crick, could have ever dreamed. To give an example of the questions that the subject of genetics has raised (and been called on to answer), I will use an excerpt from an article in *National Geographic*. The writer who had gone to have her DNA tested, is shown her extracted DNA in the form of a small gobbet in a test-tube.

> The notion that something *as complex as a human being* can *be distilled* into a test tube is of course absurd. Nevertheless, the pale residue in this vial does contain the chemical *guidelines* that have *informed the development of my body and brain* from the moment I was conceived. It holds a *detailed record* of my ancestral past and to an uncertain extent a *forecast of my personal future*. It is *virtually immortal*, a thread tying this one life to all life that has ever lived or is yet to live. But it is also the part of my anatomy *most unerringly myself*. How much do the *secrets* in that tube affect the way I look and act, how I respond to the world, and how long I will remain a part of it? *To what extent am I my genes* (my emphasis, October, 1999: 48)?

The author points out that one of the most incredible aspects regarding these questions is that we are now

> on the verge of having finite answers. Without much time to consider the implications, scientists have developed the ability to tap into the *code of life* and bring its power to bear on our daily lives … This eruption of *genetic information* is transforming the way medicine is practiced, crimes are solved and very nature of life is understood. But its power is frightening too, even to those who understand it best. Who has the right to know the *secrets written in our genomes*? How much do we want to know ourselves (my emphasis**,** ibid: 49)?

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[27] John Rennie, (the *Scientific American Editor in Chief)* interviewing James D. Watson in an article "celebrating the genetic jubilee" (2003: 50).

These are indeed conundrums that we now face because of the rapid acceleration in the study of genetics, and, yet, which genetics hopes to be able to solve in the future. Notice the use of metaphor in these paragraphs: words and phrases such as ‘informed the development’; ‘record’; ‘forecast of my personal future’; ‘secrets’ in relation to the gene; genetic causality; ‘code of life’; ‘information’; ‘written’ are all used to describe the functioning of our genes. Inherent in the *National Geographic* excerpt is the connection of DNA “code” with the “secret” to self. The intrinsic idea of a “code of life” is contingent upon the concept metaphor that sustains the image of a scientist as a detective. The scientists are portrayed as hero geneticists/explorers that discover nature’s secrets and decipher life’s encrypted code in order to solve problems, and reliant on sustaining that image is the underlying assurance that the mystery of self and life will ultimately be solved.

I will now look at how such ideas emerged and began to pervade genetics by focusing on the broad concept metaphor that I feel encompasses all of these metaphors; that is the concept metaphor of information coding. Therefore, in this chapter I will demonstrate how the overall concept metaphor of information coding began to dominate the study and consequent popular representation of genetics. This chapter will explore the effects of this; the incongruities that arise in these metaphors, and the question of how and why we became prisoners (“*To what extent am I my genes?*”) to our DNA as well as the repercussions thereof.

The concept metaphor of information coding has become integral to the very idea of DNA, where “the trope of DNA-as-instruction, code, etc., - has become so ubiquitous as to be rendered nearly invisible as metaphor – it is, in fact, DNA’s *sine qua non*” (original emphasis, Nierenberg, 1999: 217).

Nierenberg also explains that:

> *Information. Instructions. Code.* While this terminology may seem rather benign and even instructive, the problem is its effect: When DNA is the blueprint, the instruction book, the code, or the key, human existence all too quickly becomes reduced to ‘follow[ing] the orders of DNA. We have no choice. We are prisoners of our genes’ (G. Kolata cited in Nierenberg, 1999: 216-217).

The concept metaphor in question, concerning DNA, is not limited to the scientific community. Rather, it is widely disseminated in the media aimed at the general public. Hence, to begin this investigation I will corroborate my assertion regarding information coding by exploring how it is indeed the predominant concept metaphor that prevails in both Western and South African media. To accomplish this I will utilise specific selections from South African and Western popular and scientific media.

3.1. METAPHORICALLY CODING INFORMATION IN POPULAR REPRESENTATIONS OF GENETICS

Numerous examples in South African popular media validate this thinking regarding DNA and the concept metaphor of information coding. For example, in a recent South African newspaper report the description given as a definition for 'genome' was "The name for the genetic code that is derived from sequencing" (*The Star*, May 22, 2003: 15). Here the term 'code' is even used to structure this definition and, hence, DNA (that constitutes the genome) cannot escape the metaphor.

In another article which described aspects of the human genome project the definition of a 'gene' was stated as

> sections in the DNA that determine the synthesis of proteins, which govern all of the life processes from birth to death. Genes account for only 2% to 4% of human DNA. The rest is called 'junk'[28] or 'silent' DNA, and its use is as yet unclear. The term 'gene'[29] derives from the Greek word 'genos', for birth or origin (*The Star*, June 27, 2000: 4).

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[28] The term 'junk DNA' came into existence in 1972 when Susumu Ohno provided a possible theory for this DNA. He proposed "that these millions of 'silent DNA base sequences' represented genes that had died off like dinosaurs during the course of human evolution" (Kuska, 2004a: 1032). Ohno's article was titled: "So Much 'Junk' DNA in our Genome" (S. Ohno cited, ibid). "And thus was born what today is one of the most easily grasped and yet pejorative terms in the genetic lexicon – junk DNA" (ibid). A follow up article poses the question "is *junk DNA* really worthless" (original emphasis, Kuska, 2004b: 1126). Apparently most scientists say "the answer depends on what one means by '*junk*' " (original emphasis, ibid). At present it is

> a general term that encompasses many different types of *DNA* sequences. These sequences run the gamut from introns, the parts of genes that are edited out during protein synthesis; transposable elements, repeated *DNA* sequences that, like parasites, duplicate themselves, adding nothing to the genome except more redundant sequence; and pseudogenes, fossils of one-time genes (original emphasis, ibid).

[29] The term 'gene' developed from Charles Darwin's use of the word 'gemmule' in his theory of pangenesis. Only at the beginning of the twentieth century did Wilhelm Johannsen coin the word gene (as a concept) (Brosius, and Gould, 1992: 10706). "Molecular biology rescued the gene" so that it wouldn't remain "either a hypothetical entity invented to help geneticists order the results of their experiments or a 'bead' on the chromosome that cytologists thought they could see through the microscope" (Keller, 1983a: 171). Rather, the gene became "a distinct chemical entity" (ibid).

This definition serves as a useful example to illustrate the limitations of the conceptual metaphor when it is used and viewed as the only means for understanding what is occurring with regards to DNA and genes. The definition asserts that no known use or purpose can be traced to this 'junk' or 'silent DNA', or put another way, this DNA has not been found to code for anything. Thus, using the metaphor which represents DNA in terms of 'code' limits our thinking regarding DNA, in that all DNA is reduced and restricted to having to perform as instructions or encoded information. Since this junk DNA does not appear to 'code' for anything, it does not fit into our omnipresent concept metaphor of DNA. Therefore, it cannot be assigned to any function. In fact, it is the metaphor that makes the DNA 'junk' or tries to 'silence' it, when in actuality it is that the functioning of certain aspects of the DNA are, as yet, undetermined.[30] As I have already discussed, metaphor has the power to bring certain features to the fore and hide others. In this case, elements of DNA that do not fit the metaphor are viewed as unable to 'code' for any type of discernable information, and they are represented as devoid of value and actually termed 'junk'. Through this concept metaphor purpose, with regards to DNA, has been subsumed to code. Yet, this 'junk' or valueless DNA is said to account for ninety-six to ninety-eight percent of DNA, as the article reiterates: "97% of our DNA has no known function" (ibid).[31] Undeniably genes form but a diminutive portion of DNA and yet they are the present focal point of contemporary research endeavours and media representations thereof. Consequently, 'junk DNA' serves as an archetypal exemplum for explaining what I am arguing throughout this research report, which is why we need to be aware of the impact

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[30] Some scientists have conceded that the term 'junk' is not suitable, for example, where some genetic elements that were labelled 'junk', yet, "clearly hold important clues to understanding" certain aspects of protein production (Kuska, 2004b: 1127). Other scientists have suggested a name change as "they increasingly find themselves defending their *junk* against the promise of genes, a dichotomy that squeezes millions of years of genomic evolution into a concept as simple as 'good' and 'bad' cholesterol" (original emphasis, ibid). However, finding an alternative term seems to have posed a problem. Obviously, "one way around this problem is simply to invent language that is neither technical nor derogatory" (ibid). Jürgen Brosius and Stephan Jay Gould attempted this with their paper "On 'genomenclature': A comprehensive (and respectful) taxonomy for pseudogenes and other 'junk DNA' " (1992: 10706). Unfortunately, this does not seem to have taken hold in genetic nomen'culture'.

[31] Even more astounding are the findings that mice seem to have a similar proportion of genes compared to humans. Clearly, humans are very different to mice so therefore the junk DNA would seem (to me) an obvious point to turn to in order to try and discover what makes humans unique as far as phenotypic characteristics are concerned. One reason that scientists have most likely not turned to exploring junk DNA as readily as genes, is due to economic, and cultural pressures. In my introduction I explained the links between science and general society, the importance of those vested interests should not be underestimated, as pointed out in one article.

> Experts say that in this age of a booming biotech industry, the human genome for better or worse has become a commodity. And in this patent-first climate, industry has a financial stake in getting its hands on interesting genes now and worrying about decoding the *junk* later" (original emphasis, Kuska, 2004b: 1126).

and operation of such metaphors in science. This example has illustrated the power which prevailing metaphors possess and the importance of not taking metaphors for granted when attempting to ascertain biological functioning.

Despite the seemingly obvious deduction that ninety-seven percent of our DNA cannot be 'junk', this newspaper article (and many like it, including other scientific and popular reports) concentrate on the concept metaphor to the exclusion of other metaphors that could relate distinctively to DNA.[32] For instance, when the article quotes James Watson (co-discoverer of the structure of DNA) it is to describe the significance of the human genome project as the most "important set of instruction books" ever to be found by human beings (ibid).[33] The article also gives explanations for different coding aspects of genetics. For example, it defines DNA as follows: "The DNA molecule is in the shape of a double helix, linked by chemicals called bases, of which there are four kinds. The sequence of these bases makes up the cell's genetic code" (ibid). The information coding metaphor is extended in the description of how genes allow certain proteins to be produced. Under the subtitle "From code to protein" the reader is informed that "each set of three letters can be thought of as a word, with each word corresponding to one of 20 types of amino acid – the building blocks of life" (ibid).[34] There is even a section entitled: "Facts about DNA coding" (ibid). By linking facts and coding so emphatically, the figurative is completely overlooked, and DNA is literally and objectively seen as being a 'code'. DNA is reified through the effacement of the metaphor. Additionally, scientific authority is used to legitimise this reification.

In an advert aimed to increase public understanding of biotechnology, the South African Department of Science and Technology published a series of "educational adverts" in which they offered explanatory definitions of genetics terms. As part of their explanation for "What is DNA?" we are told that DNA "is a strand-like molecule in the shape of a double helix, which through its orderly make-up contains the *codes* required for life to continue" (my emphasis, *Mail & Guardian*, April 17–24, 2002: 54). Once again DNA as the code, "the instruction book," for life is emphasized. And in the same article's definition

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[32] The use of the concept metaphor of information coding leads to paradigmatic and limited thinking, since, in this case, the only purpose of DNA is viewed as coding for something and ergo if it does not code, then it has no purpose. In effect an hermetic cycle concerning DNA has been set up through the concept metaphor.

[33] Note the use of the metaphor in equating our DNA to a book of instructions, this aspect of DNA will be elaborated upon as the discussion continues.

[34] This building-block metaphor will be discussed within this chapter.

of “What is a gene?” coding is linked emphatically to information: “A gene is a piece of DNA that carries the *information* for a specific protein, such as the production of insulin” (my emphasis, ibid).

I could use many more examples[35] obtained from texts in journals, magazines, newspapers and the like, and as my research discussion continues, more examples will be used as evidence. However, in order to avoid redundancy, I will limit my use of examples at this time to the above excerpts in order to move rapidly forward with this treatise. I hope these chosen examples demonstrate the prevalence of this concept metaphor in structuring our representations of genetics and, ultimately, knowledge of this discipline. Now that the overall concept metaphor has been established, an outline of the constituent metaphors that feed into the concept metaphor will be briefly discussed in order to subsequently examine how such popular representations have arisen.

3.1.1. CATEGORISING GENETIC METAPHORS

Within the conceptual framework of information coding, there are certain sub-categories of metaphors that are routinely used, and that reinforce, this understanding of DNA and genes. I have grouped these sub-categories together in a summarised format. My intention is not only to list them, but rather to briefly explain how the major concept metaphor of information coding is fed and consolidated by these other metaphors. I also want to draw attention to why these metaphors have been utilised so readily, as well as certain features that these metaphors tend to obfuscate or conceal.

The first broad sub-category is information. Information includes communication, controls and constraints. The reason that “genetic information” has acquired “a powerful cachet” is because of “its association with physics, information theory and computer science”

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[35] To substantiate this claim I will list examples to which one can refer for additional demonstrations of the omnipotence of this concept metaphor. A journal article that substantially utilizes the information coding metaphor is one that discusses human nature, and genetic contribution to it (Dewar, 2003). In the *Longevity* magazine an article titled: “Are we really programmed to age?” makes use of the concept metaphor (as insinuated by the heading alone) (January, 2003). Throughout his book “*Genome,*” Matt Ridley exploits the information coding metaphor in his discussions.

(Oyama, 1985: 64). In fact, this metaphor has been so successful that "the active gene is now the prototype that informs our understanding of information" (ibid).

The second broad sub-category is that of code. These two are often interlinked in their modern day usage and, hence, I have structured them as the predominant concept metaphor of information coding which informs genetic discourse and epistemology. My sentiments are echoed by others such as Susan Oyama, who confirms that "the genetic code has become part of everyday language" and "is often combined with" other metaphors "as in *coded information*" (my emphasis, ibid: 70). However, Oyama points out that such a combination of these metaphors does not resolve "whatever problems arise ... by claiming that" information is "encoded in the genes rather than literally being present in them" (ibid). There are a number of problems with the code metaphor. For a start,

> a code does not alter the content of a message, only its form. While it makes sense in general to say that the primary structure of a polypeptide is encoded on the chromosomes, and while such a string generally has only a few thermodynamically stable, three-dimensional configurations (so that under most circumstances the linear structure determines the three-dimensional one), it is not clear what else may be said to be thus encoded (ibid).

Also, a "formal requirement of a code" would be for a precise form of message transmission (ibid). Yet, "in the genetic system ... several codons can code for the same amino acid" and further coding ambiguity exists "in the phenocopy, [where] several genes are associated with the same phenotype" (ibid: 70-71). Uncertainty should exist in the concept of encoded genetic information "whenever there is genetic variability that is not reflected in phenotypic variability, that is to say, very frequently" (ibid: 71). An obvious example of a single genotype associated with different phenotypes is during embryogenesis where the same DNA in a fertilised zygote is used to form differentiated cells types. Of course, "the same argument can be made for any particular environmental variable or event" and "many stimuli may be functionally equivalent for an organism, and a given stimulus may call out a variety of responses (or none) from an organism at different times or from different organisms" (ibid). What this ultimately means is that "in ontogenetic processes ... neither developmental interactants nor phenotypes are uniquely recoverable from each other. *Where then is the code*" (my emphasis, ibid)?

In elucidating the information coding concept metaphor I have attempted to expose certain discrepancies that subvert the concept metaphor. With these disparities in mind I can proceed to analyse the types of metaphors relating to genetics as sub-categorisations of this overall concept metaphor. An example of such a sub-category of metaphor is that of blueprints and plans. The use of this metaphor is illustrated in a biology textbook:

> Every cell of your body contains a complete set of all the information that went into building it. … If you were an architect planning to build an entire city, you wouldn't include in the blueprints for each building the entire set of blueprints for all the other buildings. But life does just that (Hoagland *et al.,* 2001: 254)!

In my earlier *National Geographic* extract, the metaphor of plans and blueprints was alluded to in the quote "… the chemical *guidelines* that have *informed the development of my body and brain* …" (my emphasis, October, 1999: 48). These examples demonstrate the use of the metaphors in this sub-category in relation to genetics. The blueprint analogy works because "blueprints are usually contrasted with building materials" and so "the genes are quite easily conceptualized as templates for building tools and materials," and when genes are represented in this manner "they enter the development process and influence its course" (Oyama, 1985: 46). However, the blueprint analogy "does not seem to … illuminate" how these "developmental processes" occur instead it assumes them, and this results in "imputing cognitive functions to the genes" (ibid).

An additional problem here is that the way in which

> these functions are exercised is left unclear in this type of metaphor, except that the genetic plan is seen in some peculiar way to carry itself out, generating all the necessary steps in the necessary order. No light is shed on multiple developmental possibilities, species-typical or atypical (ibid: 46-47).

Thus, although "a plan implies action … it does not itself act," therefore, if genes are blueprints "something else is the contractor-construction worker" (ibid: 46). This leads Oyama to describe genes (or this aspect of how they are understood) as the "unmoved mover."

Moreover,

> if you don't think that genes are really a blueprint it is not necessary to point out that they are not blue, but if you think that they really are a program, closer examination is perhaps justified (ibid: 61).

Leading on from blueprints and plans is another logical sub-category of metaphor, and that is of programs, instructions, rules and orders. Specifically, the genome is seen as constituting an instruction or program, and, taken in either the "sense of a plan or in the sense of a computer program, is so common a notion as not to seem metaphoric at all" (ibid: 50).[36] This is typified by the statement: "embryo development – life's building *program* – is based on *information* located primarily in the *genes* of each individual cell" (my emphasis, Hoagland *et al.,* 2001: 252). In the same way that "these molecules [DNA] can be thought of as containing organs and behaviour only by a prodigious stretch of the literary imagination" it is "difficult to understand how they could contain statements and commands" (Oyama, 1985: 50). Oyama offers the explanation that "perhaps because rules imply activity rather than objects, these locutions raise few eyebrows" (ibid).

Information coding seems to lend credibility to the idea that programs reside in the gene in order to instruct, for example, the production of protein synthesis. However,

> even without speculating on master programs, it should be evident that gene transcription and translation in no way represent instructions for building a functioning body, though they are surely part of that process. Whatever determines when a given gene will be transcribed, it is something other than the gene itself (ibid: 60).

Also, the metaphorical comparison of DNA with a computer program seems highly flawed. For instance, an essentially digital computer would contain a binary code, whereas DNA is composed of four different bases (adenine, cytosine, guanine, thymine) and, hence, is in what could be termed a 'quaternary' form. Furthermore, it should be obvious that DNA does not operate as a computer program, because when changing its state "a cell does not compute that state, refer to the genes for conditional instructions" and then change to a new required state (ibid). This metaphor of a "program" works only in biological circumstances "when it is no longer a set of instructions directing a process" but when the "program" is "identified with the process" (ibid: 61). Even the "program is itself a sort of model or metaphor" and the "many rules and strict formalism employed in computer programming are ways of telling an inflexible machine how to be flexible" (ibid).

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[36] In fact, the metaphors of programming and instructing and computing have become so widespread that they seem to be coming to life. The computer metaphors in conjunction with DNA have become literal, in the form of a DNA computer. This biological computer, contains enzymes and DNA "instead of silicon microchips" (*Jewish Report*, April 25 – May 2, 2003: 3). This biological computer has also been awarded the 'smallest biological computing device in the world' by Guinness World Records (Ball, 2003: 53).

The programmed code metaphor is too general and this description overlooks the intrinsic adaptability and flexibility[37] in biological processes. And yet, this is what programmers strive to emulate. "A program for simulating ontogeny" would be remiss if it only accounted for genes (ibid: 61-62). All conditions that are relevant to the final outcome and, therefore, to the interactions, signalling pathways and networks and all the externally and internally affecting factors "that constitute the developmental system in transition" would have to be considered (ibid: 62). Within the "biological system the 'decision' or 'rule' needn't be programmed symbolically" because we utilise "rules" and "decisions" as anthropomorphic descriptions that are ascribed to events that we observe (ibid). This institutes a reflexive practice of observing an aspect of a biological process and then anthropomorphising agency recursively back to the event, resulting in a determinism in the guise of the 'programmer'. By viewing biological processes as "programmed" it means that we cannot "distinguish the innate from the acquired, the adaptive from the nonadaptive, the inevitable from the mutable" (ibid). When experiences generate repeatedly similar outcomes they come to be regarded as 'rules' about the world in which we live. However, when it comes to rules and instructions with regard to biology and genetics, we generally confuse the multidimensional factors of a result for the process itself. Therefore rules and instructions

> are what we formulate on the basis of observation of the universe to be simulated. They are what we must use to produce results that resemble the operation of system that runs without 'rules' as we know them, but rather, produces orderly outcomes by virtue of its evolving nature and its interactions. The regularity we describe, because it is always multiply determined and is a function of the history of the system, cannot reside in a component of the system. It is a *result* of the operation of the system, not its cause (except insofar as results become causes by altering the system itself) (original emphasis, ibid).

This is especially apt for genetics discourse where genes, for instance, are seen as 'instructing' the production of proteins. However, the question of whom or what instructs the instructions is never asked or answered. Let me elaborate. There is one key commonality running through all of these metaphors. They all tacitly elide and disallow the issue of whether or not there is actually an autonomous instructor or code-maker, at work, at all. This instructor or what Haraway termed the "prime mover" and what Oyama described as the "unmoved mover" is either only a figment of the metaphor's production, or

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[37] The importance of flexibility in biological systems and the repercussions thereof are elucidated in the subsequent chapter.

is essentially there but hidden. If DNA is the code, the information, the blueprint, instruction, or program; then who or what devises the code, inputs the information, draws up the blueprint, and is responsible for instructing the instruction, or programming the program? When DNA is identified as

> an inert molecule, with a ‘code,’ ‘blueprint,’ ‘message,’ or ‘instruction book.’ All of these require *writing* and *reading*. And such activities require a *mind*. Thus, *‘written in’* to the discourse of DNA is a *mind* that is reading and writing (original emphasis, Nierenberg, 1999: 219).

As I have explained in my previous chapter, by virtue of the obvious use of certain metaphors, various aspects and features of the topic being investigated remain concealed and unexplored. In this subcategory of metaphor, what is being underwritten (no pun intended, full pun intended) is “the question of whose mind,” is responsible for DNA writing and reading (ibid). The answer has “not only [been] left unanswered by the discourse of DNA, but has remained *unasked*” (ibid). Consequently, although DNA is conceptualised as the cause of life and its properties and behaviours, expected “explicit references to ‘vital forces’, ‘special agents,’ or G-d do not usually appear in articles regarding molecular biology or behavioural genetics” (ibid).

Such questions have remained unasked, even by contemporary, highly qualified, scientists working in the field (that is to say the code-breakers). For instance, John Sulston, director of the gene company Sanger Centre, is quoted as saying that “all the information required to make a human being is *written* into our DNA” (my emphasis, *National Geographic*, October, 1999: 54). He serves as another example of how the question of who does the writing is not addressed. If this is the effect of the metaphor at present, how did it begin? How did the concept metaphor of information coding rise to the ubiquitous state it is in now? Is it due to the fact that it captures the ‘truth’ of genetics? I intend to argue that this is not the case and (without debating the science) to explore significant consequences that have emanated from the representational utilisation of this concept metaphor.

3.2. A CRICK IN DOGMATIC SCIENCE

In the preceding section I utilised examples sourced mainly from the popular media in order to demonstrate the predominant concept metaphor operating in genetics discourse. However, such concept metaphors as they appear in the popular press are not the result of misappropriations and mistranslations derived from precise, non-figurative science. It is within science that many metaphors are generated. Thus, in this section I utilise examples from science so as to demonstrate how metaphorical representations can be rooted in science.

In the previous chapter I discussed how Lakoff and Johnson have shown that it is naïve to believe that the individual scientist's views do not impact on the research that they perform, on the results that they derive and construe, and on the interpretations they make of experimental data. In fact, Lakoff and Johnson argue that it is precisely these previous experiences and suppositions (drawn, for example, from dominant language/ideas, training[38]) that affect the meaning inferred from the results.[39]

To verify that this also occurs within the discipline of genetics and molecular biology, I will use Francis Crick as a case study. The Francis Crick of the famous geneticist team Watson and Crick, who arguably have had the greatest impact on the course of genetics to date: if not only by determining the structure of DNA, then certainly by implementing and influencing the language used to describe DNA. Crick, who was viewed by many as the epitome of a scientific geneticist, must (certain people might believe) surely be free of subjectivity, presupposition, and metaphorical entanglement in his scientific descriptions and use of specific terminology. To reveal that this is not the case I will use as an example 'the central dogma of molecular genetics' which has "guided most studies on the nature of

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[38] Such dominant linguistics and ideas are usually imposed on the individual scientist via society and culture, through what Foucault would explain as predominant discourses, and what Kuhn would describe as paradigmatic: "Normal science can be determined in part by the direct inspection of paradigms" (1970: 44).

[39] Some may still think that the language employed by scientists is a very specific jargon and is implemented precisely for exact explanation of scientific concepts in the form of theories. Many scientists do indeed believe that this is the case, because, as both they and I acknowledge, the use of language has repercussions and, therefore, should be as unambiguous as possible. I, however, assert that individual subjectivity and cultural and social influences, etcetera, cannot be dismissed, even in the greatest scientists. Hence, I have used Crick as an example to demonstrate this, but not to detract in any way from his pioneering research or illustrious career as a scientist. After all, it was he and Watson who installed a new (at that time in 1953) and useful concept metaphor of information coding into genetics discourse.

the gene" (G. Stent cited in Watson, 1981: xviii). Despite that the central dogma has been proven incorrect in certain instances, nevertheless, "the existence of the central dogma" has been said to "sharply distinguished the *Zeitgeist* of the molecular biology era from that which had preceded it" (original emphasis, G. Stent cited, ibid).

3.2.1. THE CENTRAL DOGMA

Haraway summarises the central dogma thus: "The Central Dogma was about a master control system for information flow in the codes that determine meaning in the great technological communication systems that organisms progressively have become after the Second World War" (1991: 206). The dogma states as its central tenet that 'DNA makes RNA, which makes proteins', or is encapsulated in the assertion that 'information is always transferred from DNA to RNA to protein'.

Information coding terminology is infused into Crick's and subsequent discussions regarding the central dogma. For example, the following passage from a second year textbook on genetics, which explains why DNA needs to form RNA and proteins, declares that:

> The characteristic of 'storage' [in a cell] may be viewed as genetic information that is present as a repository of all hereditary characteristics of an organism. However, that information may or may not be expressed. It is clear that, where as most cells contain a complete complement of DNA, at any given point they express only a part of this genetic potential. … Inherent in the concept of storage is the need for the genetic material to be able to encode the nearly infinite variety of gene products found among the countless forms of life present on our planet. The chemical language of the genetic material must be capable of this potential task as it stores information and as it is transmitted to progeny cells and organisms (Klug and Cummings, 2000: 284).

The following excerpt goes on to explain this process in more detail, but already the terms "storage," "information," "encode," and "chemical language" all demonstrate the ubiquity of the information coding metaphor.

> 'Expression' of the stored genetic information is a complex process and is the basis for the concept of *information flow* within the cell. … The initial event is the *transcription* of DNA, resulting in the synthesis of three types of RNA molecules: *messenger RNA (mRNA), transfer RNA (tRNA),* and *ribosomal RNA (rRNA).* Of

> these, mRNAs are translated into proteins. … *Translation* occurs in conjunction with rRNA-containing ribosomes and involves tRNA, which acts as an adaptor to convert the chemical information in mRNA to the amino acids that make up proteins. Collectively, these processes serve as the foundation for the *central dogma of molecular genetics* (original emphasis, ibid).

Notice the use of terms such as “information flow,” “messenger,” and “translation.” To summarise the process I have provided a useful diagram:

3.2.1.1. DIAGRAM 1:

THE CENTRAL DOGMA OF MOLECULAR BIOLOGY

$$\text{DNA} \xrightarrow[\text{Transcription}]{} \text{RNA} \xrightarrow[\text{Translation}]{} \text{Protein}$$

In essence, the central dogma assumed that DNA was the ‘master control system’ from which information flows to the organisms’ cells. However, “it is to be noted that an essential feature of the central dogma is a one-way flow of information from DNA to protein, a flow the direction of which is never reversed” (G. Stent cited in Watson, 1981: xviii). It should also be noted that it was the central dogma together with “its ancillary ‘sequence hypothesis’ ” that “led directly to the belief that there must exist a *genetic code* that relates the nucleotide sequence in the DNA polynucleotide chain to amino acid sequence in the corresponding polypeptide chain” (original emphasis, G. Stent cited, ibid: xix)

So how did the central dogma originate and how did the details of the language and conceptual frameworks, structured by certain metaphors, cause mistakes in supposedly unequivocal, neutrally worded, objective science? I will let Crick, who derived the hypothesis, give his retrospective analysis, starting with his “sequence hypothesis” which had significant implications for the central dogma:

> What the structure of DNA suggested was that the sequence of bases in the DNA coded for the sequence of amino acids in the corresponding protein. In the paper I called this the *sequence hypothesis*. Rereading it, I see that I did not express myself very precisely, since I said ‘… it assumes that the specificity of a piece of nucleic

> acid is expressed solely by the sequence of its bases, and that the sequence is a (simple) code for the amino acid sequence of a particular protein.' This rather implies that *all* nucleic acid sequences must code for protein, which is certainly not what I meant (my emphasis, 1988: 108).

In fact, Crick pointed out other mistakes he made where he underestimated the role of language/expression and fact and the effects thereof:

> I should have said that the only way for a gene to code for an amino acid sequence of a protein is by means of its base sequence. This leaves open the possibility that parts of the base sequence can be used for other purposes, such as control mechanisms (to determine if that particular gene should be working and at what rate) or for producing RNA for purposes other than coding (ibid).

It is interesting that in the above two excerpts Crick, while admitting his previous errors in judgement, does not recognise that many of these faults stemmed from his reliance on the fundamental concept metaphor of information coding. It is this concept metaphor that has guided and misguided his thinking regarding the base sequence as *only* functioning as a code. Even though he admits that other sections of the sequence of bases may have other purposes he does not offer any other explanations, or even query the underlying concept metaphor. However, this "sequence hypothesis" led to compounded errors in the central dogma:

> The other theoretical idea I proposed was of a rather different character. I suggested that 'once 'information' has passed into protein *it cannot get out again*,' adding that 'Information means here the precise determination of sequence, either of bases in the nucleic acid or of amino acid residues in the protein' … I called this idea the central dogma, for two reasons, I suspect. I had already used the obvious word hypothesis in the sequence hypothesis, and in addition I wanted to suggest that his new assumption was more central and more powerful. I did remark that their speculative nature was emphasized by their names (1988: 108-109).

This use of the term 'information', as being dependent on the intended and presupposed result, is a distortion of Shannon's initial designation of information (which was that information was irrespective of meaningful content, or specified sequence. This shall be elaborated on in the later sections of this chapter). Here, Crick has appropriated meaning to the information, in this case, the DNA's 'intended' outcome. It is this utilisation of the term 'information' by Crick that has inadvertently led to the idea that information is not able to 'get out' of the protein. Also, Crick's account gives the impression that he carefully considered and chose words with which to convey specific scientific meaning, until:

> As it turned out, the use of the word dogma caused almost more trouble than it was worth. Many years later Jacques Monod[40] pointed out to me that I did not appear to understand the correct use of the word dogma, which is a belief *that cannot be doubted*. I did apprehend this in a vague sort of way but since I thought that *all* religious beliefs were without any serious foundation, I used the word in the way I myself thought about it, not as most of the rest of the world does, and simply applied it to a grand hypothesis that, however plausible, had little direct experimental support (original emphasis: ibid).

What these excepts reveal is how even in supposedly objective science, the use of specifically chosen terminology can be interpreted through both subjective as well as cultural influences. In this case, Crick's personal understanding of the word 'dogma', in being so different from the generally accepted meaning, had tremendous implications for the understanding of his scientific theory.[41] I chose Crick as the prime example to illustrate these points, because not only is he a renowned scientist, but he also revolutionised genetics. However, in this case he has described in his own words how he postulated a theory with only slight "experimental support," and used words such as "dogma" that led many others not to even doubt the dogmatic assertions in his theory.[42] Yet, underlying all of this is the one thing that Crick will not concede to revise or retrospectively reconsider. That is the concept metaphor of information coding in which the enciphered information only flows uni-directionally. One might, therefore, believe that Crick is unaware of the power that metaphors provide in structuring conceptualisations. This is not the case, as evidenced

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[40] Jacques Monod was an influential scientist, who co-postulated the existence of messenger RNA, from studies of operon (specific sets of genetic units) regions of DNA.

[41] Crick's subjectivity and linguistic misunderstanding, in this case with regard to personal religious misgivings, defined a hypothesis that was assumed as scientific 'truth'! The importance of linguistic effects, not only with the concept metaphor, but even simplistic language at every level should not be underestimated. For instance, in regard to words, meaning and context and how they impact on messages. In Michael Reddy's "conduit metaphor": "the speaker puts ideas (objects) into words (containers) and sends them (along a conduit) to a hearer who takes the idea/objects out of the word/containers" (Lakoff and Johnson, 1981: 10). This metaphor presumes that "words and sentences have meanings in themselves, independent of any context or speaker" (ibid: 11). As is obvious through Crick's central dogma, the words are dependent on the context, the speaker and the receiver in order to convey the intended meaning of the message. Thus, language is not an 'empty vessel' that is sent and received in pure form.

[42] The effect of this, together with the authority of science (in this case a distinguished scientist), was that the central dogma was unquestioned for many years until numerous conflicting experimental results directly opposed this theory. For example, the fact that viruses such as HIV contain RNA that is replicated and not DNA). However, to this day, the central dogma "is [still] *central to an understanding of gene function*" despite that "exceptions are known" (my emphasis, Klug and Cummings, 2000: 752). A recent example of such an exception is prion proteins. Prions are *pro*teinaceous *in*fectious particles. In other words, proteins that are devoid of nucleic acid (such as DNA or RNA) and, yet, seem to cause disease. Prions are a contentious issue, probably because of the many paradigms that their existence seems to contradict. Due to limited space I could not discuss their influence on previously upheld metaphors, but for more information regarding prions I have included some fundamental articles on them in my reference section (Ironside, 1998; Jackson, and Clarke, 2000; Prusiner *et al*., 1998; Rochet, and Lansbury, 2000; *The Star*, February 17, 2004: 8, "Italian scientists find human traits in mad cow disease").

by his own words which demonstrate how analogy affects the scientist's approach to research and to interpreting results:

> It is clear that I thought of the RNA in the cytoplasm … as a 'template'; that is, as having a rather rigid structure … It was only later that I realized that this was too restrictive an idea, and that 'tape' might be nearer the truth. Just as a ticker tape has no rigid structure except momentarily when it is actually in the ticker machine, I eventually realized that the RNA directing the synthesis of a protein need not be rigid, but could be flexible, except for that part that coded the next amino acid to be incorporated (1988: 110).

Thus by using a different metaphor science could be facilitated more expediently. Even though Crick seems aware of this, he still does not reflect on the causal concept metaphor underlying these mistakes. His principal assumption of information coding is left extant and unrecognised as a concept metaphor. In fact, it is his reiteration of the metaphor and even reinforcement of some of the central implications of the metaphor, such as control,[43] that resulted in some of his mistakes. Although he does not pinpoint the underlying concept metaphor, he does admit that a "serious mistake in my thinking" was "confusing the mechanism itself (of protein synthesis) with completely separate mechanisms that were controlling it" (ibid). In other words, he was confusing the "control mechanism" required for regulating protein synthesis for the process of protein synthesis itself.[44] Crick concludes: "I believe one can easily fall into this mistake of mixing up effects due to the nature of a mechanism itself with effects due to its control when trying to unscramble a complex biological system" (ibid: 110-111). When the discourse of genetics is so indoctrinated with the information coding conceptual metaphor this mistake is almost inevitable.

If, as the above example with Crick demonstrates, the objective explanation of data is often subjectively, linguistically, socially and culturally influenced, then it seems more and more apparent that in using information coding to describe genetics, the corresponding representation of "life and heredity in this language was not the result of discovering either the 'inner logic' or the material structure of DNA" (ibid).

In fact, the idea of 'control' and 'controlling mechanisms' in molecular biology can be attributed to information theory. Molecular biologists came to "use the language of

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[43] Information coding derives issues of control from information theory (explained later).

[44] Another reason for this confusion harks back to Susam Oyama's remarks concerning the operation of rules and theories being applied to observed aspects of events rather than the multifaceted interaction of causes (in this case it revolved around the presence of the amino acid leucine).

messages, codes and information to describe their discoveries … in the 1940's" (Nierenberg, 1999: 226). Information theory's productive application in solving military problems[45] allowed it to gain eminence and to spread "throughout the physical, social and life sciences during the 1940s and '50s" (ibid: 217).

3.3. HOW INFORMATION THEORY INFORMED GENETIC INFORMATION

> In the postwar years, 'information theory' became a legitimate discipline that also spawned related endeavors like molecular biology, … disciplines which re-conceptualized their objects as information processors. It did not matter if the object was living or not. … Information theory became the interdisciplinary schema which equated cells, molecules, animals, humans and machines, as … biologists employed a common vocabulary of messages, communication, information, codes, control and feedback to describe their respective domains in terms of data input/output devices and processes (ibid: 229).

Why did information theory affect the discourse of genetics so fundamentally? Additionally, why is it that "the history of the discipline of molecular biology is inseparable from the influence of information theory, for better and worse" (ibid: 217)? To answer these questions initially requires understanding certain aspects of information theory.

3.3.1. SHANNON AND INFORMATION THEORY

The scientific concept of information, itself, came about in the late nineteenth century with thermodynamics.[46] "Its modern incarnation is usually dated to 1948" thanks to an engineer, Claude Shannon, who laid out a specific technical definition that quantified information (ibid: 229).[47] While working at Bell Laboratories Shannon defined

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[45] Military concerns during World War II were addressed using information theory to try and control and guide missiles, develop secure communications, as well as automating computerised machinery and weaponry (Nierenberg, 1999: 229).

[46] Thermodynamics, describes energy relationships, and their affects on matter (Voet and Voet, 1995: 42).

[47] The quantification of the information was statistically calculated based on whether a particular message could be identified from among other possible messages.

> information as a function of probability with no dimensions, no materiality, and no necessary connection with meaning. It is a pattern, not a presence. … The theory makes a strong distinction between message and signal. In information theoretic terms, no message is ever sent. What is sent is a signal. Only when the message is encoded in a signal for transmission through a medium – for example, when ink is printed on paper or when electrical pulses are sent racing along telegraph wires – does it assume material form (Hayles, 1999: 18).

Hence, "the very definition of "information," then, encodes the distinction between materiality and information that was also becoming important in molecular biology during this period" (ibid). As my discussion continues, the lasting effect of this definition when applied to genetics will become evident.

It was also Shannon's work on communication systems that led to the connection of messages and code. This is because quantification of information allowed for the "statistical understanding and manipulation of the *codification* of messages," whereby communication systems messages have to be "coded" in order to be transmitted (original emphasis, Nierenberg, 1999: 230).[48]

Shannon's technical theory of information is also significant for another reason: it does not differentiate between a message that makes sense and one that does not. In other words, the contents of the information are not assigned meaningful content. This is the antithesis of our current conceptualisation of "information" and "messages." "Shannon's concept of information has to do with probabilities of the combinations of symbolic units, and *does not involve the concept of meaning at all*" (original emphasis, ibid: 231).

The reason that Shannon's notion of 'information' entered the field of genetics was because it "distinguished 'information' from 'noise' " (ibid). Thus, "Shannon's definition was seen as providing a measure of 'orderliness' (information) against a background of chaos or entropy (the potential interference of other possible messages)" (ibid). Even though it was decontextualized,[49] Shannon's definition became predominant due to its formalization of "information into a mathematical function" (Hayles, 1999: 19). In so doing, Shannon developed "theorems, powerful in their generality, which hold true regardless of the

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[48] For example, to transfer sounds over a telephone they have to be transmitted or 'coded' into the form of electrical impulses (Nierenberg, 1999: 230).

[49] Detractors argued that by separating information from context and, hence, meaning the result was a highly formalized theory. Even Shannon admitted that his theory "was meant to apply only to certain technical situations, not to communication in general" (Hayles, 1999: 19).

medium in which the information is instantiated" (ibid). This in turn was possible because "abstracting information from a material base meant that information could become free-floating, unaffected by changes in context" (ibid). Thus, this theory "reified information into a free-floating, decontextualized, quantifiable entity that could serve as the master key unlocking secrets of life and death" (ibid).

After the Second World War the power of physics to cause death, in the form of the atomic bomb, had now spawned a new, more constructive, endeavour: to learn the secrets of life. Due to the prestige that physicists had garnered, when they turned their attention to biology, especially genetics, physicists gave geneticists power by association to discover the secret of life.

3.4. PHYSICS AND GENETICS

Physics has had a remarkable impact on molecular biology and specifically genetics. This was not only due to its cognitive and technical contributions, but as Keller argues, "physics and physicists provided a resource of far greater import for the success of molecular biology than any particular skills; namely, they provided social authority" (1992: 97).[50] Although physics initially served the role of technical authority, this role was expanded and the physics discipline was enlisted to accomplish "the essentially social process of reframing the character and goals of biological science" (ibid: 98). This occurred by molecular biologists "borrowing … in a variety of ways" from physicists:

> First, through the borrowing of an agenda that was seen as looking like the agenda of physics; second, by borrowing the language and attitude of physicists; and finally, by borrowing the very names of physicists.
>
> Indeed, even the borrowing of purely technical expertise, ostensibly in the name of making biology 'better,' was instrumental in reframing biology, in making it different. And in all this borrowing – of agenda, of language, attitude, names, technique – the material underpinning of the social power of twentieth–century physics, and physicists, lay in close view, evoking in some at least the hope that that too, the technological prowess of physics, could also be borrowed (ibid).

The celebrated physicist, Leo Szilard, believed that it was not so much the skills but rather the attitude from physics that had the greatest influence on molecular biology. Up until the

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[50] The authority that physics provided was due to the technological proficiency that physics had already displayed, for example, with powerful weaponry.

end of World War II, life had been viewed by biologists as being too vastly unique and complicated to ever be comprehended completely. The most important feat that physics achieved within genetics was to bring the metaphor and the belief that, as Szilard phrased it 'mysteries can be solved'. In other words, physicists framed "biological problems in the particular terms they could understand, in the terms that could lead to what they could recognize as a 'solution' " (ibid: 105). Thus, even though "life (development, reproduction, etcetera) was not a problem that could be 'solved'; the physical basis of genetic information was" (ibid).

In this period, physics was dominated by the search for the most basic building block that could give rise to everything else. It was this same mind-set and methodology that they bequeathed to geneticists, who in turn began to search for the most fundamental entity that could make life. In other words life was atomised. This has continued to this day:

> As the search of particle physicists for the building blocks of matter leads them into the realm of the vanishingly small and evanescent, the search of biologists for the building blocks of life leads them into the realm of pure information (ibid: 179).[51]

So, if physicists brought the conviction that the secrets of genetic information could be solved, and most likely solved in an 'atomised' form of life, then Erwin Schrödinger, the eminent quantum mechanics physicist, brought the belief that the answer to this secret resided in genes.

> Schrödinger decided that this secret lay in the contents of the chromosomes (genes), which possess the quality of being like *written information*: 'It is these chromosomes … that contain some kind of hereditary code-script, the entire pattern of the individual's future development and of its functioning in a mature state.' But in addition to being a 'code-script,' the chromosomes act as an *animating force*: 'The chromosome structures [genes] are at the same time instrumental in bringing about the development they foreshadow. They are law-code and executive power … architect's plan and builder's craft all in one.' The gene is not only the plan, but it is the agent which activates and realizes the plan. It is a 'code-script' that reads and writes itself (original emphasis, Nierenberg, 1999: 227-228).[52]

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[51] This search (for the smallest particle of life) has not abated, and has led to the present day, where genes

> no longer need even their own chemical structures for their existence. The substantive component of the gene is said to lie in its nucleotide sequence, and that can be stored in data banks and transmitted by electronic mail (Keller, 1992: 179-180).

Keller also points out how this portrayal of genes "as having no need of the bodies in which they are housed for the processes of 'reading' and 'interpretation', " can be correlated with how certain "realist scientific discourse" seems to make "human subjects … invisible, their material, embodied presence … ephemeral and inconsequential" (ibid: 179).

[52] The obvious illogicality of DNA being described by Schrödinger as both a "*law-code*" and "*executive power*" has been recognized by various scientists (Nierenberg, 1999: 228). Since, by taking the idea of the " 'genetic program literally, one falls into a strange loop: one has a program that needs its own product in order

This meant that the actual secret of the 'code-script' in Schrödinger's model, and hence the secret of life itself, was 'information' in the form of genes! Schrödinger became instrumental in genetics discourse, because he argued for "the role of the gene as the basis of life – that the distinctive characteristics of living organisms reside in the fidelity of transmission of genetic information" (Keller, 1992: 102). His book *What is Life?* was specifically inspirational to Watson and Crick and to their discovery.[53] Keller argues "that Schrödinger's legacy depended … little on the utility of any of his particular biological arguments" (ibid: 104).[54] His influence was much more dependent on both the timing of his book and "disciplinary politics" because "he promoted the idea that at least one area of

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to be executed ... To carry on the program, it must already have been executed' " (F. Varela and J.P. Dupuy cited, ibid). This is an almost: 'Which came first? The chicken or the egg?' situation, regarding DNA. Donna Haraway has expanded on this situation by pointing out that humans "finally have a standard genesis story. *In the beginning was the copy*" (my emphasis, 1991: 216).

[53] Crick has said that Schrödinger's book instilled in him the motivation to try to show that areas apparently too mysterious to be explained by physics and chemistry, could in fact be so explained. "The book … conveyed in an exciting way the idea that, in biology, molecular explanations were just around the corner. This has been said before, but Schrödinger's book was very timely" (Keller, 1992: 104). Schrödinger's book also had a significant impact on Watson. Watson had initially intended to become a naturalist, but then he read W*hat is Life?* He was so intrigued by Schrödinger "stepping boldly outside of his field of expertise" (quantum physics) and arguing that "one of life's essential features is the storage and transmission of information – that is, the genetic code" that Watson decided to study genetics (*TIME*, March 3, 2003: 35). In 1947 Watson went to Indiana University to study viruses. He chose viruses based on Schrödinger speculation that the genetic code "had to be both complex and compact enough to fit inside a single cell" and therefore "this code had to be written at the molecular level" (ibid). Watson decided that since viruses are the simplest life form on earth, the genetic code could be more easily detected in them. Watson and Crick describe the course of their research and interests in their respective books, *The Double Helix* (Watson, 1981), and *What Mad Pursuit* (Crick, 1988).

[54] In fact Schrödinger's model, from which he surmised that genes are the 'secret of life', was derived from his ideas on living organisms and entropic constraints. Schrödinger was intrigued as to how living organisms seem to survive by appearing to defy the second law of thermodynamics. The second law of thermodynamics states that entropy or disorder in the universe is always increasing. Schrödinger thought he solved the problem of how cells seemed to become more ordered, through his reasoning that the "chromosome 'saved' the organism from entropic decay because of its 'orderliness' " (Nierenberg, 1999: 232). This interpretation is highly flawed. The reason that increasing entropy observed in a cell does not actually oppose the second law of thermodynamics was determined long after his theory. The reason is primarily because a cell is not an environment in and of itself. Let me explain: Living organisms take in fuel energy from the environment, in order to 'order' reactions that occur. In so doing, heat energy is released as a by-product from these reactions.

> Heat is energy in its most disordered from – the random commotion of molecules – and heat is released from the cell by the reactions that order the molecules it contains. The increase in random motion, including bond distortions, of the molecules in the rest of the universe creates a disorder that more than compensates for the increased order in the cell, as required by the laws of thermodynamics for the spontaneous processes. In this way the release of heat by a cell to its surroundings allows it to become more highly ordered internally at the same time that the universe as a whole becomes more disordered (Alberts *et al.,* 1994: 60-61).

Essentially, the cell "draws in fuel from its environment and releases heat as a waste product. The cell is therefore not an isolated system in the thermodynamic sense" (ibid: 60).

biology;" namely, genetics, was worthy of physicists' endeavours "at a time when many were seeking just such an alternative" (ibid: 104-105).[55]

It is at this point that I would like to explain how, even though Schrödinger had certain inherent contradictions in his model, these were superficially suppressed by utilisation and conjunction with Shannon's model. In Shannon's definition of information, 'meaning' was not assigned to the information. Therefore, "no specific qualities could be determined by the gene's 'information' if the word were being used in the scientific/engineering sense" (Nierenberg, 1999: 232). This implied that, a mutation, even a most deleterious one, could not have an effect on the amount of genetic information. However, "the discourse of DNA is predicated on the idea of *information as meaningful content*" and "the term 'information' [has] became the *sine qua non* of the discourse of molecular biology" (original emphasis, ibid). This occurred when molecular biologists appropriated 'information' "in the colloquial sense to indicate that DNA 'contained' meaningful content like human behaviours and attributes" (ibid). But to do so required the continued disregard for the question of meaning. By this I indicate that while Shannon's definition of 'information' encompassed probabilities of sets of symbols, Schrödinger's model viewed 'information' as the most meaningful signifier possible, that of 'the secret of life'. Thus, Shannon's technical definition, which "excluded any reference to meaning," was expropriated in order to provide the term with "scientific legitimacy and authority" (ibid).[56] In effect, Schrödinger and Shannon's designations of 'information' were amalgamated in order to grant meaning and significance to genetic 'information'. This allowed the

> opposing colloquial and scientific usages of the term 'information' … to coexist in the discourse of DNA, establishing an ambiguity which allows the 'information' supposed to inhabit the gene to have both scientific legitimacy *and* content. … Consequently, questions raised by the anthropomorphization implicit in the colloquial use of 'information,' the presumption that the DNA molecule can somehow 'read' and 'comprehend,' are masked by the technical definition of information which would presume no such thing (original emphasis, ibid: 232-233).

Yet, by circumventing the problem in this way, other problems are raised:

> questions which might be provoked by use of a precise quantitative term like 'information' in relation to the gene (i.e. quantity of what?) are effaced by the

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[55] The alternative mentioned, refers to physicists and geneticists turning to the investigation of the source of life, rather than the deaths that resulted from the use of atomic energy in the Second World War.

[56] It is such structuring of definitions regarding DNA and genes that has led to 'junk DNA'. 'Junk DNA' (as this name even suggests) has no noticeable meaningful content, in terms of what is deemed meaningful information in genetics discourse, and hence is viewed and referred to as 'junk'.

> colloquial meaning of information. This essential contradiction lies at the core of the enormous power the discourse of DNA is able to sustain (ibid: 233).

The overall consequence is the creation of a “profound and sustaining ambiguity” (ibid: 228). This powerfully maintained conceptual metaphor has resulted as a corollary of anthropomorphising the gene as the smallest possible unit for storage and transmission of information, in association with the misappropriation of the term ‘information’.[57]

The concept metaphor generated between the term ‘information’ and its explanation with regard to DNA, has “allowed for a discursive hegemony that shows few signs of abating” (ibid). You may be wondering why this is the case now. To answer this question, requires returning to Watson and Crick.

3.5. THE SUCCESS OF THE SECRET OF LIFE

The utilisation of the physicists’ mind-set that the mysteries of biology could be solved, together with Schrödinger’s exciting opinion that this ‘secret’ was to be found in genes[58] that carried coded information, culminated in Watson and Crick’s discovery of the structure of DNA.

> It was precisely … – this relocation and redefinition of life – that Watson and Crick depended upon for success in their quest for ‘the secret of life,’ and which their success, in turn, did so much to cement (Keller, 1992: 105).

In their famous articles in the journal *Nature,* Watson and Crick’s hypotheses for a structure and replication mechanism of DNA not only offered an explanation for how DNA could be the key to the “secret of life,” but also institutionalised the “deployment of information theory terminology into the domain of biology” (Nierenberg, 1999: 218). Furthermore, in Watson and Crick’s description of DNA, the information coding metaphor is obvious. Since the scientists represented the sequence of bases as ‘written’ ‘code’ carrying genetic

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[57] Subsequently, the smallest unit for life has been repositioned in smaller and smaller forms as more has been discovered over the years. Thus, in descending order the smallest unit of life has gone from DNA, to the gene, to the nucleotide and, finally, to the four chemical groups adenine, cytosine, guanine and thymine (and uracil in RNA).

[58] Schrödinger was not the first to have this opinion, “it was back in the late Twenties that a few geneticists, particularly H. J. Muller, began to urge … that the real ‘secret of life’ ” could be found “in the hereditary material” (C. Waddington cited in Watson, 1981: 205-206). Although, at that time, just what the hereditary material consisted of (for example, protein or DNA) was still unknown.

‘information’. They explained that because “any sequence of the pairs of bases” can occur in the DNA structure:

> It follows that in a long molecule many different permutations are possible, and it therefore seems likely that the *precise sequence of the bases is the code which carries the genetical information*. If the actual order of the bases on one of the pair of the chains were given, one could write down the exact order of the bases on the other one, because of the specific pairing. Thus one chain is, as it were, the complement of the other, and it is this feature which suggests how the deoxyribonucleic acid molecule might duplicate itself (my emphasis, Watson and Crick, 1953b: 965-966).

In retrospect, considering how much Watson and Crick were influenced by Schrödinger’s ideas, this situating of the sequence of bases as the “code which carries the genetical information” seems ineluctable (ibid). As Gunther Stent has noted:

> the most important point made by Schrödinger was that the gene is to be thought of as an *information carrier*. And the only reasonable way in which genes could be imagined to carry their hereditary information is by embodying a succession of a small number of different repeating elements, or symbols, whose exact pattern of succession represents an encoded genetic message (original emphasis, G. Stent cited in Watson, 1981: xiii).[59]

What better than the distinguishable pyrimidine and purine bases to fulfil this role? “In other words, the repeating elements of Schrödinger’s proposed hereditary codescript could now be identified as the four different nucleotides carrying adenine, or guanine, or thymine, or cytosine” (G. Stent cited, ibid: xv).

Watson and Crick’s proposed base sequencing and structure of DNA, as well as the hypothesis for its mechanism of replication, resulted in what a *TIME* magazine article refers to as “The DNA Revolution” (March 3, 2003: 35). Kuhn defines scientific revolutions as those “extraordinary episodes” where a “shift of professional commitments occurs” (1970: 6). Kuhn goes onto explain that such scientific revolutions produce

> a consequent shift in the problems available for scientific scrutiny and in the standards by which the profession determined what should count as an admissible problem or as a legitimate problem-solution. And each transformed the scientific imagination in ways that we shall ultimately need to describe as a transformation of the world within which scientific work was done (ibid).

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[59] The “vast informational capacity of such a coding system” was illustrated by Schrödinger “with an example that used the two symbols of the Morse code – dots and dashes – as its repeating elements” (G. Stent cited in Watson, 1981: xiii).

On all these counts, Watson and Crick's work produced a scientific revolution. In effect, their work not only elucidated the molecular structure of DNA, but also determined the linguistic metaphorical entanglements and the textual conceptualisations associated with DNA. The results of this can still be observed in the mass media today. For instance, almost exactly fifty years after Watson and Crick 'discovered' the structure of DNA *The Star* newspaper published an article celebrating this achievement.[60] The headline proclaimed: "The day they cracked the human code" (February 15, 2003: 7) with the subheading "It's 50 years since two young scientists finally figured out what they knew to be the secret of life: the molecular structure of deoxyribonucleic acid – better known simply as DNA" (ibid). The use of the information coding metaphor is obvious in the phrase 'cracking the code'. Finding the answer to the 'secret of life' in the form of DNA is also declared as the article quotes Watson, who says that "it seemed to us it had to be the secret of life, … We thought it was the most important problem to solve if you were a biologist" (ibid).

Why has this metaphorical vocabulary remained so powerful and reified genetic discourse over the last 51 years? Keller provides insight into the answer:

> the elucidation of that mechanism [of genetic replication] inevitably led to the conclusion that life itself was not complex, as had been thought, but simple – indeed simple beyond our wildest dreams. The only secret of nature was that there were no secrets, and now that secret was out (1992: 107).

In other words, geneticists were now responsible for exposing life's (more simple than expected) secrets, in fact "this particular representation allowed molecular biologists an assumption of scientific hegemony heretofore unfamiliar in biology" (ibid). And, ultimately, this portrayal of DNA speaks to social and cultural concerns, because if geneticists could understand this 'secret' and 'decode' it, that information held the promise of being used to enhance, prolong and ensure greater health and life, or to phrase it differently, promote the prospect of immortality. Therefore, Watson and Crick did indeed begin "The DNA Revolution." Since by finding a novel means "of looking at a whole group of phenomena," Watson and Crick had allowed scientists to "begin formulating" new, exciting and possibly life-altering "questions definite enough to be answerable" (C. Waddington cited in Watson, 1981: 205-206).

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[60] There were many similar articles that celebrated the fifty year anniversary of the 'discovery' of the structure of DNA. For example, another article extolled "the wonder of DNA" by listing "23 ways the molecule of inheritance has changed the world" (*Saturday Star*, March 8, 2003: 13). Accompanying the text were provocative images, such as the infamously recognizable mouse that had a human ear grown on its back. *Scientific American* also discussed some of the achievements and controversies surrounding "50 years of the double helix" (Rennie, 2003).

3.6. APPROPRIATION OF INFORMATION THEORY INTO BIOLOGY AND GENETICS

So how was information theory, via physics, appropriated into the realm of genetics? To answer this requires examining why biological scientists in the nineteen-fifties were turning to information theory. At this time, there were a number of symposiums held that were promoting the incorporation of information theory into biology. One such conference was held in Gatlinburg, Tennessee in nineteen-fifty-six during the end of October. It was entitled "*A Symposium of Information Theory in Health Physics and Radiobiology.*" This symposium was held specifically to address the importance of information theory in biology, thus, I will be utilising it as an example to elucidate the views that were prevalent at the time. To set the stage it should be noted it was at this time that the effects of radiation, specifically with regard to the induction of genetic mutations in DNA, were becoming more evident.[61] The symposium was sponsored by the *Oak Ridge National Laboratory* in Oak Ridge Tennessee. This institution was principally concerned with controlling and releasing nuclear energy, which seems an unlikely sponsor for propelling information theory into the biological fields. The director of the institution, Alvin M. Weinberg, explained why the Laboratory was "interested in sponsoring a meeting on Information theory in Health Physics and Radiobiology" (Yockey *et al.*, 1956: ix). The Laboratory at that time conducted various research programs. But two fundamental areas of research of interest to the laboratory were in the investigation of "the basic physical mechanisms and in the basic biological manifestations of radiation damage … established in the Health Physics Division and in the Biology Division" (ibid). They were interested in these areas because they viewed them as bearing:

> directly on general problems of growth and of the impairment of growth by radiation and allied agents… It is in establishing a tie-up between the physical and biological aspects of radiation damage that information theory may play an important role. We hope that this conference will help to assess the value of

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[61] This was thanks to certain significant forerunners. Two such noteworthy scientists, who worked together, were H. J. Muller and Thomas Hunt Morgan. Muller, who argued for "the gene as the basis of life, and mutation as the central problem of biology," also achieved the artificial induction of mutagenesis utilising X-rays (Keller, 1992: 97). Thomas Hunt Morgan, who worked primarily on fruit flies (*Drosophila melanogaster*), correlated the causal links between radiation, mutation and consequent genetic phenotypic expression. His work and the repercussions of it, lasting to this day, in the field of genetics are explained in depth in the book titled after him (Shine and Wrobel, 1976). For instance, the fruit fly still serves as an important component in genetic research, and the taxonomic characterization of mutations that Morgan developed is still utilized.

> information theory to phenomena involved in the interaction of radiation and living matter (ibid).

Weinberg concluded:

> The life sciences … have developed most of their theoretical structure without mathematics playing a leading role. Nevertheless, the need for mathematical methods in biology has long been felt … The possibility that the life sciences could develop mathematical systems suitably their own, so that this form of research could be added to the already powerful research tools available, was the common denominator in this symposium. In order to address ourselves to a single task, the principal emphasis was on information theory. The reader will note that in several papers there is, willy-nilly, a reference or two to the ideas of cybernetics. Perhaps this presages a greater influence in biology of this mathematical sibling of information theory (ibid).

Indeed, cybernetics would prove enormously and, yet insidiously, influential in genetics (its noteworthy contribution to genetics will be discussed later within this chapter).

The symposium's participants decided that information theory would be useful when it comes to assessing which facets of biological phenomena to focus their research on. To explain this they used a biological example that:

> if we knew the chemical constitution of all substances in all cells, together with all details of distribution, chemical kinetics … then we still would not necessarily know which of all these details are significant on the next higher level of organization, although presumably this information must be implicitly contained in the known details. Are we simply up against a psychological limitation (ibid: 400)?

In other words, the symposium's participants took for granted that "knowledge is not usable for human minds unless it is organised in blocks with not too much detail in each" (ibid). The consensus of opinion was that humans "seem able to think only of so much detail within any single train of thought" (ibid). This paradigm results in scientists feeling that they are "faced with amounts of detail considerably beyond" their "mental capacity" (ibid). This leads them to "begin to select: in the course of such selection important features are eliminated almost as readily as unimportant ones" (ibid). Thus, it becomes incumbent on scientists to select certain elements of data and disregard other pieces of information in order to arrive at conclusions from experimental results. This process of selection and interpretation is highly infused with cultural and linguistic preconditioning (that influence scientists) and, consequently, the conclusions that they arrive at.[62]

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[62] As already explained and demonstrated with Crick and the central dogma.

Such conjectures are built on previous suppositions. In this case the logical progression of thought, that we are able to only handle blocks of information, stems from an unrecognised yet highly predominant metaphor in Western thinking. This is what Lakoff and Johnson describe as the "The Building-Block Theory" which is based on the concept "meaning is compositional" (1981: 202). (This theory dominates Western culture in many areas, just one of which is science). This theory stems from objectivism. In objectivism, the world is seen as being composed of objects that have "well-defined inherent properties, independent of any being who experiences them, and there are fixed relations holding among them at any given point in time" (ibid). Due to this paradigmatic view point:

> objectivist theories of meaning are all compositional in nature – that is, they are all building-block theories – and they have to be. The reason is that, for the objectivist, the world is made up of building blocks: definable objects and clearly delineated inherent properties and relations. Moreover, every sentence of the language must contain all of the necessary building blocks so that, together with the syntax, nothing more is needed to provide the truth conditions of the sentence. The 'something more' that is ruled out is any kind of human understanding (ibid).

Thus the building-block theory extends into language, since the objects constituting the world will be named in language, and the inherent properties of these objects will then require placement in relation to one another. Keller points out that "such basic acts of naming have helped to shape the actual course of scientific development, and, in so doing, have helped to obscure if not foreclose other possible courses" (1992: 31).

When trying to understand aspects of biological and especially genetic phenomena, this building-block theory has been used to try and evaluate how certain objects and their inherent properties relate in order to create complex biological interactions. For instance, with genetics, the gene can be seen as an object in and of itself. However, its constituent objects, namely the nucleotides that compose it can also be viewed as objects. This can be extended to the objects comprising the nucleotides (namely, the chemical groups of the phosphate, the sugar, and the base).[63] The major problem with biological, hierarchically organized, systems (from a research point of view) is the diverse biological components ('objects') that react at various levels of complexity. Information theory seemed to offer a means to comprehend these biological relationships and to assign values for selecting which aspects to study. Let me clarify: for the participants at the symposium "the most

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[63] Even in current media the idea of building blocks composing DNA, which is viewed as the basis (or building block) for life, is apparent. For example: "nucleic acids that are the basic building blocks of DNA, the basic structure of all life" (*The Star*, April 1, 2004: 13).

striking feature [in living organisms] is the existence of the organizational pattern with several distinct levels of organization" (Yockey *et al.*, 1956: 400-401). Although "some levels are more sharply defined than others, and the hierarchy of levels is not always unambiguous," they are pervasive "enough that the intelligibility and validity of any statement in biology depends on proper agreement with organizational hierarchy" (ibid: 401). However,

> one of the outstanding features in biological organization is that quite obviously only a small amount of the features obtained at a given level has observable effects on the next higher level. Hence one of the most urgent problems, on any level, is that of determining what details are involved in the communication to the next higher level - but this is precisely one form of the problem of the 'whole and its parts' (ibid).

Information theory offered a possible solution, since it presented a mathematical approach to correlate the parts in relation to wholes (for example, nucleotides in relation to genes). Information theory provided an expedient formalism to explain these relations, by stating that:

> the *total information content* of the *whole* is exactly *equal* to the *sum* of the information contents of the *parts* – where the description of each part includes all possibilities of connection with other parts; the mutual *dependency of parts* being *organized* into a *whole* causes a mutual reduction of uncertainty; therefore, the amount of *non-redundant* information associated with the *whole* is *less* than the *sum* of the information contents of the *parts*; the difference is exactly the information content of the constraints, or all those propositions which apply only to the whole and not to its parts in isolation (my emphasis, ibid: 400).

To make this more understandable I have constructed my own equations to demonstrate the above explanation of information theory with regard to facets of biology.[64]

Principally, information theory seemed a legitimate means of mathematically quantifying biological aspects in order to gain understanding into how they interacted. Indeed, in exploring the work from the various scientists who participated in the symposium, some of their investigations utilising information theory have proven to be useful. In fact, several of

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[64] I have simplified the above statement into these formulae:
TOTAL INFORMATION CONTENT OF WHOLE = information contents of: PART1 + PART2 + PART3…
Therefore:
INFORMATION CONTENT OF CONSTRAINTS =
(information contents of PART 1 + PART2 + PART3…) - (non-redundant information associated with the whole).

the experiments have formed the basis for some of the knowledge of genetics, cytology, immunology and biochemistry that is now taken for granted.[65]

In summary, information theory provided a mathematically quantifiable basis for scientists to select sections of information to use for research. (Of course, the paradigm of examining and assessing portions of information is based on the long held concept of "The Building-Block Theory"). In this way the connections of the parts in relation to the wholes, could be formulated and mathematically and scientifically interpreted. Furthermore, the link that helped catapult the use of information theory from physics to biology and then to genetics, was research on the effects of radiation. Radiation is usually studied by physicists, but to study its biological effects required the involvement of biologists. When physicists and, subsequently, biologists observed the consequences of radiation at a molecular level, on DNA, molecular biologists and geneticists joined the investigations.

Personally, I do not feel that such a theory could in anyway account for all the complexity, variation and subtleties of interactions of all the elements in a biological system. To enumerate each part is virtually impossible. However, at the symposium, this was the agreed use of information theory; as a technique to try and mathematically formalise the intricacies of biologically diverse interactions through a quantifiable approach.

The symposium ended with these words that proved highly accurate (well at least for the next 48 years): "there was general agreement that … information theory is here to stay in biology" (ibid: 402).

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[65] For example, one participant, L. G. Augustine, applied information theory to his methodology in order to calculate the significant catalytic effects of enzyme substrate complexes, as discussed in his article on "protein structure and information content" (Yockey *et al.*, 1956: 103-123). Some of the other interesting and seminal experiments that scientists at the symposium utilized information theory for, included: determining whether free radicals could cause mutations and cancer (at this time it was unknown, ibid: 253-359); determining the specificity of antigens (ibid: 211-218); investigating "membrane phenomena from the point of view of information theory" (ibid: 197-203) and examining the "efficiency of information transmission by biochemical Co-factors" (ibid: 204-209). Here, even some of the titles are suffused with information theory terminology.

3.6.1. CYBERNETICS AND ITS CONTROL OVER GENETICS

Earlier on in this discussion, I pointed out how the director of the *Oak Ridge National Laboratory* had had the foresight to realise that cybernetics would have a significant effect on biology. How right he was. Cybernetics allowed for the information (from information theory) to be linked with determinism. The person who was instrumental in this linkage was Norbert Wiener, who "named and promoted the science of *Cybernetics*, a system of thought he saw as a new lens through which to interpret problems in every discipline" (original emphasis in Nierenberg, 1999: 233). As Hayles explains:

> Cybernetics was born when nineteenth-century control theory joined with the nascent theory of information. Coined from the Greek word for 'steersman,' cybernetics signalled that three powerful actors – information, control, and communication – were now operating jointly to bring about an unprecedented synthesis of the organic and the mechanical (1999: 8).

When cybernetics was in its initial stages, certain illustrious scientists "met at annual conferences sponsored by the Josiah Macy Foundation" with the intention of formulating "the central concepts that, in their high expectations, would coalesce into a theory of communication and control applying equally to animals, humans, and machines" (ibid: 7). Norbert Wiener and Claude Shannon were among the researchers attending these annual conventions held between 1943 and 1954, which came to be known as the '*Macy Conferences on Cybernetics*'. These meetings

> were instrumental in forging a new paradigm. To succeed, they needed a theory of information (Shannon's bailiwick), a model of neural functioning that showed how neurons worked as information–processing systems (McCullock's lifework), computers that processed binary code and that could conceivably reproduce themselves, through reinforcing the analogy with biological systems (von Neumann's speciality), and a visionary who could articulate the larger implications of the cybernetic paradigm and make clear its cosmic significance (Weiner's contribution). The result of this breathtaking enterprise was nothing less than a new way of looking at human beings. Henceforth, humans were to be seen primarily as information-processing entities who are *essentially* similar to intelligent machines (original emphasis, ibid).

Weiner was particularly interested in communication and control. This stemmed from his World War II work (undertaken under the auspices of the *United States Office for Scientific Research and Development*), which focused on creating weapons that guided themselves in order to hit specified targets. His conceptualisations were extended to other fields, such as molecular biology and genetics.

It was Weiner's analysis of feedback and homeostasis that would prove to be especially influential in genetics. For Weiner "*feedback* was essential to all purposive behaviour, from that of missiles, animals, and cells to human beings" (original emphasis in Nierenberg, 1999: 233). He was particularly interested in how feedback appeared to sustain homeostasis in living organisms. Until the *Macy Conferences*, "homeostasis had been understood as the ability of living organisms to maintain steady states when they are buffeted by fickle environments" (Hayles, 1999: 8). Weiner, however, defined homeostasis as the "process of *communication control*" (my emphasis, Nierenberg, 1999: 233). The significance of Wiener's metaphorical transformation of the model of homeostasis into "a problem of control and communication" allowed for cybernetics to institute its own feedback system where "a model of vital systems was applied to the inanimate world of weapons and machines, and then re-deployed to describe vital systems" (ibid: 234-235).[66] As the borders "from human to machine to animal and back again" were being crossed "the linguistic metaphors were getting lost in the shuffle" (ibid: 235).

Cybernetics resulted in establishing that "communication *is* control," and this "vocabulary soon gained hegemony in molecular biology, and the control of the flow of information became the 'reality' of the gene" (original emphasis, ibid: 235). This can be seen today in popular culture, as already demonstrated in my examples. However, here is another to illustrate the prevalence of how the notion of "control" is perpetuated in the domain of genetics even today. This example is obtained from a first year biology textbook (which is used to train future scientists). The overall concept metaphor of information theory is pervasive, and in itself controlling, where it is used in this case to facilitate an explanation regarding "gene control" in conjunction with homeostatic regulation.

> In bacteria, the primary function of gene control is to adjust the cell's activities to its immediate environment. Changes in gene expression alter which enzymes are present in the cell, in response to the quantity and type of available nutrients and the amount of oxygen present. … Cells of multicellular organisms … experience fairly consistent conditions … cells in such organisms still respond to signals in their immediate environment (such as growth factors and hormones) by altering gene

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[66] It was "during the Macy period" that "the idea of homeostasis was extended to machines," because "like animals, machines can maintain homeostasis using feedback loops" (Hayles, 1999: 8). Although "feedback loops had long been exploited" in mechanical systems to augment their stability, it was only in "the 1930s and 1940s … that the feedback loop was explicitly theorized as a flow of information" (ibid).

> expression, in so doing they participate in regulating the body as a whole. In multicellular organisms whose internal environments are maintained relatively constant, the primary function of gene control in a cell is not to respond to that cell's immediate environment, but rather to participate in regulating the body as a whole (Raven and Johnson, 1990: 350).

In this example, feedback loops for control and communication between the different levels of organisational hierarchies, as well as the control to maintain the homeostasis of the body, all emanate from cybernetic ideas and terminology. These aspects of control and communication are further developed in the biology textbook:

> changes in gene expression compensate for changes in the physiological condition of the body. Others mediate the decisions that *produce* the body itself, ensuring that the right genes are expressed in the right cells at the right time during development. … Control of gene expression is essential to all organisms … it is critical for directing development and maintaining homeostasis (original emphasis, ibid).

In these extracts, the body has been 'produced' through a carefully controlled process of switching on the "right genes" (containing the right part of the message for cell development) through the use of regulatory feedback loops. "It is precisely this link between communication and control which has allowed the 'information' contained in the DNA molecule to be interpreted as an imperative, an *instruction* or a *command*" (original emphasis, Nierenberg, 1999: 233-234). The effect of this is to ultimately create a sense of genetic determinism which extends to our construction of self. This is because, by representing our body as the constructed 'product' of our DNA, DNA becomes immutably positioned as an "instructor," and

> once DNA became an 'instructor,' the end result of development could easily be posited as the cause, obscuring the difficulties inherent in this logic, including the simple known fact that numerous, random factors can intervene between genotype and phenotype (ibid: 234).

Subsequently, "the discourse of DNA has promulgated the idea that phenotype (the observable organism) is the product that is 'intended' from the genotype (the genes themselves)" (ibid).

Another important consequence has also resulted from cybernetics, with regard to our constructed portrayal of the 'produced' self. As revealed in the excerpts, there is an implicit reliance on another of Wiener's opinion: that the "characteristic feature of the individual organism isn't a particular quality of matter … but the perpetuation of a message containing information about structure and process" (ibid). Since Shannon and Wiener's formalized definition of information "conceptualised information as an entity distinct from the substrates carrying it," it was a "small step to think of information as a kind of bodiless fluid that could flow between different substrates without loss of meaning or form" (Hayles, 1999: xi). Hence, through this conceptualisation "much of the discourse on molecular biology treats *information* as the *essential code* the *body expresses*" (my emphasis, ibid: 1). This is an inexorable conclusion given that cybernetics "proceeded primarily along lines that sought to understand human being as a set of informational processes. Because information had lost its body, this construction implied that embodiment is not essential to human being" (ibid: 4). Thus, through the incorporation of cybernetic discourse, genetics has been (re)presented with the role of both information carrier and controller, and has become separated from the rest of the body that it is said to produce. In effect a feedback loop of communication, which maintains homeostasis between the controller (our DNA) and the controlled (our body), has been created.

3.6.2. INFORMATION/MATERIALITY HIERARCHY

An information/materiality hierarchy has been established as a result of these cybernetic concepts. As Hayles explicates:

> the cultural contexts and technological histories in which cellular … theories are embedded encourage a comparable fantasy – that because we are essentially information, we can do away with the body. Central to this argument is a conceptualization that sees information and materiality as distinct entities. This separation allows the construction of a hierarchy in which information is given the dominant position and materiality runs a distant second (ibid: 12).

From my previous discussion on the Symposium, it is obvious that information theory, which strived to organise the complexities of the body into an 'organizational hierarchy' resulted in the separation of information and materiality, or the gene and the body. Yet, there is inherent absurdity in this reasoning, because:

> for information to exist, it must *always* be instantiated in a medium, whether that medium is the page from the *Bell Laboratories Journal* on which Shannon's equations are printed, the computer-generated topological maps used by the Human Genome Project, … The point is not only that abstracting information from a

> material base is an imaginary act but also, and more fundamentally, that conceiving of information as a thing separate from the medium instantiating it is a prior imaginary act that constructs a holistic phenomenon as an information/matter duality (original emphasis, ibid: 13).

Thus, there is an intrinsic contradiction if the cybernetic paradigm is taken to its logical ends in genetics. Why then has this conceptual metaphorical structuring retained such popularity and predominance in genetic discourse?

3.7. GENETIC CONTROL

There is one other major player in the story of the rise of information coding in genetics, and that is the man who coined the term "molecular biology," Warren Weaver (Nierenberg, 1999: 225). He was also responsible for "contributing to the solidification of a mechanistic logic of life, the concept of the gene as both origin and outcome, and a synonymy between knowledge, intervention and control which established the discipline of molecular biology" (ibid: 226). I, however, view his most significant insight for that period, as being his prevision regarding the possible future issues that genetics would bring to the fore:

> The challenge … is obvious. Can man gain an intelligent control of his own power? Can we develop so sound and extensive a genetics that we can hope to breed, in the future, superior men? … Can we obtain enough knowledge of the physiology and psychobiology of sex so that man can bring this pervasive, highly important, and dangerous aspect of life under control (W. Weaver cited, ibid)?

Although the idea of eugenics[67] is not mentioned anymore, 'designer babies' and choosing the sex of one's child are, for example, no longer in the realm of mere science fiction.

A recent front page headline in *The Star* newspaper read: "Designer Baby, Created to Save his Brother's Life" (June 19, 2003: 1). The article details how Jamie Whitaker "is Britain's

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[67] The term eugenics came about in 1883, when it was coined by Francis Galton, a cousin of Charles Darwin. Based on Darwin's theory of natural selection Galton believed that if human mating could be controlled then heritable human traits could be artificially selected (Klug and Cummings, 2000: 10). Following the atrocities that took place in Nazi Germany, with the instigation of eugenics policies, the eugenics movement diminished. Presently, the euphemistic term euphenics has replaced eugenics. Euphenics aims to "reduce the impact of defective genotypes on individuals" by "medical and/or genetic intervention" (ibid: 11).

first ‘designer’ baby - genetically matched while an *in vitro* fertilisation (IVF) embryo to his brother, Charlie, in the hope of curing a rare type of anaemia which threatens the older boy’s life” (my emphasis, ibid). In a follow up article, the inherent problems and possibilities that are associated with the birth of “Britain’s first ‘designer baby’ ” are raised (*The Star*, June 23, 2003: 7):

> Who would be so hard-hearted as to not want to save the life and end the daily pain of a lovely little boy like Charlie Whitaker?
> But it never stops at one case. One case always begets another, and beyond that lies the horrific prospect of human beings being created for the harvest of their organs or the cannibalising of their very life to serve another’s purpose (ibid).

A further example of how Weaver’s predictions are unfolding can be found in the article: “A Way to Choose a Baby’s Gender” (*The Star*, May 19, 2003: 23). The article discusses two methods for selecting the sex of a child. The one process called “MicroSort” separates sperm mechanically, by using the knowledge that the Y-chromosome is smaller than the X-chromosome. Another technique for gender selection is also described in the article, termed “pre-implantation genetic diagnosis” (ibid). This technique involves using *in vitro* fertilisation to create embryos that are analysed genetically before being implanted in the womb. Although these methods result in higher probabilities of obtaining the desired sex of the child, these also raise critical issues. For instance, as to what happens to the discarded embryos, that were not the desired sex. The Laguna Hills clinic which offers the Microsort technique, says that they offer this sex selection procedure for two reasons:

> to help couples avoid passing on a gender-linked genetic disease and to allow families who already have a child of one gender ‘balance’ their families by having a baby of the opposite sex.
> (More than 500 X-linked diseases, such as Duchenne muscular dystrophy and haemophilia, are passed from mothers to sons) (ibid).

As you can see from these present day articles, we are nearing the point at which (as Weaver so perspicaciously noted) “we obtain enough knowledge of the physiology and psychobiology of sex so that man can bring this pervasive, highly important, and dangerous aspect of life under control” (W. Weaver cited in Nierenberg, 1999: 226).

This answers my earlier stated question as to why this concept metaphor of information coding has retained such popularity and predominance in genetic discourse: it gives us a sense of control over our own destiny. For if we understand our genetic code then, with sufficient technological insight and experimentation, we can secure enough knowledge about the secrets of life to change the 'genetic code'. This would allow us to be able to manipulate the 'genetic code' and so rectify anything from Huntington's disease, to ageing processes, to enhancing intelligence. "The clear implication is that if we have become the information we have constructed, we can achieve effective immortality" (Hayles, 1999: 13). While the promise of control over our controller sounds enticing, there is a significant drawback: if we do not yet understand or know its secrets then we are fated to be controlled by it.

Another repercussion of Wiener's instigation of determinism in the field of genetics is that people can now blame their genes as a source of their own weaknesses. In fact, the concept metaphor of information theory has *taken on a life of its own* in the field of genetics and, subsequently, *is taking lives*: perceived innate flaws in people can now be blamed on their connate weak genes. Their lives have been taken out of their control, and have been in a sense, 'pre-programmed', 'pre-written' or to phrase it differently, their fate was determined at conception. Examples of the effect of this in popular culture are sourced from newspaper articles which in turn are fuelled by science.

There have been many articles claiming that that people can blame certain conditions on their genes. Despite the fact that geneticists are continually discovering that genes are more complex than was previously envisioned and that "most genes do not function according to the established linear, predictable, mechanistic model," the idea that we are direct products of individual, specific genes "still dominates the search for biological explanations" of "human behaviours" (Nierenberg, 1999: 215-216). Examples of such human behaviours include homosexuality, depression, criminality, alcoholism, manic depression, and even such things as homelessness or someone's likelihood to have an affair (*The Star*, June 9, 2004: 15). Nierenberg points out that "gene-of-the-week media reports demonstrate a distinct lack of limits when it comes to the supposition of genetic causality" and that "many assertions of genetic determinism" are based on research that has "been published - and publicized - despite frank admissions by their authors that the evidence they contain is inconclusive" (Nierenberg, 1999: 216). Yet, "these same authors express indefatigable confidence that these genes will ultimately be found" (ibid).

I will be using obesity as such an example, and to begin with I shall quote from a newspaper source. In this specific article the title clearly demonstrates the consistent link between genetics and determinism: "Can't help eating? Now you can blame a gene" (*Saturday Star*, May 10, 2003: 15). The article describes a study undertaken on binge-eating by the Hirslanden Clinic in Zurich, Switzerland, and which was published in *The New England Journal of Medicine*. The article opens with these highly potent words which metaphorically refer to genetic pre-scripting and determinism: "Binge-eaters who say they can't help it may be right. A study suggests a weak gene, not feeble willpower, may be the cause for some people" (ibid). The "weak gene" is represented as a feeble or ineffectual controller that disrupts the homeostatic controls that should result in optimal health for the body. The article continues, declaring that "some researchers" are starting to "link several genes to obesity" thereby "implicating heredity as an important underlying factor" (ibid). The role of choosing your diet is played down as the article maintains that "increasingly, eating problems are thought to stem from a subtle interaction of lifestyle and multiple genes" (ibid).[68]

The gene that was the focus of the study was the melanocortin 4 receptor gene. It functions to produce a protein that is implicated in stimulating appetite "in the brain's hunger-regulating hypothalamus. If a mutated gene makes too little protein, the body feels too much hunger" (ibid). However, by forgetting the effects of lifestyle and focusing only on the gene, it allows a person to abdicate their own choices, actions and responsibilities, opting for the deterministic view that: their genes made them do it. This is evidenced by Horber's (a Swiss researcher on the project) sentiments that "binge-eaters in his study felt a wave of relief from guilt when they learned of the genetic cause behind their compulsion" (ibid). Apparently "one family in that study was so ecstatic over evidence of a physical cause that they made themselves T-shirts saying, 'We've got an MC4 mutation' " (ibid).[69]

In a scientific review article from the generally highly regarded science journal *Nature*, a study on the melanocortin system and various other genes found that "although there are now several convincing common obesity loci, there are, as yet, no common obesity genes" (Barsh *et al.*, April 6, 2000: 644). Thus, even though there have been many attempts to try and 'blame' obesity on certain genes, the overall result is that there are a few possible

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[68] Even when the importance of diet is discussed in relation to genes, it is seen as a means of trying to "defy" or evade, for as long as possible, your "inherited … susceptibility to … health problems" (*Longevity*, October, 1998: 57).

[69] It seems a human trait (though I don't know on which gene it resides), that if our genes are badly 'written' in us, then we should also write it on us. For instance, during the 1990s, certain gay and lesbian bookshops in America sold T-shirts that read "Xq28 – Thanks for the genes mom." This was in response to some untenable genetic evidence of a possible link between this gene and homosexuality.

candidate genes, but no definitive evidence can be found to pinpoint genes as the culprits. However, as long as the possibility exists of using genetic determinism as an abrogation of personal responsibility, the gene's role as 'meaningful information code' will probably continue for the sake of public cultural reprieve from having to make behavioural modifications. The ultimate result of information theory and cybernetics in genetics is, therefore, that it posits the body as hostage to its DNA code. For what other conclusion can there be if we are represented as the product of our DNA's information code? When taken to this inevitable finality, the flaws in this concept metaphor become unavoidably obvious and the inherent dissonance too apparent. Due to its invasive prevalence within the discourse and conceptualisation of genetics, not only has this concept metaphor *taken on a life of its own*, but more than that, it has *taken our lives as its own*, since "the body is the victim, plaything, battleground and vehicle for the ambitions of genes" (Ridley, 2000: 107).

There is one oft quoted alternative to this. And that is if our genes aren't responsible for producing us, then our environment must be. You will notice in the last paragraph's concluding sentence, the use of a militaristic metaphor, as the internal and external boundaries of the constructed self merge or separate depending on the relevant metaphorical representations. My next chapter will focus on the effects of this, but this time dealing with the environment, specifically focusing on the biological implications in immunological discourse.

4. CHAPTER FOUR:

IMMUNE RESPONSES

"This strange disease of modern life."
Matthew Arnold

> Quite early in the development of genetics, geneticists had to face up to the fact that the phenotype of an organism can be divided into characters in an indefinite number of ways. If one such analysis is to be preferred to another some justification would have to be given. The problem was that these justifications tended to presuppose a prior knowledge of the genotype, and the genotype in turn had to be inferred from the phenotype (Hull, 1974: 17).

The phenotype is very infrequently inferred directly back to specific genes of the genotype, this would indicate that other factors must be involved. These have been termed 'environmental factors'. Whether it is our genes or environmental factors[70] that have more impact on our character traits as well as health and immunity, is still a dichotomous polemic: Where exactly the deterministic control exerted by DNA ends, and the deterministic control exerted by the environment begins, is usually contested when it comes to the 'nature versus nurture' and 'DNA versus the environment' debates. However, for the purposes of my research I will not be restating and resolving these disputes. Rather, I will be focusing on a less explored, yet significant, area of interest and outcomes in relation to DNA and the environment. The specific environment that I explore is the one surrounding us, with regard to the microscopic organisms that exist in it.[71] How these organisms affect us and our DNA, and how we respond to these effects is analysed in the study of

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[70] Examples of environmental factors include; familial and psychological events, upbringing, and even cultural rituals that are observed as affecting the final personality, and behaviour of a person.

[71] It is in this environment that questions surrounding immunology and genetics are starting to be amalgamated. For example, do people with a low level of immunity have a low level of immunity because their genes are 'programmed' that way, or because of environmental factors around them; such as viruses, or even situations that are making them depressed or stressed (which, as already discussed, could also be attributed to genes). Of course, environmental factors such as hygienic practices are known to, and do, alter susceptibility for contracting disease. However, in contrast to this is new research that suggests that when babies are exposed to less sterilised environments their immunity is enhanced.

‘immunology’. I will be exploring the predominant concept metaphor in immunological discourse, namely, militarization.

I will be extending my previous chapter’s discussion of the implications of the concept metaphor of information coding in genetics by exploring how it affects the representation of immunology and the contiguous portrayals of ‘self’. Because, as Emily Martin has explicated, “the *key* sciences for” tracking “conceptions and practices regarding ‘life’,” namely, “genetics and immunology - are both potent sites for the study of transformations in fundamental cultural concepts of *life, person, society*” (original emphasis, 1994: 14). She astutely quotes Paul Rabinow, who in 1992 said that genetics will become “an infinitely greater force for reshaping society and life than was the revolution in physics, because it will be embedded throughout the social fabric at the microlevel by medical practices” (ibid). I completely agree with this statement, and in my subsequent examples, confirmation of this will become startlingly apparent.

I want to pursue this avenue of investigation due to the immense influence that immunological discourse exerts in the locale of human health and disease. It is at this moment in time that the effect of our conceptualisations of our ‘selves’ and our immunological responses are becoming more complex and repercussive. This is particularly the case as genetics more subversively and forcefully enters the domain of health.

The infiltration of genetics into the realm of immunology inexorably brings with it the complex conceptualisations inherited into genetic discourse. Therefore, the prevalent concept metaphor in genetics affects the concept metaphor that pervades immunological representations. From the following examples (obtained from the popular media), it will become evident that scientific endeavours and achievements (regarding immunology and genetics) are not relegated and resigned to American or European concerns, but require investigation in a South African context. Due to the social and even literal influences (as conveyed in the ensuing examples) that genetics and immunology possess, this has implications as to how we view health and sickness, emanating as a consequence of the respective presiding concept metaphors of these disciplines.

To substantiate these statements, I will utilise an example that demonstrates how genetics and immunology are becoming increasingly interrelated. This example involves the use of stem cells. Stem cells are common precursor cells that can give rise to all other cells in the body, (and have also been coaxed *in vitro* to form various types of cell, and have been genetically modified for therapeutic, medical purposes). Stem cell research is inherently connected with cloning and genetics, because these cells have to be cloned and their genetic component evaluated and manipulated in order to use them for health related issues. Stem cell research (being a relatively recent technology[72]) might not be expected to have considerable implications in South Africa, and even if stem cell technology were used in this country, the impression might be that it would only be so in the slightly distant future. To invalidate such preconceptions I will use an example obtained in a South African context, specifically in Johannesburg. The story revolves around a baby, Anushka van Rooyen, who was diagnosed with Omenn's syndrome at 16 weeks. The newspaper describes Omenn's syndrome as affecting "the body's ability to build up an immune system. As a result, Anushka's body has been unable to fight off germs and infections" (*The Star*, February 2, 2004: 3). The article continues to relate that "her contact with other people, including her parents, has been limited by surgical gloves, face masks and theatre gowns" (ibid). Anushka's chances for survival were low, until specialists at Flora Clinic in Roodepoort on Johannesburg's West Rand "performed an umbilical cell process" which involved harvesting bone marrow stem cells "from the umbilical cord of a pregnant donor" (ibid). "This process has allowed Anushka to build up an immune system strong enough to allow her to go home" after having been isolated in the hospital for a year (ibid).

A more poignant follow-up article to this one, which made front page headlines, sentimentally explained that "finally, Anushka van Rooyen can enjoy what every child needs: the skin-on-skin warmth of her mother's embrace. And it's all thanks to the miracle of modern science" (*The Star*, February 3, 2004: 1). The article continues, commenting that the "miracle came in the form of cutting-edge advancements in medical science" which allowed Anushka to have "a fighting chance thanks to an umbilical stem cell transplant" (ibid). This article is mostly permeated with a tone of praise for scientific interventions, and immunologists such as Dr Michael Loubser (an immunologic specialist mentioned and quoted in the article) are cast as 'miracle' workers. Despite the awe and sentimentality of the piece, the last paragraphs try and balance this by stating that although stem cell therapy

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[72] It was only in 1998 that scientists determined how to isolate stem cells from human embryos, and then grow the cells in the laboratory, and the first animal was only cloned in 1997 (Dolly the sheep). Since then many other animals have been cloned, even in South Africa (*The Star*, April 29, 2004: 3; *The Star*, March 23, 2004: 10; *The Star*, May 8, 2003: 1; *The Star*, November 23, 2001: 14).

"offers medical science potential cures to incurable degenerative ailments" it is still "a contentious issue worldwide and many feel it could lead to attempts to create an entire human being" (ibid).[73] The article ends with the final sentence that "countries the world over, including South Africa, are grappling with moral, ethical and legal issues surrounding the use of stem cells in medicine" (ibid). However, such issues are not revealed or discussed in this article which mostly marvels at the 'miracle' that science has created for this baby.

Not all articles view stem cell research and the fruits of its labour so optimistically.[74] Yet, commonly infusing all the articles is the sense that with the combined application of genetic and immunological knowledge, the secrets to life and health may be discovered and solved.[75]

The above example and discussion revolving around stem cell research serves as one example (more will become apparent as this discussion continues) to explain how genetics and immunology are merging in laboratory experiments and, consequently, people's lives and understandings of self. I hope the above contemporary example also serves as an acute

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[73] It is interesting to note that within the same month as this article was published a human was successfully cloned in South Korea; in order to obtain stem cells for scientific advancement (*The Star*, February 13, 2004: 1). Although others have said that they have cloned humans, this is the first one that has been scientifically verified. As an interesting contemplation, Keller explores how the issues of what science works to accomplish within moral and socio-political realms is usually unasked and avoided. However, it seems that with the present advancement in cloning, this question can no longer be evaded, as a *TIME* article shows with its enticing end statement:

> Nobody pretends that Hwang and Moon's [the Korean cloners] findings are ready for clinical application or that they don't raise some disturbing possibilities. But few people deny that they raise some thrilling ones too – precisely what science is supposed to do (*TIME*, April 26, 2004: 79).

[74] Compared to the tone set in the above (more sentimental) article (*The Star*, February 3, 2004: 1) the following article stands in stark contrast. The article entitled "Now the spectre of a baby from an unborn mother" equates scientists to 'Dr Frankensteins' (*The Star*, July 2, 2003: 7). This is due to researchers who are proposing and investigating the possibility of collecting eggs from the ovaries of aborted foetuses in order to "ease the worldwide shortage" of them (ibid). The article explains that this would "raise the nightmare prospect of a child whose biological mother has never been born," in other words, the child would have to come to terms with the idea that their mother was an aborted foetus (ibid). Another article provides various reasons why cloning should be banned (*The Star*, September 24, 2003: 7).

[75] This technology is even affecting South African legislation. As a result of the success of the South Korean team which cloned a human (to obtain stem cells), the South African government has changed its stance on cloning. In the current 'Human Tissue Act' it is illegal to manipulate embryos. However, the 'New National Health Bill' will make allowances for *therapeutic* cloning. The "South African government is clearing the way for local scientists to undertake research in therapeutic cloning" (*The Star*, February 17, 2004: 8). Cloning is divided into *therapeutic* and *reproductive* cloning. The first term is applied to cloning for therapeutic applications (for example in Anushka van Rooyen's case), whereas reproductive cloning is the term used for distinguishing when cloning is undertaken to produce a new human. In my personal view this is not enough of a differentiating term, since in order to obtain stem cells, a human is technically reproduced by cloning (generally using somatic cell nuclear transfer technique), and then its development is stopped within the first few days, at the stem cell stage, in order to harvest the stem cells.

illustration as to why I feel it is so fundamentally important that we deal with the issues resulting from genetics and its inherent representations merging with and influencing immunological conceptualisations. Because, in the arena of health and vitality the stakes are high when the embodied body (with its incumbent concept metaphors) is penetrated by genetics and its concomitant concept metaphors. The prime consequences (which will become more apparent as this discussion continues) are the effects of how the "narratives of the normal and the pathological work" as a result of "the biological and medical body" being "symbolized and operated upon … as a coded text" (Haraway, 1991: 211). However, before that can be ascertained, the preponderant concept metaphor that is inherent in immunological discourse must first be determined.

4.1. THE CONCEPTION OF IMMUNOLOGY

It is my assertion that the predominant concept metaphor in immunological discourse is that of militarization. To substantiate this claim I will once again offer examples obtained from prevalent media excerpts. In order to examine the concept metaphors associated with immunology I thought it would be interesting to consult a point of reference that the majority of the populace might consult when trying to understand and conceptualise immunity. Hence, I consulted *The Collins English Dictionary*, which defines immunology as "the branch of biological science concerned with the study of immunity" (Hanks, 1988: 766). The term 'immunity' is derived from 'immune' which is defined as follows:

> **Immune** (i'mju:n) *adj*. **1.** protected against a specific disease by inoculation or as the result of innate or acquired resistance. **2.** relating to or conferring immunity: *an immune body* (see **antibody**). **3.** (*usually postpositive*; foll. by to) unsusceptible (to) or secure (against): *immune to inflation*. **4.** exempt from obligation, penalty, etc. ˜ n. **5.** an immune person or animal. [C15: from Latin *immūnis* exempt from a public service, from IM- (not) + *mūnus* duty] (ibid).

In this definition, the term 'protection' is used in conjunction with immunity from disease, as is the term 'resistance'. Both of these terms have militaristic overtones. When used in conjunction with immunity, these militarization terms are being subtly, metaphorically linked with the biological definition of ‘immune’.[76]

Continuing from the dictionary definitions of ‘immune’, one might assume that at a tertiary level of education the precise language associated with science would help ensure more clarity, and less use of figurative terms. Hence, I consulted a first year science textbook, simply and precisely enough called, *Biology*. In the opening introductory paragraph for the chapter specifically dealing with immunology students are informed:

> When you consider how animals defend themselves, it is natural to think of dinosaurs, turtles, clams, armadillos, and other animals covered like tanks with heavy plates of armor. However, armor offers no protection against the greatest dangers that vertebrates face – microorganisms and viruses. We live in a world awash with attackers too tiny to be seen with the naked eye, and no vertebrate could long withstand their onslaught unprotected. Every vertebrate body offers a feast of nutrients for microorganisms and raw materials for viruses, as well as a warm, sheltered environment in which they can reproduce. We survive because we have evolved a variety of very effective defenses against this constant attack. These defenses are the subject of this chapter (Raven and Johnson, 1990: 1118).

Although many metaphors are used in this explanation, the common representation maintained in all of them is that of militarization. In fact, the concept metaphor of militarization[77] is taken for granted through the use of such terms as ‘defend’, ‘tanks’, ‘armour’, ‘protection’, ‘dangers’, ‘onslaught’ to describe immunity. Microorganisms and viruses are designated as ‘attackers’ and are conceptualised as entities looking for the first opportunity to take over our bodies for the shelter and food that they offer. At the start of the excerpt, before any concrete explanations have been offered, the human body is already viewed as under threat from attackers that are so dangerous and insidious that they cannot

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[76] It is interesting to note that in this definition the one meaning of ‘immune’, as being “exempt from obligation,” has in no way been inferred to the biological immune system. Even in the case of a weak immune system, the system is not so much exempt from duty as it is unable to fulfil its obligations.
Apparently, the original meaning of ‘immune’ was “to be exempt from the requirement of service to the state” (Martin, 1994: 193). This was derived from the Latin *immunitas* and was first used in ancient Rome to describe the release of individuals from such duty to the state (Silverstein, 1984: 24). With the recognition, in those early times, that individuals who “survived a disease once might often be spared further involvement in its return,” the term immunity came to characterise this observed resistance to reinfection (ibid: 23-24). Emily Martin elaborates on this, explaining that these two meanings become linked when “immunization was developed and made available to the public, often without choice, through resources and personnel mobilized the state and the medical profession” (1994: 193).

[77] Although I am pointing out that the predominance of the militarization concept metaphor in immunity is so overwhelming that it is taken for granted, there are other notions that are even more overlooked. For instance “*how* it came to be that we now see illness and health in terms of the immune system in the first place” (original emphasis, Martin, 1994: 13). For a scientific historical account of the multifarious endeavors that helped bring immunological discourse to this point Arthur Silverstein provides an interesting chronicle of these events (1984: 23–39).

even be seen, only conceptualised. The concept metaphor of militarization is literalised in the portrayal of immunology long before any actual characteristics of immunity have even been described.

The textbook continues its description of immunological functioning of the immune system under the subheading: “Strategies of Immune Surveillance.” The explanation begins to tie in militarization with genetics as it informs us that:

> All organisms possess mechanisms to protect themselves from the onslaught of smaller organisms and viruses. Bacteria defend against viral invasion by means of restriction endonucleases, enzymes that degrade any foreign DNA lacking the specific pattern of DNA methylation[78] characteristic of that bacterium (ibid).

The article then continues its discussion along a hierarchically configured continuum, shifting from discussing bacteria to multicellular organisms. The militarization metaphor prevails as the description turns to how multicellular organisms have to contend with “a more difficult problem in defence, since their cells often take up whole viruses instead of naked viral DNA, as in the case with bacteria” (ibid). The article proceeds with an explanation of the immunologically imperative concept of ‘self’ (the implications of this concept will become manifestly more significant as my discursive investigation continues). The authors explain that invertebrates “solve” the “problem” of defence:

> by marking the surfaces of their cells with proteins that serve as ‘self’ labels. Amoeboid cells attack and engulf any cells lacking such labels. By looking for the absence of specific markers, invertebrates employ a *negative* test to recognize foreign cells and viruses. This method provides invertebrates with a very effective surveillance system, although it has one great weakness: any microorganism or virus with a surface protein resembling the invertebrate self marker will not be recognised as foreign. An invertebrate has no defense against such a ‘copycat’ invader (original emphasis, ibid).

Such martial characteristics are further emphasized and elaborated when it comes to vertebrate multicellular organisms. Initially, the vertebrates are compared to ‘medieval cities’ and it is interesting to note how, as each most outer ‘layer’ of the body is ‘breached’, the warfare characteristics seem to become more ‘sophisticated’. By that I mean that they seem to parallel the latest methods of warfare that are currently used against enemies at

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[78] Various bacteria have different patterns of DNA methylation. This means that DNA in bacteria has a chemical methyl group added to certain DNA bases within specific sequences. This is theorised to be a defence mechanism employed by bacteria to recognise ‘foreign’ DNA (for example from a virus). If the specific sequence of DNA is not methylated (because it has been integrated from a virus) then a so-called ‘restriction endonuclease’ (a particular type of enzyme) will cleave the ‘foreign’ DNA, thereby inactivating it.

present. Thus, as the pathogen 'invades' towards the centre or heart (if you will forgive the pun) of the body, the tactics used by the body become more 'hi-tech': "vertebrates employ a multilevel defense" (ibid). To examine how the conceptualisations of these many 'levels' of immune system defence correspond to the periods in which they were researched, I will explore these layers by moving from the exterior to the interior. In doing so, I will also be following a roughly chronological order. Thus, starting at the periphery of the body, which is described as resembling

> the way medieval cities were defended against attack by outsiders. Like *walls and moats* around a city, the skin and mucous membranes constitute the first line of the body's defense against attack. In some vertebrates such as rhinoceroses, the skin is very thick and tough, and in all vertebrates it offers a surprisingly efficient barrier to penetration by viruses and microorganisms (original emphasis, ibid).

In this case the outer skin of the body is represented as a 'barrier' like 'walls' and 'moats'. Emily Martin traces the history of such notions of health,[79] and explains that "early twentieth-century ideas about health reflected the impact of the new science of bacteriology, which brought laboratory techniques to bear on the attempt to understand the role of microorganisms in causing disease" (1994: 24). She points out that by the nineteen-forties and fifties "people were more apt to think in terms of the cleanliness of their own immediate environment, their own house and their bodies" (ibid). Therefore, at that time, "seen through the lens of popular publications, the most important threats to health were considered to lie in the environment just outside the body" (ibid). This resulted in almost

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[79] Immunology has undergone significant perceptual shifts over the course of its history. The initial one was the move from the idea of passive to a active theories, whereby passive theories involved conceptualising a pathogen as the instigator of the immune response in a host that would otherwise remain inert (Martin, 1994: 33). "Until around the turn of the century, almost all theories were passive theories. Then, with the discovery of antibodies in the 1890s, there was a transition to theories involving an active host response" (ibid). Martin continues to document the second transition which was from instruction theories to selection theories. Instruction theories used the metaphor of the body being able to 'learn' how to synthesise new antibodies "from new kinds of foreign material (antigens) with which it came into contact" (ibid). Once again (like in genetics) post World War II was the period for the development of selection theory. Selection theory developed as an explanation for copious amounts of antibodies already present in the human immune system, and "could not be accounted for by any known exposure to existing antigens" (ibid: 36). This brought up the question of how all these antibodies could be inherently present in the organism. The answer came with DNA, in that a mechanism dependent on genetic mutation and selection occurs, explained by the clonal selection theory. The clonal selection theory postulates that "a large number of antibody-producing cells exist in the animal even before it encounters a foreign antigen" (Hames *et al.,* 1997: 77), each of these cells that is committed to respond to a specific antigen displays cell-surface receptors of the specific antibody (Alberts *et al.,* 1994: 1200). "An antigen binds to cells that display antibodies with appropriate binding sites and causes proliferation of those cells to form clones of cells secreting the same antibody in high concentration" (Hames *et al.,* 1997: 77). Actually, this clonal selection theory "generated its own repertoire controversy" after it had been accepted that DNA seemed to "control" antibody structure, and the "amino acid sequences of the immunoglobulin chains" had been illuminated (Silverstein, 1984: 36). The controversy emerged as a result of contestations between those who "maintained that the entire specificity repertoire was encoded in the germ line" while "others … argued that immunologic diversity was generated by the somatic mutations or recombination of a highly restricted number of germ line genes" (ibid).

obsessive attention being "devoted to hygiene, cleaning surfaces in the home, clothing, surfaces of the body and wounds with antiseptics" (ibid). These precautionary measures were not particularly effective, since, for example, polio was still not dissuaded by these tactics. "Even though … hygiene seemed to fail, sanitary measures were frequently linked to the presence of microbes, the object being to keep them from entering the body"[80] (1994: 25), and the most important defence was viewed as "strictly preventing the entrance of any germs into the interior of the body" (ibid). It is from such notions that a "castle of health" (as in my above example from the textbook) arises. Where the "castle itself represents the body" which in the nineteen-forties and fifties had become representatively "dwarfed by … larger outer defenses" and encouraged the view of the body as "elaborately defended at its surface" (ibid: 26). Such a view has since persisted in the *Biology* textbook (and in many others).

Emily Martin documents how in the nineteen-sixties and seventies "we begin to find accounts of safeguards within the body that come into operation if the 'outer fortifications' (the skin or mucous membranes) are breeched" (1994: 32). She evinces this with an illustration of a castle, which this time, has an inner army depicted inside its walls (whereas before only the outside of the castle was depicted). "The shift … is made plain in the … view of what is inside the castle walls" (ibid: 33). Martin perspicaciously directs one to the outcome that

> as the interior comes into focus, concern with hygiene and the cleanliness of the outside surfaces of the body diminishes. It is as if, whatever is out there, and however deadly and dirty it is, the body's interior lines of defense will be able to handle it. By the time we reach accounts in contemporary biology … the interior of the body has been enormously elaborated. 'Recognition' of the disease-causing microbes is fantastically honed and refined, and the immune system 'tailors' highly specific responses that can be almost unimaginably various. Drawing on an immense, genetically generated, and constantly changing arsenal of resources, the body can hardly rely on mere habit any longer (ibid).

What this demonstrates is how, as the body was conceived of differently, different features of immunity came to light and could then be investigated. For example, when the metaphor of the body as a fortress or castle was extended to include its inner workings and functioning, the interior body with its role in immunity began to be researched in more detail. This serves as yet another example of how concept metaphors can structure and

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[80] Such perceptions still continue today and are used in advertising not only to sell household antiseptic cleaners but even for types of everyday hand and body soaps, all with the expressed desire of keeping one 'germ free', by killing the pathogens at our surface 'boundaries' and immediate environment.

influence scientific research and how changing or modifying such concept metaphors leads to new avenues of investigation.

To clarify some of the new areas of research that people started to focus their attention on, (when they began to consider the inner workings of the 'castle') I will use an example that moves further within the body.

> If an invader gains entrance to the vertebrate body, a second line of defense comes into play. Within the body, circulating cells function as *roaming patrols*, killing foreign cells by means of a battery of *non-specific defenses*, including chemicals. These defensive cells act very rapidly after the onset of infection. They employ a negative test that is similar to the one used by invertebrates but cannot be foiled by copycat foreign cells. The surface of most vertebrate cells posses self markers called *major histocompatibility complex (MHC) proteins*, which are different in each individual. The genes encoding the MHC proteins are highly polymorphic (have many forms), so that very few individuals in a population possess the same set of alleles (original emphasis in, Raven and Johnson, 1990: 1118).

Many new sectors of research have thus been revealed, due to broadening the initial metaphor. Also, aspects of the 'invasion' of the 'castle' are described in more detail. So, a pathogen such as a virus or bacterium is now seen as mimicking an individual's MHC markers so that it "may successfully *invade* that individual but not another" (my emphasis, ibid). Such metaphors can also encourage research in unexpected spheres, for instance, zoo populations.[81]

Returning to the textbook, further militarization metaphors are evident as another area of the body is explored:

> vertebrates employ a third, very powerful defensive strategy that relies on a *positive* test to identify foreign cells, as well as to detect cancer cells. This defense employs two types of cells that, like *sentries*, scan the surface of every cell they encounter. These cells possess surface receptor proteins that recognize specific "nonself" molecules. One type of cell aggressively attacks and kills any cell identified as foreign, while the other type marks foreign cells for elimination by the roaming patrols. Together these two types of cells comprise the vertebrate *immune system* (original emphasis, ibid: 1119).

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[81] "When individuals of a population are not polymorphic for the MHC gene … the entire population [is] at risk" of getting the same diseases (Raven and Johnson, 1990: 1118). An example of this would be in endangered species or a zoo population, essentially where little diversity emerges within a close species, which generally results in inbred populations that have scarce MHC protein variation. The polymorphic variation within populations is also becoming of more intrinsic interest with respect to genetic variability and heritability.

This opening explanation regarding immunology in very broad terms has run the gamut of warfare. Starting with medieval storming to get into foreign bodies, to “roaming patrols” and “sentries,” as well as chemical warfare used by the body! Thus, throughout this discussion, structured hierarchically from bacteria to vertebrate organisms, all are portrayed as having mechanisms of immunity that function through militaristic processes.[82]

From the above examples it becomes obvious that the well established concept metaphor that is operative in immunological discourse is that of militarization. Furthermore, underlying this concept metaphor is a primary basis of a “conservative discourse” that “clings to” distinguishing “between human and ‘disease’ ” (Fraiberg, 1991: 5). That is to say, in order for the militarization concept metaphor to operate in immunological discourse, the core assumption that is required is that there are boundaries between the human body and pathogens. And, that these boundaries must be maintained and protected. In other words, a body defends itself against enemies, thereby distinguishing between ‘self’ and ‘non-self’. “The strategic construction that urges keeping ‘it’ out of ‘us’ relies primarily on a projection since ‘it’ would not be if it were not for ‘us’ ” (ibid: 4-5). Therefore, underpinning the militarization concept metaphor is the assumption and reinforcement of ‘boundaries’ between ‘self’ and ‘other’, and ‘inside’ and ‘outside’. In this way, the integration between the human and the “disease” is repressed. Obviously “the first rhetorical manoeuvre involves anthropomorphizing” the expression of the disease “into a live” virus, protein, bacterium, fungus, gene, etcetera “and then militarizing its context” (ibid).

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[82] Even in the stem cell example that I presented earlier, the militarization concept metaphor is obvious when the reporter explained that baby Anushka’s immune system needed to be ‘built’ up to become ‘strong’ so that it could “fight off germs and infections” (*The Star*, February 2, 2004: 3).

4.1.1 ORIGINS OF THE MILITARIZATION CONCEPT METAPHOR

The militarization of disease is not a recent invention. Even in the nineteen-thirties the Polish immunologist Ludwik Fleck demonstrated great prescience in his ideas on the "concept of infectious disease" (Fleck, 1981: 59). He explicated that such a conceptualisation

> is based on the notion of the organism as a closed unit and of the hostile causative agents invading it. The causative agent produces a bad effect (*attack*). The organism responds with a reaction (*defense*). This results in a conflict, which is taken to be the essence of disease. The whole of immunology is permeated with such primitive images of war. The idea originated in the myth of disease-causing demons that attack man. Such evil spirits became the causative agent; and the idea of ensuing conflict, culminating in a victory construed as the defeat of that 'cause' of disease, is still taught today (original emphasis, ibid: 59-60).

To illustrate how "disease is often experienced as a form of demonic possession" one need not look far. In cancer, "tumors are 'malignant' or 'benign,' like forces" (Sontag, 1978: 73). This idea of malevolent "disease-causing demons" has been around for centuries. Even "in the *Iliad* and the *Odyssey*" disease manifests "as supernatural punishment, as demonic possession, and as a result of natural causes" (ibid: 47). Thus, "for the Greeks, disease could be gratuitous or it could be deserved (for a personal fault, a collective transgression, or a crime of one's ancestors)" (ibid). With religion, additional "moralized notions of disease" evolved to allow a "closer fit between disease and 'victim' " (ibid). The perception "that a disease could be a particularly appropriate and just punishment" resulted from "the idea of disease as punishment" (ibid). Traditionally, sexually transmitted diseases have been "described as punishments not just of individuals but of a group" for "general licentiousness" (Sontag, 1988: 54). This impression has remained for certain diseases such as AIDS, as discussed by Susan Sontag and Allison Fraiberg. "The moralizing trope serves as the building material for the construction of boundaries" (such as bodily boundaries), where " 'good' in the 1980s functions euphemistically to mean monogamous heterosexual relationships with people who 'just say no' to drugs" and practice safe sex (Fraiberg, 1991: 7). Therefore, "those who abstain from sex altogether become 'very good' people" and those who are "promiscuous, or use IV drugs, bring on infection 'themselves' " (ibid). However, complications arise when, for instance, haemophiliacs (through blood transfusions) and "babies born testing positive for HIV antibodies can occupy a position of 'wholly innocent' " although, the babies' mothers "depending on their backgrounds, await textual, moral assignation" (ibid: 6-7). From such inconsistencies, "the notion that the disease fits the patient's character, as the punishment fits the sinner" is being "replaced by the notion that it expresses character," that "disease can be challenged by the will" (Sontag, 1978: 47). It is now virtuous to 'fight' the 'good fight' against disease, through the use of pharmaceutical and psychological intervention.

The militarization trope that involves, *fighting foreign* (microscopic) organisms and disease derives from foreign invasion, in the form of soldiers and seamen etcetera, bringing new diseases with them whenever they entered or invaded new territory. Susan Sontag elaborates on this: "illness is a species of invasion, and indeed is often carried by soldiers" (1988: 48). Sontag provides the example of the "bubonic plague that reappeared in London in the 1970s," (ibid: 49). The plague "arrived from Marseilles, which was where plague in the eighteenth century was usually thought to enter Western Europe: brought by seamen, then transported by soldiers and merchants" (ibid). This continued, although, "by the nineteenth century the foreign origin was usually more exotic, the means of transport less specifically imagined, and the illness itself had become phantasmagorical, symbolic" (ibid). Thus "one feature of the usual script for plague" is that "the disease invariably comes from somewhere else," in other words, it is *foreign* (ibid: 47). For instance, "the names for syphilis, when it began its epidemic sweep through Europe in the last decade of the fifteenth century, are an exemplary illustration of the need to make a dreaded disease foreign" (ibid). The English labelled syphilis the "French pox," while Parisians called it *morbus Germanicus*, it was "the Naples sickness to the Florentines, the Chinese disease to the Japanese" (ibid: 48). Even today, in South Africa, over the past few years we have received the "Hong Kong flu" and "Sydney flu." This reveals the "link between imagining disease and imagining foreignness. It lies perhaps in the very concept of wrong, which is archaically identical with the non-us, the alien. A polluting person is always wrong" (ibid).

It was in the eighteen-eighties that "the military metaphor in medicine first came into wide use" due to the "identification of bacteria as agents of disease," where "bacteria were said to 'invade' or 'infiltrate' " a body (ibid: 70). In fact, "talk of siege and war to describe disease now has … a striking literalness and authority" where, "not only is the clinical course of the disease and its medical treatment thus described, but the disease itself is conceived as the enemy on which society wages war" (ibid).

The development of this militarization concept metaphor has obviously been influenced by social, political and cultural concerns. However, once disease has been extensively represented in this way (due initially to societal concerns), it can be fed back to society. When "feelings about evil are projected onto a disease" the disease becomes imbued with meaning and the disease is then "projected onto the world" (ibid: 63). Thus, "the disease itself becomes a metaphor" subsequently "in the name of the disease (that is, using it as a metaphor), that horror is imposed on other things" causing "the disease [to] becomes adjectival" (ibid). Hence, "something is said to be disease-like, meaning that it is disgusting or ugly" (ibid).

In fact, "throughout the nineteenth century, disease metaphors become more virulent, preposterous, demagogic" (ibid: 78). Sontag points out that at present "there is an increasing tendency to call any situation one disapproves of a disease" (ibid). Although, "illnesses have always been used as metaphors to enliven charges that a society was corrupt and unjust" (ibid: 76). This is especially utilised in politics, by identifying "the subjects of deepest dread (corruption, decay, pollution, anomie, weakness) … with the disease" (ibid: 63), and then using "disease imagery … to express concern for social order" (ibid: 76). To demonstrate this, I will use a quote by John Dean, when he described "Watergate to Nixon: 'We have a cancer within – close to the Presidency – that's growing' " (J. Dean cited, ibid: 86). Thus, "modern disease metaphors specify an ideal of society's well-being" that is "analogized to physical health" and can be "a call for a new political order" (ibid: 79).

Now that the development of the militarization concept metaphor has been contextualised, I can explain the implications of foreign organisms with regard to 'self' and 'non-self'.

4.2. BODY BOUNDARIES

In the previous chapter I explored how information theory established a means of dividing and separating the body into compositional elements. Ultimately, this had repercussions for the information and materiality schism that developed directly due to the conceptualisation of an organic, hierarchical organisation of the body. The most important of which (for the purposes of this research) was the split between the body and DNA, with the latter symbolised metaphorically as an information code for the former.

As I explained in my earlier chapter on metaphors, metaphors serve to highlight certain aspects and hide others. Certain aspects that the metaphor of information coding hides revolve around the question of where DNA ends and the body begins, or vice versa, and where does the body itself end?

To answer this last question one might argue that the body ends at the boundaries of our outermost epidermal layer of skin. In fact, with the above described castle and its moat boundaries this seems immunologically legitimate. Thus, our body and everything inside of it, all encapsulated in our skin, represents 'self' with the surroundings comprising 'non-self'.[83] This of course, for physical interaction with the world, makes convenient and appropriate sense. However, our cognition of our boundaries of 'self' as opposed to 'non-self' can be perturbed, when it comes to certain areas of immunity (explained below), that test our perception of boundaries and our concepts of where our bodies and/or our DNA begins and the surroundings end.

To agitate and direct the reader's attention to inherent artefacts that seem to subvert an otherwise obvious conceptual distinction between 'self' and 'non-self' I will use an example from Emily Martin. She argues that "when the nonself is a disease-causing microbe, the model works quite logically" (1994: 59). However, when "the nonself is a fetus growing inside a woman's body, the model quickly runs into difficulty" (ibid). Since, "as the popular media explain it, … the fetus is a graft of foreign tissue inside the mother"

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[83] Such a system of delineating boundaries of 'self' and 'non-self' can also be assessed through Lakoff and Johnson's description of container metaphors, where "each of us is a container with a bounding surface and an in-out orientation" (1981: 29).

(ibid). Therefore, according to the normal paradigmatic representation, the mother's body should 'attack' the foetus, given that it has a different genetic constitution to the mother (ibid). Martin continues to explicate that "lack of an attack is even more mysterious given that pregnant women have antibodies to certain antigens expressed by the fetus" (ibid). The term tolerance is used to account for this "reduction in the woman's normal immune response" which would usually "destroy the fetal 'nonself', whatever the mechanism" (ibid). Tolerance is also used to describe how our own tissues are not destroyed, but rather, tolerated, except in the cases of autoimmunity diseases. In fact, "immunologists have yet fully to answer the question of how the body achieves tolerance" (ibid). Martin then brings up the similar point that I am discussing throughout this chapter, when she considers "whether other images of the body less reliant on hard boundaries and strict distinctions might produce another set of questions altogether" (ibid).

To continue to demonstrate the inherent limitations in conceiving of the body as 'self' compared to 'non-self' I will use as an example the human intestinal flora. In humans, bacteria constitute a proportion of the intestines. These harmless but mutualistically, symbiotic bacteria aid in the human digestive process and produce certain vitamins that humans require, while the bacteria in turn gain access to nutrients. These bacteria, obtained from yoghurt, etcetera, are regarded as 'non-self' organisms and yet are included in our presented and perceived boundaries of 'self', and are necessary for efficient functioning of the individual human. As Fleck realised in the nineteen-thirties,

> an organism can no longer be construed as a self-contained independent unit with fixed boundaries, as it was still considered according to the theory of materialism. That concept became much more abstract and fictitious, and its particular meaning depended upon the purpose of the investigation. For the morphologist it has changed into the concept of genotype as the abstract and fictitious result of hereditary factors. … A whole scale of complexes exists which, depending upon the purpose of the investigation, are regarded as biological individuals (1981: 60).

He points out that this "whole scale of complexes" varies, hence, "for some investigations the cell is considered the individual, for others it is the syncytium, for still others a symbiosis, or, lastly, even an ecological complex" (ibid). Therefore, to emphasize the idea of an organism as a "life unit" is a prejudiced and highly anthropocentrically subjective view, which projects the human perception that we are each self-contained units onto the whole living world. Despite homologation among scientists that "some species exhibit for their vital functions an even greater dependence upon others" and that these species' "metabolism and propagation, indeed their entire life cycle, depend on a harmonious interference by other species," the notion of the self-contained 'self' persists. (ibid: 60-61). Even though humans could be considered "as a complex to whose harmonious well-being many bacteria," for example intestinal bacteria, "are absolutely essential" (ibid: 60).

Now that the boundaries of what constitutes a 'self' have become a little more doubtful through descriptions of these mundane examples, I will move onto other examples where diseases are involved.[84] The examples that I have selected all involve cases where modern science is experiencing significant difficulty in understanding how to cure these pathologies. In all these cases commonly established interpretations of *how* these diseases occur seem to be accepted, but *why* they occur in some people and not in others remains unanswered. By directing your attention to these cases which remain incompletely resolved, I hope to point to the necessity for analysis and reinterpretation of these explanations. With respect to this research, this inspection is in terms of concept metaphors. Since, by assessing the inherent metaphors utilised in conceptualising diseases, this can lead to proposing new, more empowering metaphors that serve to illuminate aspects of pathological processes which are, at present, irresolvable. The success of such new conceptualisations would be easily determined by *in vitro* and *in vivo* research.

4.3. PRECEDENT PATHOLOGIES

Let me begin by offering the first example of a disease in which the process of the disease is seemingly understood, but why it functions in some and not others is inexplicable. The example is cancer. Obviously certain carcinogens such as cigarette smoke and ecological factors (for example, over-exposure to the sun) are known to increase the probability of

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[84] Another example that evinces this suggestion of requiring complex symbioses for continued successful survival and evolution of a species comes from the 'endosymbiont hypothesis'. Mitochondria are oxygen utilising and energy producing organelles that exist in our cells. What makes them so interesting is that they are the only organelles to have their own DNA (besides DNA that resides in the nucleus). These organelles seem to have a prokaryotic (or bacterially reminiscent) genetic constitution. The hypothesis is that our ancient eukaryotic cells were originally anaerobic organisms without mitochondria. These anaerobic cells "established a stable endosymbiotic relation with a bacterium, whose oxidative … systems they subverted for their own use" (Alberts *et al.,* 1994: 714). As an example of the complex nature of the 'self' it is interesting to alert the reader's attention to the idea that

> although many of the genes of these ancient bacteria still function to make organelle proteins, most of them have become integrated into the nuclear genome, where they encode bacterial-like enzymes that are synthesized … and then imported into the organelle (ibid: 717).

cancer development. Yet, the immune system should be able to combat the formation of cancer cells and, indeed, does so in many instances. However, there is a distinct lack of consistency in predicting cancer formation, and this incongruity has been attributed to genetic factors. Thus, there is a continued infiltration of genetics into areas that were previously the sole preserve of immunological discourse. For instance, at the moment, there is increased interest in trying to determine if people have genetic predispositions for certain diseases.[85] Cancer also serves as a blurring of the distinction between 'self' and 'non-self', since cancerous cells are essentially the same as the rest of the body (which is why they can metastasise so easily and obtain their own nutrient supplies from the body).[86] However, the immune system in many cases can still recognise cancer's pernicious potential and reverse cancer cell formation.[87]

Let me provide a further example, this time of viruses.[88] Especially the class of viruses called retroviruses, and the virulent example of this class, the Human Immuno-deficiency Virus or HIV. I will be focusing on this virus due specifically to its relevance in South Africa. This virus is also a useful prime example (for the purposes of this research) since this virus manipulates our own DNA. At such a level of parasitism, the body's boundaries with the external environment, as well as the DNA/body division together with the

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[85] The continued infiltration of genetics into areas of immunology such as cancer is examined in an article in the *Sunday Tribune,* that gives an account of how "scientists have discovered a natural 'marker' in breast cancer victims which may predict the chances of the disease returning after treatment" (*Sunday Tribune*, March 19, 2000, 14). The marker is a certain gene that, if found in large amounts, appears to presage the re-occurrence of breast cancer. The articles states that this "discovery adds to a growing body of research which experts claim will allow doctors to build genetic profiles of patients, enabling them to apply cancer treatments more effectively" (ibid). At present, in genetic testing, the idea of finding marker genes to serve as indicators for individual susceptibility for certain diseases is becoming a recognised medical practice.

[86] Since cancer appears to emanate from aberrant cells of the body, it has been viewed "as a scourge" the metaphoric "barbarian within" (Sontag, 1978: 66). Susan Sontag details how "the *controlling metaphors* in descriptions of cancer are, drawn … from the language of warfare" where "every physician and every attentive patient is familiar with, if perhaps inured to, this *military terminology*. Thus, cancer cells do not simply multiply, they are 'invasive' " (my emphasis, ibid: 68). And (as with many other diseases) there is said to be "the 'fight' or 'crusade' against cancer; cancer is the 'killer' disease; people who have cancer are 'cancer victims' " (ibid: 62). Even "treatment has a military flavour" (ibid: 69). For instance, "radiotherapy uses the metaphors of aerial warfare; patients are 'bombarded' with toxic rays" while, "chemotherapy is chemical warfare using poisons. Treatment aims to 'kill' cancer cells (without, it is hoped, killing the patient)" (ibid).

[87] Stem cells are also thought to contribute to the formation of cancer cells on many occasions. This is because stem cells divide to make copies of themselves that, in certain instances, remain with unspecified functions. If such a cell were to divide too rapidly then these could easily develop into cancerous cells with abnormal functioning.

[88] Before electron microscopy, viruses were suspected to be "naked genes that had somehow acquired the ability to move from one cell to another" (Alberts *et al.,* 1994: 274). However, far from disputing this impression, "the idea that viruses and genes carry out similar functions was confirmed by studies on bacteriophages" (bacteriophages are viruses that infect bacteria) (ibid). Such experiments, "led to the notion of viruses as genetic elements enclosed by a protective coat that enables them to move from one cell to another" (ibid).

differentiation of 'self' and 'non-self' becomes more complex. Since the virus integrates into the human's DNA, causing a merging of the 'non-self' with the 'self'.[89]

To examine the pervading concept metaphor revolving around AIDS and immunology in general, especially in a South African context, I have sourced varied pamphlets that serve to inform the public about their immune systems, health, hygiene, viruses, bacteria, AIDS and HIV. Also, in order to identify the concept metaphors that seem to prevail in many sectors of the populace I have obtained a variety of information resources aimed at different target audiences. I will start by examining the South African series, *Soul City.*[90] In its print media *Soul City* has distributed over seventeen million copies of fifteen information booklets. Apparently the majority of their content (in the region of sixty percent) has dealt with issues regarding HIV and AIDS. (*Ten Years of Soul City,* Pamphlet: 2). The reason I am using the *Soul City* enterprise is due to its high influence in the lives' of South Africans.[91] Since *Soul City's* multimedia reaches seventy-nine percent of South African's, and many use it as their leading source of information, especially regarding AIDS and HIV, I will be using *Soul City* information packs, and analysing them for their metaphors, and determining the most predominant concept metaphors that arise and the effects of this. However, due to the limited space of this research report, I will not enter into discussion concerning the radio and TV productions, but rather focus on the textual and corresponding graphics visuals in the AIDS packs and workbooks and pamphlets.[92]

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[89] In many areas, not exclusively in terms of DNA, "the bringing to consciousness of the presence of AIDS" has diminished "the traditional demarcations of the body, blurring the boundaries between inside and outside" (Fraiberg 1991: 20). Fraiberg delves into these other areas of body boundary blurring that are not the focus of my research.

[90] *Soul City* (as part of the *Institute for Health and Development Communications IHDC*) is a South African non-governmental organization. In 1992 it was established in order to "harness the power of the mass media, and to promote health and development in South Africa and beyond" (*Ten Years of Soul City,* Pamphlet: 1). The institute has created "two multimedia communication vehicles" in the form of *Soul City*, "targeted at the general public" and "*Soul Buddyz* targeted specifically at children" (ibid). These "popular vehicles" function in order to "deal with a range of health and development issues" (ibid).

[91] From five independent evaluations of *Soul City* it has been concluded that:

> 47% of members of the South African public spontaneously quoted Soul City as their leading source of information on HIV and AIDS in television. … Soul City's multimedia intervention reaches 79% of South Africans. This is more than any other social change intervention. This includes 65% of rural people and 50% of people without any formal education (*Ten Years of Soul City,* Pamphlet: 4).

[92] Since scientists hardly produce radio and television programs aimed at other scientists regarding their own cutting edge research, it seemed more logical to trace and compare these representations throughout the scientific and popular media by means of printed text. In doing so, it allowed me to compare the representations in various texts that deal with similar subject matter but are aimed at different target audiences, from children to scientists.

In the *Soul City HIV and AIDS pack* is the *User Guide*. The obvious intention of this guide is to try and make viruses and diseases more understandable to the general public and, hence, uses the term "HIV germ" throughout the guide. Their textual explanations utilise formats such as comic book types of stories as well as posters. All of these seem to mainly focus on how the virus (or as they classify it, "HIV germ") is spread, and how people can live with it. The overall idea is to use a facilitator to talk to groups and encourage discussion, however, none of this appears to make the actual cause of the disease more understandable, but rather how to cope with, or prevent it. In the first workbook, titled *Living with HIV*, the emphasis is on differentiating between HIV and AIDS. Their explanation distinguishing between the two is given under the heading of "Our immune system and HIV":

> There are lots of germs around us all the time, but most of them don't make us sick. This is because our bodies have a special army to protect us against germs and help us to heal when we are sick. This army is called the immune system. As long as our immune system is strong, we can stay healthy. If our immune system becomes weak, then our body has no army to protect it from sickness.
>
> HIV is a very strong germ that attacks our immune system. It makes the immune system so weak that it cannot fight other germs, and then we get sick with many different sicknesses. This is when we have AIDS (*Soul City*, Workbook 1: 4).

From analysing this short explanation the overall concept metaphor that arises is undoubtedly that of militarization. The immune system is directly compared to an army, with sickness, and the "germ"[93] alluded to as the enemy. The immune system and HIV are portrayed as 'fighting' combatants, with HIV emerging as the 'stronger' competitor, in this example of germ warfare.

In their other workbooks and booklets, as well as cartoons and posters, similar terms, explanations and diagrams are used to convey various aspects of AIDS, HIV and immunity[94] (such as dealing with AIDS, clinical testing, and health care practices). To

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[93] On a personal note, I feel that the use of the term "germ" is inappropriate. I realize that it is intended for an audience with little understanding of biology, and the authors intended to make this aspect of immunity as comprehendible as possible. This, however, (for me) raises the question, that if the audience has none to little knowledge of biology, is using the term "germ" any more useful than using the term virus? At least using the term virus may at least allow for the association with the term HIV. Neither the term "germ" nor virus is explained, and these serve as the fundamental basis for understanding the other components of the disease. In short, I feel that such an explanation, presented as factual and simple for everyone to understand actually tends to obfuscate the relevant issues.

[94] Should you be interested in *Soul City* materials the relevant contact details are: Tel: (011) 616-2980; Address: PO Box 28510, Kensington, 2101.

avoid repetition I have only included this example which is similar to the others, and serves as an exemplar, since in all the materials the pervading concept metaphor is undoubtedly that of militarization. Given that *Soul City* exerts a large influence on the population when it comes to providing information, this is a case in point of where the majority of people would get these messages of militarization and war when approaching the subjects of immunity and HIV and AIDS.

To more fully explore how the concept metaphor is carried through different age groups and target audiences I will examine a book, aimed at children. On the front cover a visual representation of the AIDS virus is portrayed by a green sphere, with green bulbous protrusions sticking out of it. These obviously represent the protein coat of the virus. In the middle of the sphere is a face, of two red eyes, a nose and a red mouth with two fangs shown. This conveys a mischievous, refractory, foreign being. The fact that it is dangerous is conveyed both by the visual representation and is further confirmed by the heading of the book: "*STAYING ALIVE, fighting HIV/AIDS*" (Balkwill and Rolph, 2002: book cover).

The concept metaphor is being firmly laid down at an early age for children by the following militarization metaphor in the introductory paragraph:

> All over the world, and every minute of the day, invisible germs are trying to attack human beings, including you!
>
> But don't worry! Your body is made of millions and millions of clever and complicated cells. And the cleverest cells of all protect you from most germs… (ibid: 3).

The passage ends with ellipsis and then the following words represented in a speech bubble coming out from one of the children's mouths that are drawn around the edge of the page. The words in the speech bubble are: "most of the time" (ibid).

Following this, the demarcated surfaces of the body that prevent microbes entering the body are simply explained. The skin, stomach acids and hairs along the "cells that line your breathing tubes" are described as expelling germs from the body by providing a "tough … cell layer"; acid; and sweeping function, respectively. While the nose and lung cells make mucus "that traps those sneaky germs" (ibid: 4). Despite these measures,

> some times and somehow, germs can and do get inside you. Then they face the cleverest cells in your body, your germ busting defender cells! Defender cells work

> together to keep you well, and make you better if you get ill. They patrol your blood stream and protect the places where your insides meet the outside world (ibid: 5).

On the following pages various cells that are involved in the immune response are visually represented with explanative text. For this target audience the macrophage is depicted with two crude eyeballs, a large dark blue speckled mouth and a mass of blue body that has an amorphous shape. The 'foreign' microbes are represented by small cylinders in green and yellow, with spikes along them. The speech bubbles emanating from the macrophage contain words such as "zap" and "chomp." The text explains that "macrophages (mack-row-fages) clear up the mess wherever germs and dirt collect. They are also very good at zapping germs" (ibid: 6). In their explanation of other types of cells the militarization concept metaphor is more apparent. Especially with the term "natural killer cells" that are depicted as functioning due to their ability to "punch deadly holes in infected and damaged cells" (ibid). Or the neutrophils, that "love to eat juicy germs. They zap them with powerful chemical weapons! Germs just melt away" (ibid)! Here is a direct link to chemical warfare. As for lymphocytes, they are characterised as follows: "some lymphocytes are killers. They destroy other cells that are infected with germs" (ibid: 7). All of these cells are classified together as being "some of your special defender cells" (ibid). The book goes on to explicate that "one hundred thousand million defender cells are made in your bone marrow each day. They replace those that have died of old age or from fighting germs" (ibid).

Subsequently the book elucidates, in simplistic terms, what a bacterium is, and gives a crude visual approximation of what one looks like under a microscope. The book does a service in pointing out that "nearly all bacteria are harmless to humans," and many are useful (ibid: 8). This is perhaps the first hint from these texts that not all bacteria and viruses are the 'enemy'. The book then progresses into an explanation surrounding viruses and what they are, and how they function in relation to humans. Their description of a virus is that of "another sort of germ. They are much smaller than bacteria. They cannot live on their own. They need to get right inside you and your cells" (ibid: 10). Complemented by diagrams of viruses represented by swarms of green particles, the text expounds that "a virus takes over the cell so that it makes more viruses, which escape and infect more cells" (ibid). The book then introduces its readers to HIV with these words: "There is a new and deadly virus that threatens your world – a virus called HIV" (ibid: 12). The same green alien type of creature, as I explained before, is shown again here, with the description:

> HIV is especially dangerous because it attacks the very cells that should destroy it – your germ-fighting defender cells. But you can protect yourself and the people around you, if you start to understand HIV and all its tricky ways (ibid).

Here once again, terms such as “dangerous,” “attacks,” “destroy,” “fighting,” “defender,” “protect” are all used metaphorically, and the virus is personified as a “tricky” enemy, since it integrates into your own DNA and parasitizes it.

The process of how the virus overwhelms the immune system’s cells is illustrated and culminates with a visual depiction of many small green particles, representing viruses all around blue cells. The words “zonk!”; “bonk!” and “clonk!” are shown around the viruses and lymphocytes. This diagram essentially depicts a fight going on between the lymphocytes and viruses for supremacy of the body. A term that has been widely used in the media is that of ‘fighting HIV and AIDS’. This book brings this militaristic message across with its ending statements for children:

> All over the world, people are fighting the HIV virus. Some are trying to find new medicines or vaccines; others help and support those who are already infected.
> This is YOUR battle as well.
> Children of the world can win the war against HIV and AIDS (ibid: 32).

Here finally, the metaphor is no longer realised. It has pervaded and infiltrated the text to such an extent that it ends with the message telling children that it is their “battle,” and that they can “win the war”!

Literally speaking, it would be impossible to wage war against a virus. It is only possible to take preventative measures against being infected. Nevertheless, the ubiquity of this metaphor is highly apparent. It is also not just in a South African context, since this book was the result of a collaboration between *LoveLife*, scientists and doctors from South Africa, the UK and USA. As I am only concentrating on the Western metaphors it is interesting that all these countries have collaborated in using the same metaphor for describing immunity, especially with relation to HIV and AIDS.

That is the child audience, what about the teenage audience? *LoveLife* has taken the initiative to periodically produce various booklets aimed at teenagers. Examples of these booklets include *S’camto* and *thethaNathi.* In the *thethaNathi* edition specifically dealing with HIV and AIDS, they also employed metaphorically bellicose language.

> Whether we like it or not, we are all being affected by HIV/Aids. The virus, and its destructive path, is on our TVs and radios, in our magazines and newspapers … and even in our schoolrooms (September 6, 2002: 4).

The authors also explain that the virus that causes AIDS is "like any other virus … except that it attacks the immune system itself" (ibid). The militaristic metaphor is still used even in this article to point out that "you have no *defence* against pneumonia, TB and a whole lot of other nasty illnesses" (my emphasis, ibid).[95]

4.4. MERGING METAPHORS

Now that the concept metaphor which pervades immunology has categorically been determined as militarization, I can return to the question I posed at the beginning of this chapter, of how the concept metaphor of information coding in genetics affects the representation of immunology and consequently perceptions of 'self'. After all, as Haraway explains:

> Organisms are not made; they are constructs of a world-changing kind. The constructions of an organism's boundaries, the job of the discourses of immunology, are particularly potent mediators of the experiences of sickness and death for industrial and post-industrial people (1991: 208).

Such recognition of "knowledge as an active part of the apparatus of bodily production" has never been as important as at this moment in time, because "scientific objectivity (the siting/sighting of objects) is not about dis-engaged discovery, but about mutual and usually unequal structuring" with the "various contending biological bodies" materialising "at the intersection of biological research, writing, and publishing; medical and other business practices; cultural productions of all kinds, including available metaphors and narratives; and technology" (ibid: 208-209).

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[95] The same overall concept metaphor of militarization is also found imbuing international magazines such as Reader's Digest which in the May edition of this year, had the largest heading on the front cover stating "Germ Alert! How to Protect Your Family" (*Reader's Digest,* May 2004: front cover). In fact, like the *Soul City* booklets, this article also seems fond of using the word "germ," and the same militaristic concept metaphor is evident, even in the opening paragraph: "You can't see, hear or feel them – but harmful bacteria, viruses, moulds and parasites relentlessly try to invade and infect your body" (*Reader's Digest,* May 2004: 53).

The reason that we recognise the importance of these social constructions of the body, at this time, is because at no other time has science wielded such power not only for constructing conceptualised bodies through its metaphors and technology, but also for its present ability to physically construct humans in the form of genetically altered clones (for example by genetically altering stem cells)! The power of the figurative for conceptualising organisms is eventuating in the physical construction of organisms. The metaphors for instantiating 'coded information' into material morphs of 'self' that are healthy enough to fight of the 'non-self' is resulting in the figurative forming the functional. And yet, the incongruity in such a sentence is obvious, for how can DNA from different sources, amalgamated together be called a 'self' that recognises 'non-self'?

A similar problem arises in the face of HIV and AIDS. In this disease, together with preconceived paradigms of immunology and genetics, the militarized fight for 'self' versus 'non-self' is taken to a new battleground. The arena of militarization becomes our genes, or our information code. To give an example of this I have used an excerpt from an article dealing with HIV and how HAART (Highly Active Anti-retroviral Therapy) medication works to try and impede its deadly effects. In the article the virus is described as "an RNA retrovirus" which "has the unique ability to *rewrite* or *transcribe* itself backwards into the DNA, *becoming part of* the body's genetic *code* or make-up of cells it *attacks*" (my emphasis in *The Star*, April 1, 2004: 13). Here the merging of both immunology's and genetics' predominant concept metaphors are obvious, with the virus portrayed as insidiously 'attacking' the body's cells in order to "rewrite" and literally merge into the "genetic code." And once a virus has integrated itself into our DNA this raises new issues. For instance, where exactly is the viral DNA of 'non-self' in relation to 'self'? In other words, a new code has formed a new hybridised 'self'![96] This could be applied and

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[96] What may be even more interesting to note is that this is not just the case for pathogenic viruses, actually the perception of certain viruses (in various scientific communities) as housing genetic elements (footnote 88) has allowed for them to be hypothesized as having "almost certainly played an important part in the evolution of the organisms they infect," because of their "unique ability to transfer nucleic acid sequences across species barriers" (Alberts *et al.,* 1994: 286). In other words, viruses may have helped in the evolutionary structuring of organisms genomes. Many viruses

> recombine frequently with their host-cell genome and with one another. In this way they can pick up small pieces of host chromosome at random and carry them to different cells or organisms. Moreover, integrated copies of viral DNA (proviruses) have become a normal part of the genome of most organisms. Examples of such proviruses include … the so-called endogenous retroviruses found in numerous copies in vertebrate genomes. The integrated viral DNA can become altered so that it cannot produce a complete virus but can still encode proteins, some of which may be useful to

extended to Haraway's notion of cyborgs: "bodies have become cyborgs – cybernetic organisms – compounds of hybrid techno-organic embodiment and textuality. … The cyborg is text, machine, body, and metaphor – all theorized and engaged in practice in terms of communications" (1991: 212). The ultimate result of this conflation is that disease emerges as a "subspecies of information malfunction or communications pathology; disease is a process of misrecognition or transgression of the boundaries of a strategic assemblage called self" and even individuality becomes "a strategic defence problem" (ibid).

Operating in such cyborg and postmodern theories "of representation, are approaches and practices that locate 'the body' within systematized networks and circuits" this results in "presenting scenarios in which traditional tropes of discreteness, of discretion, dissolve and the focus shifts to formulations of connectedness" (Fraiberg, 1991: 1). If so, then where would one begin discussing the boundaries of human bodies? Or, as Haraway enquires: "what is constituted as an individual within postmodern biotechnical, biomedical discourse" (1991: 215). She explains that

> there is no easy answer to this question, for even the most reliable Western individuated bodies, the mice and men of a well equipped laboratory, neither stop nor start at the skin, which is itself something of a teeming jungle threatening illicit fusions, especially from the perspective of a scanning electron microscope (ibid).

However, she does point out that "an account" of what she terms the "biomedical, biotechnical body must start from the multiple molecular interfacings of genetic … and immune systems" (1991: 211).[97] To endeavour to 'interface' these molecular interactions, I will commence by reviewing immunology and then continue into genetics and finally combine them through their concept metaphors.

I have already outlined using an example how, over time, the ideas of the nineteen-forties onwards have coagulated into a system of 'layered' defence, with the outer defences of the skin and, for example, mucous membranes serving as primary defences. As more was discovered about the internal functioning of the body, analogies to chemical warfare and surveillance systems entered into immunological dialogue and the complexity of the militarization strategies of the body seemed to grow proportionally with the deeper the

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the host cell. Therefore, viruses, like sexual reproduction, can speed up evolution by promoting the mixing of gene pools (ibid).

[97] Indeed, in order to examine "the relationship between immunity and genetics" a new field of study has developed called "immunogenetics" (Hanks, 1988: 766).

pathogen ‘penetrated’ the body. In other words, the evolution of warfare outside of the body seems to have paralleled the evolution of the species with regard to immunological specialities. At this point the pathogen has entered the nucleus, specifically the DNA; the cybernetic, information, controlling, coding system of the body. Does this mean that the next order of warfare will turn to tropes of *nuclear warfare*? Although I would have expected this as a result, it does not seem to have occurred (from analysing various popular media representations).

With the idea of DNA being coded information, information used to produce the body, the question arises (one that is usually tacitly elided): who instructs the code to begin producing the body, and which sections of the body will be produced at which specific time? For instance, let us take the idea of a virus or bacterium in the body. The conceptualisation is that the body will recognise the antigen and then produce specific antibodies to counteract the antigen, to do so requires that certain genes are actively transcribed into RNA and consequently into protein to form components of the antibody. By following this logic to its ultimate conclusion, the DNA is thus posited as taking orders or instructions from the body. This confounds the biological hierarchy that information theory helped to establish. The body that was viewed as a subservient creation morphologically derived from coded information can now be viewed as orchestrating its own production. This results in the hierarchical reorganisation of the organism, with DNA seen as subservient to the body.

How can ambiguities; such as, the DNA versus body or, as in the above example, T cell hierarchy be resolved? In this early twenty-first century, it seems a new metaphor has emerged, and is starting to overtake the hierarchical structuring of the body. This new metaphor aids in the integration of the concept metaphor of information coding that prevails in genetic discourse, and which “coexists uneasily,” with the militarization concept metaphor that predominates in immunological discourse (Martin, 1994: 61). The metaphor is of the *systemic* body and immune *system*. This representation allows for “the traditional tenuous limits of the body” to dissolve “into fused networks, into open circuits of interconnectedness” (Fraiberg, 1991: 9) with “dispersed control … and flexible adaptation” (Martin, 1994: 61).

How and why has this ‘systemisation’ emerged as a means to conceptualise and contextualise the body? Haraway describes how it has grown “from the eighteenth to the mid-twentieth centuries, [where] the great historical constructions of gender, race, and class were embedded in the organically marked bodies of woman, the colonized or enslaved, and the worker" (1991: 210). "The marked organic body" served as a "critical locus of cultural and political contestation" which was "crucial both to the language of the liberatory politics of identity and to systems of domination drawing on widely shared languages of nature as resource for the appropriations of culture" (ibid). However, it is since the "mid-twentieth century, [that] biomedical discourses have been progressively organized around a very different set of technologies and practices, which have destabilized the symbolic privilege of the hierarchical, localized, organic body" (ibid: 211).[98] Emily Martin adds to this by indicating how

> the selectiveness of (immune) systems thinking comes about because it seems to represent an escape from earlier forms of discipline that constrained bodies and groups in the mass production era, the strict mobilization of the body in rigid postures and limited movements in factories and prisons or the detailed rules that governed mind and body in schools and the military (1994: 247).

Emily Martin has traced the relations that seem to link between science, culture, social, economic and political[99] realms where, just as the current market seems to value the flexible, agile "worker/person/body" this flexibility seems to have been incorporated to conceptualise the immune system (ibid). She inferences how the "models in the science of immunology shift away from the defended castle to that of the part embedded in a complex whole" and in doing so allow for the reduction of "the strict self-nonself distinction" (ibid: 246). Martin explains how this new metaphor for the body has materialized as a result of being "partially influenced by a cultural environment in which this shift of body image has *already taken place* in many areas outside science and in the private musings of many

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[98] Instead of the hierarchical body the idea of a body linked by systems came into effect, and thus the concept of the 'system' in '*Immune System*'. Martin explained that she (similarly to me) wanted to "explore in some detail media coverage of the immune system" (1994: 49). She points out that "perhaps the notion of an immune 'system' was first widely disseminated to the reading public through an article condensed in the *Reader's Digest* in 1957 (Brecher and Brecher 1957)" (1994: 50). I managed to source this article in the South African version of the *Reader's Digest* (which because it was the South African version was printed a few months after Martin's referenced edition, in November 1957). The systematic nature of immunity comes across from the article's explanation of how cells, such as leukocytes and macrophages, engage with diverse elements of the body, such as bone marrow, the spleen and lymph fluid, in order to maintain health. These 'layers' of immunity seem to form a synergistically functioning system. The militarization metaphor still prevails, as it together with the systematization metaphor fuse cohesively in the article's introductory statement that "nature has provided us with a miraculous *system of defences* against the disease germs that *attack* us by the millions daily" (my emphasis, *Reader's Digest*, February 1958: 55). This merging of these metaphors is also evident in the article's concluding remark that "it seems unlikely" that mankind "could … survive without the human body's miraculously *co-ordinated* '*defence in depth*' " (my emphasis, ibid: 59).

[99] Claude Lefort, details how politics especially, totalitarianism, has utilized images and analogies with the body in order to maintain allegiance to the 'body politic' (1986: 300-306). Shakespeare also used "many variations on a standard form of the metaphor, [of] an infection in the 'body politic' "(Sontag, 1978: 76).

scientists as well" (original emphasis, ibid). Martin points out that this "nearly universal understanding of health in any of its aspects in terms of the immune system" is a process that

> fueled by the findings of scientific research on the immune system as translated by the media, surely must influence the thinking of the politicians who approve financial allocations, the scientists who approve research grant applications, the scientists and editors who select what papers get published, and so on (ibid: 246-247).

Adding another metaphor, Martin contends that

> a ten-lane superhighway would barely be sufficient to handle the ideas and practices treating the body, self, and world as complex systems that must be shuttling back and forth between the general culture and the scientific community involved in research on the immune system (ibid: 247).

This is highly reminiscent of Keller's quote that I used in chapter one, in order to relate how science and culture are inexorably vested in each other.

If this is the contemporary overall concept metaphor that is developing, then Haraway elegantly poses the question of how the "narratives of the normal and pathological" will be influenced by the "biological and medical body" being "symbolized and operated upon … as a coded text, organized as an engineered communications system, ordered by a fluid and dispersed command-control-intelligence network" (1991: 211)?

Ultimately, the result seems to be biology's new embodiment in terms of

> recognition and misrecognition, *coding errors*, the body's *reading practices* (for example frameshift mutations), and billion-dollar projects to sequence the human genome to be published and stored in a national *genetic 'library'*. The body is conceived as a strategic system, highly *militarized* in key arenas of imagery and practice … The biomedical-biotechnical body is a *semiotic system*, a complex meaning-producing field, for which the discourse of *immunology*, that is, the central biomedical discourse on recognition/misrecognition, has become a high-stakes practice in many senses (my emphasis, ibid).[100]

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[100] Fraiberg offers a different result, where she extends Donna Haraway's "cyborgs ontology" through AIDS to "resurface" the body "from within the networks" in order to advocate "a very different kind of discreteness, and consequently a revised type of agency, into a postmodern context" (1991: 2). She points out that AIDS has led to the recognition of the interdependency and the disintegration of boundaries in society, since (as she offers as one example) "sex depends on a recognition of interconnectedness, of indiscretion" (ibid: 9). But, out of this "a consciousness focused on clearly delineating the boundaries of bodies" has arisen (ibid). Because in order to avoid infection, an awareness of surfaces has developed and "any exchange of fluid, that is, any disclosure of an open, leaking body threatens" (ibid: 10). Fraiberg argues that this results in "a closed, self-contained body" that has resurfaced "from within the integrated network" (ibid). She then explains how "in this sense, discretion returns, not in the form of a reactionary denial, but as conditioned by a cyborg-like system" (ibid). Of course this "resurfaced, discrete body/subject is different from its predecessor because the recognition of blurred boundaries is precisely that which makes the body resurface" (ibid). However, I feel

In other words, the result of this new metaphor (with regard to genetics and immunology) is that this systemisation serves as a means to connect the respective concept metaphors. Hence, facilitating the codification of diseases in order to, hopefully, understand the *secrets* of the disease process and, thereby, be able to *fight* it.[101] Thus the concept metaphors and all that they entail are feasibly linked.

In my previous chapter I discussed the paradox that scientists "while disavowing that language plays a part in structuring and representing their objects, … have attributed language use to an inert molecule" and have personified DNA with the ability to read and write (Nierenberg, 1999: 239). Haraway has deepened that discussion by extending this reading and writing into a "semiotic system" relating to the immune system. Nevertheless, even with the presentation of the systematic networked aspects of the body, underlying it is the infiltrated genetic 'code' which seems to persist in belying the body as its production. Therefore, (through the conflation of the concept metaphors between genetics and immunological discourses) the disquieting repercussion is that the

> standard reference work called the human genome would be the means through which human diversity and its pathologies could be tamed in the exhaustive code kept by a national or international genetic bureau of standards. … Access to this standard for 'man' will be a matter of international financial, patent,[102] and similar struggles (Haraway, 1991: 215).

Thus, disease becomes predicated on a code and people are contextualised in order to try and determine what diseases they are predisposed to getting based on their semiotic code.[103]

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that Fraiberg's analysis forms as a consequence of her perspective of viewing the body in terms of social impact from AIDS, from a decade ago. Since my focus is from the perspective of genetic encroachment into immunological discourse (that has only really occurred in the last few years), I feel that my described results take more than AIDS into consideration and are more consistent with the current biological, medical and technological progressions.

[101] An example of a disease that has been genetically 'codified' is Huntington disease. This disease is thought to be caused by having the DNA sequence CAG 'written' too many times in the human genome.

[102] The first animal to be patented was a mouse. It was granted the patent number 4736866 in April nineteen-eighty-eight. Scientists at Harvard University patented the mouse which carried a gene implicated in breast cancer. This patent opened the way for the frenzy of genetic, research-animal patents that is currently occurring (Kindersley, 1991: 21).

[103] Other metaphors have been presented which also account for scientific aspects, yet, they have not taken hold in popular media as predominantly as militarization has. I will discuss these other metaphors briefly. Common to all of them is a systematic flexibility of approach in their perception of immunity and disease. Perhaps these alternatives portend the "medicine of the future – integrative medicine that focuses on improving health, not treating disease" (*The Star*, March 24, 2004: 17).

Such an example is one offered by Fleck, that although different, it is nonetheless a viable view of disease as a "complicated revolution within the complex life 'unit' rather "than of an invasion of it" (1981: 61). He discusses how the perceptual shift from considering immunology and biology in terms of "chemically defined substances" and rather speaking "of states or structures" allows for the "possibility that a complex chemico-

At this point one might argue that if such metaphoric structuring of the body is resulting in enhancing lives, why contest it. I am not contesting metaphor specifically, but I am contesting the reliance on such sole conceptualisations of the body. Even with the systematised, fluid, flexible, communications network that is becoming a new metaphor for the integrated immune system and body, we should still not lose sight of

> the challenge [which] is to sustain our critical perceptions in a culture that prizes being flexible [and] adaptive without allowing our perceptions to become so flexibly adaptive that they can only compliantly perpetuate – instead of calling attention to – the order of things (Martin, 1994: 249).

The reason for this required perceptual flexibility and vigilance is because at stake are "the kinds of bodies we imagine" and metaphorically conceptualise "will be able to survive the next eruption of Ebola or the development of a more virulent flu" for example the recent eruption of the SARS (Severe Acute Respiratory Syndrome) virus (ibid: 244). In essence, survival, life, death, and health are all at stake. Since metaphors hide certain aspects, by overlooking the metaphor one dismisses the characteristics that it conceals. This has terrible implications in the forms of anything from unexplained asthma, and cancer cases to genetically impaired babies being born.

Taking the metaphor of the literal text of the DNA code literally, ultimately demonstrates the prepotency of such metaphors, because as they take on a life of their own, they are taking and creating new lives. The tremendous consequences of utilising them literally in

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physico-morphological state is responsible for the changed mode of reaction instead of chemically defined substances of their mixtures being the cause" (ibid: 62-63).

Haraway provides another view of immunology "as in some sense a diagram of relationships and a guide for action in the face of questions about the boundaries of the self and about mortality" (1991: 214). Such immunology "discourse is about constraint and possibility for engaging in a world … full of 'difference', replete with non-self" (ibid). Presenting immunology in this way allows for conceptualising alternative approaches to disease that are capable of contesting "notions of pathology, or 'breakdown', without militarizing the terrain of the body" (ibid). An example illustrating such an approach is provided by Winograd and Flores who describe "breakdowns" as playing "a central role in human understanding" because, as they explain it, "a breakdown is not a negative situation to be avoided" rather "a situation of non-obviousness, in which some aspect of the network of tools that we are engaged in using is brought forth to visibility" (Winograd cited, ibid). Viewing a "breakdown" in this manner "reveals the nexus of relations necessary for us to accomplish our task" and in so doing "creates a clear objective for design – to anticipate the form of breakdowns and provide a space of possibilities for action when they occur" (Winograd cited, ibid).

Such thinking seems to offer an alternative to the "hi-tech, modern medicine practice" that has been compared to " '*Star Wars* medicine' " in that it is "characterised by 'some knowledge about parts of the body, only modest understanding of the whole, and little, if any, wisdom' " (Ali Majid, president of the *American Academy of Preventative Medicine*, quoted in *The Star*, March 24, 2004: 17). Ali promotes "integrative medicine" which is "bio-energetic in approach, compared with biochemical and drug-based orthodox medicine" (ibid).

scientific productions of ‘self’[104] (and all that this encompasses in terms of disease, health and life) by the literati, are now becoming patent.

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[104] As in Anushka van Rooyen’s case.

5. CHAPTER FIVE:

CONCLUSION AND THEORETICAL IMPLICATIONS

"The real voyage of discovery consists not in seeking new landscapes,
but in having new eyes."
Marcel Proust

Coming from the disciplines of genetics, biochemistry, microbiology and immunology, the use of metaphor and analogy in furthering the understanding and perception of various aspects in science, has opened my eyes. As an undergraduate, I had been utilising such metaphors and unconsciously assuming them to be the absolute 'truth'. (With hindsight, and considering the copious amounts of scientific research predicated on these concept metaphors, this was a likely result). However, from this research the multifaceted interlinking of many cultural, political, social and economic practices, which impinge on science and its role in society, has become substantially more apparent. By my focusing on both scientific and popular representations, what has also become abundantly clear is "how crucial it is to recognise the interrelations between different kinds of cultural productions, specifically literature and science" (Hayles, 1999: 24). Since, both scientific and literary portrayals:

> would not have the same resonance or breadth if they had been pursued only through literary texts or only through scientific discourses. The scientific texts often reveal, as literature cannot, the foundational assumptions that gave theoretical scope and artifactual efficacy to a particular approach. The literary texts often reveal, as scientific work cannot, the complex cultural, social, and representational issues tied up with conceptual shifts and technological innovations … [therefore] literature and science as an area of specialization is more than a subset of cultural studies or a minor activity in a literature department. It is a way of understanding ourselves as embodied creatures living within and through embodied worlds and embodied words (ibid).

Through my investigation of both popular and scientific texts it has become apparent that the popular representations of scientific knowledge that use metaphor and tropes for readers are adapted from the analogies and metaphors that are inherent in the scientific hypotheses, theories and practices that are the basic ingredients in the synthesis of science itself. In other words, the recursive cycling between science and the popular media has assisted in disseminating and proliferating certain predominant understandings. The role that metaphors play in these 'truths' has been largely overlooked by journalists and scientists, and this exemplifies both the difficulty of dissociating the metaphoric from 'scientific fact' as well as the importance of doing so. The main reason why I am advocating that the use of metaphor should not be disregarded, is because of the influence that metaphors exert in explaining complicated scientific concepts, as in discourses of genetics and immunology. These two disciplines are both wielding remarkable authority within the scientific as well as the general population, due to their impact on biotechnology. This results from the nature of these subjects which deal with life and health, and our understandings thereof, and what could be more important than that? With cloning and stem cell research affording the possibility of making people's lives longer and healthier, and obliterating many diseases, these disciplines are exerting more and more power. It is amazing how the metaphors that have been used to conceptualise and promote people's perceptions of these subjects are insidiously taking on lives of their own.[105] Not only is the genetic *code* viewed as the basis of life, but the *information* the *code* contains is thought to *militarily* be able to *destroy* disease. The many facets that these metaphors cannot explain are relegated to nonsense ('junk') or elided as unimportant. Otherwise, the general thinking is that these scientific aberrations will be discovered later by further research (which of course is predicated on

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[105] I have previously demonstrated how the metaphors used in both genetics and immunology are 'coming to life'. Other interesting points that also illustrate the power of metaphor (at the molecular level) to come to life include the following. The first is the DNA computer, but that I have already explained earlier (footnote 36). Thus, I will turn to the second example which deals with the creation of a truly 'cybernetic organism'. Scientists have mated "a healthy human cell with an electronic circuitry chip" (*Sunday Tribune*, March 19, 2000: 14). The idea is to command "the chip by computer" in order to "control cell activity" (ibid). The third example involves using nanotechnology. In *New Scientist* it was reported that a German chemist, Günter von Kiedrowski, is on the verge of making "self-replicating objects just nanometres" in size (Ball, 2003: 50). What is most amazing about this is that Kiedrowski is creating these self-replicating "nanobots" based on Watson and Crick's original 1953 articles, which "showed that molecules can be imbued with information" (ibid). These "self-replicators" are based "on the same principles that enable DNA to copy itself to pass on their own assembly instructions to a new generation" (ibid). In these examples, of the DNA computer and the DNA based 'replicators', immunological discourse is linked with genetics. Where, in the first case the DNA computers could be used to monitor health by being small enough to be injected and float around in the human body. In the latter case the plan behind the "nanobots" is that they "might prop up failing immune systems for example, by helping to distinguish friendly cells from dangerous foreign invaders" (ibid). In a *Fair Lady* article, examining possibilities for the future, the use of nanotechnology is regarded as useful because it could hold "detailed medical information" (*Fair Lady*, May, 2003: 42). Here, once again genetics and immunology are irrevocably merging.

using the same metaphors to try and understand new scientific concepts that are hidden by those self-same metaphors).

What I am advocating is not the elimination of metaphor in science. After all, metaphors are valuable in facilitating the comprehension of new theories pertaining to scientific advancement. Rather, I am contesting the reliance on sets of predominant concept metaphors with which to frame research. Because, for example, when such concept metaphors are tacitly consigned to absolute scientific truths they obscure certain factors and results that arise in research. These results are unexplainable (at least within the confines of the concept metaphor) and are generally omitted or relegated to inconsequential artefactual outliers. So, instead of relying on the same concept metaphors I advocate the continued utilisation of new metaphors in science, in order to make use of metaphors and analogies in scientific theories[106] as a means to investigate and uncover aspects of scientific characteristics that would otherwise remain hidden by the previous metaphors. To illustrate this point, I would like to bring to light certain pieces of scientific knowledge and data, pertaining to genetics, which are usually concealed or dismissed as nugatory occurrences through the concept metaphor of information coding. Furthermore, I intend to demonstrate how these scientific details, that are usually discounted, could be of significance in advancing genetics in new regions of research through the use of unfamiliar and slightly unorthodox metaphors.

The first piece of, rather obvious, scientific knowledge which is generally disregarded is DNA’s whole structure. By virtue of the information coding metaphor the nitrogenous bases, that are but one part of the DNA structure, are said to form the DNA ‘code’ and are granted a great deal of attention. However, besides constituting an ‘information code’, the bases are a component that assists in configuring the overall structure of the DNA double helix, though this is rarely considered.

When the overall structure of the DNA molecule is considered, an important characteristic becomes apparent: Although DNA is commonly conceptualised as the exact, repetitive

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[106] Keller argues that “scientific theories … may be thought of as tools” and “good theories are theories that work, that facilitate the kinds of action for which they are intended” (Keller, 1992: 95). In other words “that enable an ‘us’ to act in and on the world in ways that a ‘we’ deems desirable” and, therefore, scientific theories as tools “reflect both the subjectivity of human objectives and the objects of human action” (ibid). It is in such a context that I propose the utilisation of new metaphors as tools with which to expand upon the current repertoire that is used to conceptualise genetics.

structure that Watson and Crick described and diagrammed[107] in their historic articles (1953a and 1953b), this is an inaccurate representation. Since, within living cells, DNA is not found in this precise shape. Biologically, DNA can be highly condensed in certain sections, whereas in other portions it may be bent and wound around specific proteins. Watson and Crick educed their theory (of DNA's structure) based upon X-ray diffraction patterns that Rosalind Franklin had determined from crystallised DNA. In living organisms DNA is not generally found in crystallised form. Subsequent analyses over the years have shown that "any given nucleotide sequence" has "local irregularities, such as tilted nucleotide pairs or a helical twist angle larger or smaller than" the idealised angle in Watson and Crick's originally described DNA helix (Alberts, *et al.*, 1994: 406).

Another interesting statistic, that I already discussed in chapter three, is that the parts of DNA that are said to 'code' for 'information' only comprise approximately *three percent* of DNA. The other *ninety-seven percent* is said to be 'junk DNA', since it has not been found to code for anything particularly discernable. A genetics textbook explains that "a gene *encodes* the chemical nature (the amino acid composition) of a protein, the *end product* of genetic expression" (my emphasis in, Klug and Cummings, 2000: 7). If this statement is analysed, what it points to (besides the ubiquitous information coding concept metaphor) is the reliance on the protein being the intended product of the gene. Furthermore, this statement also alludes to the idea that we only know genes through their actions. In other words, only by extrapolating backwards from the functional protein do we recognise the action of the gene. It is likely that since junk DNA's action cannot be deduced 'in reverse' from the action of a protein, and indeed is not found to code for proteins, this could mean that it has another action that is less discernable through the phenotypic "end product."

To me, as well as various scientists, common logic would indicate that such a large proportion of our genome (ninety-seven percent) must be important, and not the result of remaining 'evolutionary vestiges' as has been suggested. Perhaps our genes are actually but a fraction of a much larger area of genetic significance. After all, looking at the 'information coding' genes has not answered the question of why everyone who is said to have a gene coding for, for instance, breast cancer will not get breast cancer. Or why the age of onset of the disease can vary vastly between individuals who do get breast cancer.

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[107] The diagram of the double helix in Watson and Crick's celebrated 1953 papers was actually drawn by Francis Crick's wife Odile, who usually painted nudes (Ball, 2003: 53).

Genes are frequently perceived as operating in a linear, sequentially coded manner, however, there are certain known factors about DNA that contradict this view. The first one is that certain segments of genes (called exons) appear to be 'interrupted' by variable sections of 'non-coding' or 'junk DNA' known specifically as introns. Introns are especially unusual since they seem to be spliced out of the final gene product. Although, long relegated as incidental 'interruptions' or 'junk' in the genome they have recently been found to be implicated in certain cancers, and they are now known to play a role in creating variability in immunoglobulin genes,[108] so that the immunoglobulins or antibodies can recognise a variety of antigens. However, the specific function of introns is still unknown. What does seem apparent, though, is that by following a "reductionist approach" of "reverse genetics," in other words, trying to deduce the gene from the product has, as John Mattick (the director of the *Institute for Molecular Bioscience at the University of Queensland* in Australia) has indicated, caused "the introns within genes" to "immediately [be] assumed to [be] evolutionary junk" (J. Mattick cited in Gibbs, 2003: 2).

The second fact about DNA that seems to contradict the belief that it operates in an orderly sequential manner is the presence of so-called 'transposable genetic elements' or 'transposons'. Transposons are sections of DNA that can travel or be transposed to different regions of the genome.[109] They have not been determined to *code* for any particular *information* and occasionally seem to cause mutations when they insert into genes.[110] Yet, they make up approximately *ten percent* of the human genome compared to the *three percent* that genes constitute. The fact that transposons constitute a substantial proportion of our genome indicates that they must offer a selective advantage. Since, (as various

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[108] Different exons are put together in various combinations in order to create different genes. For example, to create similar but different immunoglobulins (for targeting a specific antigen) different exons are spliced together. Thus, the introns must aid in regulating which specific sections are linked together to form the final gene and consequently final immunoglobulin.

[109] Barbara McClintock was the first person to study transposable elements. In the book *A Feeling For the Organism* (1983a), Evelyn Fox Keller describes the difficulties McClintock encountered in trying to get other scientists to accept "the idea that genetic information was not *fixed* within the genome of an organism" (original emphasis in, Klug and Cummings, 2000: 484). (I am not so sure that McClintock has yet succeeded in convincing all of them of this idea).

[110] Transposons and other types of 'junk DNA' have been theorised (by others) as areas to allow for genetic mutations, in order to facilitate evolution, and the possible creation of genes that can give the organism selective advantages (in a Darwinian sense). These sections, because many of them are transposable (or can 'jump' between genes) have been thought of as 'selfish DNA' sequences that try and retain themselves (in a parasitic fashion) by moving between genes, and replicating themselves, thereby forming repetitive sequences of DNA in genomes. For more on the theory of 'selfish DNA' I direct one to read Richard Dawkins work, (1982).

scientists have pointed out) “a key feature of biological organisms is optimal energy expenditure” and carrying large “amounts of unnecessary molecules is contrary to this fundamental energy saving feature of biological organisms” (Kettlewell, 2004: 2).

What the above examples of anomalies seem to reveal is that, at the very least, the *plasticity* of the human genome is not as linear as expected. With parts of DNA coiling or binding to protein or condensing, while other segments are transposing into different sections, to me this indicates that DNA does not seem to be a static code of information. It does not even appear to be a passive, stationary “instruction book,” but rather a dynamic, fluctuating, interactive and responsive ecological body.[111]

If DNA was to be considered as a dynamic body that can react and respond to its environment, in other words, be an extension or part of the entire body, (which it is if you apply common sense) that would imply that DNA would need a means of interacting with the rest of the cell in which it resides as well as the body (in a similar way to an organ, or a gland such as the pancreas reacting to a decrease of insulin in the body). It would also contradict the central paradigm in the central dogma, since the central dogma maintains that information is transferred only from DNA to RNA to protein. Accordingly, information is assumed as being unable to enter the DNA. If DNA were able to interact with its environment that would mean that it could react to its surroundings and thereby, in a sense, gain ‘information’ from the environment.[112] Does this occur? Particular types of proteins have been found to attach to certain sections of DNA in order to activate specific genes. Thus, DNA could be described as being ‘informed’ of which genes to express.

Cloning serves as another example of how DNA can obtain ‘information’ from its surroundings and interact with its environment. The technique of cloning works on the principle that any cell of your body containing DNA (provided it is not a gamete) can be transformed into a genetic replica of you. This is done by taking the nucleus (containing the DNA) from your body/somatic cell and introducing it into an enucleated donor oocyte. The egg cell is thought to be necessary in order to provide the requisite environment (in terms of proteins, nutrients and energy) for the DNA. After adding electricity to the cell, a technique

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[111] I would like to thank Ms Ridgway who, through personal communication, helped me to reach this epiphany.

[112] Of course, in this sense, information is interpreted to mean interacting and responding to the environment and does not adhere to Crick’s formal meaning of ‘information’.

known as “electroshocking,” an embryo is created (Kerschen, 1998: 1). How is it that by taking a cell from an udder (as in the case with Dolly, the first cloned mammal) and placing its nucleus in an egg cell, a new embryo that is genetically equipollent[113] to you is formed? The DNA ‘code’ is still the same in both the udder and the embryo, however, the surrounding environment is different! Thus, this environment must have an impact on the DNA. Indeed, it appears to, because not only are different genes expressed, but the overall *figure or frame* of the DNA *body* is altered. By this I mean that certain regions of DNA are compacted in the udder which are more unwound in the embryo, even though the genetic code remains the same in both. This is also the case in an adult body where the configurations of condensed DNA (or the DNA *body’s physique*) are different in, for instance, a heart cell compared to a liver cell. You will notice that in this example I have utilised a distinct metaphor of the *figure* of the DNA *body.* Thus, by acknowledging the entire *framework* of the DNA it allows us to observe differences in the genome that are otherwise hidden by the concept metaphor of information coding.

The metaphoric conceptualisation of the DNA *body-shape* or *framework* permits me to suggest a possible role for ‘junk DNA’. Many of the sections of condensed DNA are considered ‘junk’, however, these areas of condensed DNA, especially those lacking a significant amount of genes, could very likely be involved in the differentiation of tissues and so facilitate one type of tissue becoming a heart cell rather than a skin cell. The reason I say this is because when differentiated types of cells are contradistinguished a difference between them is the *figuration* of the DNA body: where different cell types have different proportions of coiled and uncoiled DNA.[114] To further develop the idea that ‘junk DNA’ is involved in tissue differentiation I would like to return to the topic of introns.

There is another important inconsistency regarding genes and introns that I would like to expose: From the completed draft of the human genome project the number of genes that humans contain has been estimated at approximately twenty to forty thousand. Besides the fact that this is appreciably less than was expected, the really surprising detail is that “there is no clear correspondence between the complexity of a species and the number of genes in its genome” (Gibbs, 2003: 2). This is demonstrated by the fact that “fruit flies have fewer

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[113] The mitochondrial DNA would be obtained from the egg cell, and so would not be the same as the mitochondrial DNA in your cells.

[114] These condensed and uncondensed sections of DNA are known as heterochromatin and euchromatin, respectively.

coding genes than roundworms, and rice plants have more than humans" (J. Mattick cited, ibid). Scientists expected humans to have more genes, not because they were being anthropocentric, but due to the complexity that humans exhibit in terms of tissue specialisation. Thus, in terms of complexity and tissue differentiation this seems an incongruous result. If genes were responsible for such cellular contradistinguishing then surely humans, being highly differentiated, would have more genes? This leads me to suspect that it is in the junk DNA that explanations for differentiation may more likely be found. Although, to many scientists, "why 'most genes of higher organisms are broken up into short exons separated by huge stretches of seemingly useless DNA' is particularly puzzling" (C. Wills cited in Bergman, 2001: 4). I would submit that if these introns (between the exons) are responsible for generating cellular diversity then it would explain not only why their products could not be determined in the form of synthesised proteins, but also, why the amount of introns that an organism contains seems to correspond to the level of complexity that the organism exhibits: scientists have noted that "an important finding which may help researchers to understand the role of introns is the more primitive and simple the organism generally the fewer the introns" (Bergman, 2001: 4). This correspondence has been explained by numerous scientists in evolutionary terms.[115] I, however, would suggest that organisms such as bacteria do not have introns because they are less diversified. After all, bacteria are comprised of a single cell and so do not need to generate different types of specialized cells (such as eosinophils and basophils in the human immune system) that occur in humans. In my opinion, introns may actually be a means of 'saving' the genome from having to have excess DNA, because the strategic use of exons and introns creates differentiation without requiring complete new genes. As I already pointed out, immunoglobulins have been found to be differentiated due to introns, why not other types of cellular and developmentally distinguished processes as well? In other words, perhaps introns are not present in DNA in order to intersperse between genes but rather to differentiate between them or make them multiform. Considered from a slightly different perspective perhaps it is the genes that are interspersed between the introns.

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[115] An example of such an evolutionary hypothesis is that "putative early organisms might have lost their introns through evolutionary development" (Bergman, 2001: 4). This is a plausible explanation but it does not explain why humans developed and retained introns. Another hypothesis is that introns developed later in order to serve as areas where mutations could arise, rather than in the genes, in order to provide a means of evolving selective advantage for the organism.

Now that I have supplied a possible hypothesis for the existence of introns, namely, introns as 'genetic differentiators', I would like to continue my discussion on junk DNA. By describing how other types of junk DNA could function by *responding* to their environment. To accomplish this I will be extending my dynamic, reactive DNA body-shape metaphor.

To expand upon this conception of the DNA frame, I would like to draw your attention to another way of looking at DNA. By viewing the DNA double helix (in any newspaper, magazine or textbook) from a new perspective: you may notice that it appears to resemble a three-dimensional *oscillating curve*, or *wave*. By looking at the whole structure in this way, and not solely fixating on the bases as a code, one can begin to see how the bases help maintain the structure of the DNA molecule, and also how they affect the comprehensive framework of the molecule. For instance, certain sequences of nucleotides have been found to cause the DNA helix to bend. Sometimes this bending is necessary in order to facilitate DNA-protein binding (Alberts *et al.*, 1994: 406).[116] Moreover, the proteins that bind to these nucleotide configurations are generally involved in regulating genes, in other words, determining which genes are activated and which are no longer expressed. It has also been found that "specific nucleotide sequences can be detected as a pattern of structural features on the surface of the DNA double helix" (ibid: 407). It is even known that "a gene regulatory protein recognises a specific DNA sequence" specifically due to the fact that the protein's surface is "complementary" to the "special surface features of the double helix in that region" (ibid). And the DNA structure on the surface of the double helix is so specific as a result of the arrangement of nucleotides.[117] This evidence, leads me to propose that certain portions of junk DNA may serve, not for coding, but for maintaining the structural framework of DNA in order to enable the correct *compositional modelling* or (figurative) *figuration* of the surface of the double helix. By doing so, it allows for DNA flexure in order to help create the specific composition of structural forms and chemistry that the proteins can 'recognise' and bind to. It is also possible that the transposable elements might translocate into areas of the genome a number of nucleotides away from the site of protein binding. This in order to compensate for, or eliminate, DNA torsion and create the requisite

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[116] In footnote 78 I explained that methyl groups are added to DNA, such methylation has been shown to have no effect on the base pairing sequences, but rather on the external surface of the DNA molecule and the methyl group has been found to facilitate protein binding to the DNA in certain cases.

[117] DNA-protein bindings between proteins and DNA surfaces are so specific that they "are among the tightest and most specific molecular interactions known in biology" (Alberts, *et al.,* 1994: 408).

helical twisting further down the helix where the protein will bind. Such transposable elements and other regions of junk DNA might also be involved in the compaction/condensing and expansion that occurs with DNA.[118]

I would now like to extend the metaphor of the DNA *body-shape* into DNA having the shape of a *wave*. By conceptualising DNA as a wave, certain elements usually associated with a wave can be applied to DNA. And when the wave metaphor is linked with the idea of DNA as being responsive to its environment, an explanation for a genetic phenomenon which is barely understood can be derived. How so? To answer this I first need to explain that the genetic phenomenon is DNA's ability to conduct electricity: "Biochemists have shown beyond a shadow of a doubt that purified DNA molecules can conduct charge" not only *in vitro* but "in living cells the DNA duplex seems to soak up charge and transport it over long distances" (Ball, 2003: 38). This has lead to "many researchers … starting to think that the phenomenon must have a biological function" (ibid). In fact Jackie Barton, a DNA chemist working in Pasadena at the *California Institute of Technology*, is quoted as saying "I can't imagine that nature has not exploited DNA charge transport in some context" (ibid).[119] I feel that my hypothesis (to follow) offers an explanation for DNA's ability of "conducting charge like an electric cable" (ibid).[120]

I pointed out that DNA could be conceptualised as an oscillating curve or a wave. An electric wave is usually viewed as carrying a signal. It is my hypothesis that DNA due to its structure (that is to say, the three dimensional wave) has the capacity to, and probably does, transmit signals in an electro-chemical format. The troughs and peaks of the waves would be determined by the DNA structure. Thus, if DNA was more condensed or uncoiled, or it had differing angles and varying helical turns, this would affect the electro-chemical signal

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[118] This idea of the importance of structural *shape* may also be significant with regards to introns. Utilising my hypothesis, another possible function for introns (besides 'genetic differentiators') would be to assist in creating functional three dimensional shapes of the *RNA* molecule, and that would explain why"introns are all painfully transcribed into RNA only to be snipped out … and thrown away almost immediately" (C. Wills cited in Bergman, 2001: 4).

[119] The article (Ball, 2003) offers a possible explanation for DNA's ability to transport charge, namely, controlling and trying to prevent DNA damage and repair. However, their discussion about these aspects is filled with contradictions, and no decisive result is drawn. I will not argue the in-depth science here, but just point out that their discussion is more focused on the effect of DNA's ability to conduct electricity within the confines of the concept metaphor of information coding. Hence, they focus on the effects of electricity with regard to the DNA bases and their information code. (For more information I recommend this interesting *New Scientist* article).

[120] Furthermore, it is a generally accepted fact that most organisms, including humans, have weak electrical and magnetic currents running throughout their bodies.

being conducted or generated.[121] On a molecular level the dips and peaks along the microscopically structured DNA backbone would constitute and influence the electro-chemical impulse that is being produced.[122] Thus, the varying angles and coils of the DNA could correlate to changes in amplitude, frequency and phase of the electro-chemical impulse or waves.[123]

I will offer a brief overview of how this electro-chemical signalling could function, and then follow it up with specific examples. A DNA binding protein that initiates gene expression could bind to the specific section of DNA, which it 'recognises' through electrostatic chemical bonding. This protein could in a sense act as an *aerial* for *transmitting* the signal that the DNA is conducting. Thus, after binding to the DNA, the protein could convey the electro-chemical impulse either from the DNA to the rest of the cell, via cellular pathways, or from the cell to the DNA, where the signal would be conducted along the DNA.[124] My metaphor could even be broadened to conceptualise the signal, obtained from the DNA, as a *ripple* effect emanating from the DNA *wave* as a type of gradient that results in the necessary cellular reactions taking place. Since the rest of the cell and proteins are known to react to each other through electro-chemical signalling, why not DNA?

To demonstrate how electro-chemical signalling could form a means of coordinating cellular activities, I will use the process of 'transcription' as an example. For instance, if a certain gene in question (that is needed to be transcribed) is condensed and thus not yet able to be expressed, a binding protein could relay the signal to other areas of the cell (this is how cell signalling is theorised to work). Hence, this would cause other proteins to bind to other sequences of DNA in order to cause the DNA to uncoil and allow the gene to be expressed. By the way, these other proteins that seem to be attracted to, and bind to the initial binding protein are known to exist. An example of one of these 'secondary' binding proteins is the 'SWI/SNF complex' that is described as "remodelling" certain sections of

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[121] The electrical activity could possibly be generated through the chemical interactions that occur when a protein binds to DNA in order to activate certain genes.

[122] Even DNA coiled around certain specific proteins (called histones) still maintains its helical/sinusoidal wave structure, but at different wavelengths and frequencies etcetera.

[123] In this context, the electro-chemical wave is oscillating, and most likely sinusoidal and discontinuous in nature.

[124] The electro-chemical impulse may either be specifically localized in one area or it may be *conducted* along the DNA molecule until an appropriate area is reached. An example of an 'appropriate area' could be anything from a DNA-binding protein to histones.

DNA, in other words, unwinding the DNA (Klug and Cummings, 2000: 441). Such "complexes are targeted to specific gene regions by" the initial DNA binding protein (ibid). In doing so, the required segment of DNA uncoils and the necessary gene is switched on.[125] According to my hypothesis, this would induce the frame of the overall structure of the DNA molecule and thus the electro-chemical signal to concomitantly alter. Therefore, the electro-chemical signal could be continuously adapted and relayed, so as to ensure successive and correct protein binding interactions and, consequently, modulation of gene expression.[126]

To further illustrate electro-chemical functioning I will provide an additional example of DNA-protein interaction.[127] This time I will use another group of proteins which are also known to bind specifically to DNA in order to activate certain genes. One such protein in this category is the so-called 'zinc-finger', named as such due to its profile which resembles a finger. Zinc fingers "are involved in many aspects of gene regulation" (Klug and Cummings, 2000: 439). Zinc fingers, as their name suggests, have a zinc ion incorporated into their structure. My possible explanation as to the requirement of the zinc atom in the protein would be that this metal, which can conduct electricity, would help to conduct an electro-chemical signal from the DNA, through the protein to the rest of the cell. Or approached another way, the zinc ion may help the protein to conduct the signal *from* the cellular pathway *to* the DNA in order to adjust gene expression. This then serves as a possible explanation for just how the environment and gene activity could interrelate. In this view, the cellular pathway (activated by the environment) could result in the protein (for example, the zinc finger) binding to the DNA, and *transmitting* the cellular electro-chemical impulse through the zinc ion *to* the DNA. Thus, the stimulus would then be conducted along the DNA electro-chemically until it reached either the gene that needed to be expressed or the regulatory regions for the gene that needed to be switched on.[128] In this model, the relation of the environment, the cell and the DNA directly opposes the central

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[125] Various genes are known to be active when in the expanded DNA form and when in the condensed state these genes are inactive and unexpressed.

[126] Genes are not only fully expressed or unexpressed, there are gradations of expression where genes can be 'up-regulated' or 'down-regulated'. This hypothesis helps explain how genes can be modulated in this manner, through the electro-chemical signals.

[127] Since "chromosomes contain even more protein than DNA," the role of protein and DNA interactions should not be underestimated (G. Stent cited in Watson, 1981: xiv).

[128] Circumstantial evidence to support my view comes from the fact that when the zinc finger protein in the fruit fly (called *Krüppel*) is altered so that it does not have a zinc ion (but is otherwise normal), the protein completely loses its function and the gene it usually activates is not expressed.

dogma, because in this instance, the protein is entering 'information' *into* the DNA. However, in this context the information is not in the form of a genetic code but rather information in terms of which genes and other sections of DNA are to activated and respond to the environment.

Before summating, I would just like to point to one other fact which I mentioned earlier that can serve as circumstantial evidence to support my 'DNA wave' hypothesis. That is, when cloning, the process of electroshocking is required in order for the process of creating an embryo to begin. Why would electricity have to be added to the cell? After all, the proteins and materials for energy for the cell are already present in the donor egg cell. According to the established theory "electroshock induces the fusion of" the nucleus and oocyte (Kerschen, 1998: 1). While the "rebooting of the human genetic program[129] is believed to be initiated by the replacement of donor cell protein signals by egg cell protein signals" (ibid). However, "the electroshock might assist in moving those protein signals across the nuclear membrane as well" (ibid). What this points to is that while the information coding concept metaphor (largely predicated on the central dogma) denies the effects of electricity on the DNA, the electricity can influence protein signals. But surely if electricity can mobilise protein signals across the nuclear membrane it can mobilise them to affect the "egg cell protein signals" which, in turn, can signal effects on the DNA?[130]

In summation, throughout this investigation I have striven to demonstrate the importance of not taking metaphors for granted in science. I have done so by examining the concept metaphor of information coding, especially as it infiltrates into immunology. This merging of the concept metaphors of information coding and militarization is currently impacting the conceptualisation and application of biotechnology. This conclusion serves as a vivid exemplar of what I have been discussing all the way through my analysis, which is: how metaphors that are taken for granted in science can conceal or tacitly disregard certain anomalies that have arisen from empirical studies. In this case I have used genetics as the scientific field with which to illustrate how these disparities are usually ignored by the concept metaphor of information coding. Furthermore, through the application of new,

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[129] Note the use of the computer program metaphor in this description.

[130] If such a conjecture were proven to be practicable then it could have implications for cloning. One such implication would be to explain why so many deformities result from cloning: certain deformities may stem from the incorrect application of electricity (in terms of voltage etcetera) when it is applied to the cell and affects cellular signaling.

unorthodox metaphors I have endeavoured to show how these incongruities may be significant. I have utilised these new metaphors in order to conceptualise elements of genetics differently and thereby obtain plausible explanations for these anomalies.[131] These explanations can be easily verified or refuted through empirical research, but at least they allow empirical research to be undertaken in areas not otherwise analysed. This exemplifies how the use of novel metaphors permits new, constructive conceptualisations to form. These new metaphors can also enhance the previous ones as well as assisting in the creation of new avenues for further scientific research. If such metaphors prove to be useful and filter through to the popular media, they enable us to consider ourselves, our genetics and our physical capabilities differently. Thus, instead of viewing our genes as 'producing' us they become an interactive component of our bodies and rather than being held captive by our genes we can merely be captivated by them.

By conceptualising DNA metaphorically as an interactive body, framed as a wave, that can participate in cellular signalling and react to its environment, new representations and characteristics become exposed. Such a complex ecology of interactions moves away from the type of atomized science that prevailed with the information code. It also de-emphasises the two dimensional activities of reading and writing, and reveals the three dimensional wave of the DNA structural shape. Most importantly, these metaphors open research into other areas of genetics which may not have been considered before. If nothing else, I hope this 'DNA wave' hypothesis of mine, together with my speculations on introns as 'genetic differentiators' at least opens one's mind to the exciting possibility that there is still room for viewing many aspects of genetics differently.

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[131] Another anomaly which my hypothesis may aid in explaining is the "position effect."[131] Due to restrictions on the length of this report this research report I have not entered into a full discussion on this topic. Hence, I will give a brief overview. The "position effect" describes the condition in genetics whereby a gene, if moved into a new position in the genome, produces a different genetic result. Geneticists studying the fruit fly (*Drosophila*) have determined (as early as the 1920's) that "not only" does "a change in the position of a gene affect its functioning, but also such a change might affect the functioning of other genes as well" (Hull, 1974: 18). To explain the phenotypic effects, I will use the fruit fly as an example: a certain gene in fruit flies produces a red eye colour. When the gene is moved to another section of the genome, the typical result is that the eye's phenotypically express as a variegation of red and white patches (Klug and Cummings, 2000: 98). According to Watson and Crick's theory/metaphor, the code is technically the same for the gene, so the result should be the same, but it is not. Depending on how you define the gene it can be viewed as the same gene (with the same code) or different, because its position has moved and it produces a different result. My hypothesis could help to explain this, since the electro-chemical signaling conveyed along the larger structure of the DNA would be changed if part of the impulse being conveyed (the section of DNA) were moved to another region of the genome.

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6.1.3. EDUCATIONAL BOOKLETS

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***PPASA (Planned Parenthood Association of South Africa)* endorsed book:**
BALKWILL, F. and ROLPH, M. 2002. *Staying Alive. Fighting HIV/AIDS.* New York: Cold Spring Harbor Laboratory Press.

***Ten Years of Soul City,* Institute for Health Development Communication. Pamphlet.**
Soul City HIV and AIDS Pack Comprising:
“HIV and AIDS User Guide”; “Workbook 1 – Living with HIV”; “Workbook 2 – Women, Children, and HIV and AIDS”; “Workbook 3 - Caring for a Person with AIDS”; “Comic 1 – George’s Story”; “Comic 2 – Simanga’s Choice”; “Living Positively with HIV and AIDS”; “AIDS in our Community; HIV and AIDS Action Now!”