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ON THE LOGIC, METHOD AND SCIENTIFIC DIVERSITY OF TECHNICAL SYSTEMS: AN INQUIRY INTO THE DIAGNOSTIC MEASUREMENT OF HUMAN SKIN

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ON THE LOGIC, METHOD AND SCIENTIFIC DIVERSITY OF TECHNICAL SYSTEMS:

AN INQUIRY INTO THE DIAGNOSTIC MEASUREMENT OF HUMAN SKIN

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Abstract

This dissertation explores some of the scientific, technical and cultural history of human skin measurement and diagnostics. Through a significant collection of primary texts and case studies, I track the changing technologies and methods used to measure skin, as well as the scientific and sociotechnical applications. I then map these histories onto some of the diverse understandings of the human body, physics, biology, natural philosophy and language that underpinned the scientific enterprise of skin measurement. The main argument of my thesis demonstrates how these diverse histories of science historically and theoretically inform the succeeding methods and applications for skin measurement from early Greek medicine, to beginnings of Anthropology as scientific discipline, to the emergence of scientific racism, to the age of digital imaging analysis, remote sensing, algorithms, massive databases and biometric technologies; further, these new digital applications go beyond just health diagnostics and are creating new technical categorizations of human skin divorced from the established ethical mechanisms of modern science. Based on this research, I inquire how communication practices within the scientific enterprise address the ethical and historical implications for a growing set of digital biometric applications with industrial, military, sociopolitical and public function

Introduction:

An Approach to Critical Thinking and Technical Inquiry

"And what does 'pointing to the shape', 'pointing to the colour' consist in? Point to a piece of paper. And now point to its shape; now to its colour; now to its number (that sounds strange). How did you do it? You will say that you 'meant' a different thing each time you pointed. And if I ask how that is done, you will say you concentrated your attention on the colour, the shape, etc. But I ask again: how is that done?"

Ludwig Wittgenstein – "Philosophical Investigations #33"

What constitutes a idea? In many cases, this may be an impossible question to fully address, yet it remains a vital question to ask when researching history and philosophy, science and technology, communication and society, methodology and logic, ethics and culture, research collectives and individual observers. Thus, as I examine the topic of human skin measurement in this dissertation, it is also important to keep in mind that I am inquiring to understand how scientific ideas are formed and communicated. For this reason, I go into considerable depth to describe my own specific methodology for examining technological and scientific ideas with the goal of connecting different eras of skin measurement through a set of identifying technical features.

Scientific ideas usually begin with an observation. Before you can communicate an idea sprouting from observation, you must have a symbolic culture, a social infrastructure, a technological medium, communication tools, and not least, a reason to communicate your idea. How are all these things even traceable? One possibility is to view the communication of an idea as a social action, and the mechanisms of social actions (or interactions) are a great place to begin inquiring about ideas. However, social actions are certainly not the end of what constitutes ideas.

There is in fact a diverse range of individual skills and abilities involved in shaping and communicating our ideas. Our ideas are impacted by how we interact with the environment around us. There is an art to the communication of ideas, and a natural history of thinking that leads to ideas. Ideas are often attributed to and articulated by *the individual thinking mind*, but can individuals (or 'other minds') ever be studied separately from their social situations and activities? Can social situations and activities ever be studied separately from their natural history? The *individual*, the *social* and the *natural* are bound up together after all, and the interrelatedness of these categories have profound implications for the formation of ideas and human understanding. The Western traditions of philosophy and science have, at times, divided up the way we think about ideas by discriminating between the idea itself (episteme) and the way an idea is communicated (techne); and the commitment in Academia to this tradition has ushered in an of era reflexive thinking for science and philosophy (More on this in Chapter 1). Our modes of communication reflect the great care and respect that our academic traditions have for ideas. We promote some ideas, and reject others. We are constantly thinking about our own thinking, and searching for ways to refine and test our ideas. We care about the 'ends' of our ideas. We make distinctions between our own private ideas and the ideas of others. How do we do this? And, we have formed our mechanisms of communication around these distinctions.

Conversely, the parsing of ideas has received deserved skepticism and refinement by scholars across disciplines. Some have asked – Can we ever be certain about our ideas? Can the certainty we have in our ideas lead to misfortunate ends? As we seek to refine our thinking, is that ancient adage, *know thyself*, the key to unlocking what forms our ideas? Or, is the universality of our ideas the ultimate test for them? Are ideas rationally or empirically constituted? Our academic traditions, at different times and in different ways, have told us both approaches are correct. But can we even understand empiricism without our rational minds? Could we ever begin to understand our rational minds without empiricism?

The pragmatic approach to scientific, technological and social ideas suggests that we should take both rationalism and empiricism seriously, with inquiry into not only the origin of ideas, but also how ideas are communicated, and thus change over time. Again, how is this done? If the answers were easy or solved, we could dispense with the philosophy of critical thinking all together. Consequently, the diversity of human thinking, with questions towards the epistemology and the social transmission of ideas, come to foreground in this dissertation. For many reasons, my inquiry begins with ideas formed within Western science and philosophy, but not all the ideas in this dissertation are bound to these traditions.

The Topic: The Diagnostic Measurement of Human Skin

The ideas I am engaged with in this dissertation all relate to the diagnostic measurement of human skin, and in particular, I investigate the historical and epistemological roots of the methods and technologies used in these diagnostic practices. Although today we associate skin diagnostics with medical practices and human health, I will note that this history has a long and sometimes murky history in the annals Western science, and I have identified four general eras of this history that describe a changing mixture of methodologies, purposes and applications. The ideas under examination are, in part, to explain the epistemological changes in these eras, which include 1) linguistic matching, 2) visual matching, 3) spectrometry (or light-based measurement) and 4) digital imaging analysis; additionally, I focus on medical, scientific and philosophical texts that span over two thousand years of the Western tradition of science and philosophy as a way to link today's skin diagnostic applications to the past.

One unifying idea behind these historical investigations is that observations of human skin can tell us something about an individual person or a groups of people, through their underlying pigmentation or changing complexion, and this premise has always underpinned the questions that individual observers have asked. Conversely, skin is also one of the most complex organs of the human body and its aesthetic features are determined by complex genetic and environmental variations, making it extremely difficult to measure and categorize. The progress of these methodologies and applications has been slow and not always straightforward. Additionally, the history of skin measurement provides many case studies of scientific and social biases that have plagued its interpretation and legacy, including the era of scientific racism and eugenics movements. Thus, I approach the history of skin measurement in science with inquiry into three different sets of possibilities and constraints under which the sciences have worked to investigate human skin and informed the logic of scientific change – the biophysical, the technological and the social.

What I seek to address with this investigation is to not only track the methodological changes in the diagnostic measurement of human skin, but to inquire towards the diverse ideas that have influenced this sociotechnical activity. Indeed, some of the puzzles of skin diagnostics and changes in the scientific practices that place an emphasis on skin measurement have relied on a wide body of scientific knowledge and practices. This investigation is intended to open an inquiry into these diverse influences, and examine the implications of collected knowledge and the tools at our disposal for the examination of ideas past and present.

The Scope and Relevance of the Study

The informed reader of this dissertation may have difficulty in orienting the content within a single academic discipline. This is, in part, due to scope of the project, which spans major changes in medicine, science, technology and philosophy; thus, approaching a topic with such a long (and connected) history of changing knowledge requires questions about the epistemology that informed the working knowledge of the individual observer. Since much of the long history of skin diagnostics relied principally upon visual observation, I have sought explanations for the historical logic of visual observation in the history of vision science and visual theory, which I found explains some of the major methodological shifts in the practices of observation. Because the primary data I have collected is a set of historical texts, this research has also required a focus on the rhetoric and communication of science and technology. In particular, I focus on how the nomenclature and categories used in these historical observations of human skin correlate to the methodologies, technologies and applications being engaged by the principle observers in these case studies. Many of the questions I ask of this research comes from a specific discourse in the philosophy of technology, which is meant to probe the definitions and role of technologies used in scientific practices that also require human values. Further, I explore the implications and legacy that the scientific and technological communication of skin diagnostics has left behind, which very much makes this project relevant to the discourse on science, technology and society. Lastly, and importantly, some of the connections I make in this history of skin diagnostics have future implications to the field of digital media studies; in particular, I explore how the turn to digital media and computational technology applications in the practice of skin diagnostics brings old problems found in the history of science, such as stereotyping, racism and dehumanization, to the foreground. In summary, this collection of case studies on the diagnostic measurement of human skin makes both broad and specific connections between ideas in the history and philosophy of science and technology. Additionally, I argue that the methodology I have developed for this study serves as a strong example of how to connect different disciplinary perspectives in these domains; in particular, my method serves as a model for how rhetoric, communication, digital media and visual studies can be studied in the larger context of science and technology studies (STS), which ultimately examines how the practices of science and technology impact society.

The Chapter Overviews

The centerpiece of this dissertation is the collection of primary texts found in the **Appendix**, and it might be helpful to read through this primary data before, or in conjunction with, reading the first chapter. In **Chapter One**, I introduce a few of the major historical shifts in History of Skin Diagnostic Technology, and I lay out the framework and methodology that you will see reflected in the primary data. My goal in this chapter is to develop and explain a methodology for examining the history, epistemology, logic and technologies used in the measurement of skin. This chapter also introduces some of the major themes in the philosophy of science and technology that help contextualize the historical and epistemological connections that I make in the research.

Chapter Two focuses on the language and terminology I found in my research used to categorize humankind and skin color. Much of my research on the history of skin diagnostics demonstrates the changing syntax and semantics of scientific categorization, and I theorize about influences that have informed these changes. The goal for this chapter is to show how the diverse language and scientific categorizations are influenced by a matrix of biophysical constraints, cultural and social mechanisms, as well as technological and scientific knowledge. I argue that to understand the history of skin measurement, in part relies on how we came to understand both the biological and cultural inheritance that informs our linguistic categories used in the sociotechnical applications of skin diagnostics.

In **Chapter Three**, I examine the first chromatic skin color scale developed in the field of Anthropology, which allowed observers to quantify their visual observations of skin. I then place this measurement technology and method in the the historical conversation on scientific racism. In this chapter, I address some of the important changes in the purposes and applications of skin measurement, and how individual scientific observers and entire scientific disciplines have had a deep impact on how society views human beings and human biology. I argue for how technological and scientific methods factor into the logic and rationalizations for skin measurement studies and in many ways have historically set the postulates for both scientific and public conversations about human skin, and skin color.

Chapter Four discusses some of the major problems posed by methods of visual observation. I explain these problems through the classic theory of

Descartes known as mind/body dualism, and I demonstrate how this theory shaped the scientific understandings of human skin through visual observation, and then theorize how the rationalization and logic changed through advancements in science and technology. The bulk of this chapter is dedicated to explaining the changes in the logic and reasoning of visual science that led to the creation of the CIE color space in 1931. Here, I tell the story of how this mathematical model to convert analog measurements of light into a digital format had a profound impact to the measurement of human skin and still serves as the model of the future technologies that diagnose, measure and visualize skin in a wide variety of applications. Yet, in spite of these changes, there is evidence for the lingering problems left over from the era of visual observation that still impacts the practices of diagnostic measurement.

Chapter Five serves as the conclusion for this dissertation. In this section I summarize the historical shifts in methodologies, technologies and applications of skin measurement, and then make some predictions about the future of Digital Imaging Analysis and the biometric measurement of human skin. This chapter is intended to synthesize some of the major ideas identified throughout the chapters as way to suggest directions to build upon this research with further inquiry.

Chapter 1:

Histories of Skin Diagnostic Technology: Logic and Methodology from a Pragmatic Point of View

"Concepts, like individuals, have their histories, and are just as incapable of withstanding the ravages of time as are individuals"

Soren Kierkegaard – "The Concept of Irony"

"I have engaged in what seems to be a historical excursus not for the sake of giving historical information but in order to indicate the origin of the distinction between empirical knowledge and practice, on the one hand, and rational knowledge and pure activity on the other; between knowledge and practice, that are admittedly of social origin and intent on insight and activity, were supposed to have NO social and practical bearings. This origin is itself social-cultural. Such is the irony of the situation."

John Dewey – "Common Sense and Scientific Inquiry"

1.1 Prelude: From 'What 'Problem' Am I Studying?' To Identifying Scientific Diversity

The centerpiece of this dissertation is a collection of primary scientific texts that all in some way address the diagnostic measurement human skin, and by proxy, the appearance of human skin color (See the Appendix). At the outset of this inquiry, I seek to align the conceptual and technological changes that eventually informed digital biomedical imaging of the human body. The historical trope of 'skin as an object of scientific measurement' emerged as the primary focus in the process of this research, thus the methodology and the connective threads that I am presenting in this study are the result of generative questions that came emerged in the middle of intense research. To begin, I will provide some context for the project by briefly describing a few of the entry points of how I came to this topic, and direction it has taken me.

As a scholar and teacher of visual studies, scientific and technical communication, digital media and rhetoric, I have a keen interest in the science of human color vision and the history of technologies that has developed through science to visualize the human body. The philosophical and scientific discourse on visual perception, visual theory, and color theory in particular, opened up pathways to explore the shift from analog to digital imaging technology as a new tool used in biomedicine. My initial hypothesis coming into the project was that changes in the scientific understanding of visual perception had an overt effect on the applied visual technologies used to create biomedical imagery, especially human skin, which in turn effects our perception and knowledge of the human body. I chose to look at case studies of diagnostic technologies that used digital computation of images with the potential for the digital display of biometric information. Conversely, I quickly found this approach was shortsighted, and perhaps overly deterministic. Of course conceptual change can influence technical change, both directly and indirectly, but more often than not in the case of biometrics, new technologies built for different purposes were used to take biometric measurements of humans and then refined as conceptual shifts from the data became shaped through specialized application. Describing the logic of scientific change, I discovered, requires inquiry into what the Philosopher Stephen Toulmin calls "the variety of rational enterprises," and it is central to my method of historical research where I consider in the study of conceptual changes within science[1] As Toulmin points out, a common mistake in describing scientific change is "to confuse the rationality of scientific theorizing itself with the logicality of the inferences within scientific theories."[2] I interpret this to mean that logic and methods of scientific experimentation carried out by science professionals can be distinguished from the accumulation and critical interpretation of logic and methods developed by a scientific disciplines; and by doing so, we can better recognize the historical and cultural diversity of our interdisciplinary scientific

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[1] Stephen Toulmin *Human Understanding: The Collective Use and Evolution of Concepts* Princeton, NJ: Princeton University Press. 1972. Print.

[2] Ibid. 1. (Toulmin, 478)

concepts. Consequently, with an eye towards the changing epistemological practices of scientific disciplines, and the logic and methodology of its practitioners, I engage the topic of skin measurement as a socially and historically complex, influenced by dynamic changes from many different areas of the human and natural sciences.

Importantly, this delineating principle of variety and complexity (what I refer to as *the diversity principle*), between individual, professional and disciplinary logic, is not a radically new concept. We can see one formation of it reflected in the standard peer-reviewed journal article, where the science professional begins by explaining the internal logic and methods of the study, and usually ends with a discussion of how the results of a study fit into the larger framework of disciplines.[3] In the more in-depth journals, the peer-review process makes the logic of disciplinary discussion more transparent and public by publishing a collective of disciplinary responses to the logic, methods and conclusions of the professional scientists. Professional scientific publications and their disciplinary peer review processes, then, are just two pathways to understanding how conceptual changes take place under the logic of diverse sets of professional and disciplinary practices. However,

[3] The ideas of widely publishing articles and emerging roots of the peer-review process can be partly traced back to the 17th century (1665) and the emergence of the journal *Philosophical Transactions* published by The Royal Society of London.

because of the diversity principle, understanding science as a rational enterprise demands that the logic of the science be investigated under different disciplinarily constraints and professional commitments. As Toulmin explains, the rational enterprise of scientific inquiry is less about the internal logic of a procedure or method; instead, what must be demonstrated is "how the formal structures and relations of propositional logic are put to work in the service of rational enterprises at all."[4] What the diversity principle means for my own historical investigation into scientific change is that it gives me a means by which to distinguish between the conceptual (and logical) choices made by *science professionals* in pursuit of their problem-solving, while acknowledging the mechanisms of various *scientific disciplines* that collectively and systematically assess and apply scientific theories for different means and ends.

A second implication for the diversity principle in my study on biometric measurement is that it gives me a way to re-assess my own disciplinary commitments to the collective discourse on visual perception, visual theory, and color theory. My original inquiry question, in retrospect, was a product of these disciplinary commitments. By asking a specific research question of 'how did conceptual changes in visual theory influence the design and application of biometrics technology?', I was committing the

[4] Ibid. 1 (Toulmin, 479).

very error Toulmin warns about by conflating the rational enterprise scientific disciplines with the internal logic professional practices.

In putting together my collection of primary artifacts, I was able to account for this error by expanding my focus on conceptual and technological changes in the practice of biometrics by asking: *How do different professional and disciplinary viewpoints collectively add to the 'rational enterprise' of understanding the formation and the changes of biometric science?* Consequently, this question and approach to historical inquiry required me to re-examine my definition of scientific theorizing and to consider a more complex account of epistemological changes.

Further, I began to ask different sorts of questions as I collected and interpreted the primary texts presented in this dissertation. While the application of different concepts and technologies followed some similar logical patterns in the history of human skin measurement, the problems that skin color measurement presented to both the science professional and to the disciplinary mechanisms that structure the sciences, revealed a wider set of classifications in which to build a basis of historical comparison. Each artifact in the Appendix, then, is coded with nine categorical headings which forms *a* basis of comparison intended to track the historical changes in the practices of skin measurement:

- Type of Artifact

- Date
- Measurement Method
- Measurement Technology
- Results of Data or Illustration
- Sociotechnical Application
- Terminology for Skin
- Author's Nomenclature or Viewpoint of Human Categorizations
- Disciplinary Commitments

Much of this dissertation is dedicated to explaining the interconnection of these categories, but I introduce them here to define the overall objectives for the project:

1) To develop a historical perspective of skin measurement as a scientific undertaking.
2) To introduce a comparative method for historical inquiry into skin measurement.
3) To acknowledge and learn the disciplinary perspectives and junctures that inform an epistemology of biometrics.

While my original problem and questions focused exclusively on the technical and conceptual changes of diagnostic technology, I shifted towards understanding the historical complexities underlying the science of measurement and refocused on a wider set of epistemological change. In other words, my questions seek to explain what undergirds the sociotechnical systems of skin measurement practices. Correspondingly, this dissertation can be described as historical and philosophical inquiry into the logic and methods ("the variety of rational enterprises") that underpins skin measurement as a scientific practice.

1.2 Historical Methods of Skin Measurement and The Diversity Principle.

In order to establish a basic historical understanding of skin measurement I think it is important to begin by identifying changes in both the measurement methods and measurement technologies over time. There are many variations found in the methods developed by science practitioners that measured skin, for many purposes, but I have divided the most widely applied methods covered in my research into four general categories, or eras, of measurement – *linguistic matching, visual matching, spectrophotometry* and *digital imaging analysis*. In the later chapters, I explain these changes in methods in more detail, but here I want to give a general description of these categories and explain how a nuanced definition of technology can help bridge the diverse disciplinary and historical understandings of measurement methodologies.

To begin, *linguistic matching* is a term used to describe the method of observation when an observer visually inspects the skin color of a human subject and compares that observation to a set of linguistic color categories set by the language of the observer. To use a common (and problematic) scenario, let's say a hypothetical observer holds a pre-determined set of color categories for human skin; for this example, let's say those categories are white, black, red, yellow and brown. To describe the skin color of a human subject, our observer matches the analog color of skin to their set of pre-determined categories. But what if the analog color doesn't clearly fit into a linguistic category? Our observer then must decide what linguistic category, or combination of categories, best matches the analog skin color. If the observer doesn't find a matching description satisfactory, there is always the option to alter the linguistic categories in order to accommodate a better description.

As the primary texts collected for my research indicate, this central principle of linguistic matching was the only method used to distinguish different skin colors, or skin types, for two thousand years in Western discourse. Readers of this dissertation will see this method listed in the earliest artifact in the study (Aristotle's "Generation of Animals" cir. 336 B.C.E.) to one of the more recent studies (Hoschild and Weaver's "The Skin Color Paradox and the American Racial Order" 2007).

In the late 1800s, a different kind of method called *visual matching* emerged as a technique to measure skin color. The method of visual matching still requires our observer to interpret the analog skin color of a human subject, but instead of matching the color(s) of skin to a set of linguistic categories, the datum is visually matched to a numeric scale that represents a spectrum of known skin colors. The method is less-arbitrary than matching linguistic categories because skin color scales are built to standards that can be agreed upon by multiple observers, and are based on fixed units of a color spectrum that are measured in numerical, thus quantifiable degrees. This method lets our hypothetical observer share her observations more easily across distance and time. As long as the other interlocutor has access to same scale and units of measurement, visual observations taken at different places and times can be compared to the same scale, which allows our Observer to accumulate data and collaborate with more accuracy. My primary research shows this method developing under the discipline of physical anthropology in the late 1890s, beginning with the Von Luschan Chromatic Skin Scale. Other scales followed, including the Broca Scale, The Milton-Bradley Colour Top and the Fitzpatrick Scale – which is still widely used today in the medical practice of dermatology. Although this era of visual matching dominated the practices of skin color measurement for only a short time, the measurement methods and technologies developed in the early 20th century created many different disciplinary frameworks that employed skin measurement for a variety of purposes, some of which were adaptable to the methods and technologies used in the science of *spectrophotometry*.

Spectrophotometry (also known as reflectometry) is a part of a common set of techniques used in many disciplines of modern science to measure specific wavelengths of light that are reflected from the surface of an object. As physical anthropologist Nina Jablonski explains, the application of spectrophotometry to measure skin color is fairly straightforward, and a big improvement over the arbitrariness of previous methods of linguistic and visual matching.[5] Jablonski notes:

> The principle of reflectometry is simple. The reflectometer measures skin color by shining light through filters of different colors onto the skin and measuring the amount of light that is reflected back. Each color filter allows light at a specific wavelength of the visible spectrum to pass through. Skin color is measured by the percentages of the different wavelengths of light reflected. Light skin reflects more visible light of all wavelengths than dark skin and gives higher reflectance

[5] pp 16-19. Nina Jablonski, *Living Color: The Biological and Social Meaning of Skin Color.*
Berkley, CA: University of California Press. 2012.

values, but different skins reflect different amounts of different wavelengths.[6]

The modern standard for reflective measurements of human skin color, then, are taken with a spectrophotometer. Today, there are many devices engineered specifically to take skin reflectance measurements; however, the earliest record using spectrometry for a study on human skin color was by Charles Sheard in 1926, using the "Keuffel and Esser Color Analyzer" – a spectrophotometer first developed to take light spectrum measurements of agricultural soil.[7] Going back to our hypothetical observer, the methods of spectrophotometry allowed human skin to be measured with great precision, with reflectance data expressed in 'universal' units of nanometers (nm) that correlate to the electromagnetic wave spectrum. The observer can now choose whether or not to use linguistic categories for human skin at all. Essentially, the methods of spectrophotometry allowed observers to develop a more objective science of skin measurement, bringing it from a practice of aesthetics to a practice of physics. Consequently, skin color measured in units of light allowed the problems of subjective visual perception and environmental lighting to be avoided, and skin color measurement data could

[6] Ibid. 5, p.19.

[7] Sheard, Charles "Analysis of the Color of the Skin and Its Significance" *Science, New Series*, V. 64, No 1646 (Jul. 16, 1926), pp. 70-72. Print.

then be compared universally and described in similar language to how light interacts with all known material objects in the universe, thus making spectrophotometry compatible with a diverse number of emerging technologies and methods that are still being refined today in the fourth era of diagnostic skin measurement, *digital imaging analysis.*

It is important to my argument to note that these historical "eras" of skin measurement are not to be viewed as sequence of linear 'replacements' of the previous method. Rather, the primary research demonstrates how these four general methodologies – linguistic matching, visual matching, spectrometry and digital imaging analysis – became intertwined with each other. Both linguistic matching and visual matching are still used in science today, for a variety of purposes and to varying degrees of effect. My historical inquiry shows how both science professionals and scientific disciplines actively engaged several methods, or omitted others, in ways that exemplify some classic problems within scientific epistemology. This collection of skin measurement practices includes examples of the problem of induction, the conflation of causation and correlation, as well as the issues with verification and falsification of knowledge; additionally, the historical arc of these changing methodologies demonstrate how the systemic practices of refine scientific knowledge over time, through comparative methodologies and application of new technologies.

The milieu of changing methodologies and technologies used to measure skin also demonstrates some of the ways the diversity principle works in the history of science. Historian Lorraine Datson has described the era from c.1600-1800 as "The Empire of Observation."[8] During this time, methods of observation became "an essential aspect of both theory and practice of natural knowledge," Datson claims.[9] In this era, an emphasis was placed on not only developing new technologies to observe the natural world and refine experimental practices, but it also saw advances in the way observations were measured, recorded, stored and communicated. In other words, methods of observation changed the reasoning and language of science. As Datson mentions, scientific 'collectives' like the Royal Society of London had a big impact on science as they gathered reports, methodological practices and observational data, and then published the information to a wide audience in the journal of *Philosophical Transactions* starting in 1665.[10] This journal is the oldest surviving publication that focuses on specialized audiences concerned with scientific practices. The publication also had the effect of normalizing and standardizing much of sciences, allowing specialized disciplines to form. Additionally, as observational methods became

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[8] Lorraine Daston "Empires of Observation" *Histories of Scientific Observation* ed. Daston and Elizabeth Lunbeck. Chicago, IL University of Chicago Press. 2011. pp 81-113.

[9] Ibid. 8, p83

[10] Ibid. 8, pp84-85.

synonymous with epistemology and scientific rationalizing, the definitions for technology and methodology used in scientific practices changed as disciplinary logic became collectively informed by the logic of individual observers in an broad exchange of ideas.

In the era of linguistic matching, my primary research shows a wide degree of diversity in skin color terminology. Individual observations made by physicians, naturalists and anatomists of this era represent diverse viewpoints on human categories that had a wide variety purposes and applications for measuring skin. Following the textual history in the era of visual matching and eventually the age of spectrometry, however, we can see how skin terminology and viewpoints on human categories are decreased by the disciplinary influences of Newtonian physics, Baconian science and Darwinian evolution, respectively; while the diversity of measurement methods, technologies, variety of publications and disciplinary uses for the data increase significantly as scientific disciplines emerge. Even in the limited sample of data, one can see the effect The Royal Society and other research collectives had on the science of skin measurement. It makes sense, then, that scientific communication and collaboration had a significant impact on the diversity of science and its methodologies, and this also offers a way to understand the patterns found in these historical record. (Fig. 1.1)

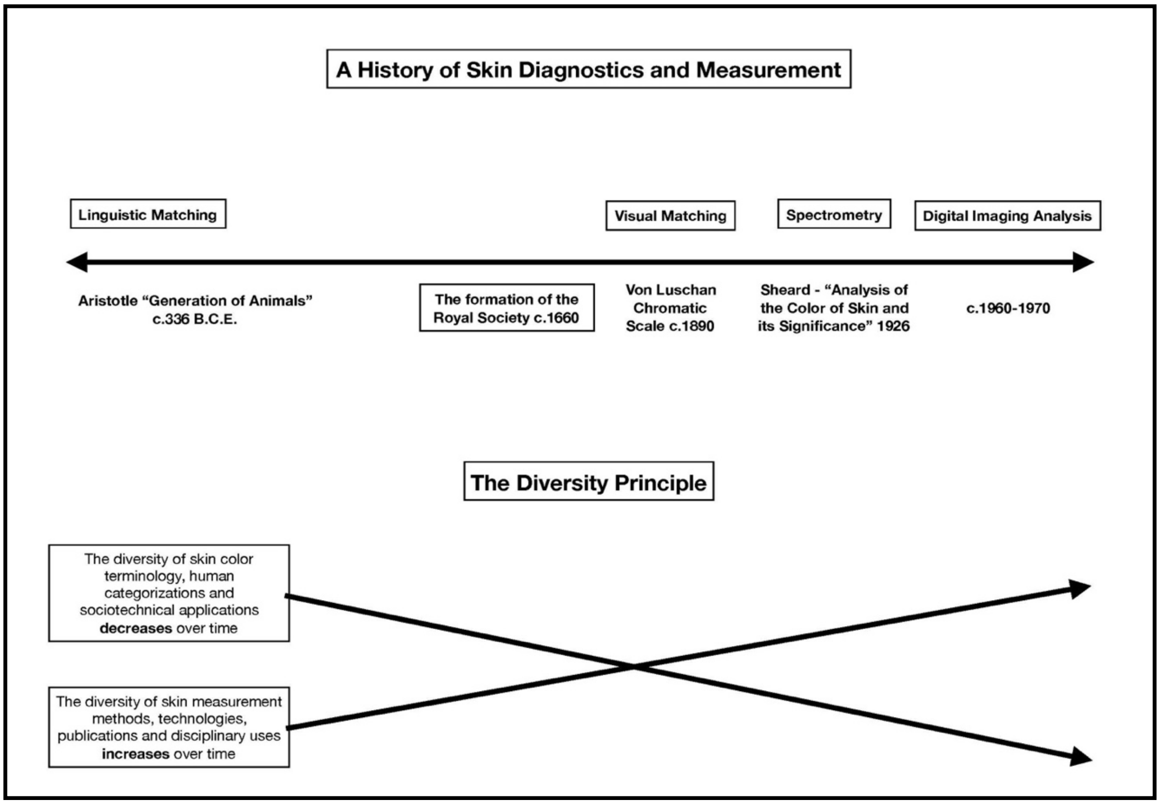

Fig 1.1. A Timeline of Skin Measurement "Eras" & The Diversity Principle

1.3 Defining Skin Measurement Technologies and Methodologies within a STS Framework

A significant challenge to address in this history of skin measurement technology is to define what I mean by word technology. As this history of skin measurement reveals, there is an obvious correlation between measurement technologies and measurement methodologies. One, in part, defines the other. But as you may infer, the technology of spectrophotometry must be defined much differently than the ‘technology’ used with methods of linguistic matching. The technology used to measure spectral wavelengths are clearly material artifacts, or hardware, with a specific purposes and operational standards. Linguistic matching, on the other hand, relies on visual observation and what I call diagnostic techniques, that rely on the skill set of the individual observer. For instance, the Greco-Roman physician Galen developed a diagnostic schema to observe human skin based on the four humours theory of the body.[11] This method resided on the Observer’s skill to determine subtle changes in a subject’s skin color between yellow, white, black and red, which also corresponded to different types of “bile” in the body. In order to establish a basis of comparison between starkly contrasted historical concepts of technology, I will first establish a classic definition of technology, before describing how a classic definition informs this project through the broad approach of Science and Technology Studies (STS).

In classical epistemology, ‘technology’ is usually associated with the Greek cognate *techne*, which perhaps can be best explained in relation to the other cognates, *episteme* and *phronesis*; and, together formed an early system to

[11] Galen, “On the Natural Faculties” *Hippocratic Writings* (1952). Trans. A.J. Brock. Chicago, IL: Encyclopedia Brittanica Inc. – Galen wrote this text in approximately 170 A. D., and it is noteworthy because it became the standard method to observe skin color in medicine for over two millenniums.

describe human knowledge. Perhaps the most concrete, or expedient, way of explaining the terms episteme, phronesis, and techne, is through Aristotle's often repeated and popular rendering of the concepts in his Nicomachean Ethics.[12] Episteme, for Aristotle, is a type of knowledge that can be described by several qualities - knowledge that proceeds by way observation, by way of accumulation, by its exactitude, and by its universal qualities which can be demonstrated by inductive and deductive inferences.[13] Episteme (scientific knowledge), in conjunction with *nous* (human understanding), is the highest on the hierarchical order of knowledges that Aristotle calls *sophia* (wisdom). Thus, episteme can also be described as a theoretical knowledge that is ultimately grasped in the mind (which for Aristotle this 'intellect' is distinct from the body).[14] Aristotle, then, is clear in distinguishing episteme from two other types of knowledge: phronesis (Intelligence) and techne (craft-knowledge). Phronesis is described as "intelligence that grasps truth, involving reasoning and concerned with action about what is good or bad for a human being."[15] Therefore, since this intelligence of the good and the bad is

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[12] Aristotle. (2009). "On Techne and Episteme" (Scharff, R. et. al., Eds.). In *Philosophy of Technology* (pp. 19-24). Malden: Blackwell Publishing.

[13] Ibid. 12

[14] I will note here that Aristotle's view of "mind/body" is a contested issue among scholars.To summarize my understanding, Aristotle's view of the mind is not as starkly distinguished from the body as Plato's immaterial "forms", yet Aristotle regarded the soul as a form of the body, but without an organ (qtd. in De Anima III,4; 429a10–b9). Hence, the debate is over the extent of Aristotle's dualism, if one could call it dualism at all.

[15] Ibid. 12 pg 20.

tied in bodily action, Aristotle describes phronesis as a "virtuous knowledge" that is "preserved by temperance" (bodily restraint, or moderation), which is found in "a state of grasping truth" rather than knowledge found by reason alone.[16] Techne, on the other hand, is a "craft-knowledge" that is concerned with production as its end, not action.[17] Philosopher Joseph Dunne summarizes Aristotle's techne as providing "a kind of knowledge possessed by an expert in one of the specialized crafts, a person who understands principles underlying production of an object or state of affairs e.g. a house, a table, a safe journey or a state of being healthy"[18] In summation, Aristotle's concepts of episteme, sophia, nous, phronesis and techne are differentiated into a taxonomy of knowledges in his Nicomachean Ethics, each with an attached description of the scope and boundary of the knowledge, and placed into a hierarchy of importance, or usefulness.

I mention these categorizations by Aristotle due his widely attributed influence in shaping the structure of the arts and sciences in the university system, thus influencing the structure and perception of knowledge in Western sciences. In regards to his influence on modern science and technology studies, the ideas of Aristotle (along with Plato) hold a special

[16] Ibid. 12 pg 21.

[17] Ibid. 12 pg 20.

[18] Dunne, Joseph. Back to the Rough Ground: Practical Judgment and the Lure of Technique. Notre Dame, IN: University of Notre Dame, 1997. Print

position in the arts & sciences that is reflected in the way these ideas have historically been taken up by scholars from almost every scholarly domain. However, as many historians and philosophers in the field of STS and Technology Studies have noted, the way Aristotle's domains of knowledge have been interpreted historically has resulted in heightened divisions between rhetoric and philosophy that have arguably been detrimental to the way we understand, practice, and make use of the knowledge in the arts and sciences today. Even though Aristotle draws clear divisions in the scope and domain of various forms of knowledge, the way scholars throughout the centuries have accommodated these divisions was largely ignored. Thus, understanding episteme, techne and phronesis as historically situated concepts with profound effects on modern science, technology, philosophy, the arts and in turn, modern society, has resulted in important scholarship that addresses the way these divisions have formed through a variety of methods.

Taken at its most general and aesthetic levels, we can see how Aristotle's categorizations of knowledge influence western science, with its emphasis on specialization, the structure of divisions between the arts and sciences, the hard sciences and soft sciences, as well as the basic distinctions we make between theoretical, practical and productive modes of knowledge. Although the scholarship on Aristotle's divisions is numerous, the majority of philosophical discourse involves continuous re-interpretations of Aristotle's nuanced thought and compares it to the more concrete notions of Plato. For instance, Joseph Dunne explains that traditional interpretations of Aristotle attribute his division between "real knowledge/fact" (episteme) and "practical knowledge/opinion (doxa) to the philosophy of Plato, who deemed the spheres of theory and practice as incommensurable.[19] So, there is very little difference in the way Aristotle and Plato structured theory over practice (episteme > phronesis); however, Dunne's thesis recognizes the significant difference between Aristotle's definition of phronesis and techne by a re-aligning techne with episteme in Aristotle's philosophy. For Dunne, there is an explicit difference in the way Plato separates theoretical knowledge from practical knowledge, and the way Aristotle separates theoretical knowledge from practical knowledge, and this difference becomes exemplified in the way techne is understood as an inseparable part of gaining theoretical knowledge.[20]

Yet another discussion that can generally described as a 'philosophical approach' to technology and the theory/practice divide in Aristotle and Plato comes from Philosopher Carl Mitcham's *Thinking Through Technology*. He interprets Plato's techne to be "all human activities that can be talked or reasoned about that are neither spontaneous or intuitive," but rather techne

[19] Ibid. 18. p 238.
[20] Ibid. 18. p 245

"possesses greater exactness and precision…that involves the greatest quantitative precision."[21] Therefore, Mitcham claims that Plato's discussion of techne points towards a modern conception of modern technology: "A rationalized production made maximally efficient through mathematical analysis."[22] In comparison to Plato's techne, Mitcham characterizes Aristotle's taxonomy also as "a specialized knowledge of the world that informs human activity", and he also suggests that Plato and Aristotle agree in their general hierarchy of knowledge, with techne subordinate to episteme.[23] Since techne is bound to logos, or practical reasoning, it is distinguished from episteme, but where Plato and Aristotle differ is in the character of logos, which for Mitcham marks a precise point of departure between Plato and Aristotle. Plato's techne (and logos) emphasize the quantitative, the precise and the mathematical, and excludes qualitative arts like rhetoric. Aristotle, by contrast, joins techne and logos, and brings rhetoric into the domain of technical knowledge, with an additional degree of uncertainty.

It stands to reason, then, that while Aristotle drew a distinction between theoretical knowledge (episteme) and productive knowledge (techne),

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[21] Mitcham, Carl. Thinking through Technology: The Path between Engineering and Philosophy. Chicago: University of Chicago, 1994. Print. pp. 118-120.

[22] Ibid. 21 p119.

[23] Ibid. 21 p120

he may have also implicitly defined techne as 'a rhetorical practice' with dynamic power, and as a vehicle to transcend theoretical knowledge across social (and disciplinary) boundaries. It is then possible to characterize techne as a rhetorical activity that bridges the theory/practice, episteme/phronesis divide; however, this notion of techne as a rhetorical practice is not a universal proposition in the same way episteme is understood to be. Instead, I argue we should question how techne and productive knowledge have been addressed by both individual observers and disciplinary collectives at specific moments in the epistemology of skin measurement, and this begins with an examination of archived materials and communications that are contextualized within a system of productive knowledge.

The above description of technology – as part of a system of knowledge – begins to define the way in which STS has been organized. Stephen Klein (1985) succinctly describes the four different meanings that science and technology scholars have used to define the word 'technology'[24]

- Usage 1: Hardware or Artifacts (objects)
- Usage 2: Sociotechnical System of Manufacture
- Usage 3: Knowledge, Technique, Know-How or Methodology

[24] Klein, Stephen "What is Technology?" *Bulletin of Science, Technology & Society.* 1 (1985) pp 215-18

- Usage 4: Sociotechnical System of Use

While there are problems with labeling any single 'usage' of the word technology under just one these labels, these different definitions are helpful in addressing the scope and plurality of meanings embedded in the word. These usages are especially helpful when considering the basic differences in the way techne/technology has been historically configured in the epistemology of science. Usage 1 and Usage 3 imply a disconnected view of technology that is distinct from theory and practice, while Usage 2 and Usage 4 allow ways in which to inquire how technology crosses the theory/practice divide through interactions in social activity systems. Acknowledgement of these meanings is key to understanding a history of any technology and within a system scientific applications.

For the purposes of this historical study, **I define *technology* as active and productive inquiry within a system of knowledge in order to address a specific task, problem or question.**[25] This broad definition has important ties to the diversity principle and to the categorical patterns that I track in the primary research because I see technology as not just a neutral artifact, but as a system of interconnected tools that must logically cohere to be effective.

[25] I do, at times, refer to technology specifically as 'hardware' which should be distinguishable in the context of a sentence.

Understood this way, our observer's language for skin and skin color, their conceptual understanding of biology and humankind, their status as a scientific professional, their disciplinary commitments, and their communicative practices, all contribute to the methodological and technological undertaking of measuring skin. Additionally, it is through the comparative method of these technological tools that I have developed this project, and it offers a way to understand the diverse practices of science professionals and the collective practices of scientific disciplines in the history of skin measurement.

1.4 Epistemological 'Dualisms' in the Science of Skin Measurement

At present, as a researcher investigating the topics of skin measurement methodologies and technologies, I find much of historical literature of these areas have already been pre-categorized into sets of epistemological binaries (or dualisms). Just from my collection of primary data alone, you may be familiar with some the following distinctions. (Fig. 1.2)

Qualitative		Quantitative
Subjective		Objective
Theory		Practice
Emic	**The Great Divide**	Etic
Relativism		Positivism
Coherentism		Foundationalism
Apparent		Real
Naturalism		Supernaturalism
Subjectivism		Realism
"The Particular"		"The Universal"
The Mind		The World
Mind		Body

Fig. 1.2 The Great Divide of Traditional Dualisms

While I recognize there is a history to each of these terms, it seems counter-intuitive to think of these terms as mutually exclusive. In fact, the terminology comes from a long tradition of dualist modes of thinking. Much has been written about these dualisms, and many disciplines in the arts and sciences have worked to reconcile them. The pragmatic philosophy I use to address my topic could be categorized as perspective that avoids some of the traditional categorizations formed and maintained by academic tradition; instead, pragmatism uses the mode of 'inquiry' to address contingent problems that arise in the experience of research and seeks to makes knowledge and practices coherent to each other. As philosopher of technology, Larry Hickman, has argued extensively, John Dewey's pragmatic philosophy is particularly equipped to address some of the false binaries embedded in the modern paradigms of epistemology. Because the central question of epistemology in the western tradition focused around individualistic skepticism (How is it I can have certain knowledge of the world?), philosophers at least since the Enlightenment attempted to treat certainty as "knowledge possessed by an individual thinking mind."[26] This meant the pinnacle of "certain knowledge" was to achieve the most accurate internal mental representations (the subjective) of the world outside of the mind (the objective) – which Dewey called the "picture theory" of knowledge. Knowledge gained through pragmatic inquiry, on the other hand, is not just "capturing a picture impression" of reality; for Dewey, inquiry is "an active and experimental involvement of the entire organism"[27]

In Hickman's summary, Dewey's massive collection of writings on philosophy and pragmatic inquiry is characterized by the knowledge generated through the instrumental use of technology, which can be formulated as "invention, development and cognitive deployment of tools and other artifacts, brought to bear on raw materials and intermediate stock parts, with a view to the resolution of perceived problems"[28] Thus, Dewey's

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[26] p27. Hickman, Larry *Philosophical Tools for a Technological Culture: Putting Pragmatism to Work.* Bloomington, IN: Indiana University Press. 2008. Print.

[27] Ibid. 26, p. 27

[28] Ibid.. 26, p 26

“instrumentalist” account of technology is a move to reconfigure enlightenment epistemology away from the certitude of an “individual thinking mind” to a mode of “active productive inquiry” through experimentation with ‘technical’ means, at a particular time, place and situation.[29] Dewey located many of these philosophical dualisms in the work of Aristotle and Plato and tracked the development through Descartes until his present day, where philosophy and science had become largely divided. As Hickman explains, many dualisms inherited from Western thought are a direct result of its “mislocation of technology” within a schemes of knowledge.[30]

By focusing on specific cases studies of skin measurement technology in this project, I hope to demonstrate how the reconfiguration of epistemological certainty into a form of pragmatic inquiry has been crucial to understanding the history of our advancing knowledge of the human body, and has enabled scientists and engineers to better address the problems related to implementing biometric technologies for specific uses. As I will show in later chapters, observational theories of human skin color are often presented conceptually in the traditional theory/practice paradigm, divorced from the

[29] p. 3, Hickman, Larry *John Dewey’s Pragmatic Technology.* Bloomington, IN: Indiana University Press: 1992. Print.

[30] Ibid. 29, p 96.

technological inquiry that can provide deeper understanding of skin color measurement within a socio-technical system. The potential for crossing disciplinary divides, then, is a secondary theme of this project (Fig. 1.3).

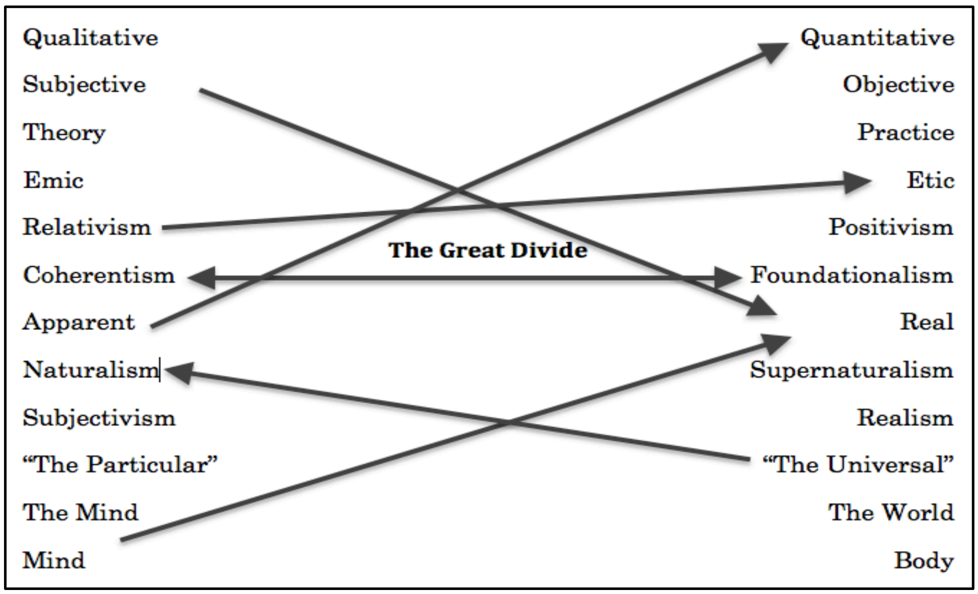

Fig. 1.3 Crossing the Great Divide of Traditional Dulaisms – How does technology and inquiry complicate old dualisms and the boundaries set by disciplines?

How have the instrumental uses of measurement technologies complicated the boundaries set by academic disciplines? These research paradigms have already determined the research path and goals for many of the researchers in my collection of primary texts. Physics, physiology and psychology are three ready-made paradigms for skin color research, and much of my project follows the interactions of this knowledge. Yet so much of the history of skin color measurement demands research into the rich cultural history of skin color and its meanings. Anthropology, Linguistics and Philosophy are also vital to the history of skin color measurement as well. As most historians and philosophers of science will avow, crossing these boundaries of culture and science becomes part of the experience. Additionally, I contend, research into the history of skin measurement and observation runs into similar problems, regardless of disciplinary boundaries. What I want to emphasize is that the way researchers address these problems is usually determined by the underpinnings of a discipline, although an individual observer's native language and understanding of skin color also plays a role. Successful researchers, I also argue, have learned to make these disciplinary understandings logically coherent. Therefore, this project seeks to question how technology, as an active mode of inquiry, facilitates interdisciplinarity within the modern paradigms.

But while these 'boundary' crossings clearly question old dualist arguments, I'd like to stress that technology is anything but deterministic or value free. There are many examples where the application of technology has forced compatibility. Dewey clearly states that some tools "are not appropriate to the settlement of a particular situation", usually forced by means of "authority, imitation, caprice and ignorance, prejudice and passion"[31] Therefore ethics and technology are inseparable within productive human activities, and is crucial to pragmatic inquiry.

1.5 Re-configuring Epistemology with Pragmatic Inquiry and a System of Scientific Knowledge Based on Evidence

Another basic question for traditional epistemology is: *What am I justified to believe?* If we are to accept Dewey's claim that traditional epistemological justifications are flawed by the placement of the "individual thinking mind" at the pinnacle of knowledge, then a reconfiguration of epistemological justification for knowledge should A) adopt a socio-technical method of experimental inquiry and B) address the role of 'uncertainty' in formulating what counts as knowledge. So, I will begin with the following argument presuppositions[32]:

1. We exist.
2. Some of our perceptions are accurate, thus reflect and help verify reality.

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[31] Ibid. 29, p. 21;

[32] I use 'we' instead of 'I' as a deliberate way of emphasizing the collaborative aspects of pragmatic inquiry. It's a shift away from the 'individual thinking mind' model that has plagued traditional epistemology. Since technology can always be defined within a socio-technical system, the 'we' implies the processes and evaluation of the ways in which knowledge is made and applied.

While these statements may seem trivial, traditional philosophy has yet to find consensus on these foundational beliefs. The knowledge problem, or infinite regress problem, has yet to be fully explained through epistemology. Further, to what extent we can trust our sense perceptions is very much an ongoing question (especially in visual science studies). Thus, I must state these as presuppositions for a very good reason. Doubting existence and doubting our all of our sensory experiences is neither beneficial nor productive. Additionally, these statements can be restated to fit a pragmatic model of inquiry. I exist, and I don't generally question the existence of others. Also, it is fairly well established that our human senses work in similar ways even though, there are many patterns of anomalies that put 'reality' into question (i.e. hallucinations), we agree that these states of the mind actually reflect our connectedness within human variation.[33]

The first two suppositions lead to a major premise:

3. We use physical evidence as a basis of justification for acceptance/belief.

And three minor premises:

A. We form justified acceptances/beliefs based on physical evidence, both directly and indirectly observed. (Dewey, Toulmin)

[33] Oliver Sacks's book, *The Mind's Eye,* has a great detailed and humanistic view of visual anomalies and what they imply.

B. The strength of our acceptances/belief is proportional to the quality and amount of evidence. (Hume)

C. If we ever doubt the validity or reality of our conclusions, we can return to the evidence and test the conclusions. (Dewey, Pierce Popper)

Using the experimental inquiry model, Dewey says that new theories of physical evidence changed science when it moved just beyond observation and into the era of experimentation. Further, technology and experimental methods developed together, in order to move beyond direct observation and into indirect methods of observation. However, as Dewey's pragmatic mode of inquiry dictates, the instrumental uses of technology combined with experimentation sometimes produce a high level of uncertainty. Technology gives us access to more evidence, no doubt, but it also brings about contingencies that require careful examination of evidence. Thus, multiple lines of evidence, that logically cohere and can be agreed upon by multiple observers, has become a mainstay in science.

I also distinguish here between acceptance and belief. "Knowledge" produced by evidence-based technical inquiry, as Dewey says, can be challenged in different ways, especially by new contingencies, new observations and new knowledge. Using the word 'acceptance' in relation to 'evidence' avoids the common pitfall of 'certainty' that has plagued traditional epistemology.[34] Therefore, a central aspect to an evidence and inquiry based model for justification is the idea of falsification of evidence through continued experimentation. Anytime you are in doubt about your conclusion, you can return to evidence and retest it, or you can come up with new experiments that falsify other ones. So, acceptance of evidence may be a better word than belief in relation to evidence-based knowledge. Together, these premises form *a coherent epistemological structure for evidence based inquiry.* (Fig. 1.4)

Justification of evidence is then based on a system of reinforcing properties that includes constant experimentation, application, observation and evaluation of physical evidence. This structure involves both quantitative and qualitative analysis, and collaboration is preferential to individual evaluation. Absolute certainty (or absolute belief) almost disappears in this model, whereas the uncertainty embedded in pragmatic inquiry diminishes by distinguishing between stronger and weaker evidence.

[34] This is the topic of John Dewey's famous work *A Quest for Certainty*

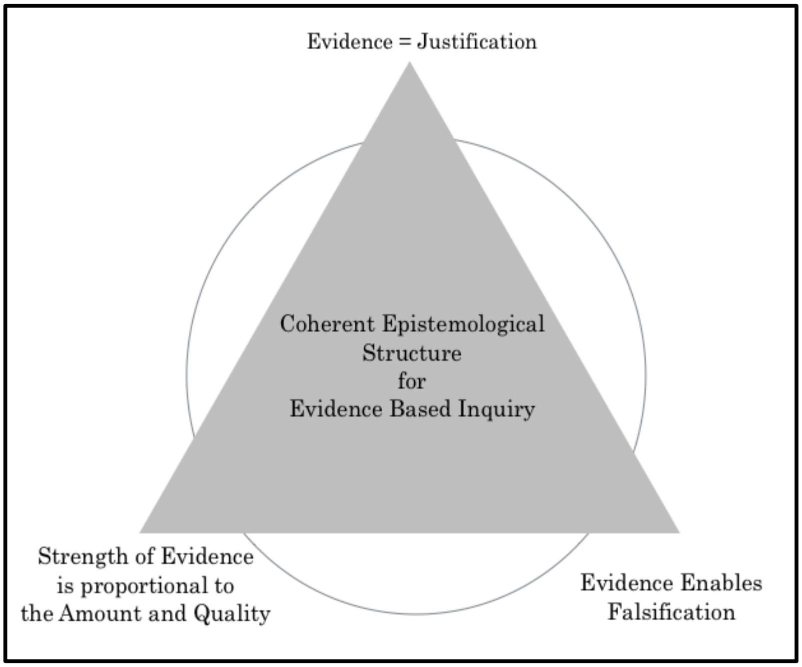

Fig. 1.4: A Coherent Epistemological Structure for Evidenced-Based Inquiry

One classic example to demonstrate how this model works comes from John Dewey's *Logic: The Theory of Inquiry,* where he subjects a basic and 'universal' mathematical proposition (2+2=4) to a method of falsification. Because "counting and calculations" are considered to be rational operations similar to "deliberation, pondering and reflection," mathematics is constrained by a set of possibilities within a symbolic system.[35] This means that even a seemingly self-evident proposition like 2+2=4 can be considered a 'hypothetical universal' rather than a 'universal physical law' because the proposition has not yet exhausted its applicability.[36] Due to the reliability of

[35] Dewey, John *Logic: The Theory of Inquiry* pp 395-396.
[36] Ibid.. 35. P 398.

this proposition that can be easily calculated with a mental operation, we forget that 2+2=4 is constantly reinforced by physical evidence. Two pens on my desk plus two pens on my floor equals four pens. If I ever collect these pens together, and I end up with five pens I can go back and check my calculation and determine that my error lay in the quality of my observation. Still, in this simple scenario, the evidence for the calculation 2+2=4 was being subjected to system of falsification and verification based on physical evidence. To achieve the justification that 2+2=4 and not 2+2=5, I had to determine the quality of my evidence, which also can invite collaboration with others to verify the result. To state it another way – We shouldn't forget that our everyday experiences are actually interactions with evidence that form our most basic propositions and that our social interactions help verify and falsify those propositions.

Dewey grounds his system of logic in physical reality due to what he calls the 'transformation' of material reality into a conceptual system that reflects reality. Evidenced-based inquiry, then, can be thought of as establishing the relationship between 'a map and a country'. Dewey uses this metaphor to state that "any errors that result in the map from inadequacy in the operations of surveying will also be found in the propositions about the relations of the country."[37] Thus, this system of inquiry based on physical

[37] Ibid. 35 p 401.

evidence can also identify errors in the conceptual tools we use as 'surveyors' to logically establish coherent propositions about reality. So, evidence-based inquiry is a model for establishing relationships between conceptual propositions (maps) and reality (country). However, due to the contingent nature of experience and constant experimentation, the mode of inquiry is used to establish patterns of these relationships rather than 'absolute' universals. There are degrees of uncertainty in this model, and it actually demonstrates how a simple mental abstraction like 2+2=4 becomes a reliable concept in relation to reality based on evidence. Using physical evidence and inquiry, then, gives us a framework to evaluate and reevaluate even the most basic knowledge we consider to be justified.

1.6 Conclusion: Uncertainty, Logic, Method, Technology and The Diversity Principle in the Epistemology of Skin Measurement

Epistemological uncertainty, I argue, is one of the important structuring ideas for reading the historical literature and case studies I have collected on the scientific enterprise of skin measurement. In my collection of primary texts, you can see how uncertainty (or certitude) define the logic and methodologies of each study as well as shape how the findings are applied, published, and distributed. It is this rhetorical component of epistemological uncertainty expressed in these texts that can help evaluate how technology (as hardware) and technological rationalizing (as methodology) work in an evidence-based system of knowledge. For example, in presenting a new methodology for measuring skin color in 1926, Charles Sheard acknowledged a modest value of visual observation methods for the medical profession to see "appreciable color changes occur in the skin;" still, he argues that visual methods "do not in any manner analyze light reflected by the skin and therefore cannot record skin color in terms of these attributes of color, that is, brilliance, hue and saturation... The eye is a poor instrument for analyzing or resolving constituents of color."[38] From Sheard's opening description of skin color as a combination of "pigmentation, or melanin, and the character, amount distribution and velocity of the flow of blood in the capillary bed of skin," he recognizes the complex anatomical structure of skin, and how changes in the conditions of light potentially distorts methods of visual observation.[39] The rest of his paper then makes an argument for using the spectrophotometer for measuring light at specific wavelengths reflected from the skin, that are also optimal for normal trichromatic vision. And it is here we can see the uncertainty of one methodology being mediated by a technology in the pursuit of a new methodology.

Sheard's commitment to developing the method of spectrophotometry also reflects the terminology he uses for human skin, and his commitment to

[38] Ibid. 7, p70. See Artifact 31 in the Appendix.
[39] Ibid. 7, p70

acknowledging a single universal human category. He makes a claim that "Normal blondes and brunettes differ in the amount of pigmentation only."[40] This type of clarification is not unusual in a scientific article, but it takes on extra significance due to the social circumstances in American medical science at the time. Just fifteen years prior, an American physician and eugenicist Charles Davenport wrote two extended volumes called "Heredity of Skin Pigment in Man" where he made the argument for 4-5 different sub-categories of human beings that could be identified by skin color. Davenport used the methods of visual matching and quantitative analysis to construct chart with the following terminology for skin color mixtures:

- blonde
- brunet
- Intermediate
- yellowish-white
- olive yellow
- dark yellow-brown
- dark olive
- copper colored
- chocolate
- sooty black
- full black

[40] Ibid. 7, p70

- three-fourths black
- one half black
- one fourth black

Davenport's chart was then used as a heuristic to figure out the 'race mixture' of individuals based on heredity and skin color, in addition to other phenotype measurements.[41] Of course, Davenport's commitment to the eugenics movement significantly influenced this study which was designed to discourage miscegenation, or 'race' mixing. I address the historical backdrop of scientific racism further in Chapter 3, but I think it emphasizes the choices of Sheard's terminology for skin types and human categorization, and also his application and disciplinary commitments for developing this new methodology. Sheard used the words blondes and brunettes as a way to denote a spectrum of skin pigmentation, from dark to light, and he argues that a visual description should include the attributes of hue, value and chroma, which confer skin's interactions with light. Sheard is clearly narrowing the terminology he used for skin color, reducing it to scientific descriptions of melanin/pigmentation, blood changes and how these material substances interact with light. In this way, Sheard's disciplinary commitment

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[41] Charles Davenport, Gertrude Davenport "Heredity of Skin Pigments in Man" *American Naturalist,* Vol. 44, No 527, (Nov. 1910) pp 641-672. (See Artifact 29 in Appendix).

to biophysics is influencing his description of skin; thus his terminology is constrained.

This case study is important to the epistemology of skin measurement because is highlights not only some of the significant changes in the technology of measurement, but it also represents a turn in the era of visual matching that began with Von Luschan's Chromatic Skin Scale. As the historical record reflects, this era is marked by the rise of 'scientific racism' which coincided with a variety of new methods to measure the body, record data and apply methods of statistical analysis for determining its usefulness. In the following sections, I hope to bring some clarity to the science of skin measurement, and how technologies such as a spectrophotometer, were built to address the problems with visual observation, but also put to work for more and less ethically appropriate applications. The diversity principle is an important part of this narrative as well because there was no precise cutoff between the old methods and new methods, and even though the technology of spectrophotometry allowed some areas of science to understand skin in a new perspective, it didn't change the fact that methods of visual observation was still very much a part of science and still added to the epistemology of skin measurement.

Sheard's uncertainty regarding methods of visual matching, that relied strictly on the visual observation of skin through human eyes, embodies the important function that individual observers play in a scientific inquiry. Sheard's uncertainty led to a new and more technical way of thinking about skin. Spectrophotometry eventually became the dominate method of skin measurement, thus it was the most important tool used to collect and accumulate evidence that increased disciplinary knowledge of human skin. Even though the evidence and mechanisms of human variation were still poorly understood in 1926, spectrometry offered a more accurate technology in which to examine chromatic variation in humans

Chapter 2:

The Colors of Our Language: Human Categorization, the Human Body and the Technological Mindset in the Observation of Skin

"We have categories for biological species, physical substances, artifacts, colors, kinsmen, and emotions and even categories of sentences, words, and meanings. We have categories for everything we can think about. To change the concept of category itself is to change our understanding of the world. At stake is our understanding of everything from what a biological species is to what a word is."

George Lakoff "Women, Fire and Dangerous Things"

"The power of understanding symbols, i.e. of regarding everything about a sense-datum as irrelevant except a certain form that it embodies, is the most characteristic mental trait of mankind. It issues in an unconscious, spontaneous process of abstraction, which goes on all the time in the human mind: a process of recognizing the concept in any configuration given to experience, and forming a conception accordingly. That is the real sense of Aristotle's definition of Man as 'the rational animal'."

Susanne Langer "Philosophy in a New Key"

2.1 Introduction: Skin Color, Technology and Uncertainty in the Logic of Human Categorization.

Charles Darwin writes in *The Descent of Man* (1872) of a hypothetical "young naturalist" that would be investigating "the races of man, viewing him in the same spirit as a naturalist would any other animal."[1] Under the constraints of his disciplinary logic, Darwin walks his readers through the traditional rationalizations for human categorizations before offering a strong rebuttal against distinct biological categories, or races, of human beings. He admits that the color of the skin "is the most conspicuous and one of the best marked" differences between human groups, and that many human observers begin their scientific inquiry through visual observation and comparison of differences in phenotype, and to use Darwin's words: "must have been struck with the contrast" between human groups, from different geographical regions of the world with variances of both 'slight and considerable importance'.[2] The naturalist would then find that some differences between human groups, such as skin color, have existed for at least 4,000 years according to the historical record at the time. Additionally, he may even

[1] Charles Darwin, *The Descent of Man and Selection in Relation to Sex* New York, NY:
D. Appleton and Co. 1871. p207.
[2] Ibid. 1. p232, p208

argue that the distribution of different colored people correlated well with the distribution of distinct species of other mammals.[3] This is the point that Darwin's naturalist will start begin to 'feel himself fully justified in ranking the races of men as distinct species' and will begin to test the similarities and differences in fertility, sterility, hybridity and heredity as they would any other domestic or wild animal.[4] Following this logic, Darwin says: "a naturalist…might urge that the mutual fertility of all races has not yet been fully proved; and even if proved would not be absolute proof of their specific identity."[5] But this is the part of the argument, Darwin emphasizes, that the logic of his hypothetical naturalist breaks down under the diversity of disciplinary classifications for *race*.

Darwin argues quite convincingly that disciplinary uncertainty, and the wide diversity of human categorizations among those who study mankind, means there is no consistent way to make distinct characterizations between human groups. What separates human groups is inconsistent at best. Darwin writes:

> Man has been studied more carefully than any other organic being, and yet there is the greatest possible diversity among capable judges

[3] Ibid. 1 p211
[4] Ibid. 1 pp212-216
[5] Ibid. 1 p216

> whether he should be classed as a single species or race, or as two (Virey), as three (Jacquinot), as four (Kant), five (Blumenbach), six (Buffon), seven (Hunter), eight (Aggissiz), eleven (Pickering), fifteen (Bory St. Vincent), sixteen (Desmoulins), twenty-two (Morton), sixty (Crawford), or as sixty-three, according to Burke. This diversity of judgment does not prove that races not be ranked as species, but it shows that they graduate into each other, and that it is hardly possible to discover clear distinctive characters between them.[6]

Further, Darwin extends the rebuttal of his traditional disciplinary logic to argue that variations of skin color evolved through many many generations natural selection within a population, and that the effects of this adaption were passed on through direct inheritance. What this demonstrates is that Darwin recognized the diversity principle in individual scientific thinking and how it might have influenced the disciplinary logic within science; additionally, Darwin exercises epistemological uncertainty in the conclusion of his chapter on "The Races of Man" before expanding on his theory of natural selection and more description of the mechanisms and processes of biological evolution. He states:

[6] Ibid. 1 p218.

> Although with our present knowledge we cannot account for the strongly marked differences in color between races of man, either through correlation with constitutional peculiarities, or through the direct action of climate; yet we must not quite ignore the latter agency for there is good reason to believe that some inherited effect is thus produced.[7]

Darwin's descriptions of human skin also changed in the conclusion of this section where he refers to human skin variation as 'lighter and darker tints' and 'shades of difference' that graduate into each other rather than become an identification marker of a distinct biological races. Thus, Darwin's strong rebuttal against the logic behind the scientific categorization(s) of human races stands as a way to examine the language of human categorization, as well as the diverse language used to describe skin colors in historical scientific rationalizations of skin measurement.

Although Darwin acknowledged the uncertain limitations on current scientific theories of skin color evolution, his recognition of science as a system of knowledge is on display, and it is this mode of thinking that exposes that logical fallacies of scientific theories of skin color based on visual

[7] Ibid. 1 p236

observation without the benefit of the knowledge of biological evolutionary mechanisms that clarify the appearance of skin and its spectrum of colored variations. From the artifacts on the history of skin measurement that I have collected for this dissertation, there is a pattern of individual scientists using predetermined sets of linguistic categories in the technological activity of linguistic matching that carried over into the era of visual matching, and in some cases still continue today. As the previous chapters have indicated, the language used to describe skin color often plays an important functional role in scientific practices of measurement, but as some case studies demonstrate, critical reflection on the language of skin color and human categorizations is inconsistent and often obscures the interpretation of scientific claims.

As the diversity principle suggests, the scope and influence of linguistic categories that have marked the science of skin measurement is a massive empirical undertaking that requires acknowledgement of great cultural diversity. In previous chapters, I have exemplified a few historical moments that show how technological and epistemological inquiry have influenced the language used to describe the human body and biophysical processes. Perhaps the best example is how Newton's theory of light and color changed the way scientists described skin as interaction with the properties of light. Here, the linguistic categories change from constructed and concrete objective colors like black, white, brown, yellow and red to more of an interactional set of biophysical descriptions of skin based on gradations of hue, value and chroma. This change in conceptual knowledge, I argue, had the effect of narrowing the diversity of linguistic descriptions based on individual visual observations and localized languages towards more unified and scientifically clear sets of disciplinary descriptions. However, I have only thus far discussed linguistic categories for human skin color within contexts that have not explained their origins or theorized about the formation of linguistic categories used for methods of skin measurement. Therefore, the purpose of this chapter is to extend inquiry into the language of scientific observation towards a theory that can explain the diversity and similarities of linguistic categorizations of the human body found in the historical record of biometric measurement.

In this chapter, I will introduce several interdisciplinary perspectives that will help contextualize the history of linguistic categories for both human classification and skin color. As I hope to show, the scientific record has brought much needed clarity to understanding the human body, and the collected artifacts in the appendix demonstrate some of these historical changes. What needs clarity, however, is how we can read the history of skin color measurement through modern scientific perspectives when so much of the diverse cultural history is lost and at best untraceable. Indeed, a theory that recognizes both the biological and cultural diversity that has influenced the language of science will be beneficial to understanding the historical record of skin measurement, thus I will introduce several thematic concepts concerned with language, biology, culture and technology before returning the salient changes of linguistic categories that correspond to other historical threads.

2.2 Why Do We Categorize? Syntax, Semantics and Lexicons in the History of Skin Measurement

One interesting approach to interpreting the history of skin measurement is to examine how the categories for skin and skin color have changed along with the methodology and technology of measurement. The human activity of 'basic-level categorization' could even be called a 'pre-cursor' to the human activity of science and human reasoning.[8] As psycholinguist George Lakoff states: "The idea that categories are defined by common properties is not only our everyday folk theory of what a category is, it is also the principle technical theory – one that has been with us for more than two thousand years."[9] The early history demonstrates a practice of visually observing human skin, and then using linguistic matching to correlate visual observations to a lexicon of color categories. For much of this era, categorizing in this way wasn't a problem for scientists since definitional

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[8] George Lakoff, *Women, Fire and Dangerous Things: What Categorie Reveal about the Mind. (1987).* Chicago, IL: University of Chicago Press.

[9] Ibid. 8 p5

categories were assumed to be true. As Lakoff points out, the classic theory of categorization changed from mere background assumptions to become part of the empirical hypothesis itself; therefore, part of the 'linguistic turn' in the history of skin measurement that marked the change from linguistic matching to the more technical visual matching was a change in the sciences in general that considered the reflexive activity of categorization to be synonymous with scientific reasoning.

As Darwin cogently pointed out about the various categories for humankind, there is a basic error in the method of visually observing skin color and linguistically matching it to a set of categories, and under the logic of scientific rationalizing, this meant that scientists had to reconsider both the syntax and semantics of their language categories. Traditionally, linguistic syntax is defined as the relationship between symbols, and semantics considers how we derive meaning from symbols; however, studies in neuro-linguistics that consider cognitive function and symbolic language further break down mental representations into depictive and propositional formats of symbolic reasoning.[10] Depictive representations are interpretations of raw visual sensory information that we automatically process through the visual and neural system, and propositional

[10] Stephen M. Kosslyn, William L. Thompson and Giorgio Ganis *The Case for Mental Imagery* (2006) New York, NY. Oxford University Press. Print.

representations are the descriptive categories that we assign symbolic information through rational means. Thus, the syntax of symbols in a propositional statement can be defined as a form of logic that considers the relational concepts, entities and properties of an object; whereas the syntax of depictive symbols interprets an object's physical properties such as size, shape and color. For comparison, consider the following examples in Fig. 2.1:

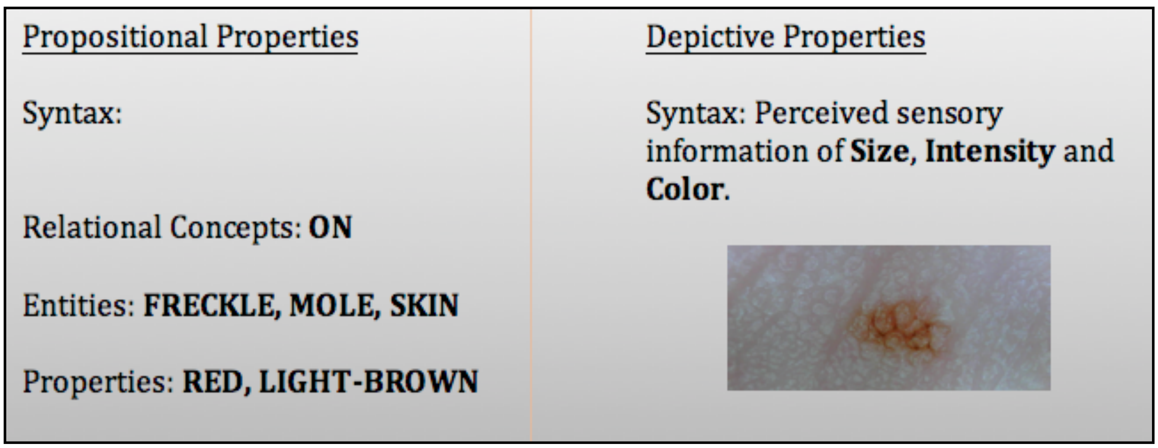

Fig 2.1 – The propositional and depictive properties of syntax based on the summary of neuro-linguistic functions and case studies by Kosslyn *et al* (2006). On the left is a list of linguistic categorizations of certain properties of a small mole on the surface of skin. On the right is a digital photographic depiction of a mole on my small finger.

As can be inferred from the schema in fig. 2.1, propositional syntax requires a set of propositional symbols in order to categorize the properties depicted in this scene. However, propositional syntax serves a very important function in human communication, it allows us to make meaningful and memorable categorizations that can be used to create and anchor meaning. We can also describe propositional and depictive meaning as semantics, or the study of how our minds understand the relationship between symbols in order to make meaning from it. Because of my human ability to learn and use linguistic categorizations, I can take the properties of syntax that describe the categories from depicted in the scene in fig 2.1 and arrange them into a semantic order that constitutes a propositional statement: *There is a light-brown mole on my skin.* Thus, propositional statements are subject to the logical claims of truth and falsity, and follow semantic rules embedded in the social norms of language. On the other hand, depictive semantics correspond to the relationship between perceiver (the subject) and the perceived object. Although still considered a nascent area of neuroscience, the way our visual system and neural mechanisms interpret and categorize information is the central concern in the study of depictive semantics. As mentioned in earlier chapters, the modality of vision is under sets of physical, biophysical and technological possibilities and constraints. In this case, the depictive representation of the mole is dependent on my bio-physical abilities to distinguish color, size and shape of the mole in three dimensions based on my situated cognition. In addition to these abilities, the hypothesis of as neurolinguists like Lakoff and Kosslyn demands a neural mechanism that can automatically categorize sensory information without the input of propositional language, but is still subject to it.[11]

While the full implications of the neuro-linguistic model for syntax/semantics and propositional/depictive interpretation are beyond the scope of this dissertation, this basic schema provides an important framework for understanding both human categorization and skin color terminology in the history of skin measurement. First, we can begin to address the assumptions of semantic categorizations for skin color as well as human categories, just as Darwin began to do. Additionally, we can begin an inquiry into how propositional statements requiring a lexicon of words shaped the interpretations of visual observations and compare how sensory information was interpreted under the methods of linguistic matching, visual matching and spectrometry. Further, we can begin to infer how technology and the accumulation of scientific knowledge impacted our categorical lexicon used in the interpretation of human skin. Nevertheless, in the following sections I will describe just a few of the biophysical preconditions that underpin the language of color categorizations and reflect the technical

[11] Ibid. 10, Ibid. 8. This connection between the rational logic of categorizations and innate cognitive abilities of humans is the subject of both Lakoff and Kosslyn's *et al* work as they explore this very difficult and unsettled topic in the study of neuro-linguistics.

mindset of socio-cultural intentionality that underscores the technical application of color categories.

2.3 Prehistory I: The Biological Inheritance of Visual Color Discrimination

Human beings are primates. Our human vision has been shown to be a particular kind of trichromatic primate vision that evolved through natural selection. Today, most humans share our particular kind of trichromatic color vision with apes and most Old World monkeys (Nathans 1986; Neitz and Neitz 2000; Neitz, Carroll and Neitz 2001; Changizi, Zhang and Shimojo 2006; Dehaene 2009; Nilsson 2009; Jacobs 2009; Changizi 2010; Land and Nilsson 2012). While most of us carry pigmented genes (ospins) that give us retinal sensitivities to light/dark (rods) and spectral sensitivities (cones) at three different wavelengths (trichromats), some humans only have two spectral sensitivities (dichromats), and in even rarer cases people carry no cones and just see in a grayscale of light to dark (monochromats), while some others have a fourth cone (tetrachromats) that allow them to have a larger visual spectrum than any other type. To see in 'color,' a human subject must have at least two different pigmented cones in order to distinguish light specific intensities and wavelengths in the visible spectrum (between 400-

700nm).[12] Three different cones that absorb light at approximately 400-500nm (S cones), 450-630nm (M cones) and 500-700 nm (L cones) are considered 'normal' for human vision.[13] Whatever our spectral sensitivities (photoreception) may be will partially determine our biological constraints in discriminating colors, shapes and lines in a visual scene; therefore, we can consider our genetically based spectral sensitivities and its interaction with our evolved neurophysiological processes and cognitive abilities as part of our biological inheritance.

Additional components to the biological inheritance of our primate color vision are found in the physiological mechanisms that process light signals into electrical signals (transduction) along the visual pathways from the retina to brain. Our light sensitive photoreceptors in the retina absorb light at different wavelengths, and in doing so, a photon's varying attributes of wavelength and intensity are no longer distinguished by individual receptors (rods and cones.)[14,15] Thus, light processing must take place downstream of

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[12] p 35. Land, Michael F.; Nilsson, Dan-Eric *Animal Eyes.* Oxford, United Kingdom: Oxford University Press. 2012. Print.

[13] This is an important point for addressing visual technology and human diversity, and for understanding the challenges of human diversity when it comes to addressing vision and visual problems.

[14] P 276. Solomon, Samuel G.; Lennie, Peter "The Machinery of Colour Vision" *Nature Reviews/Neuroscience.* Vol. 8 April (2007). pp. 276-286. Web. www.nature.com/reviews/neuro. Accessed: 9/26/15.

[15] Rushton, W.A.H. "Pigments and Signals in Colour Vision" *Journal of Physiology. (1972), 220, pp. 1-3 P.* – First given in a lecture to the Physiological Society at Chelsea College London (17, April 1970), Rushton called it the

the retina before the signals used to distinguish one visual attribute from another and can be perceived as color. Much of the current research on the mechanisms of primate color vision has revealed that a variety of physiological processes in various cells and circuitry of the retina, primary visual cortex and the higher-order visual areas of the brain. Therefore, many different physiological processes occur between the stages of stimulus response (input) in the photoreceptors and the colors we can perceive and experience (output). For this reason, Conway *et al* (2010) claims, "color has become the premier model system for understanding how information is processed by neural circuits, and for investigation the relationship among genes, neural circuits, and perception"[16] However, there's nothing straightforward about this process; as Conway *et al.* notes, "both the physical stimulus for color and the perceptual output experienced as color are quite well characterized, but the neural mechanisms that underlie the

"univariance principle," this initial processing of light was first described by Rushton (1970), and it explains part of both Young and Hering's observations that when we perceive a color such as yellow, it doesn't matter if the source is a pure spectral yellow or a mixture of spectral red and green, trichromatic vision just perceives yellow Consequently, parts of Young, Helmholtz, Maxwell and Hering's theories that located color processing in the retina were eventually falsified, as the complicated mechanisms of the visual pathways were being explored. Thus, this is one of the moments where trichromatic and opponent color theories merge.

[16] Ibid.. 4 p14955,

transformation from stimulus to perception are incompletely understood."[17]

Classifying human color vision under the general order of "The Visual Vertebrate System" (Polyak 1957), and more specifically "Trichromatic Primate Vision" (Conway *et al.* 2010, Jacobs 2009, Neitz, Carrol and Neitz 2001) is beneficial to visual research because it allows comparisons to be made between species with different anatomies, cognitive functions and abilities. It also provides the basis for an experimental model that explores the relationship between the visual systems, visually guided behavior and biological inheritance. The science of comparative biology has also established part of the evolutionary history of human vision through experimental methods that test genes, neural circuits and perception. For example, Neitz, Carrol and Neitz (2001) report that genetic calculations estimate the mutation for the L/M pigments that correlate to the red/green parts of the visual spectrum to have evolved around 30-50 million years ago in Old World primates, while the divergence of Old and New World primates is estimated at 60 million years ago.[18] Other reports estimate the emergence of trichromatic vision from dichromatic vision in Old World primates to around

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[17] Conway, Bevil R. *et al.* "Advances in Color Science: From Retina to Behavior" *The Journal of Neuroscience* November 10, 2010. Vol. 30 No. 45. pp. 14955-14963. Print.

[18] Neitz, Jay; Carrol, Joseph; Neitz, Maureen "Color Vision: Almosst Reason Enough for Having Eyes" *Optics and Photonics News* (January 2001) pp 26-33.

30-40 million years ago, and is due to the duplication of a single X-chromosome ospin gene found is most primate species with dichromatic vision.[19] The approximate timeframe for the emergence of trichromatic vision is important to establish for human studies for several reasons: 1) It is assumed that the jump from distinguishing 1 million surface colors within the blue/yellow system afforded by dichromatic vision to the roughly 2 million distinguishable surface colors within the blue/yellow and red/green system of trichromatic color vision had a significant impact on visually guided behavior of primates. 2) This historical timeframe allows researchers to consider how trichromatic color abilities affected the evolution of the primate brain, which Jacobs describes as a " large, agile and plastic brain that allows them to use color information in a multitude of ways generally unavailable to those species with more limited central processing capability"[20] Therefore, understanding the biological inheritance of trichromatic color vision is important for inquiry into how our species, *homo sapiens sapiens*, apply our visual abilities of color discrimination along with higher order cognitive functions such as complex language, symbolic systems of communication,

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[19] Jacobs, Gerald H. "Evolution of Colour Vision in Mammals" *Philosophical Transactions: Biological Sciences.* Issue: The Evolution of Phototransduction and Eyes (Oct. 12, 2009), Vol. 364, No. 1531. pp 2957-2967.

[20] Ibid. 7. Jacobs (2009) p2964.

individual and group intentionality, tool use and technological applications.[21] Within the neuro-linguistic framework for categorization, this evolutionary perspective also theorizes part of the important biophysical connections between our language abilities of depictive and propositional syntax and semantics.

2.4 Prehistory II: Blombo's Cave, Language and The Technical Mindset of Early Color Production

Based on both genetic and fossil data, it has been proposed that anatomically modern humans evolved in Africa between 150-200 thousand years ago (McBrearty and Stringer 2007; Watts 2009). However, tracking the evolution of cognitive behaviors that define "modern" human cultures is less certain. One set of theories described as the "the great leap forward" proposes that human groups evolved a capacity for syntax (complex language) from a single neural mutation around 40,000-50,000 years ago.[22] Conversely, another set of theories questioning *how* and *when* behaviors we associate with modern humans emerged stem from careful comparisons of

[21] Tomasello (1999) and Botha & Knight (2009) both provide a basis for addressing these questions
of biological and cultural inheritance of visual guided behavior.

[22] Described by Chris Knight (2009) in the introduction, pp1-15, of the anthology *The Cradle of Language (*eds. Botha and Knight 2009). Knight attributes this nominalism to a 1992 article by Jared Diamond.

archeological data with interdisciplinary knowledge of genetics, biology, paleoanthropology and cognitive science. This set of theories focuses on the evidence for a 'symbolic culture' that is proposed to have gradually evolved over the course of the Middle Stone Age (285,000-45,000 years ago) in Africa; and this evidence also can be used to distinguish behaviors as uniquely human.[23] Perhaps the strongest evidence for this view is found in the discussion of the production and uses of ochre "red" pigment used as a coloring agent and painted onto artifacts associated with the earliest archeological evidence for groups of *homo sapiens*. While technologically produced ochre pigments are found at many archeological sites along the southern coast of Africa dating back to at least 165,000 years ago (at Pinnacle Point), the evidence gathered from Blombo's Cave perhaps holds the most insightful evidence of a distinctly human symbolic culture associated with color.

Ian Watts (2009) explains the early occupants of Blombo's Cave engraved small symbols onto their stone tools used to make a specific hue of ochre red pigment used for body painting as far back as 100 thousand year ago; additionally, the same 'deep blood red' pigment is found on shell bead

[23] McBrearty, Sally; Stringer, Chris "The Coast in Colour" *Nature.* (October 2007) Vol. 449 No. 18 pp. 793-794. Print.

necklaces from 75 thousand years ago that also indicate body painting.[24] During this time however, sea level changes and sand cover had made the ochre deposits close to cave hard to reach, while other materials used to make different shades of lighter red, yellow, black and white pigments were more easily accessible to from Blombo's Cave; therefore, Watts concludes that this ochre pigment of a specific saturated 'blood red' hue held a special symbolic significance for this occupants of Blombo's Cave, spanning tens of thousands of years.[25] Because this evidence suggests a high amount social investment and resources to procure a specific color of pigment, the technology used to produce the pigment is also a significant indication of human behavior. The ochre pigment found in Blombo's Cave was made from a hard hematite enriched stone that would have required extensive processing that only produced a little bit of pigment at a time. Combined with the evidence from engravings found on the stone artifacts, the evidence suggests that pigment-making at Blombo's Cave required a technological system of production, safekeeping, and habitual use of tools and materials needed to make a specific hue of ochre red pigment. This type of technological mindset also indicates a sophisticated form of cultural investment and social coordination

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[24] p 82. Watts, Ian "Red Ochre, Body Painting and Language" eds. Botha, R.; Knight, C *The Cradle of Language.* New York, NY: Oxford University Press. 2009. pp62-92. Print.

[25] Ibid. 12 p90

that involves a tradition, a ritual and an epistemology of knowledge regarding the technology, as well as the symbolic system needed for ritual. As the evidence also indicates, the technological an cultural production of ochre red was primarily produced for cosmetic use on the body, or body painting, which also inductively indicates a correlation between hue (blood red) and ritual use (body painting).[26]

There are many similarities in color profiles of the different pigments found on artifacts of personal ornamentation from the Middle Stone Age dig sites that are scattered along southern coastal Africa. Due to this, many have concluded that it was during this time that "technological and behavioral complexity emerged gradually…[and] resulted from human innovation, sometimes in response to the pressures of population growth or environmental change."[27] As many anthropologists have indicated, body painting and ritualistic use of ochre pigments are ubiquitous throughout early human cultures; additionally, the colors most consistently favored are the 'brilliant blood reds' similar to the pigments found in Blombo's Cave.[28] What this fact about the widespread use of 'red' pigment indicates about its human makers and users has been a matter of contention among anthropologists, but it offers an interesting questions regarding biological

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[26] Ibid. 12, p90
[27] Ibid. 11, P793
[28] Ibid. 10, p5

versus cultural inheritance of early homo sapiens groups and what trichromatic color vision enabled these groups to do. Some use this evidence as support for the "the great leap forward" hypothesis that holds an innatist *view* of our language faculty, while others say this evidence indicates the long and gradual emergence of language through a symbolic culture specific to *Homo sapiens*. For this project, I don't extensively promote either position; however, the evidence from Blombo's Cave exemplifies some important features of cognitive abilities that are uniquely human, with biological and cultural roots, and also resonate with the way we should research color language and technology today.

2.5 Logic and Method in Modern Sciences: Distinguishing Between Biological versus Cultural Inheritance

I would like to reflect for just a minute on the evolutionary frameworks discussed above. Natural selection is a slow process that occurs on a population level. Our species, *Homo sapiens,* is a result of a long evolutionary process. As already indicated, around 30 to 50 million years ago it has been estimated that Old World primates evolved the genetic ospins to enable light photosensitivities at what we refer to as the M/L (red/green) wavelengths, which allowed the species to see color in the full spectrum of light we see today with normal trichromatic color vision. The current narrative of our phylogenic history indicates a group of bipedal primates of the genus *Australopithecus* became isolated from other conspecific primates in Africa around 6,000,000 years ago and diverged into several lineages. Of these lineages only one species remains, which we call the genus *Homo,* that diverged around 2,000,000 years ago.[29] Recently, somewhere around 100,000 to 200,000 thousand years ago, in Africa, a group of anatomically modern humans emerged into a lineage we define as *Homo sapiens.* Around this time, along the southern coast of Africa, evidence has been found indicating a symbolic cultural tradition and technological production involving a specific hue of red.

Now, I will compare this narrative of evolutionary history to the recorded archeological record, the cultural history of technological production and cultural applications involved in color production in different societies today. Our biological inheritance, which includes our visual and cognitive abilities as well as our aptitude for tool making and tool using, took tens of millions of years to evolve. It's only been within the last 100,000 – 200,000 years or so that our species have been producing pigments, and have continuously made particular red pigments of a specific hue and for a specific symbolic purposes, that only our lineage of primates have the biological

[29] p 1-2. Tomasello, Michael *The Cultural Origins of Human Cognition* Cambridge, MA: Harvard University Press, 1999. Print.

inheritance to perceive. Thus, from the earliest evidence for the technological production of colored pigments to today's highly complex measurement tools and technological applications that quantify light information into color information, presents the problem of time to the evolutionary framework. How can a slow process like organic evolution account for the major changes human cognition and behaviors that account for our complex technology and applications today? According to Max Plank evolutionary anthropologist, Michael Tomasello, the only biological mechanism that can explain this puzzle "is social or cultural transmission, which works on time scales many orders of magnitude faster than those of organic evolution."[30]

Calling our particular type of human-specific cultural inheritance The Ratchet Effect, Tomasello compares the cognitive abilities (in particular abilities with language, vision and social tasks) in order to describe how human's abilities for complex language, joint attention and shared intentionality towards social tasks, can produce a system of cultural transmission that accounts for the rapid development of systems of knowledge and technological development.[31] In comparing human and non-human primates, cognitive researchers have identified different levels of 'group intentionality' and 'cultural learning' that separate humankind form

[30] Ibid. 29 p4.
[31] Ibid. 29 pp1-12.

other primates, and it is these advanced social abilities that 'ratchet' the speed of cultural evolution, Tomasello claims. Two of these abilities is our social-cognitive skill to perceive other minds as fully intentional beings, with the added ability to imagine the subjectivity of others; additionally, we use symbolic communication and language that 'pools resources' for these social ends in ways that other animals cannot.[32] Language systems are functionally important in this model because it allows individuals to adopt multiple perspectives, thus, Tomasello argues, "frees human cognition from the immediate perceptual situation not simply by enabling references to things outside the situation, but rather by enabling multiple simultaneous representations of each and every, indeed all possible situations."[33] Out of this empirical work, Tomasello hypothesizes that from this biological function of language and social transmission of human thoughts, *Homo sapiens* experienced a cultural evolution in new forms of cumulative learning that optimized our shared intentions, our abilities for joint attention, and the benefits gained from the accumulation of perspectives; further, he concludes:

> Understanding other persons as intentional agents like the self makes possible both a) processes of sociogenesis by means of which multiple individuals collaboratively create cultural artifacts and practices with

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[32] Ibid. 29 p5.
[33] Ibid. 29 p9.

> accumulates histories, an b) processes of cultural learning and internalization by means of which developing individuals learn to use and then internalize aspects of collaborative products created by conspecifics[34]

This view is helpful for several reasons. It helps in understanding how the biological inheritance of our primate visual and cognitive systems affords particular kinds of perceptual abilities with trichromatic color vision. This view also postulates how our cultural inheritance can accumulate a categorical lexicon of colors that that are available for propositional syntax and semantics.[35] Consequently, since The Ratchet Effect explains cultural learning, shared intentionality and joint attention within particular social groups and between social groups, this model holds the potential to understand the diversity cultural artifacts and technical systems that make use of our common biological inheritance in the formation of cultures invested

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[34] Ibid. 29 p15.

[35] In a highly influential study, linguistic anthropologists Brent Berlin and Paul Kay (1969) attempted to explain the gap between our physiological and psychological concepts of colors across cultures, and environments. Their Basic Color Terms (BCT) theory attempts to establish a physiological basis for our mental and cultural color categories; out of this work they revealed that many cultures, with languages that developed independently, share eleven basic color terms, with similar categorization. This study of color categories framed the discussion of how nature dictates the possibilities as well as places constraints on our human biology, but also opened the door to question how our shared culture invents and extends what is possible with color concepts. A a case study in color categories, Berlin and Kaye's work remain a foundational text the leads to several diverse ways of thinking about language and perceptual color used today across disciplines in the human sciences.

in color production and applications. In the history of skin measurement, this means the various categories for skin color and human categories are functionally significant for the technical systems built on the principles of shared intentionality and joint attention that are unique to the socio-cognitive learning systems of human cultures.

2.6 Color Terminology in Greco-Roman Antiquity

The claim being made here about the early color production in human cultures is that cosmetic usage of a specific color would also require a name to describe it. What this natural and archeological pre-history shows can be described as some of the pre-conditions for our color concepts – if you examine any human made system for color measurement, you see a history of technical knowledge, a common ground for cultural investment and a close association between color and the human body. Further, the evidence suggests human cultures have assigned both natural and technically-engineered objects specific color categories for as long as our species has been around; consequently, this requires not just individual names for color, but a lexicon of color terminology that theorizes how colors relate to each other. In other words, a system of color words is required for propositional syntax and semantic associations, and this extends to the colors that humans cultures use for skin.

To examine how sophisticated these principles can become in a culture, both the ancient Greek and Roman societies provide some vivid examples of the ratchet effect, cultural transmission and the relationship between color, culture and technology. We still use the Greek word *chroma* to describe individual colors on the visual spectrum; however, this word originally was associated with the color of flesh in ancient Greece.[36] The Hippocratic writers developed theories of medical ailments and treatment based on chromatic colors associated with the body. Black bile, yellow bile, blood and phlegm eventually became central to the doctrine of the four humors, where external physiological colors of the body were thought to reveal inner psychological temperaments, as well as physical conditions. Early Greco-Roman doctors were trained to distinguish small variances in the coloration of the body, and successful treatment of an ailment was measured by restoring balance to external coloration.[37] Historians have demonstrated how these early practices in medical treatment, which also serve as the basis for modern Western medical science, were influenced by the prevalent color concepts of the dominant Greek culture at the time. Long before the Hippocratics developed their medical practices, colors of the external body (skin pigments, blushes,

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[36] Bradley, Mark *Colour and Meaning in Ancient Rome.* Cambridge University Press. 2009.

[37] Wooten, David *Bad Medicine: Doctors Doing Harm Since Hippocrates* Oxford University Press. 2006. Print

pallor) were considered to be manifestations of inner morality and ethics.[38] As historian Mark Bradley describes it, "what one looked like and how one came across – took on considerable currency as a tool for character evaluation in a wide range of genres."[39] Bradley also points out that entire industries of manufactured colors grew out of need to establish a positive public persona through cosmetic manipulation of the body's natural colors.

By the time of ancient Rome, the cultural investment in manufactured colors had become very complex; colored costumes, fabrics, dyes, pigments, wigs and cosmetic makeup, were all used to decorate the body and also became closely associated with public rhetoric. This visual complexity in the Roman culture, Bradley claims, allowed a person "to undermine the straightforward relationships that had been established in Rome between color and meaning"[40] Thus, while there was a large scale social investment in color technology, consequently, some very negative connotations associated with colors of body sprouted in this era as well. Cicero, the Roman Philosopher, wrote that "shifting color, voice, eyes and breathing, does not indicate a sound mind."[41] Because embarrassment, fear and anger can all be revealed in the changing colors and expressions of our face, public speakers

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[38] Ibid.. 36
[39] Ibid.. 36, pp127-8
[40] Ibid.. 36, p129
[41] Ibid.. 36, p115

and politicians learned to discriminate and discern the dispositions of the rhetor based changing bodily complexion. In this context, a healthy color marked moral qualities, while a changing complexion marked a negative mental state. As a result, their word for color also took on the additional connotation of concealment, as if the speaker had something to hide; therefore, by embellishing one's public persona with cosmetic colors, negative associations between color and the body began to spread throughout Roman culture.

By reflecting on the function of color language in the societies of antiquity, we can see the foundations of color concepts that influenced Aristotle, Galen and their followers. Through a modern understanding of color science, we can examine the early medical writings of the the Hippocratics and Galen, and find the false correlations between physiological and psychological understandings of color being mapped out. We can also find examples of the reciprocal influences color technologies and science had on the cultural concepts of color and the body in the larger society. As medical practitioners learned to distinguish colors on the body, they eventually moved away from the conflation of mental and physical states revealed by skin color, yet the many histories of color categories and language terminology of the body reveal the continued cultural associations between physical colors and all that is passionate, emotional, and even ethical and moral.

2.7 Visual Observation and the Emergence of Four Humours Theory

It is within the emergent context of the humoral theory that I have placed my first two primary artifacts in the history of skin measurement, which also illustrate the how the practice of Hippocratic and Galenic medicine had a lasting influence on interpretations of skin and the human body. In the *Generation of Animals*, Aristotle reports of a light skinned woman from Elis who had a child with a dark skinned 'blackmoor' man (See Appendix, Artifact 1). Their daughter was light skinned, but then their daughter's daughter was dark skinned. Aristotle's theory of color gathered from other writings suggests that he believed all colors derived from four basic categories: White and Black, Yellow and Red.[42] These colors reflected the four basic elements: Earth, Air, Fire and Water, from which all organic material is made. However, in contemplating the how properties of the flesh are passed on to future generations, Aristotle postulates how properties of "color" might be physically drawn different 'uniform' parts of the body of both parents and then past on through fluids (male/female semen) to a child. Thus, properties of colored flesh are "assembled" in the offspring, and

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[42] J.L. Benson (2000), *Greek Color Theory and the Four Elements.* Paper 6. Published by: Scholar Works: University of Massachusetts Amherst. Web. (7/1/2000). – Aristotle is attributed this basic schema of colors that align with the four elements of earth, fire, wind, water.

different assemblages may result in 'non-uniform' appearances in later generations.[43]

Aristotle's color categorizations, based on the theory of four basic elements, are also bound up in his categories for human beings and his theory of environmental causes for differences in human groups. As historian Benjamin Isaac explains, Aristotle furthered the widely held view that the environment and climate are what determine peoples fixed mental and physical traits, claiming that human acquire certain traits through heredity, but then certain traits are permanently fixed by environmental factors; additionally, Aristotle expanded on this view by arguing between superior and inferior people based on the environments they lived in.[44] Of course, according to thinkers at the time, the Greek people lived in an environment that optimized their physical and mental traits and this served as a justification of imperialism. "Features of the body and mind," Isaac contends, were viewed by ancient Greeks "as qualities that couldn't be changed" and resulted in ethnic stereotyping.[45] It is plausible, then, that Aristotle's visible observation of the woman from Elis's child was not only an observation about

[43] Aristotle. *Generation of Animals.* Trans. Arthur L. Peck (1943) Cambridge, MA: Harvard University Press. Pp 49-59. Print.

[44] Benjamin Isaac *The Invention of Racism in Classical Antiquity* (2004). Princeton, NJ: Princeton University Press. pp 503-515.

[45] Ibid. 44 p513.

heredity and colors of the body, but also a method of linguistic matching between skin color to mental faculties that permanently respond to environmental factors.

In the second century, the Greco/Roman physician Galen wrote about the methods of linguistic matching and visual observation through monitoring blood changes beneath the skin (See Appendix, Artifact 2). In his work "On the Natural Faculties", he used the conceptual schema of the four humours as a theoretical model in which to interpret his patient's bodies. Galen suggested the 'palm of the hand' was the best access point to gauge the balance of warm/cold and moist/dry qualities in of a person's physiological state, which for him reflect some inner psychological qualities.[46] Skin color played a role in this diagnostic taxonomy as well; 'dark blood' was attributed to 'black bile' which was interpreted to mean the patient was 'melancholic,' which meant they were despondent, serious, quiet and reflective .[47] In the humoral model, the counter-point to melancholic was sanguine, which was denoted by reddish color of blood under the skin and associated with youth and vibrancy. This axiom of balance between darker and lighter, colder and warmer, and despondent and vibrant turned the human hand and other

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[46] See Robert Stelmack and Anastasios Stalikas. "Galen and the Humour Theory of Temperament" (1991) *Perso. Individ. Diff.* Vol. 12, No. 3, pp 255-263. Print.

[47] Arikha, Noga "Passions and Tempers: A History of the Humours" New York, NY Harper Perennial. 2007. Print.

places on the skin into a sort of visual monitor for Galen and later practitioners of the four humors theory. Eventually, Galen's followers used this color schema as a way to diagnose very real medical conditions such as jaundice, dysentery, cholera and intestinal disorders; however, as many historians have noted, 'colors of the body' were a catalyst for discussion that marked a person's behavior, personality, disposition and ethnographic origin.[48] Still, just as Aristotle, Galen developed a technical system for his visual observations of skin through a syntax of similar color categories: black, white, red and yellow. Conversely, the big difference between Aristotle and Galen's use of color categories is found in the method of linguistically matching those observations to correlate to a specific and fixed semantic meanings for skin color even though the balance of the humours was in constant response to mental faculties and the environment.

To compare, Aristotle's nomenclature for ethnicity, or 'race', was based on his deterministic environmental theory that caused an 'assemblage' of inherited traits to become permanent, which then reflected fixed physical and mental characteristics. His linguistic categories for skin color can be considered a correlate of racial determinism based on a human category. In contrast, Galen's nomenclature for human categorization was also based on

[48] Ibid. 36, p 159.

the accepted environmental theory of human behavioral, intellectual and physical differences. Just like Aristotle and the early Hippocratic writers, Galen attributed superior intelligence and character to the climatic regions of Greece and Rome, yet he also creates a ethnic and racially marked hierarchy when he mentions "those living [in the North] have a body and soul that are opposite in character of those who live near the region burnt by the sun [in the South], while those who live in a more well-tempered region are better than those peoples, as regard their body, the character of their soul, their intelligence and good sense."[49] What distinguishes Galen from Aristotle however, are the semantic meanings, or interpretations, of color changes on the body. Galen's methods of visual observation led to a highly technical practice of medical observation that derived meaning from small, subtle changes in skin color and other factors involved with four humours theory. Thus, in addition to 'permanent' and 'seasonal mixtures' of the humours in the body, there were also local and dynamic responses that could change the balance of the humours, such as disease, physical exertion, responses to weather, responses to anxiety, fear, anger, joy and other emotional states.

The legacy of Galen's four humours schema reflects convoluted semantic categories for colors of the body that reflected medical expertise through

[49] Ibid. 44 p86 – Isaac is quoting Galen in translation from *Airs Waters Places.*

careful examination of shifting color changes on the body, yet maintained social embedded meanings for ethnicity and skin color; and both had implied meanings that falsely misinterpreted physical and mental characteristics based on visual observation. What this movement from Aristotle to Galen's methods also indicates are the increasingly complex and technical applications for the discipline of medicine that began to emerge out of the era and adopted into Western science and medicine. Whereas the full scope of Aristotle's influence on the sciences wasn't realized for many centuries, Galen's humoral theory and medical philosophy were widely practiced, and there was a continual process of adaption for the four humours theory. For the purposes of this historical inquiry, the four humours theory serves as a central understanding for terminologies and the methodologies of skin measurement in the early 1600s when scientists found an experimental platform for measuring and describing skin using variations of linguistic matching.

2.8 The Legacy of the Four Humours Theory on the History of Skin Measurement

In 1614, the Italian physician, Santorio Santorio, attempted to measure changes in skin color along with changes in bodily fluids (See Artifact 3). He used the categorical lexicon of the four humours schema, including mixtures of black and yellow bile, as the technical method to match his observations to his semantic categories. His question, described in the work *De Statica Medicina,* was to inquire whether skin color was derived through biological inheritance (nature) or as a reaction to the environment (nurture). He attempted to record the changes in skin color when exposed to heat, and concluded that the complexion of black skin could be attributed to black bile. While his language was influenced by Galen's epistemic framework of medicine, his disciplinary purpose was a matter of causation rather than diagnosis, which aligns him with Aristotle's theoretical categorizations for the body.

In 1665 another Italian anatomist, Marcello Malpighi, continued Santorio's work by investigation the seat of color within darkly pigmented skin. He too used the terminology of the four humours to identify "black bile" as the cause of dark skin (See Artifact 6). His experiments with the skin samples of a deceased Ethiopian man resulted in him identifying the three layers of the skin - the *stratum corneum,* the *stratum basale aka,* the Malpighian layer, and the *dermis.* His visual observation led him to identify the translucent qualities of the upper and lower layers of the dermis and epidermis, with the "black bile" found entirely in the middle layer. He reported that he had discovered the source of dark skin, and speculated that the presence of black bile was a result of the established 'environmental theory' as the cause.

This era in Western science was also heavily influenced by the competing theories of monogenism and polygenism, which both drew from Christian doctrine and religious myths[50] While these religious influences were widely accepted in the various disciplinary logic of naturalists, anatomists and medicine, there was great diversity and interpretation among science professionals in how these doctrines influenced their observations. It's important to note this shift because polygenism and monogenism had an apparent effect on the language used to describe skin in scientific practices, and this offered a challenge to the four humours theory that dominated scientific views of the body. For example, in 1644, the Irish chemist and philosopher Robert Boyle, sought to put the 'environmental theories' that informed the four humours understandings of skin color into question by comparing the materiality of many different objects (See Artifact 4). He used words like black, white, tawny, olive, ash and copper to describe different complexions of skin. Even though he held the monogenist view that all men were descendants of Adam and Eve, his investigations were only partly driven by trying to explain heredity and observed skin color mixtures between different ethnicities; instead, his experiments with various chemical

[50] See Joseph Graves' "The Emperor's New Clothes" – Chapters 1-3

mixtures were used in the discussion to theorize about the pigment found between layers of the skin, and this expanded view of color explains Boyle's broader lexicon of color words for skin. As a methodology, he is still using visual observations and linguistic matching, but his nomenclature for human categories and skin are shown to be more diverse than previous investigators bound by the constraints of the four humours doctrine.

In 1646, the English polymath Thomas Browne was also wrestling between the ideas of monogenism and the four humours theory. He sought to reconcile the visual observations and reports of 'dark skinned people' by Aristotle and Greco-Roman medical writers with that of his contemporary observers. He also questioned the biblical story of Noah and his three sons that was typically used in monogenist explanations of skin color at the time, labeling it an 'improbable' theory.[51] His language reflected a wide range skin tones and colors as he described black skin in terms of lighter to darker complexions; thus his lexicon of words were shaped by visual observations that put these competing theories into question. Browne concluded that skin color could be solely attributed to a reaction to the sun, and became permanent to a person's lineage. He is also one of the earliest thinkers to use the words 'indigenous' and 'native' in the context of skin color and race, which

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[51] See Thomas Brownes's *Pseudodoxia Epidemica: Enquiries into Received Tenants and Commonly Presumed Truths.* Book 6, Chapter 10 – "On the Blackness of Negroes"pp 397-405

became a fixture in future nomenclature and discussion of climate theory and race.

The Royal Society of London had a profound effect on the disciplinary focus and scientific observation of skin. Cristina Malcolmson explains that "studies of skin color promised to consider population groups, or nations as the Royal Society put it, in order to understand the relationship between them."[52] Malcolmson claims they had an invested interest in resolving the questions brought forth by the four humours doctrine and climate theories, and to investigate the interactions between geography, heredity and skin color.[53] One noted example of this is found in a letter to The Royal Society titled "An Extract of a Letter of Mr. Lister Containing some Observations Made at Barbados" and it was published in *Philosophical Transactions* in 1675 (See Artifact 7). In this report, Mr. Lister describes an "experiment on negroes blood" that claims to refute the climate theory associated with the four humours, and instead correlate black skin with the presence of black blood.[54] This report also reflected a polygenist view of humankind, where 'blackness' was inherent to a person based on blood type (nature) and not a

[52] p9, Cristina Malcolmson *Studies of Skin Color in the Early Royal Society.* (2013) Burlington, VT: Ashgate Publishing. Print.

[53] Ibid. 52 p9

[54] "An Extract of a Letter of Mr. Lister Containing some Observations Made at Barbados" Mr. Lister. Phil. Trans. Jan. 1, 1675, 10, 399-400.

result of climate (nurture). The only backing for this claim was based on visual observations and linguistic matching between the color of blood and the color skin – with no precise language used to describe the comparison. The only color word used is 'black' in relation to 'white' skin of Europeans.

To compare this case study to another polygenist viewpoint, I would like to mention the work of geographer Francois Berneir called *A New Division of the Earth According to the Different Species or Races of Men Who Inhabit It,* published in 1684 (See Artifact 8). Berneir was a French Physician and a world traveler who came up with came up with a classification system for different 'races' based on phenotype observations, including skin color, facial features and shape. It can be inferred that he was a polygenist due to his descriptions of human groups as distinct species particular to a region. His lexicon and syntax of descriptive words for skin were very diverse and reflected multiple influences of language and descriptive categories. He used words like light, dark, very dark, sunburnt, oily, polished, olive, fair, black, brown, livid pallor, yellowishness, bright, sparkling and white, in order to describe his observations of skin. Joseph Graves contends that Berneir did not consider skin color to be adequate for racial classification, but he did correlate skin color with other phenotype qualities. Because Berneir wasn't bound to any particular climate theory (the four humours) or a theory of direct inheritance (monogenism), his language for skin color reflected a diversity of disciplinary and linguistic influences in order to describe his observations.

This era of skin color observation in the seventeenth century offers a few important insights into disciplinary logic, scientific methods and language categories of skin measurement. From these case studies, we can see how the techniques of the four humours theory and the associate lexicon of color terminology constrained the linguistic descriptions of skin observations; but as the experimentation methods became more elaborate and disciplinary influences became more diverse through widening viewpoints of monogenism and polygenism, the terminology used to describe visual observations correlate an expanding milieu of categories for 'races' of men. As mentioned in earlier chapters, racial discrimination and the placement of human groups into superior and inferior racial categories was a phenomenon that grew out of an era of imperialism and discovery, and led to the era of scientific racism and disciplinary practices of racially classifying human groups.[55] However, as the legacy of Galenic medicine and the four humours theory indicate, the practice of making hierarchical human classifications based on skin color has deep roots into Western culture and societies of antiquity. Words of skin color held significant semantic meanings for physical and mental characteristics of

[55] See Gould, Graves, Sussman and Jablonski covered in Ch.3

human subjects. Even as the 'seat' of skin color became increasingly investigated, the legacy of the four humours doctrine had a big influence as modern racial concepts began to form, and these different trajectories of language and semantic categories are an example of how cultural transmission and *The Ratchet Effect* lead to such a diverse set of human categories that Darwin addresses in the *Descent of Man.*

2.9 The Influence of Newtonian Understanding of Light and Skin Interactions

In 1704, Isaac Newton published his work on the physics of light in *Opticks*, which eventually changed the way most of the world understands light, thus changing cultural views on color. Newton's theory of light marked big changes in the way we describe the interactions of light, the environment, and our biophysical processes, and this had a great impact on the history of skin measurement and the language used to describe skin and light interactions. It was after Newton we begin to see changes in terminology of skin color. Basic color categories like black, white, brown and yellow were still used in science, but Newton's theories on the principles of light reflectance and absorbance opened up a new way of talking about how light interacts with objects, including human skin.

To exemplify how Newton's theory of light impacted the language of skin measurement, I point to a report published by The Royal Society in 1744, titled "An Essay Upon the Causes of the Different Colours of People in Different Climates" (See Artifact 10). This highly technical and detailed report is notable because the authors, John Mitchell and Peter Collinson, were not anatomists, medical doctors or traditional naturalists; they came from a specialized disciplinary background of botany. Their study was in response to the "Prize Problem" put forth by the Academy of Bourdeaux, that questioned whether climate and social modes of life are sufficient to account for skin color differences among human beings. Further, this study was in response to the larger inquiry set by the Royal Society that desired to explain 'dark skin.' As the author's stated in the introduction to the study, it was an "enquiry into the strange phenomenon on nature – the cause of the Colour of Negroes."[56] They still relied on the method of linguistic matching and visual observation, but Mitchell and Collinson were working from an entirely different terminology for skin based on Newton's doctrine of light and contemporary understandings of human anatomy, and more sophisticated techniques of comparative anatomy that used measurements of skin thickness, observed the opacity capabilities of dark and light skin and also made theoretical calculations of skin pores in different types of pigmented

[56] p102. John Mitchell and Peter Collinson. "An Essay upon the Causes of the Different Colours of People in Different Climates" (January, 1744) *Phil. Trans.* 1744-1745. Vol.43, pp102-150

skin.

The language used to describe skin in this report is put into terms of both anatomy and light reflectance. Skin is described by the redness and blueness of blood changes, its epidermal layers that reflecting rays of light, its color of "juices" such as the yellowness of jaundiced skin, and additionally they describe the "skin of negroes" as thicker, coarser, dryer. These observations are also put into direct antithesis to Malpighi's argument for the discovery of 'black bile' and the four humours doctrine.[57] The authors explain the whiteness and blackness of skin according to Newton's "Doctrine of Light and Colors" and claim that it refutes the four humor theory because the actual reflected colors of the pigments were found to be more red, yellow or brown, which rules out the "black fluid" or black bile theory. Within this discussion of light exposure and skin, the authors also address how cultural habits may result in more or less exposure to sun light, and how this may effect skin color along with hot/cold and environmental adaptions. Therefore, while the authors are discussing the fixed structure of skin thickness, 'colored fluids' and skin color changes (nature), they also maintain the language of ethnic categories of like Negro, European, Indian and Moors which are correlated to long term exposure and cultural habits that influence

[57] Ibid. 56. p115.

complexion within human groups (nurture).

In their conclusion, Mitchell and Collinson use color terminology related to both ethnic types and structural anatomy in order to explain their observations. They use color categories like black, white, yellow, red, tawny and copper, along with ethnic categorizations like Indians, Egyptians, Mullatos, Moors, Negroes, and "White" Europeans; yet, these terms seem to be a function of communicating new and unfamiliar sets of scientific descriptions based on understandings of physics, anatomy and interactions of light and skin. Words such as reflection, absorption, refraction, transmission, light rays, thickness and density all reflect new understandings of physics while the authors still relied on more familiar syntax and semantic meanings in order to describe the appearance of skin colour and complexions based on traditional categories and causes.

Several key factors make this report by Mitchell and Collinson a real anomaly in the context of this history on skin measurement. Even though they were still bound to a disciplinary method of linguistic matching visually observed colors to a set of propositional categories, they were using both mathematics and the technology of microscopes to calculate and describe the dimensions of the skin layers as well as the structural conditions they were observing. Additionally, their diversity as scientific observers were not bound to the traditions of scientific disciplines like anatomy, medicine or natural philosophy; instead, they were working under the logic and methodology that considered skin just as they would any other organic material, with properties unique to itself, but also similar to other organic material in how it responded to light. Lastly, their disciplinary commitments led them to combine the language of Newton's descriptions of light and color with the interactions light had with the complex medium of skin layers, pigments and blood. And it is this insight that allowed their observations to take on more sophisticated psychical descriptions and separate skin color from the semantic meanings that reflected permanent psychological and behavioral implications that were attached to skin through traditions of the four humours doctrine, monogenism and polygenism.

On the other hand, the authors offer a synthesis to the monogenism view at the end of their report. They reason that it is implausible that mankind descended from either a very dark or very light skinned group of humans, but speculated that mankind descended from a 'medium' shade described as 'tawny.'[58] From their observations, they then attempt to reconcile the 'descendants of Noah myth' with the reports of modern geographers that noted skin colors of different human groups in different regions, and this includes a serious discussion of cultural habits and

[58] Ibid. 56. p147

behaviors that expose some groups to the environmental sunlight more than others. They reason that the absence of sunlight and social activity in the sun is also a major contributing factor the inherited "shade" or skin tone within a group of people. Therefore, they argue against the hierarchy in the tradition of monogenism that sets "white skin" as the original color of mankind and reduces all other skin tones to a degeneration of a pure "form."[59] Thus, this case study not only shows how Newton's theory of light and color began to have a profound narrowing effect on the language that scientists used to understand and describe skin and skin color, but it also demonstrates an increasingly interdisciplinary logic that complicates conclusions and discussion in the scientific reporting. Still, the overall purpose for this study is a result of a scientific enterprise that identified groups of people marked by 'dark skin' and held an underlying Eurocentric assumption that demanded human groups be explained in relation to Caucasians.

2.10 Conclusions About the Changing Language for Skin and Human Categories

When Darwin wrote about his 'young naturalist' in the Descent of Man, he was targeting his own traditions and disciplinary logic that had

[59] Ibid. 56 pp

traditionally classified mankind in to separate 'kinds' or 'races.' Darwin was clear to note the uncertainty and the lack of knowledge surrounding the causes of skin color variations that had traditionally stood for evidence of racial classifications in the scientific thinking of his day. Even while hypothesizing about the mechanisms of evolution and natural selection that could explain human variation, he was careful to mention there was not enough evidence to conclude either environmental climate theories or inherent "constitutional properties" of skin as the cause for human skin color diversity, although the evidence pointed that climate adaption played some role in the biological inheritance of skin color.[60] While we can read Darwin's argument in this passage as a change in direction for the natural sciences, we can also read this argument as a rebuttal of the diverse semantic categories for human skin color and human classifications brought about by the disciplinary commitments and social belief systems of observers. As Darwin addresses in this text, monogenism and polygenism, in a traditional sense, failed to explain the observations made of the knowable world; thus, it is not a coincidence that Darwin's argument begins with a focus on the nomenclature and language of human categorization rather than specific methods and techniques of measurement. The language of categorization was

[60] Ibid. 1. p236.

rooted in a socially embedded syntax with assumed semantic meanings anchored in Western understandings of humankind.

Eventually, Darwin's theory of natural selection, Newton's theory of light, along with advanced understandings of human anatomy and chemistry, had a profound effect on the way scientific observers categorized and described skin (See Artifact 25). But as Darwin cogently pointed out, the correlation and causation of skin color differences remained an open question. As a result, much of the linguistic descriptions of the four humors theory and outdated understanding of 'races' and 'race mixtures' remained in the discussions of human skin measurement with the added assumption that skin color was an adequate marker for human categorization.

In summation, what I hope to demonstrate with these examples from the era of visual observation and linguistic matching is the that delineation of our biological and cultural inheritance is a slow and still ongoing process, and this is a fact not realized throughout most of the history of Western science. Instead, we can see how *The Ratchet Effect* of rapid cultural learning and transmission can influence a scientific observer, the practices of an entire discipline and the understandings that comes from these activities. Through the view of modern linguistics and inquiry into how and why we form linguistic categories helps us understand the misinterpretations of nature and biology that plagued the Western tradition of medicine, anatomy. and natural philosophy. In spite of the complex techniques used in the observation of skin, we can see how disciplinary commitments and fixed semantic meanings conflated biological and cultural inheritance. It's for this reason that I have introduced several interdisciplinary perspectives that help contextualize visual observation and linguistic categorization, for these proto-methods and technical systems are still with us and part of our traditions today.

Our evolutional history, in part, explains the way we observe the world visually under the constraints of our biology. Our cultural history infers that visual language and social investments in color technology have also been a part of human culture since the beginning. One could describe this contextualized approach to history as teleological, because in fact I am reading history through modern understandings of science, technology and culture. The purpose here is to use scientific knowledge to better understand the thinking and rationalizations of scientific practices and uses of measurement technologies throughout history. Consequently, this history can also be greatly informed by diverse understandings of human nature from across disciplines and offer a way to understand our language through propositional logic and our shared capacities for symbolic language.

Chapter 3:

Skin Color, "Race" and Technology: Re-articulating a Murky Narrative

"There is no topic more illustrative of human history than skin color. It unites us in evolution and divides us by walls of bias and stereotype. It invites us to learn about the life and times of our distant ancestors and taunts us with evidence of the psychological manipulation of modern people. Human beings are highly visually oriented and suggestible primates, ever willing to accede to the beliefs of people who have power over us and ever able to change our behavior."

Nina Jablonski – "Living Color" (2012)

3.1 The First Skin Color Chromatic Scale and the Development of Visual Matching

In the late 1800s, one of the leading German anthropologists, Felix von Luschan, developed a set of 36 glass tiles of different colors that represented the entire range of variation in human skin pigmentation. In what became known as the Von Luschan Chromatic Scale, this set of colored tiles became the standard technological system for recording skin color data for the field research of anthropologists until the 1950s.[1] The typical method in which the

[1] Swiatoniowski *et al.* (2013) "Technical Note: Comparing von Luschan Skin Color Tiles and Modern Spectrophotometry for Measuring Human Skin Pigmentation" – As Swiatoniowski et al. notes, this system was originally called "*Hautfarbertafel,* meaning skin color board or tablet."

the tiles were used was to 'visually match' a subject's skin tone on the forehead, the inner arm and the back of the hands to a correlating tile, and then calculate the mean in order to determine a general skin "color" that was then recorded with other biometric data from the human subject. However, as physical anthropologist Nina Jablonski states, "color matching methods were better than verbal descriptions, but they were still not satisfactory because [the results] could not be easily reproduced."[2] The issue Jablonski refers to here is the biological constraints placed on color technologies that rely on the subjective visual matching. Because of individual variations in human color vision (the observer), variations in environmental lighting conditions (the situation), and variations in the psychical properties that reflect light from the human body (the object), visual matching methods using von Luschan's Chromatic Scale were limited compared to the more precise measurement techniques of reflectance spectrophotometry that replaced it in the mid twentieth century. However, what these tiles did add to the practice of measuring skin color is an objective standard on which to compare visual information. In this case the information was human skin color and it was for

[2] Bradley (2009) "Colour and Meaning in Ancient Rome"– The 'four humors' schema for reading the body is very much a system relying on verbal description and a taxonomy of words used to describe the visual information that the physician sees. Bradley has an in depth review of these words derived by physicians in the Hippocratic tradition in Rome, and as he keenly observed, this taxonomy uses metaphor to describe both 'natural' and 'unnatural' colors of the body, with positive and negative connotations.

the purpose of placing the human subject on a scale of known skin pigmentations of human beings. The placement of all varieties of human skin colors onto a single chromatic scale was no small matter for Felix von Luschan; in fact, it was a color technology built according to his belief in a single universal category for human beings, in a time of rapidly changing empirical and social views on what it meant to be a human being. Thus, the first chromatic scale for measuring skin was as much a social statement in support of a single "racial" category as it was an effective way to correlate human skin tones and environmental factors.

In many ways, this rudimentary technology was antithetical to conventional viewpoints and practices in anthropology at the time. In late nineteenth century Germany, the discipline of *Anthropoligie* was focused on a physical anthropology "concerned with the classification of human psychical forms and the systematic study of the origin of the human species."[3] [4] Felix

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[3] Sussman (2014) "The Myth of Race" – Sussman notes that Kant introduced the term *Anthropolgie* to German science, and also points out the paradox that he was highly influential for his moral philosophy, while he is also attributed by many for introducing our modern concept of "race" and "scientific racism." Kant based his racial classifications on color and climate, and in his philosophy, tried to make them correspond to intellectual ability, with affixed moral limitations; he created a dichotomy between "whites" who can educate themselves, and thus have free-will, and "blacks" who are dependent on other races for their education, and thus are denied free-will (27-28). This notion is also supported Evan's "Anthropology at War" (p 2).

[4] It is also important to note that Kant uses his own version of the four humours doctrine to justify making classifications between human types based on a science he calls *physiognomy* – which he claims allows one to make classification based on

von Luschan, as an advocate for physical Anthropology, argued as early as 1882 against the dominate viewpoint of many anthropologists at the time that there were separate 'kinds' or 'subspecies' of human beings; instead, von Luschan promoted the idea that man was one species and that "members of 'primitive' races were not necessarily inferior to members of supposedly civilized races.[5] It was during this time in his career that von Luschan traveled throughout Western Asia conducting anthropological fieldwork and working as a physician, where he purportedly developed his chromatic scale and system for measuring skin color; consequently, he also shaped many of his views on race, ethnicity and culture during this time as well.[6] By 1905, von Luschan's tiles were widely adopted into the field research for anthropology and was considered "a great advance on anything hitherto

visual biomarkers, but only after inductively deciding if one's outward characteristics (including color), like facial expressions, gestures, emotions, are derived from 'imitation' or a mix of natural disposition and 'education' which denotes freewill. (For a fuller explanation see Part II of Kant's "Anthropology from a Pragmatic Point of View" and then compare to Sussman's assessment of Kant pp 27-30) It seems there is a teleological order to the way Kant uses the four humours as a

visual heuristic for judging inner states, which is only after an 'inferior' or 'superior' racial classification has been determined.

[5] Qtd in Smith p24

[6] Smith (p 25) notes that von Luschan publicly repudiated anti-Semitism by establishing a connection between Jewish and Aryan ancestries. He also forged a relationship with Franz Boas during this time period, who putatively had a big influence on von Luschan's views on distinguishing between the biological and cultural influence on human behaviors.

available" for measuring skin pigmentation, "European or otherwise."[7] In 1911, von Luschan participated in First Universal Race Congress, which was a gathering of scientists from across the world to discuss the improvement of race relations. In his address, he stated:

> We now know that colour of skin and hair is only the effect of environment, and that we are fair only because our ancestors lived thousands, or probably tens of thousands, of years in sunless and foggy countries. Fairness is nothing else but a lack of pigment, and our ancestors lost part of their pigment because they did not need it.
>
> "Universal Race Congress"[8]

These comments by von Luschan on the topic of skin color coincided with his very public position and empirical views on the "unity of mankind" showing his respect for the separation between physiological and psychological differences. Although von Luschan never stated his thoughts on the biological importance of skin color (other than to say it was an evolved adaption to the environment), he did not view skin pigment as a marker for 'good' or 'bad'

[7] Qtd in Thomas.
[8] P14 "Papers on Inter-Racial Problems" ed. George Spiller

qualities of heredity.[9] In fact, in 1915 von Luschan spent several months touring and speaking at American universities through the southeast. During this time he conducted research on American populations that included recording skin colour, determining that "up to 75% of the 4,000 children he studied came from mixed African American ancestry."[10] After his American tour, von Luschan wrote several public rebuttals of racist American medical doctors that he described as "so-called anthropologists" who added "next to nothing of value on the race question, and of real science less than nothing."[11] Therefore, von Luschan's chromatic scale was repeatedly used as an empirically applied technology to combat lingering biological myths of 'racial kinds' or 'inferior people' based on skin color.

As some have noted however, there was an ambiguity to this technique, because it allowed those within the institution of anthropology to make 'racial' classifications based on the scale as well, at a time where "race" and "ethnic" mixing was being discussed. Consequently, many who have

[9] I make this inference due to his public statements on "racial" mixing as nothing nothing to cause alarm. He often referenced the "mullato" as a person who was visibly identifiable as a mixed ethnicity, but that is had no bearing on "their moral intelligence or social value" (qtd. in Smith 35).

[10] Qtd in Smith p36

[11] Qtd in Smith p32 -von Luschan refers specifically to W.B Smith's "The Color Line"(1905) and Robert Schufeldt's "America's Greatest The Negro" (1915). Both advocate for racial anti-mixing and purity laws, as well as racial purity and eugenics.

researched this era of anthropology have portrayed von Luschan as a racist because his chromatic scale was also used to "separate races taxonomically by color".[12] This stance is further corroborated by von Luschan's political commitment to Social Darwinism, as he often throughout his career took positions on "creating reserves" for indigenous peoples; and after visiting America, he lamented African Americans as the 'negro problem' and advocated for 'racial hygiene' movement that would "improve" America's black population "in terms of health, morals, and intellect."[13] As elitist and dehumanizing as this position was, it has been noted that von Luschan repeatedly throughout his career advocated that "language, religion, nationality and race" were quite distinct conceptions that the general public often confused.[14] Therefore, von Luschan's notions of Social Darwinism were rooted in cultural heredity, not environmental factors. He advocated that there were "criminals and persons with inferior morality and inferior intellect in every human group, white and colored; but we shall sooner or later learn to eliminate them."[15] In one of his speeches to American students, he even suggested for them "to control the destinies of their future offspring by careful selection mates. Indeed, you must make Eugenic doctrines part of

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[12] Smith p20

[13] Qtd in Smith pp 26-35

[14] Smith p 30

[15] Von Luschan, Felix "Review of America's Greatest Problem: The Negro" *American Anthropologist.* p 574

your religious creed".[16] Consequently, it is statements like this that ultimately cast a shadow on Felix von Luschan's empirical stances on anti-racist science, and offer up some interesting questions about the instrumental use of his skin color measurement technology. Perhaps American sociologist and civil rights activist W.E. Dubois summed up Felix von Luschan the best after listening to his speech at the First Universal Race Congress – While praising him for giving hope to a scientifically supported view of equality in all men, he was equally frightened by von Luschan's insistence that nations protect their "vital interests…with blood and iron."[17]

One could claim that Felix von Luschan was ahead of his time in advocating for a scientific view for the "unity of man" which was reflected in the design of his chromatic scale, but his commitment to nationalist concerns is not distinguishable from his advocacy for Social Darwinism as an anthropologist. To elaborate on what could have frightened Dubois in his speech at the 'race congress', von Luschan also said "racial barriers will never cease to exist, and if ever they should show a tendency to disappear it will certainly be better to preserve than to obliterate them…The brotherhood of man is a good thing, but the struggle for life is a far better one…As long as

[16] Qtd in Smith p 34
[17] Smith p 37

man is not born with wings, like the angels, he will remain subject to the eternal laws of nature."[18]

How and should this change the way we view his chromatic scale for skin measurement? Does Felix von Luschan's actions and statements justifying the cultural and social determinism of racial boundaries undermine von Luschan's career long commitment to a universal view of mankind? Is his acquiescence to the preserve 'social categories' of race only to determine them to the eternal "laws of nature" just another kind of biological determinism?

Since von Luschan died in 1924, he was spared the full realization of Social Darwinism and National Socialism when the Nazis rose to power pre-World War II; but based on his statements, we can't help but conclude that von Luschan was aware of the violent ramifications of his position, and that his view that the technological dominate social groups are just instrumental shortcut for nature. Still, the Von Luschan Chromatic Scale was used as a skin color measurement system for decades in physical anthropology and even in more specialized medical applications like dermatology. This technology found a use outside of just recording of anthropometric data, but the classification of skin type by color, and the problems of visual matching remained part of the technology, thus it disserves a deeper inquiry as a

[18] "Papers on Inter-Racial Problems" ed. George Spiller. p 24

technology that marked a significant change in the way science viewed human skin.

In the following sections, I will examine the technology of von Luschan's chromatic scale by first offering a historical context for a few of the social and systemic conditions regarding "race" under which the technology was produced, including the ethics behind technologies designed for the purpose of determining the 'racial classification' of human beings. I will then suggest ways that this system works and doesn't work as a functional color technology in light of today's skin color measurement systems. Finally, I will demonstrate how this visual technology works within the epistemology of science, as his 'skin measurement technology' was repurposed under new technologies.

3.2 Looking Back: A Review on Modern Views of the "Race" Concept in Science at The Turn of the Twentieth Century

In his book *Mismeasure of Man,* Stephen J. Gould's main focus is on the macro social and political uses of the *biological determinism* argument for racial categorization, as an enterprise that has effects on the cultural or interpersonal micro levels. As a way of defining his terminology, he claims that biological determinism "holds that shared behavioral norms, and the social and economic differences between human groups - primarily races, classes, and sexes - arise from inherited, inborn distinctions and that society, in this sense, is an accurate reflection of biology."[19] This definition is also supported by his many examples of biological determinism argument being used in man made bio-political and socio-economic contexts that support scientific racism. More specifically, Gould turns his attention towards scientists, those who claim to be scientists, and the practitioners in the science lab. Gould describes science as a "socially imbedded activity" in which "facts are not pure and unsullied bits of information"; instead, since culture influences what we see and how we see it, theories are not just "inexorable inductions" from facts. However, Gould criticizes culturally relativistic claims that "scientific change only reflects the modification of social contexts, that truth is meaningless, and that science cannot provide enduring answers." He states clearly: " A factual reality exists and that science, though often in an obtuse and erratic manner, can learn about it" (835). Here, Gould is clearly carving out his position as a practitioner of positive science who doesn't fully accept the enlightenment ideals that science is an objective enterprise, and "free from social and political taint".[20]

Developing this position is important to Gould's *ethos* as a credible scientist struggling to undo the antithesis created in the usual public discussions on evolution and eugenics. He frames this discussion as the

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[19] Stephen J. Gould. *Mismeasure of Man.* Kindle loc. 798

[20] Gould 799

"determinists" versus the "anti-determinists" debate. Although he doesn't deny these positions exists, Gould is careful not to enter the discussion through moral accusation. Therefore, Gould isn't out to contrast "evil determinists" from "enlightened anti determinists"; he says, rather, "I criticize the myth that science is an objective enterprise, done properly only when scientists can shuck the constraints of their culture and view the world as it really is." (835) Simply put, Gould is addressing scientific weaknesses and its relation to political contexts. The antithesis Gould refers to is brought about by the fact that "new" scientific discovery often has enormous social importance, and the information that supports is often just a small amount of reliable information. Further, he argues, "since biological determinism possesses such evident utility for groups in power, one might be excused for suspecting that it also arises in a political context[21]"

So, what is Gould saying here? There seems to be a two parts to his position that 1) a factual, objective reality exists and science can "know" about it, and 2) science is socially embedded, therefore is influenced by political and economic forces, among other things. Gould recognizes this paradox and craftily builds it in as a secondary argument to his thesis. He says:

[21] Gould 799

> Science cannot escape its curious dialectic. Embedded in surrounding culture, it can, nonetheless, be a powerful agent for questioning and even overturning the assumptions that nurture it. Science can provide information to reduce the ratio of data to social importance. Scientists can struggle to identify the cultural assumptions of their trade and to ask how answers might be formulated under different assertions. Scientists can propose creative theories that force startled colleagues to confront unquestioned procedures. But science's potential as an instrument for identifying the cultural constraints upon it cannot be fully realized until scientists give up the twin myths of objectivity and inexorable march toward truth. One must, indeed, locate the beam in one's own eye before interpreting correctly the pervasive motes in everybody else's. The beams can then become facilitators, rather than impediments.[22]

This illuminating passage defines Science as an important social practice because it tethers rhetoric and praxis, as socially embedded activities, to "the scientist" in a non-pathologizing way. However, this rhetorical 'move' of

[22] Gould 860

induction shouldn't be construed as a disembodied Cartesian dualism; nor is Gould suggesting that the explanatory power of science is found only when the individual scientist rationalizes a correct interpretation. Contrarily, Gould is suggesting here that a rationalization of a scientific theory is often influenced by the dominant myths of a particular culture or society – in this case, the "twin myths of objectivity and the inexorable march towards truth".[23] Thus, Gould critiques the deterministic positions of certain scientists as a matter of implicit bias, reflecting an uncritical acceptance of cultural myths that impede science from being "an instrument for identifying the cultural constraints upon it" (860). For Gould, this assertion suggests that a scientific praxis that doesn't locate itself as a socially embedded activity, will fail to see its error.

For von Luschan's era of Anthropology, the "new science" was Darwin's theory of natural selection. Gould says Darwin's theory "swept away the creationist rug that supported intense debate between monogenists and polygenists, but satisfied both sides by presenting an even better rationale for shared racism" (1673). Before Darwin, there were two general camps of science to explain racial categories: 1) Monogenism – which is that all mankind came from a single source, and then "degenerated into different

[23] Gould 860

types of man. [24] 2) Polygenism – which categorized humans as separate species with separate origins, nature, intellectual abilities.[25] After Darwin, the racial science didn't go away, but only became more entrenched as old ideas of monogenism and polygenism were formed in an "unholy alliance" of evolution and quantification.[26] Thus, von Luschan's persistence to collect anthropometric data of both skin color, along with cranial measurements, can be viewed as an activity supported by a system that emphasized rigorous measurement as the pinnacle of objectivity. The data collected from his chromatic scale, which supported of his views on monogenism, did little in the way of erasing the boundaries of racism as a social category, and as a new racial science formed under the auspices of evolution, more precise measurements of skin color meant more "objective" feedback data for eugenicists unwilling to examine their own cultural assumptions. Von Luschan himself may have never used his data to argue for social distinctions, but the activity system of anthropologists that had access to his technology did, and theory of monogenism supported by the more nascent and incomplete theory of evolution, provided little buffer against bias.

[24] Monogenism is typically modeled after the 'descent of Adam narrative' from the Christian creation story

[25] Polygenism is typically modeled after the Great Chain of Being introduced by the Greeks and later developed by Aquinas

[26] Gould 1676

Evolutionary biologist Joseph Graves offers a slightly different approach to racial science after Darwin, noting the irony that the modern scientific views "race" as a biological myth, while remaining a social reality.[27] As he points out, "race implies the existence of some nontrivial underlying heredity features shared by a group of people and not present in other groups".[28] He argues from the evidenced-based standpoint of modern genetics, stating: "there is more genetic variability in one tribe of East African chimpanzees than in the entire human species!."[29] Further, all the physical features used to distinguish between "races" of men – skin color, hair type, body stature, blood groups, presence of disease – can be tested for correspondence to the supposed 'racial groups' that society has constructed, and no evidence has confirmed biologically different races.[30] Simply put, biological races do not exist. Therefore, Graves concludes that only a political and racially stratified society could hold our ideas of race together for as long as they have; but to understand this "ideology" of racism, one has to "understand the history of racial anthropology".[31]

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[27] Joseph Graves *The Emperor's New Clothes: Biographical Theories of Race at the Millennium* p9

[28] Ibid. p5

[29] Ibid. p9

[30] Ibid.. 5

[31] Ibid.. 7

In an interesting comparative study of beliefs among scientists about the putative category of the "negro race", Graves compares a selection of naturalists from the eighteenth century, before Darwin, and a group from the nineteenth century coinciding with Darwin. The eighteenth century naturalists varied in their beliefs of 'inferior' and 'superior' people, but despite the persistence of creating hierarchy, "they saw all races as members of the human species" and generally relied on the idea of 'heritable' physical traits.[32] One representative of this era, Carl Linnaeus, was the founder of the classification system we still use today, and in 1758 he placed a hierarchy of humans being (Europeans, Africans, Asians, Americans) onto his classification chart. As Graves points out, just the very presence of this classification system meant that naturalists invented ways in which to organize hierarchies of human beings within the systems by choosing methods of distinguishing between groups. This is the era when physical differences between humans began to be measured 'scientifically' as a way of institutionally classifying species and subspecies – often, human classification was determined by skin color and cranial size.[33] However, Graves contends that biological 'theories' are usually reflected in the

[32] Ibid.. 43

[33] Ibid.. p40. Graves attributes Petrus Camper (1722-1789) as the first to measure skulls of different animals and compare them in a systematic way that inferred significance for 'taxonomic importance' (40).

structure of classification systems, thus monogenism was reflected in Linnaeus's *Systema Naturae,* but the scientific developments that made fluid biological classifications reasonable did not originate until the nineteenth century and "were perfected in the twentieth century".[34]

There was an identifiable social shift reflected in the scientific views on "race" in the nineteenth century, as it saw "a resurgence polygenists thinking, particularly in the United States."[35] According to Graves's study, these nineteenth century naturalists still falsely examined different physical traits to determine 'race', but more of these scientists placed the 'negro race' as inferior to Europeans, and determined them to be an entirely separate species"; additionally, this brand of polygenism denied that the environment was a factor in determining "racial categories.[36] Again, just as Gould contends, these "beliefs" are correlated to an increase in biometric measurements used as evidence for polygenic theories; however, Graves's study reveals that polygenists relied more heavily on cranial measurements rather than skin color measurement. This move also correlates a 'paradigm shift' within science to study human intelligence.[37] Even with the lack of emphasis on systematic color measurement to classify human types, skin

[34] Ibid.. 38
[35] Ibid.. 43
[36] Ibid.. 44
[37] An assessment covered by Sussman (2014), Evans (2010) and Graves (2000).

color played a significant role in the public arguments against 'racial mixing' in this era. Graves reports that American Eugenicists, Morton and Agassiz, had visceral reactions to "negroes" that was "undoubtedly motivation for their polygenists leanings".[38] That 'God' created separate species of human played heavily into their political stances that used 'racist science' to support segregation and laws against inter-breeding between 'races.' It makes sense, then, that a chromatic scale for skin color wasn't necessary in this era of racial science – the fact that 'racial mixing' produced unique skin tones presented a problem for polygenists; whereas more objective cranial measurements were found to be a better choice for the empirical rationalization of racism.

Historian of science, Robert Sussman, makes a similar assessment as Graves and Gould about the biological myth of race, while acknowledging its social reality. For an example, Sussman cites the latest research on skin color variation distributed across the globe; since skin color is a result of exposure of solar radiation on a population over a long period of time, and since many of the other genetics traits in the same populations are not similar (like hair and eye color), then different genes and genetic pathways can be studied in what is called convergent and divergent evolution: "Our genes have been

[38] Ibid.. 44

mixing since we evolved" Sussman contends, "and our genetic structure looks more like a complex, intermixed trellis than a simple candelabra" [39] Yet, these social categories of 'race' based on ethnography and/or phenotype remain. Like Graves, Sussman emphasizes "the shift from geography to a hierarchical ordering of human diversity" as a moment that aided the institutionalized ideas of 'scientific racism' into Western science. But, he demonstrates how arrangement of identifiable 'types' of human beings into a hierarchical order turned "Linnaean cartography to linear ranking by putative worth".[40]

The German anthropologist Johan Friedrich Blumenbach (1752-1840) is an important figure in this unfortunate direction as well, as it was his classification of humans into a 'five-race scheme' that became the foundational taxonomy for cranial measurements that were widely used later for justification of 'racial sciences'. His schema of different types of man: Caucasian, American Indian, Malay, Oriental and African also became coded by skin color – white, red, brown, yellow and black, respectively. As Graves

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[39] p 4 Sussman says that to look at 'race' as a scientist, it means determining the "racial category" as a subspecies by way of genetic and morphological differences through barriers in mating, "with little or no genetic exchange over a long period of time, thus giving individuals within a population a common and separate

evolutionary history"(6). Given the evidence, none of the classic claims of biological races hold up against the tests of molecular genetics.

[40] Sussman p 20

notes, Blumenbach was a naturalist in the 'monogenism' camp that sought geographic and environmental factors for these differences. However, as Sussman argues, placing these geographically different human 'types' into a hierarchical scheme (with Caucasian/white on the top and African/black on the bottom) set into place a 'degeneration' theory of scientific racism that continued and grew stronger as monogenism found support from Darwin's theory of natural selection.[41] 'Degeneration Theory', then, later became part of the justifications for 'Regeneration Theories', or in other words, theories of positive eugenics, racial hygiene, racial purity and Social Darwinism movements.[42] By the time of The First Universal Races Congress in 1911, both polygenists and monogenists had been developing empirical systems to support their racial theories, based on a mixture old Western ideas of 'race' going back to Greco-Roman thinkers and an incomplete understanding of Darwin's theory of evolution; and, it is within this framework of 'racial science' that Felix von Luschan produced his Chromatic Scale to measure skin color. As Sussman suggests, this mixture of different perspectives gave an 'aura of wide acceptance' to the goals of Eugenicists that eventually

[41] The most widely repeated narrative of 'degeneration theory' that placed Caucasians on top of the hierarchical chain, then, assumes that white men represents the 'original creation' in the Christian creation story of Adam in 'Garden of Eden' – with separate lines of degenerating descent from a more 'pure' form of human being.

[42] Covered in Sussman pp 20-63

institutionalized selective breeding, sterilization, castration and testing for intelligence between racial and ethnic groups; additionally, this happened in spite of the debates over monogenism and polygenism for both of these ideas found empirical support, including the measurement of skin color.[43]

3.3 The Pragmatic Ethics of Technological Inquiry

Given the historical context of Von Luschan Chromatic Scale, it is easy to see how a modern scholar of science and technology can overlook a system for measuring skin color is arguably the worst era in the history of institutionalized scientific racism. As demonstrated and argued by Gould, Graves and Sussman, science eventually found its correcting mechanism toward identifying racism. Biological Racism is a myth, and is recognized as such by scientific consensus. The same cannot be said for today's wider social setting. Confusion lingers and often remains a taboo in public discussion on the relationship between science and racism. Eugenics and Social Darwinism are condemned (or shunned), as they should be, but this also is to the detriment of a discussion of the sciences that study 'mankind.' I think that is why the 'mantra' of this chapter – "Race is a biological myth but remains a social reality" – is so important to repeat. Recognition of the murky past regarding scientific racism is vitally important to informed public discussions

[43] Sussman p63

of race and racism, of which modern science has a lot to say about its logical coherence based on evidence.

Physical anthropologist, Nina Jablonski, takes this dual premise of racial myths/realities the basis for her groundbreaking work on the evolution of human skin color. Because “skin color has been the primary characteristic used to assign people to different races,” Jablonski states, “the association of color with character and the ranking of people according to color stands out as humanity’s most momentous logical fallacy.”[44] Thus, much of her work as a public figure in science is to show recognition of the “social ramifications” of categorizing social groups by skin color, both past and present, embedded within science and beyond. I argue that in order for Jablonski to advance skin diagnostic technology forward using the biological data collected with the Chromatic Skin Color Scale, her work needed to recognize the murky history of skin classification in anthropology in order to clarify its use.

As stated earlier, Jablonski describes the movement from early color classification systems (such as a the four humours heuristic) that relied on verbal description to more slightly more advanced systems that used visual matching to measure skin color to a color standard. Eventually, these visual matching systems gave way to modern *reflectance spectrometry*.[45] Skin

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[44] Nina Jablonski “Living Color” p4

[45] Ibid. Jablonski cites Nigel Barnicot as the first to compare averages in skin color using a spectrometer in

reflectometry works by reflecting light off of skin through a series of different colored filters. Once the percentages are calculated, a researcher can then determine the precise wavelength of light for the particular patch of skin measured. Different systems built for more precise measurement have evolved over time, but the basic measurement standard of the electromagnetic spectrum has allowed new measurement techniques and technologies to emerge over time, and as a visual heuristic for measuring skin, we can now describe the technological shift from *verbal description*, to *visual matching* to *quantification* of light waves.

Jablonski has also found von Luschan's chromatic data to be quite useful for her field research into the study of human skin evolution and the evolutionary mechanisms by which they have evolved.[46] Jablonski's research team conducted a series of tests on the original brick tiles of the Von Luschan Chromatic Scale using a skin color relfectometer; they were then able to build a conversation chart in which to read historical data collected using the von Luschan tiles.[47] Using this method, Jablonski was able to survey human skin skin color from populations all over the world dating back to the late nineteenth centruy with an accuracy rate of 90% compared to modern

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1958; however, this history of the spectrometer and its application is the subject of study in the
later half of this chapter (18).

[46] Jablonski "Skin" (2004) p 615

[47] Swiatoniowski et al. p. 327

reflectometry devices; thus, this allowed Jablonski to create a map of human skin color variation from before wide-spread globalization and compare it to todays data, which in turn allowed her to test and refine hypotheses about the evolution of skin pigmentation.”[48] This allowed Jablonski and others to empirically establish the correlation between human skin color as a local environmental adaption in human populations to the presence of ultra-violet radiation, which has been described as “bringing clarity to a confused field.”[49] field.”[49] Jablonski and Chaplin’s research not only corroborated the genetic and fossil records for the “out of Africa” theory of how *homo sapiens* dispersed across the globe from a tropical environment, it offered a refinement to Darwin’s theory of how human’s developed different skin types, which he thought was primarily through sexual selection. Jablonski and Chaplin’s work established that it was primarily through intense natural selection that produced different gradients of skin tone in human populations throughout the globe.[50]

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[48] Swiatoniowski et al. p. 329

[49] Jared Diamond (2005)

[50] Jablonski and Chaplin. pp 8863. This research from Jablonski and Chaplin is part of an interdisciplinary effort that assesses research only available from breakthroughs in genetics and UV light research and its effects on human skin. This has produced new ideas on the photosynthesis of vitamin in the human body, and established vitamin d as a selective force in the evolution of skin pigmentation. This study has also proven useful to explain more of the puzzle of human variation and adaption to new environments as *homo sapiens* migrated out of Africa.

Felix von Luschan's chromatic scale plays only a small but important role in this research that has helped fill in the evolutionary narrative of a single human race, supported by modern science. One could say this technology continues to support the monogenists' theory of evolution, and supports the environmental factor for skin color differences as well; however, it no longer supports the social hierarchies based on phenotype that is at the heart of scientific racism. Nina Jablonski's work is not to classify human groups, but instead explains the wide variety of human variation through evolution, and this is important because our unique skin pigments and its relation to the type of UVR light we are exposed to in our everyday environments play a crucial role in our overall health. The data collected with von Luschan's tiles was re-purposed for a different use, more positive use.

This case also speaks to an important ethical component in the application of technology that also helps address the duality of race as a both a myth and reality. As Carl Mitcham explains, pragmatists have long identified technology as neither "evil" nor "neutral or value free" as both determinist and antideterminist positions have caste it at times.[51] Instead, Mitcham cites John Dewey's description of technology as an "intellectual tool employed in experimental operations for the solution of the problem which

[51] Carl Mitcham. "Thinking Through Technology" p 71

arise in experience", which means that application of a technology is always an application within a socially embedded system of activity that shapes the overall experience.[52] In technical applications, the idea of instrumentality or use-value becomes a way to examine a technology. As Mitcham suggests, since science usually provides a clear pattern of thinking for applying a technology, then judging it's instrumental function is a way to examine a technology across the theory/practice boundaries – which some say reduces technology only to its functionalism, which is another form of determinism that promotes 'neutrality.'[53] However, as Dewey has responded to critics of functionalism, they "presume the existence of a sharp line between organism and environment…but for the purposes of inquiry, the skin is not a very good indicator of where the organism stops and the environment begins."[54] In contrast to the deterministic view, Dewey's articulation of technology as a mode of inquiry upends the notion of technological determinism because it is submitted to an epistemological framework that relies on uncertainty and cohesiveness rather than establishing monolithic knowledge.

What I interpret Dewey's philosophy to mean is that in developing our methods of pragmatic inquiry into the ethical applications of technology, we must question how the user of technology, the surrounding environment and

[52] Ibid.. p73
[53] Ibid.. p74
[54] Ibid.. p75

the technology itself merge and interact upon each other. It's ironic that Dewy uses the metaphor of skin as an example of understanding instrumentality, but this concept of understanding that 'boundaries' are sometimes not boundaries as all, and that we should look at the practical application in order to make a judgment of the value of a technology. For example, the mechanism of visual matching between von Luschan's colored tiles and the colored skin of a human subject is a boundary, or at least it's a method for crossing one. There's a sense in which in which von Luschan's original use for the technology erases the boundaries set by racial categorization and language, for it did not require those for the technology to work. As Jablonski's research reveals, there's also a sense in which the color of a subject's body from the nineteenth century crosses the technology threshold only to be recorded by a corresponding number and then read a hundred years later. Put that way, the instrumental value of the chromatic scale is useful indeed, and I argue we can determine its value as well, but only limited to what we can experience of its application. But what of the activity system in which the chromatic scale is being applied and its potential implicit bias that Gould and others have warned about? Where does Jablonksi include the reflexive assessment of bias? How does Jablonski's positive modern view on 'race as a biological myth and a social reality' differ from those von Luschan's view of race?

One ought to look at Jablonski's entire body of work to make a comparison. As a professional physical anthropologist, she obviously recognizes the need to engage the social aspects created, in part, by her profession's historical past. She not only found a way to engage the technology of von Luschan's scale and make it useful in her research, she also uses the technology as a catalyst to engage public discussion about the social myths of race, and the history of science that tells the story of the evolution of skin color. Not unlike the public exchange of ideas at the First Universal Race Congress, that both excited and frightened Dubois, Jablonski engages the public and her discipline by including a wider audience into her bold discussion about what science can better articulate about the evolution of skin color. She chose to name her latest book, "Living Color: The Biological and Social Meaning of Skin Color." Her dedication to reaching a wide audience as possible is applying ethics of recognition – recognition of the social realities of "race" and the recognition of her scientific contributions within a socially embedded activity system. In a poignant conclusion, Jablonksi blends her recognition of the dichotomy 'race' presents to scientific and social views of race:

> We understand how skin color evolved, how it is perceived, how it came to be judged, how it came to be associated with other traits in race categories, and how judgments about it have come

> to be rigid, collectively reinforced, and spread through time and space. We also know from ancient history that the suffering caused by color-based discrimination has cost millions of lives and, for many, is still acute. The diminishing of a human being on the basis of skin color lays bare the worst aspects of our visual orientation, suggestibility, imitativeness and status consciousness…The bodies of understanding we have now are matched by the will to change. This is a process in which no one is a spectator: we are all participants.[55]

The statement moves Jablonski's work beyond its function within a theoretical discourse to a practical activity on the level of public participation; and, this is, I argue, what Gould meant when he said scientists need to locate their practices within a socially embedded activity system. It is a bold and challenging invitation for all people to participate in change. It is also risky. Is this the move of a logical positivist? Could Felix von Luschan have presented this invitation to wide and global audience? Would he have extended this type of invitation to Dubois while he was arguing for the 'unity in mankind'? I think we can positively distinguish between an empircally informed scientist such as Jablonski and the empiricism of von Luschan, and

[55] Nina Jablonski "In Living Color" p197

it can be found in the way they go about their activities as anthropologists. Dewey says "the distinctive characteristic of a practical activity, one which is so inherent that it can't be eliminated, is the uncertainty that attends it."[56] Thus, practical activity is precarious and adaptive to the individual situation, and this logical requirement of epistemological justification is what we see in Jablonski's research on skin color. You see it in the way she conducts and presents her research, finding opportunities to invite the people that matter to the discussion. Here we can identify the balance that Gould suggests is the way to see its own error. Without this broad understanding of the history of 'scientific racism', I wonder if Jablonski would have viewed von Luschan's color tiles and data in the way that she did? Could she have repurposed an old and outdated color technology by subjecting it to her practical work as a scientist without letting go of the certainty in which anthropologist from the past had used it? Or, perhaps to von Luschan's credit, did he design a skin color measurement technology that worked to 'promote the unity of mankind' for the long term, even though some of his other activities did not? Either way it's hard to view the Von Luschan Chromatic Scale as 'neutral' or 'value free'.

[56] John Dewey "Logic" p382

3.4 A Comparison of Color Matching Functions Between the Von Luschan Chromatic Scale and the CIE Color Space.

As stated earlier, Felix von Luschan accepted the empirical evidence for the biological unity of all humankind, but he promoted a socially constructed viewpoint based on old biases that cultural and ethnographic histories had created vast 'racial' differences between human groups; additionally, the differences were so big that it led him to stand behind some of the practices of the racial hygiene and eugenics movements that promoted ethnic cleansing. Clearly though, he stated that skin color was not an identity marker for morality or the 'inner' psychological profile of human subjects. From this we can conclude that his chromatic skin color scale functioned more as a technology to record and map skin color as it related to the ethnographic history of a specific human group, and not skin color as a marker for different human sub-species. This means that the von Luschan's tiles served to measure and record the skin color of individual human subjects, but only as part of the data set reflecting a larger population determined by geographical region rather than biologically determined races based on skin pigmentation.

To examine the logical coherence of the Von Luschan Chromatic Scale, it might be helpful to compare its function to the CIE color space (the subject of Chapter 2). Both of these color systems have a visual matching function for the purpose of standardizing color appearance based on 'normal' trichromatic color vision. Figure 3.1.

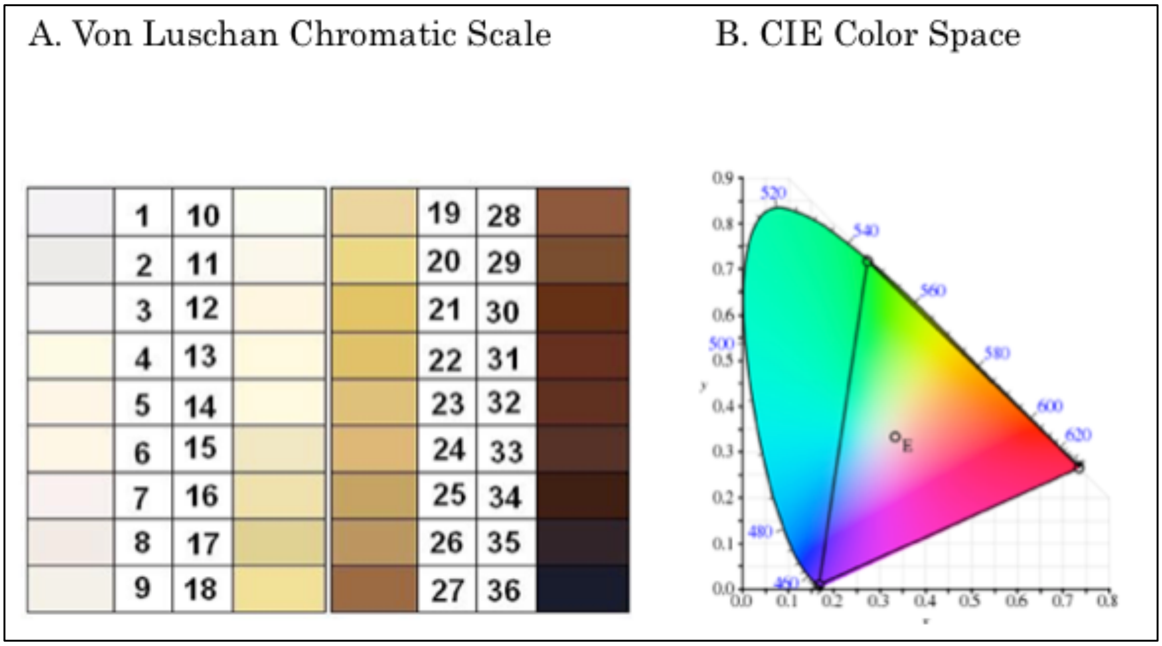

Fig. 3.1 – A side-by-side comparison of the Von Luschan Chromatic Skin Color Scale (A) and the CIE color space (B)

The CIE color space is based on the constraints of a biologically determined visual spectrum that allows humans to distinguish wavelengths as color.[57] Most versions of the CIELAB color space used today are represented by constraints of 'normal' trichromatic color vision, although the

[57] See the work of Wright (1932) and Guild (1928) to see how the spectral sensitivities of the retina were first measured and recorded.

system is adaptable to all the human variations of visual abilities.[58] The CIE space is a technology built for the purpose of standardizing the manufacture and application of colored pigments, dyes and illuminants. It does so by quantifying the visual spectrum as it appears to the observer, turning reflectance measurements into coordinates that can be symbolically represented. This color 'appearance' includes not only the measured reflectance profile of the material object, but also can be adjusted to various environmental lighting conditions under which it is observed. The symbolic representation of the CIE system works upon an operational logic by allowing users to calculate and predict what a color made from dyes, pigments or illuminants will look like to other human observers. Visual matching, in this instance, means that the colored imagery of the reconstructed output will match the input, or match the intentions of the user. There's an additional limitation to the CIE system that is crucial to explain here – although the CIE space theoretically can represent any range of colors in a human observer's visual spectrum, the input process that converts analog signals of surface reflectance measurements to digital coordinates, is technologically and biologically limited. For instance, a camera (or sampling device) is

[58] Since the CIE color space is a 'theoretical' system, a color space can be re-conceptualized to match the constraints of vision we find among human being including dichromatic and tetrachromatic color vision. Thus, the technology is versatile even though the predominate use of CIE color space doesn't reflect its adaptability to human variation.

limited to tristimulus values of the device's RGB coordinate system that converts and maps data into the CIE color space for visual matching.[59] Known as color gamuts, any RGB system's color measurement data used in input and output process must work within the boundaries of the CIELAB color space in order to function properly and for visually matching to occur. There is a biological limitation imposed by our visual system in this process because most light sensors in digital cameras pick up a lot more light reflectance information that our eyes can pick up. During the color processing and reconstruction phases, digital software can use this information to visualize that 'extra' light information in a reconstructed image, but I argue this changes the definition of visual matching, and extends into a different type of digital image reconstruction: digital image enhancement.

The Von Luschan Chromatic Scale, on the other hand, shares a number of similarities to the CIE color space, but with some key differences. The opaque colored glass tiles that von Luschan constructed are also based upon the biological constraints of human variation in skin pigmentation. This linear scale quantifies pigmented skin by assigning correlates of each shade skin observed to an assigned colored tile. The scale can also be considered a

[59] As I will explain in a later chapter, the light sensors in some digital cameras can sample much more information that our eyes can distinguish. Thus through additional computations, the data can be reconstructed to reveal that information. However, this is beyond the CIE's visual matching function, and gets into to visual enhancement through technology.

theoretical color space because the glass tiles are symbolic representations that can be adapted according to new or refinements to observed data of human skin variance. Von Luschan spent over 20 years refining his tile sets as he observed different populations of people throughout the world, but it was modified and later used by others to create their own scales, demonstrating a progressive logic to the technology.[60] In the application phase of the technology, operational logic that is both mental and material was used to visually match the skin color of a subject to the scale. Anthropologists would match the skin pigment of the subject to the tiles at several places on the body (usually the forehead, underside of the arm and the back of the hand), and they would often discuss their observations as they matched the data with other observers in order to achieve consensus on the data.[61]

To highlight some key differences between these systems I will start with their general purposes. As stated above, the original intent of the CIE system was to standardize color management used to manufacture products. Eventually, as the digital screens emerged to dominate a globalized media landscape, the CIELAB system became crucial to the reconstruction of

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[60] Thomas, N.W. "Hautfarbentafel by von Luschan" *MAN,* Vol, 5 (1905), p. 160. Print. – Thomas describes the wide spread use of the Von Luschan Chromatic Scale and its applicability in the field by anthropologists.

[61] Ibid. Swiatoniowski *et al.* (2013) p325

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imagery in the output phase. This system, however, constantly adapts to input technology, which varies greatly in quality. In comparison, the Von Luschan Chromatic Scale was built to record skin color data of human subjects and intended for use in the fieldwork of anthropologists. This data set of skin color appearance measurements was added to a larger data set of biometric measurements of a target population, which was then compared and averaged. While some scientists used anthropological data to theorize on human racial categories, most physical anthropologists have long recognized the importance of skin pigmentation has in adapting to local environments. Thus, the scale was widely used by anthropologists to study human populations for a variety of reasons, including human migration patterns, cultural practices, human health and human adaption to their environment. But as Jablonski and early users of the scale have pointed out, the Von Lucschan Scale's method of visual matching for skin color measurement posed some serious problems in terms of consistency between data sets, and that is due to biological and technological limitations placed on the *input process* of data using Von Luschan Chromatic Scale.[62][63] While the input processing of CIE system relies on technical surface reflectance measurements of light that roughly correlate to our trichromatic cone

[62] Ibid. Swiatoniowski *et al.* (2013) p325
[63] Ibid. (Thomas) p160.

sensitivities, the Von Luschan Chromatic Scale relies entirely on visual calculating the appearance of light reflectance –this means there was a high amount of variability between human observers and lighting conditions (perception problems), which effected the consistent reproducibility of results (falsification of evidence).

The practical problem posed here is that human eyes are under biological constraints when interpreting light. One example of a biological constraint can be described by the univariance principle, which state that when light is absorbed by our photoreceptors, the photonic characteristics of wavelength and intensity are no longer distinguished by individual receptors.[64] As the CIE system demonstrates, color appearance models become much more predictable when light intensity (aka luminosity or chroma) is distinguished from color hue. Our eyes have trouble calculating this feature of light when making visual judgments. Fig. 3.2

[64] Rushton, W.A.H. "Pigments and Signals in Colour Vision" *Journal of Physiology. (1972), 220, pp. 1-3.* Print.

Fig 3.2 – "The Cornsweet Illusion" provides a nice example of the *univariance principle*.[65] The top bar was created using a linear gradient tool from lighter gray in the middle of the image (L*59.513, a* 0.000 b* 0.000) to darker gray on the outer edges (L*55.538 a*0.000 b*0.000), and measured using a built in iMac color meter, set to express CIELAB values. In this system *L values represent the luminance or brightness scale from light to dark (0-100), *a** represents the *red/green* color opponent channels, and *b** represents the *blue/yellow* color opponent channel. Since the image is presented in a monochromatic grayscale, the hue values represented by a*and b* channels are at zero, representing an image desaturated of color, while the L* values are representing the *luminosity* of the image only.**

[65] Purves, Dale; Shimpi, Amita; Lotto, Beau R. "An Empirical Explanation of the Cornsweet Effect" *The Journal of Neuroscience* (October 1999) 19 (19), pp 8542-8551. Print. – This article provides an in depth explanation of the 'Cornsweet Illusion' according to cognitive science. I'm using the illusion as a primary source to test and explain an important point about the *univariance principle,* which is exemplified across many different illusions and images where luminosity discrimination is featured.

Notice the top bar of Fig. 3.2, and the unified appearance of its luminance, even though the luminance values are lighter in the middle of the image than on the edges. The second bar is the same image, only split in half, with the right half flipped 180 degrees so that the darker edge is directly adjacent to the lighter middle. The luminance of the right side of the image is clearly perceived to be darker than the left side; thus the visual arrangement of the scene affects perceived luminosity. The third bar in the image is identical to the second bar, with an additional black stripe placed across the middle to cover up stark line. As you can see, the perceived luminosity difference goes away (for most of us) viewing the third bar, and both the left and the right sides can be perceived as equally luminescent.[66]

As the above example illustrates, biological limitations imposed a practical problem for users of the Von Luschan Chromatic Scale. The varying environmental lighting conditions at the location of the observations, combined with surface imperfections of the tiles, limited the accuracy of this type of visual matching. Thus, while this scale helped solve the problem of anthropologists of comparing and contrasting skin color information among and between populations of people, which was a vast improvement over the

[66] You can test this image using any color meter software applications that will express values in CIELAB coordinates. For my test, I used the Classic Color Meter (Version 1.6) for the iMac.

previous system relying solely on linguistics descriptions of color, the Von Luschan Chromatic Scale was eventually replaced by a much more accurate input/sampling device, the reflectometer, which significantly "minimized the impact of human error and lighting conditions."[67] However, as Jablonski's work has demonstrated, the Von Luschan Chromatic Scale can be used as evidence in a predictive color appearance model through careful testing and calculation; and her team achieved this by mapping the old data collected with the scale into usable data for the CIELAB color space.[68] Additionally, I argue that this was possible because of the *progressive* and *operational logic* of von Luschan's visual matching technology. Using a symbolic and numerical ordering system, that attempted to represent the entire spectrum of human skin colors, allowed future researchers to build upon the technology and open the data up to a process of verification and falsification. Jablonski's team was able to create a reliable method for converting all the skin color data recorded by late 19th and early 20th century anthropologists and then use that data to make accurate models and predictions of how human populations developed such a vast variety of skin pigmentations. One important point of inquiry I want to ask is that if Felix von Luschan had not held a *monogenism* mindset, that says that all human groups evolved from a

[67] Ibid. Swiatoniowski *et al.* (2013) p325

[68] Ibid. Swiatoniowski *et al.* (2013) goes into great detail on the methods of these conversions.

common ancestor, would he have constructed a chromatic skin color scale that includes all shades and pigments of human skin types into a unified system of human variation? At a basic level, this technology forced its users (mostly anthroplogists) to question the human variation of skin color at a time in racial categories based on phenotype were being heavily questioned. Therefore, this skin color scale can be viewed as reinforcing the postulational logic of that era, where a wider range of empirical evidence was being tested that could help explain human variation and the possibilities and constraints enacted by both our biological and cultural inheritance.

3.5 Epistemological Changes in Optical Science: The Development of Spectrometry and 'The Death' of Visual Matching for Skin Color Measurement in the early 20th Century.

The visual matching feature of the Von Luschan Chromatic Scale (c.1890) is an important technology to discuss in terms of measurement systems because it represents a transition in the way light was measured and, consequently, how measurement technologies were developed. Before Newton's "Opticks" (1706), color systems were described in terms of linguistic categories and thus the categorical problems of color matching based on language placed constraints on the compatibility between color technologies. Newton's experiments with light and invention of the 'color wheel' set both light measurement and color technology onto a new trajectory. Newton's 'Color Wheel', which was subsequently refined by Goethe (1810), Runge (1810) and many others, began an era of visual matching colors systems to a quantifiable color map based on the human color spectrum. Like those rudimentary color wheels, von Luschan's chromatic scale worked similarly as it quantified a spectrum skin colors based on hues without distinguishing between wavelength and intensity. The 'color wheel' took a big leap forward with the Munsell System (1905), which turned the color wheel into a 3-dimensional color 'sphere' that separated color by hue, value and chroma.[69] This allowed for more accurate visual matching practices, and made transactional problems between color systems more manageable. The Munsell Color system reflected advancements in the fields of visual science and optics, which produced more accurate ways to measure light through reflectance measurements (aka sampling and input devices). Reflectance Spectrophotometers, then, became the standard technology to measure surface reflectance of objects, which our visual system interprets as color. In particular, the practice of reflectance spectrometry, also became the standard means for measuring human skin for a variety of applications (Dlugos and

[69] Munsell, A. H. *"A Pigment Color System and Notation" The American Journal of Psychology,* Vol. 23, No. 2 (April, 1912), pp. 236-244. Print.

Taylor 2015, Pershing *et al* 2008, Weiner 1951, Williams 1933)[70] As Jablonski Jablonski and others have stated, the structure of human skin poses a particular problem for reflectance measurement standards due to the extremely complex way light interacts with the skin, which is the human body's largest organ.[71] Most skin measurement applications for the medical analysis of human skin don't require image reconstruction, thus visual matching data in the output phase is not necessary. What matters in these applications, is that measurement data and methods used to collect it is reliable.[72] However, the science of colorimetry (as discussed in Ch. 2) has become an important visual science that predicts color appearance through color modeling technology like the CIE color space. Colorimetry, then, benefits from more accurate methods of spectrometry; and it also represent how the visual matching function of color technology has changed. More

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[70] These sources track the historical progression of reflectance spectrometry used used

in the measurement and diagnosis of skin, and also corroborate Jablonski's work by explaining how spectrometry work with the CIELAB system that informs a sub-discipline of *Colorimetry* and *Color Appearance Models*.

[71] *Ibid.* Jablonski (2012; 2006; 2004)

[72] Jablonski, Nina G.; Chaplin, George "Human Skin Pigmentation as an Adaption to UV Radiation" *PNAS* (May 11, 2010) Vol. 107. Suppl. 2. pp 8962-8968. Print. – Jablonski and Chaplin, for example, explain how reflectance spectrometry data can help identify UV light sensitivities of different skin types and how it is important for diagnosing vitamin D production and a host of other health related responses to light.

precise methods of input into these systems have enabled visual matching in the output phase of image production.

3.6 Inquiry and The Diversity Principle in a Changing Sociotechnical Landscape

In conclusion, I want to emphasize the correlation between the changing ideas on racial categorizations based on phenotype, and the changing ways in which skin color was measured and classified as a scientific practice. The science of light and 'color' that produced technologies can be traced to Newton's *Opticks* (although there a many more influences than this study can't cover). The early ideas for monogenism were around in this era as well, but took on significant empirical robustness with Darwin's publication of *Origin of Species* (1859), which produced a flurry of new supported and unsupported claims regarding racial categorization.[73] As Graves and Sussman summarize, this era in science gave an experimental foothold to falsify 'race' as a biological myth, while it remains a social reality. Additionally, Jablonski's work succinctly points out that assumptions about skin color still hold dire consequences for most human populations. While the turn of the twentieth century brought about new understanding in the

[73] Sussman (2014), Graves (2001)

difference between biological and cultural inheritance, old notions of 'race' are still reflected in our ethnic categorizes (either by ethnographic region or color, or both). In the English language in particular, our taxonomy for skin color categories remain and even perpetuate confusion.[74] thus, the categorical problem is a constant throughout this era of changes in our understanding of light, color, skin, and how to measure it with technology. I can't help but question what extent the role of technology played in this narrative? If we follow Dewey's logic of inquiry, which describes technology as a mode of inquiry, we can see how it did in fact provide ways to produce new questions and theories, as well as play an important epistemological function in verifying/falsifying evidence that makes scientific logic coherent. Still, as in the case of the application of von Luschan's Chromatic Scale, technical inquiry doesn't guarantee an ethical bridge between theory and practice because of the wide variety of social influences involved in the application of ethics in science. The technical system under which his color technology applied was imbued with problems that did not make the technology neutral or value free, even though it did replace a previous skin classification system based on language categories and phenotype that was severely flawed. But, if

[74] Both Jablonski (2012) and Graves (2001) go into detail about the problematic linguistic categories of black, white, brown, yellow, red ect.

we further pursue Dewey's epistemological logic, the purpose of technical inquiry is not certain knowledge, but a type of knowledge (warranted assertibility) that is constantly under refinement through continued uncertainty and questions that build an epistemological foundation for ideas based on quality and quantity of evidence. Consequently, this system of knowledge produces a paradox in the inquiry about the nature of human biology.

So, why do we care so much about the skin color? Why do we go to such great lengths to build technologies to measure it and represent it? There are functional reasons. We want recognize that knowledge of skin and its interactions with the environment are crucial to our health. Jablonksi, I think, also offers us an alternative answer – "the bodies of understanding we now have about skin color need to be reached by the will to change" – and for her this means our most important questions and our most confounding problems should motivate us to do so, and this constitutes a positive value for our technologies and all known measures of skin color.[75]

[75] Jablonski (2012) p197

Chapter 4

Color "Spaces" for Digital Screens: How Methods of Visual Observation Pose Problems for the Science and Technology of Skin Biometrics

"It is obvious without argument that when men inquire they employ their eyes and ears, their hands and their brains. These organs, sensory, motor or central, are biological. Hence, although biological operations and structures are not sufficient conditions of inquiry, they are necessary conditions"

John Dewey – "Logic: A Theory of Inquiry"

"Inquiry is a technological activity because where inquiry takes place there is a shift from passive acquiescence towards the beginnings and endings of nature, its contingencies, to the active construction of artifacts to effect their control. Immediate use and enjoyment give way to the production of consequences. When human beings were content to just enjoy fire or to think of it as a gift from the gods, there was no inquiry, no technology, no effective control of it. But when they began to make fire, they began to institute a 'method of procedure'."

Larry Hickman "Dewey's Pragmatic Technology"

4.1 Introduction – Visual Observation and Two Bothersome Case Studies of Human Skin Diagnostics

Consider, for a moment, these two distinct and problematic descriptions of human skin constructed almost three centuries apart:

#1. 1759' – from "An Account of the Remarkable Alteration of Colour in a Negro Woman" ***Philosophical Transactions,*** **by James Bate** (See Artifact 12 in Appendix):

> "Her skin was originally as dark as that of the most swarthy African, but about fifteen years, observed that membrane, in the part next adjoining to the fingernails, to become white. Her mouth soon underwent the same change, and the phenomenon hath since continued gradually to extend itself over the whole body; so that every part of its surface is become more or less subject of this surprising alteration. In her present state, four parts of five are white, smooth, and transparent, as in a fair European, elegantly shewing the ramifications of the subjacent blood-vessels. The parts remaining soot daily lose their blackness, and in some measure partake of the prevailing colour: so that every few years will in probability induce total change. The neck and back, along the course of the vertebrae,

maintain their pristine hue the most, and in some spots proclaim their original state: the head, face, and breast, with belly, legs arms, and thighs, are almost wholly white; the pudenda and axillae partly coloured; the skin of these parts, as far as white, being covered with white hair; were dark with black [hair]. Her face and breast as often as the passions anger, shame and have been excited in her, have immediately observed to glow with blushes; and also when in pursuance of her business, she has been exposed to the action of the fire upon these parts, some freckles have made their appearance. After having described her present appearance, as well as I am able, I shall not pretend to offer any conjectures of my own upon the subject."[1]

#2. 2015' – from "Analysis of Yellowish Skin Color from an Optical Image and the Development of 3D Skin Chroma Diagram™" ***Skin Research and Technology,*** **by Han, J.Y,** ***et al*** (See Artifact 55 in Appendix)**:**

"Human skin is a turbid medium with a multilayered structure. Melanin and hemoglobin pigments are contained in this medium. Slight changes of pigment construction in the skin produce a rich

[1] James Bate , "An Account of the Remarkable Alteration of Colour in a Negro Woman" *Philosophical Transactions* Vol. 51 (1759 - 1760), pp. 175-178

> variation in skin color. Freckles and suntan, caused by melanin pigment, and the enhancement or suppression of the appearance of blood circulation, caused by hemoglobin pigment, are the major reasons that Asians apply cosmetics on their faces. In Asia, it seems that more subtle or natural changes in skin color and cosmetics for skin care purposes, such as whitening essence, are generally preferred. In addition to this, Asian females want to improve dullness and yellowness of their skin by using cosmetics. However, there is no definition or detecting method for yellowish skin color yet. Therefore, in this paper, as the first step, we analyzed skin color on the basis of hemoglobin and melanin pigment and extracted yellowness of skin color by using rendering techniques with subsurface scattering. To confirm the reliability of this study, we carried out a clinical study that verifies the efficacy of whitening cosmetics."[2]

From a history of science standpoint, how did we go from describing '*skin as dark as the as the most swarthy African'* to '*skin as a turbid medium with a multilayered structure*?' Even though the gaps in context, methods, technologies and systemic knowledge of the observer's make these

[2] Han, J. Y., Kim, E. J., Lee, H. K., Kim, M. J. and Nam, G. W. (2015), Analysis of yellowish skin color from an optical image and the development of 3D Skin Chroma Diagram™. *Skin Research and Technology,* 21: 313–318.

descriptions almost incomparable, both contain dubious assumptions about their human subjects and pose serious issues to the intent and applications of skin measurement in these cases. In the first article, an eighteenth century American physician is examining a female African-American slave named Frank, and attempting to describe a skin condition that over several years had caused a large portion of her body to lose pigment. In the later article, the corporately sponsored researchers have conducted a study of 22 female consumers of a cosmetic product that whitens skin. Their purpose to construct a visual model that shows the effects the product can potentially have on the baseline skin tones of consumers. Even though the earlier observer uses the method of linguistic matching and the later observers employ spectrophotometry to describe skin complexions, the visual observation and the visual appearance of their human subjects play central roles in the interpretation of their observations.

In this chapter I would will draw upon two examples from the history of visual theory and optics in order to address some of the fundamental issues with methods of visual observation. First, I will present the philosophical rationalism of Rene Descartes and the visual problems he addresses in his work, some of which still pose unanswered questions for the methods of visual observation. Second, I present an empirical history of visual theory at the turn of the twentieth century and detail its influence in the engineering of the CIE "Color Space." I place both of these examples in discussion with of John Dewey's philosophy of logic as a way to explain how visual theory, as a both a rational enterprise and a diverse science, can explain a few of the revolutionary changes in science across the three eras of skin measurement I presented in chapter one. As I will demonstrate in this chapter, Descartes's rationalism and dualistic model for visual observation played a significant role in the history of two main engineering collectives responsible for many of the measurement technologies in my primary texts. Both the Optical Society of America (OSA) and the International Commission on Illumination (CIE) laid the groundwork for the science of spectrophotometry, which included the engineering of new technologies, the development of new methods and communicating the theoretical underpinnings of vision science that enabled widespread use of the technology.

I will then return to these two problematic descriptions that I have presented in here in the chapter introduction as a way to demonstrate how diversity in language and observation practices can lead to problematic descriptions of skin color and uses of skin diagnostic technology. My goal is to address the ways in which modes visual observation have changed, yet in many ways have remained poorly understood and are still used for unethical ends. Although I have previously argued for the benefits and clarifying role of spectrophotometry had on skin measurement, I will also argue that a progressive technical logic divorced from a humanistic rationale poses many problems for the future of biometric sciences.

4.2 Classic Problems for the Method of Visual Observation Within Epistemology

When we open our eyes and focus our attention onto a world full of light and colored objects, what does it mean to say: I see the world in front of me? It is a question scientists and philosophers have pondered for at least 2,000 years and have yet to find a consensus. The everyday problems from human visual experiences have been documented for at least as long, and often, these visual problems have driven the investigation. One prime example of a visual problem–driven investigation comes from the thought experiments of Rene Descartes (1596-1659), where he contemplates the changing aesthetic properties of wax after throwing a honeycomb into a fire.[3] Descartes suggested that even though fire drastically changes the wax's color, shape, smell, taste and texture, we still know that it is still wax through our reasoning and intellect; thus, he concluded, it is only through the mind and not through my senses that I experience wax.[4] Descartes arrived at his

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[3] Rene Descartes. *Meditations on First Philosophy.* "Second Meditation: The Nature of the Human Mind, and How it is Better Known than the Body" Toronto, Ontario, Canada: Harper Collins Publishing, 2013. Epub.

[4] Ibid. 1. Loc.346

famous rationalization by first, 'purging his mind of all prior knowledge" and concluding: *cogito ergo sum* (I think, therefore I exist); and even though our bodily senses allow us to experience the physical object of wax, our bodily senses alone can mislead us into error; therefore, we only come to "understand" the true nature of wax with our minds. To emphasize the point, Descartes compared the degree to which the aesthetic properties of wax are changed by fire, from a honeycomb to a molten shape that seem to hold none of the same properties it once did. Since then, Descartes's conclusion has been referred to as the 'mind/body problem,' or 'Cartesian Dualism', and this thought experiment has become a starting point for many investigating the problems of human vision and perception.[5]

Most scientists and philosophers today would probably agree with Descartes' foundational assumption of "I exist," and recognize that the human ability to rationalize influences our understanding of our existence; but where many differ from Descartes, including myself, is in his particular brand of skepticism regarding our sensory experiences that eventually led him to the conclusion of a disembodied mind.

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[5] As John Dewey points out in "Experience and Nature", Descartes's conceptual split of mind and matter (Cartesian Dualism) marks an epistemological split in the study of objects (the physical) from the subjective experiences with objects (the psychological) – Dewey logically calls the inevitable result of dualism "the abandoning of acknowledgment of the primacy of gross experience"

Descartes embeds a basic distrust in the relationship between concepts of rational subjective understanding and perceived objective properties (the mind/body split). He describes the mental and the physical as separate realms, but locates the 'seat' of their interaction in the brain (in the pineal gland). Because humans regularly misperceive, misinterpret and misrepresent the objective world through our senses, which often fail us, Descartes says "I am at risk of being led astray by them"; thus he concluded that only a disembodied and rational view of wax (through reflection) can he eliminate the errors of bodily perception that hinder a full 'understanding.'[6] However, I think Descartes missed a major piece of information in this particular thought experiment, and that is his experience and knowledge of fire. It is highly probable that if Descartes had looked at the honeycomb and the molted wax separately, that he would have drawn the conclusion that it was the same object, with different properties. He probably wouldn't have made the connection at all unless there was a reason to think they were the same object. Therefore, a prior physical experience of throwing wax into the fire or the prior knowledge that fire can change the aesthetic properties of certain objects, I argue, was part of Descartes's understanding of the change in the wax's properties. Additionally, this was a considerable oversight in his

[6] Ibid. 1.

rationale and conclusion that became known as Cartesian dualism, which is the idea that the physical appearance and mental understanding are separate experiences for the observer. In other words, he omitted a knowable physical process in order to justify his belief that the true meaning of wax is entirely feature of our mind with no material correlative. Thus, the major mistakes of Cartesian Dualism are A) to understand our rational beliefs of everyday visual experiences as being 'self evident' and B) to practice radical skepticism concerning our sensory modalities of the physical world. Since Descartes, both of these conclusions have been modified throughout the history of visual theory and science, but there is a reason so many disciplines that study vision invoke Descartes, and it is due the presence of interrelated problems that I call 'visual problems.' I will be referring to these throughout this dissertation in the following terms:

1. Logical: "The Problem of Induction"
2. Rational: "The Mind/Body Problem"
3. Categorical: "The Language Problem"
4. Perceptual: "The Problem of Vision"
5. Transactional: "The Practical Problem"

These sets of 'problems' should be somewhat familiar, because they are a result of a long history of issues identified in classical epistemologies and theories of vision. The problems will, in turn, inform my larger inquiry into the history and function of color technology, and the arc of this chapter will demonstrate how various visual epistemologies and technologies since Descartes addressed the problems related to the vision and perception of color. More specifically, this chapter reviews some of the history of visual theory, vision science and visual technology that together inform a color theory of technology. Another primary aim is to show how these visual problems shaped the color systems that we use today in almost all areas of digital and visual communication.

The wax example is most known for highlighting Descartes's perceptual problems of visual experience and rational problems that stemmed from his inquiry, but from a modern perspective of Descartes's larger body of scientific work, we can see he was dealing with different sets of problems related to the vision and perception. As neuroscientist Stanislas Dehaene points out, Descartes can be credited for a few major shifts in the study of vision and the brain.[7] First, he described the visual and nervous systems in mechanistic terms and created a theoretical model for perception that linked the brain, vision and bodily action. He also began to theorize how these functions of the body were connected to intelligence; however, he

[7] Dehaene, Stanislas. *Consciousness and the Brain: Deciphering How The Brain Codes Our Thoughts* New York, NY Penguin Group. 2014. Print.

quickly ran into limitations with his model. "Descartes could not see how a machine (brain) might ever use words," Dehaene says, and his model "failed to provide a materialist solution for the higher-level abilities of the human mind"[8] Thus, in addition to the perceptual and rational problems, Descartes quickly bumped into the limits of logic, and the categorical problems associated with language.

The last problem that I want to address in Descartes's account of vision is what I define as the 'transactional' or the 'practical' problem. Practical problems are the vital and everyday problems that arise in the application of a technology or theory, and I argue it is how we primarily identify with both the visual object and technology; put simply, practical problems are contingencies that arise when the new knowledge gained from an activity or application of technology is not yet coherent with other knowledge, situations and concerns. Resolving practical problems is what leads to identifying and classifying the other problems faced, and I call it 'transactional' because these problems tend to trigger new knowledge to cohere with older knowledge. Therefore, many transactional problems are epistemological in nature and the catalyst for a 'coherentist model of knowledge.'[9]

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[8]Ibid.. 5, p6.

[9] The 'coherentist model of knowledge' is explained later as part of my epistemological framework for applying color technology.

The practical problems that arise from Descartes's mechanistic physical model of vision and brain (as exemplified in his detailed drawing, with coordinates and descriptions), and their putative connections to the immaterial spirits, or soul, stemming from continuous application of Descartes's theoretical model of the body over time. Because he developed a mechanistic model, a technical model, of how vision and the brain worked, the translational/practical problems exposed the incoherence of his mechanistic descriptions. Descartes could never explain how his mechanical model of the body could give rise to the higher capabilities of the human mind, thus, he made his model fit with previously held beliefs in immaterial explanations.[10]

4.3 **John Dewey's Embodied 'Circuit' Model' and Critique of the "Reflex Arc"**

One of the major criticisms of Descartes's concepts of the visual system comes from John Dewey (1859-1952), who I reference throughout the chapters of this dissertation due to the breadth of his philosophy of technology. In an important essay on the epistemological paradigms of psychology, Dewey describes a concept he calls "the reflex arc" that connects "the older dualism of body and soul" to "the current dualism of stimulus and

[10] Ibid. 5 p. 6

response."[11] Dewey noticed a trend for practicing Psychologists of his day to make rigid distinctions between sensory sensations, thoughts and actions, which lead to a disjointed view of bodily coordination with the senses. Much like Descartes's original model of the hydraulic brain, the 'reflex arc' model always begins with a stimulus from an outside world, then our inner sensory inputs cause a reaction in the brain, and then our brain, somehow, sends an output message for bodily action. In Descartes's model, sensory information (such as the image of a stick) would be sent to the pineal gland near the middle of the brain, the pineal gland would react by moving leaning in the direction of bodily action and releasing 'spirits' that would cause bodily movement (such as an arm grasping the stick).[12]

Although later models abandoned the concept of an immaterial spirit physically interacting inside of our head, and focused more on how the material mechanisms of the central nervous system reacted to electromagnetic stimulus, Dewey suggests that the dualist model where a objective physical world is acting upon a passive human subject still existed

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[11] Dewey, John "The Reflex Arc Concept in Psychology " *The Psychological Review.* Vol. III, No. 4 July, 1896. pp 357-370.

[12] Descartes, Rene *Treatise of Man.* Trans. Thomas Steele Hall. Amherst ,New York: Prometheus Books, 2003. Kindle.

in the working models of psychology and biology at the time. In contrast, he says this model approaches sensory input in the wrong way; instead, Dewey says, "we find that we begin not with sensory stimulus, but with sensorimotor coordination…the movement of the body, head, eye muscles determining the quality of what is experienced."[13] This model can also described as the 'circuit model' where the human body is not just a passive receiver of information, but a mobile organism, enabled by sensorimotor coordination, that actively probes the environment. In the case of the visual system, Dewey suggests that we begin with the movements of the body, because the activity of looking will shape the experience of sensory input. Because sensorimotor coordination is so important in this circuit, physical movement becomes primary in understanding how we interact with the environment through the senses, and the sensations we experienced become a secondary feature in the circuit. Therefore, Dewey contends, "in the physical process, as physical, there is nothing which can be set off as stimulus, nothing which reacts, nothing which is a response. There is just a change in the system of tensions."[14]

The main point Dewey is making here about the dualist model is based on the assumption that the 'central process' between sensory input and

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[13] Ibid. 9. p.358.
[14] Ibid. 9. p.364

mental output that causes action is based on a 'mixed materialistic-spiritualistic' understanding of the workings of the brain.[15] The false dichotomy of 'purely physical' actions and 'purely psychological' mental operations defines the 'reflex arc' concept, and ultimately, is a formulation that's "neither physical, physiological nor psychological."[16] The advantage of the sensory-motor circuit model is that it recognizes the unity that our physiology has in coordinating action, without the immaterial assumptions.

The modern visual observer is in a constant state of negotiation between technologies, language and visual science and those lingering questions of perception and subjectivity. While there are some compelling philosophies out there that engage this reality about human's subjective relationship to visual 'knowledge' (in particular O'Regan & Noe (2001)), and the "interactional" approach to color vision, presented by George Lakoff and Mark Johnson (1999), it is an 'embodied' view of vision that I think addresses central problems in the 'reflex arc' model that Dewey initially described.

Lakoff and Johnson say color vision is the consequence of four interacting factors: lighting conditions in the environment, wavelengths of electromagnetic radiation, the color cones of our visual system and the neural

[15] Descartes's "central process" was the detailed description of the pineal gland, which literally was referred to as "seat of the soul" because it was thought to be the "place" where the physical world interacted with the spiritual. The pineal gland's putative function is described in detail throughout Treatise of Man.

[16] Ibid.. 9. p365

circuitry of our brains.[17] They call color concepts 'interactional' because color is not 'objectively' part of the world (color needs a subject with a visual system and neural circuitry); nor is color completely subjective (color is not radically relativistic, or socially constructed by culture); instead, "color is created jointly by our biology and the world."[18] This isn't just limited to an individual perceiver; here, *world* means not only environment, but also the social milieu of shared color concepts, color categories, color languages and color application. Thus, color perception involves a set of cultural possibilities and constraints that influences knowledge and understanding of color and vision. However, Lakoff & Johnson contend that although color does vary in significance from culture to culture, it is only within the constraints of what he describes as 'embodied realism', where culture is a function of "our world and our bodies" interacting.[19] This is very important to making a distinction between perception/conception, and how visual concepts (including color concepts) are structured by our bodily interactions with the world and function by our interpersonal relations in the world.[20]

With this notion of *embodied realism*, important questions emerge that are relevant to contemporary visual theory. Despite the differences in our

[17] Lakoff, George; Johnson, Mark *Philosophy in the Flesh* (1999) Kindle loc. 327

[18] Ibid. 15 Kindle loc 342.

[19] Ibid. 15,16

[20] Ibid. 15 Kindle loc. 511

individual 'interactions' of body and world that enable us to perceive color, how is it that a culture establishes a common color concept from individual color experiences? Why do these concepts have some 'universal' similarities and also seemingly relativistic differences? Additionally, although it is easy for Lakoff to limit culture's part in shaping color perception, the question of how our perceptions shape culture remains an important one.

Taking a functionalist approach to the many disciplines that inform visual theory, I contend that we can begin to answer these questions by first identifying a pattern of constraints that run throughout the history of visual theory; and by proxy, identify a correlating pattern of possibilities as well. Since the interactionalist view demands a body and a world to function as a theory of color, it would seem that a set of natural possibilities and constraints would be a category. However, can we distinguish nature from culture? Or, can we inject nature into the other parts of interactionalism, like electromagnetic wavelengths that may come from a man-made technology? The question – *what is natural?* – has a long history of complications in both philosophy and science, and using it to categorize in this way demonstrates that tension. For this reason, a broad definition of nature is not an ideal category for establishing patterns in the history of color theory. However, the possibilities and constraints of biological mechanisms, and in particular human biology, is an established thread throughout visual theory, and as

Lakoff & Johnson explain, this can be distinguished from electromagnetic wavelengths and other environmental interactions. Thus, it can be said there is a set of biological possibilities and constraints in relation to color that can be categorized in any contemporary theory of color. Because of the language problem, culture, is another category that imposes possibilities and constraints on our understanding of color.

Going back to that first question that is asked over and over again in the epistemology of vision – *what does it mean to see?* – one can understand how these two distinct models to explain vision are answered much differently, even in today's terminology. At a base level and simplified description, the Neo-Cartesian model (Hubel 1963; Marr 1980; Livingstone & Hubel 1983; Lee 2008; Gouras 2009; Conway 2013; Dehaene 2014) says that when we open our eyes, light enters and stimulates a response mechanism in the retina of our eye where visual information in the form of light is transduced to electrical impulses, passes through the visual pathways (LGN), then initially processed in brain's the striate cortex.[21] On the other hand, the

[21] Darrigol, Olivier (2012-01-26). A History of Optics from Greek Antiquity to the Nineteenth Century. Oxford University Press. Kindle Edition. Darrigol defines Neo-Cartesianism: "Neo-Cartesian, comprehends authors who pursued Descartes's project of reducing all interactions to mechanical contact but did not necessarily follow the details of his theory of light and were willing to adopt some concepts of Newton's optics. How the visual information and visual consciousness connects from here is very much an ongoing project of the cognitive and neuro-sciences. Thus, Neo-Cartesianism is still one describable approach to these problems.

sensorimotor activity model, or embodiment model (Dewey 1896, Gibson 1986; Lakoff & Johnson 1999; O'Regan & Noe 2001), says that when we open our eyes, our conscious and unconscious movements of the eyes, head and body are already attuned to our environment, and actively work together to visually probe the world around us. Visual *attention* and *access* to objects with visual features in the environment are codetermined by the *physical attributes* present within the environment, and the physiological and psychological activities of the perceiving animal. Seeing, then, has a variety of definitions under these two distinct approaches to vision. While most visual theorists contend these two approaches are not mutually exclusive, both are designed to challenge particular 'problems' that I view as transactional and are centered on the underpinning problem of visual consciousness. The embodiment camp says that vision, since it involves active experiences by the perceiver, cannot be reduced to the input/output model of a brain processing information. The 'reflex-arc' or 'Neo-Cartesian' model emphasizes the brain as the location of study for visual consciousness. I argue that both these basic approaches are correct, but that each begins in a different place due to their definitions and philosophical commitments to the word consciousness.[22]

[22] Which has also been aptly named by many in the field as 'The Hard Problem."

What I have learned from this study on visual perception is that the complex problems involved with visual observation challenge the ideas of traditional epistemology and create a system where learning the differences in transactional problems is often more beneficial than the pursuit of certainty. What I am arguing in this chapter is that the observation methods of human skin color benefit when observers began look at skin color as a transactional problem, involving both the possibilities and constraints of the input/output model of visual consciousness in addition to active experiences of the embodiment model that includes language and culture into the equation. The two descriptions of skin at the beginning of the chapter are a demonstration of what happens when observers do not recognize the ways in which their own experiences and culture effect their methods and results.

To make the Descartes's example and the described visual problems more salient to modern technical systems, let me restate my original question: When a scientific observer open their eyes and focus their attention onto a digital screen full of light and colored objects, what does it mean to say: I see an image on the screen in front of me? The question of vision doesn't get any simpler when experienced through a digital medium, and all of the problems Descartes encountered in his thought experiment are still present when they look at objects on a digital screen, only with the additional layers of computation and digital imaging. Descartes' brand of rationalization and skepticism will still have to be modified if we are to get any closer to addressing the questions of visual technologies – and they have.

The epistemology of vision science and visual technologies demonstrates how far functional knowledge can advance with only partial understanding of the physiological and psychological mechanisms of the visual system. As Dehaene points out, "Descartes challenges to materialism stands to this very day."[23] Still, there is very little consensus on how to even define the word consciousness, but we do understand more about the biological mechanisms of vision and this can be demonstrated in the technical 'color space' that have standardized the colored images we see digital screens.

4.4 What Does It Mean 'To See' an Image on a Digital Screen? – A Review of Dewey's 'Logic' and Bonjour's 'Coherence Theory of Empirical Knowledge'

Whenever we see an image on a digital screen, we can make some inferences about its constitution: A) there's a set of technical possibilities and constraints involved in the making of the image, B) because images are technical, there are a sets of social possibilities and constraints that influence its manufacture, usage and application, C) there are a set of natural possibilities and constraints that determine how the image is made and

[23] Ibid. 5

viewed, and D) because images are both technically, socially and naturally constituted, we can empirically and rationally inquire about their production.

I would like to focus on just one aspect of digital image production and that is the 'color technology' involved in the reconstruction of images, from analog to digital, also known as the *input/output* process. The color technology under examination for this chapter is the CIE color "space", but before I go into the problems with the model and the history behind it, I want to recognize the very important function that CIE color space serves in the input/output process by describing where it interacts:

A digital camera samples an analog scene by allowing light through the lens and past the shutter. For this scenario, let's say the analog subject is a patch of lightly pigmented human skin with a pinkish hue. The light travels through a colored RGB filter in the camera and then makes light impressions on an image sensor. This data is then converted into digital pixels with the light information now being coded in RGB values. Before the RGB values are reconstructed, they are calculated and mapped onto a specialized CIE color space that was designed to *visually match* 'normal' human vision. For the most part, today's imaging technology reconstructs imagery, such as pinkish skin, at a very high quality; however, because of a milieu of problems identified in the epistemology of visual science and visual theory, digital imagery does not outrun its visual problems (logical, rational, categorical, perceptual and transactional), which have also traditionally been approached through incommensurable dualisms (mind/body, subject/object, theory/practice). Conversely, I argue that because digital imagery uses a matrix of technological tools, in this case 'color tools', careful inquiry into the usages of color technology will produce a coherent and logic epistemological structure in which to address visual problems. Thus, for this chapter, I wish to demonstrate how an applied color technology, as a mode of inquiry, has both challenged and shaped traditional paradigms of visual knowledge.

My question – *what does it mean to see a colored image on a digital screen?* – then can be considered the beginning of an evidence-based inquiry that follows a coherent epistemological structure for evaluating the quality and quantity of evidence, falsifying evidence and determining the strength of evidence which ultimately just acceptance. Therefore, knowledge (*episteme*) of the images we see on a digital screen can be subject to a method of inquiry based on logical coherence.

The logic of technology can be assessed through pragmatic inquiry. In Dewey's foundational work, *Logic: A Theory of Inquiry,* he describes six implications for logic as a mode of inquiry:[24]

[24] Dewey, John *Logic: The Theory of Inquiry* New York, NY: Henry Holt and Company, 1938. Print. – I will refer to this work hereafter as "Logic*"* – These 6 quotes and paraphrased descriptions come from the introduction pp 14-22

1. “Logic is a progressive discipline.” Meaning: Logical analysis corresponds to the best methods at the time of inquiry; thus as methodology improves, so does the development of logical analysis.
2. “The subject-matter of logic is determined operationally.” Meaning: Dewey splits *operational* logic into two conditional forms: material and existential. Simply put, logic can involve physical observation and activity, or it can be done with symbols and mental operations that have physical pre-conditions.
3. “Logical forms are postulational.” Meaning: Logic works under a system of constraints that are neither immutable nor arbitrary. As an inquiry advances, *postulates* are those practical limitations found in the act of logic that shape the scope of an inquiry.
4. “Logic is a naturalistic theory.” Meaning: Since logical inquiry is observational, there is an assumed continuity between biological and physical operations. Observation practices within any logical inquiry require the methods to be open to public inspection and verification, which means

'mysticism' and 'intuition' fail to meet the conditions for logical inquiry.

5. "Logic is a social discipline." Meaning: Logical inquiry is "socially conditioned" and has "cultural consequences" through communication practices and a "relation of symbols." Therefore, through language, the socio-cultural environments are always in the background of an inquiry even if the "problem" that prodded the inquiry is considered purely physical. Dewey calls his position on language considerations underlying logical inquiry as *cultural naturalism.*
6. "Logic is autonomous." Meaning: Inquiry assumes a psychological foundation that allows us to think about our own thinking. We don't necessarily need to reach conclusions about consciousness, sense-data, sensations or mental faculties in order to set pre-conditions for logical inquiry and the type of 'knowledge' it can produce.[25]

By describing logic in these terms, Dewey gives philosophical moorings for a epistemological structure based on empirical evidence. The definition of

[25] *Ibid.*. Dewey, "Logic" p21. – Dewey even states: "Personally, I doubt whether there exists anything that may be called thought as strictly psychical existence." For him, logical 'thought' is not an inner state of mind; it is instead a mode that makes thought explicit through actions of verification, falsification and refinement.

knowledge in this model is less certain than when it is stated in absolute terms; instead, logical inquiry can produce what Dewey calls *warranted assertibility*, which to him means scientific inquiry plus "the criterion of what is taken to be settled, or to be knowledge, is being so settled that it is available as a resource in further inquiry; not being settled in such a way as not to be subject to revision in further inquiry"[26]

What Dewey's description of logic means for this study on color technology is that it provides framework not only to evaluate how inquiry informed the logical progression of visual science and technology, but also examine how logical inquiry is shaped by the application of color technology that potentially verifies and falsifies evidence.

While a full review of literature on the philosophy of coherentism is beyond the scope of this chapter, Laurence Bonjour's work, The Coherence Theory of Empirical Knowledge (CTEK), is particularly applicable to the case study of the CIE Color Space.[27] Bonjour's account of coherentism adds a philosophically robust perspective to understand the changing epistemological justifications for its continued application as a color

[26] *Ibid.*. Dewey "Logic" pp8-9

[27] Laurence Bonjour *The Structure of Empirical Knowledge.* Cambridge, MA: Harvard University Press. 1985.

technology.[28] Traditional accounts of a coherence theory for epistemic justification contend that in order for a belief to be justified, it must 'cohere' logically, and in relation with, other epistemological beliefs that are internal (and arguably external) to the system that can be demonstrated to be consistent.[29] Bonjour synthesizes a few earlier iterations of CTEK with what the following coherence criteria:[30]

1. A system of beliefs is coherent only if it is logically consistent
2. A system of beliefs is coherent in proportion to its degree of probabilistic consistency
3. The coherence of a system of beliefs is increased by the presence of inferential connections between its component beliefs and increased in proportion to the number and strength of such connections.

[28] For the purposes of this paper, I will be using a broad definition of 'technology' through what Stephen Kline ("What is Technology?" 1985) describes as the Four Usages of Technology that have traditionally defined the term: Usage 1 – Hardware of Artifacts (Objects); Usage 2 – Sociotechnical System of Manufacture; Usage 3 – Knowledge, Technique, Know-How or Methodology; Usage 4: Sociotechnical System of Use. In the course of this paper I describe the technology of the CIE under all four these usages as it embodies all the connotations of these definitions, and offers a simple, yet effective way to think of the CIE Color Space, especially in relation to a coherent system of logic.

[29] Ibid.. P 93. - Bonjour calls this concept of coherence as a 'Hanging Together' of inferential, evidential and explanatory relations that involved mechanisms of explanation, confirmation and probability.

[30] Ibid.. pp 95-99.

4. The coherence of a system of beliefs is diminished to the extent to which it is divided into subsystems of beliefs which are relatively unconnected to each other by inferential connections.
5. The coherence of a system of beliefs is decreased in proportion to the presence of unexplained anomalies in the believed content of the system.

One important addition to this account of CTEK is what Bonjour calls an *observation requirement*, which consist of "cognitively spontaneous beliefs" that non-voluntarily arise within lived experience.[31] The example he uses for this class of beliefs is to consider the observational knowledge of seeing a red book placed on a desk.[32] The approximately size, shape and redness of the object "strikes" the perceiver instead of being logically inferred. It is these types of specific beliefs that occur in cognitively spontaneous experience that must be accounted for in a logical system of coherent justification. In other words, observations and experiences that lead to cognitively spontaneous beliefs can account for both increasing coherence of a logical system or the diminishing of coherence. Additionally, I argue that Bonjour's observational requirement offers a crucial component to the epistemological function of the CIE Color Space by explaining how theoretical justifications for the

[31] Ibid.. Pp 117-124.
[32] Ibid.. p 117.

application of the technology could have remained consistent through an era of significant epistemological changes in biological. In following sections of the article, I will give an account of the construction of the CIE color space with additional theoretical context that I think best describes the above framework of logical inquiry I am applying to the technology.

Going back to the image of the pink patch of skin – I contend that the applied technology of CIE color space and the many color appearance models that followed, opened a line of inquiry that logically cohered with new epistemological justifications for color vision. Although it was not the end goal of the CIE color space, the category of 'pink' presented a problem to engineers of the technology that it actually shaped the design of it. Additionally, the category of pink still presents a problem to what we know about color vision today. In this way, color technology has bridged the analog and the digital; additionally, color technology allow for inquiry into the matrix of biological, technical and social constraints of our biggest visual problems, to smaller problems, such as images of pink skin, as well.

4.5 Technology and the Digital Image Process

To view a digital image on a screen, several general and technological 'phases' of the digital process must be understood (Szsliski 2011; Green

1999). First, a technology must be used for *sampling* an analog scene, and therefore have a mechanism for capturing light and converting light information into digital information, also known as *encoding*. A third phase is the *transmission* of that code, or signal, to a computing device, which then requires an additional transmission to a display device. To then see an image on a screen, the code/signal must go through a *reconstruction* phase that will convert the code back into light intensities that we see on a display screen. This process is also known as the *input/output* process, and can be visualized in the following scheme. (Fig. 2.2)

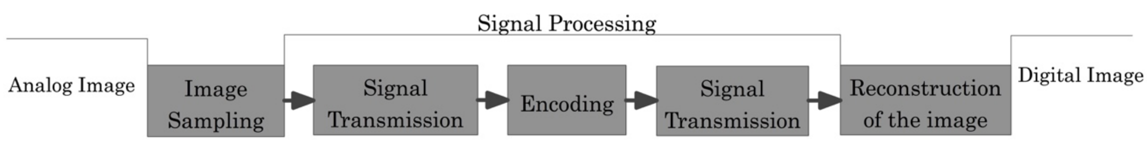

Fig. 4.1 The Input/Output System - from Analog to Digital Imaging.

The technical devices needed to facilitate the input/output process are somewhat fluid. For instance, a digital camera is a sampling device that initially processes information then transmits it to a computer for additional processing and encoding with a graphic card. However, some cameras have both input and output capabilities, which sample, encode and directly transmit a signal to a specifically designed screen that completes the image reconstruction process. Color management is an important part of this process because color processing is independent to each device. For this reason, all technologies in the input/output system must be compatible for the system to work.

Because the structure of the analog to digital, input/output imaging system relies on successful interface and translation of light information between technologies, and because the user interface between the screen and the perceiver demands an optimum reconstruction of an analog image, the system of color management from sampling to reconstruction has been identified as the Color Appearance Model (CAM) (Fairchild 2005).[33] Fairchild describes the CAM model as containing both linear and non-linear processes, and he defines it as a 'model' due to A) the complexity of its parts, which include psychophysical, biophysical and technological interactions, and B) a user of the model can make a prediction about how analog images will appear post-reconstruction.[34] The main premise behind all of the technology and theorizing is that a system user can make a prediction of how an image will appear to an observer. The system can produce an image that either 1) visually matches the analog sample, or 2) visually matches the intent of the designer. One of the biggest leaps forward in color technology that essentially standardized color appearance models was a series of reports in by the

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[33] Fairchild, Mark D. *Color Appearance Models.* Hoboken, NJ: John Wiley and Sons. 2005. Print.

[34] *Ibid.*. Fairchild, p183.

Optical Society of America (OSA) (1922) and the *Commission Internationale de L'éclairage* (CIE) (1931).[35][36]

The OSA and CIE reports relied on the latest data from vision science as a way to create a profile for what they called "the standard observer" which included their stated goals of 1) standardizing color terminology, 2) standard interpretations of psychophysical data in relation to light stimulus, 3) a standard for measuring radiance, or light intensity, 4) a standard for the methods of measurement and 5) a standard of comparison between these different scales.[37] The early work from OSA's report in 1922 on colorimetry led to the creation of the CIE Color Space in 1931.[38] Colorimetry refers to the measurement of color appearance, which is based on the measurement technology of spectrometry that measures light at different wavelengths; the differences being that colorimetry measures light in order to predict the way our visual system interprets it. In other words, colorimetry measures light in units of distinguishable wavelengths as they appear to human observers. The CIE color space is a model representing the entire visual spectrum that a human with normal trichromatic color vision can see. This model can be

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[35] Troland, L. T. "Report of Committee on Colorimetry" *Journal of the Optical Society of America and Review of Scientific Instruments.* Vol. 6, No. 6 August, 1922.
[36] Ibid. Fairchild, pp 53-82.
[37] Ibid. Troland, p 530.

broken down into data points in a X,Y,Z graph. Colorimetry, then, allows a sampling technology to measure any point of light in an analog scene, and give it a tristimulus value, usually is expressed in RGB (red, green, blue) values. These RGB values also putatively correspond to the light sensitive cones in the normal human eye (long, medium and short wavelengths, respectively) and can be accurately converted to CIE color space by converting RGB to XYZ conversion values; therefore, in theory, a reconstructed image using RGB values for its digital output will visually match the input sample.

The problem with RGB values is realized when mapping it onto a graph, where both positive and negative values are shown along the R (long) wavelength. (Fig. 2.3)[39]

[39] Of note here is how light is represented on a Cartesian plane itself. The horizontal (x) axis depicts the wavelengths of long medium and short electromagnetic waves. The vertical (y) axis represents the intensity of the wave. When sunlight strikes the cells in the human retina, the properties of light (wavelength and intensity) are indistinguishable (aka univariance principle). What is being measured in the long, medium and short cones of the retina are the differences in how they respond to light wavelengths. Intensity is represented in the graph, but undetectable to human perception.

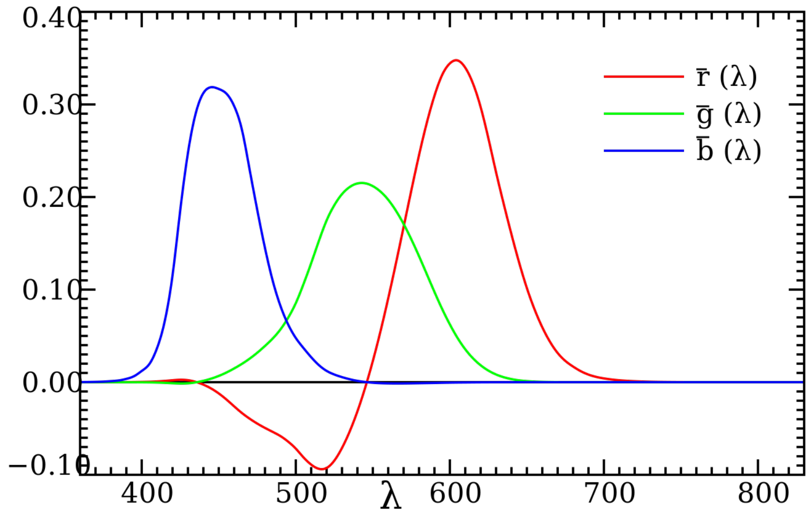

Fig. 4.2 Visual representation of the CIE's initial tristimulus, or RGB Color Space, based on surface reflectance measurements of S,M,L wavelengths. Note the negative value along the R wavelength, which means it was difficult to use RGB values to accurately match a sampled image.

This means that spectral reflectance measurements, or RGB Tristimulus values, alone, could not account for the range colors that humans can see, and this was the problem that those early engineers and mathematicians had to overcome; therefore, reflectance measurements were not "color" as it appears to us. This 'problem' can be described from a current perspective as a technical constraint coming under a biophysical constraint, and it is something the writer's of 1922 report on Colorimetry report were aware of. The report states:

> It is impossible to identify color with radiant energy, or wavelengths of radiant energy, although energy is the adequate

> stimulus for color. This is because color is known to depend upon the presence of the perceiving individual and because it is directly recognized to be something radically different in kind from its stimuli. Consequently, nothing but confusion can result from the use of the word "color" as a synonym or wavelength…Color cannot be identified with or reduced to terms of any purely physical conception; it is fundamentally a psychological category[40]

What this language infers, however, is a philosophical approach to vision that suggests a strict division between subject and object, and consequently the problem rested on a "fundamental" divide between psychological and physical processes. In terms of logic, the authors of the report identified a new set of postulates that limited the definition 'color,' but operationally, they were able to solve the technical dilemma in a way that met criteria for logical coherence.

Another indicator on the OSA report comes from the definition of "color" as purely a psychological term:

> Color is the general name for all sensations arising from the

[40] *Ibid..* Troland, pp 553-534.

> activity of the retina of the eye and its attached nervous mechanisms, this activity being, in nearly every case in the normal individual, a specific response to radiant energy of certain wavelengths and intensities.[41]

It is here that Dewey's critique of the "reflex arc" (stimulus leads to response) becomes helpful. In the *reflex arc* model*, v*ision is described as the objective physical world acting upon a passive human subject, which Dewey attributed to the vestiges of Cartesian dualism. Embedded in the OSA's ground-breaking report on color, the very definition of color in coded with the language of the much older mind/body dualism. There is also a bridge here between "sensation" and "specific responses" to "certain wavelengths" indicating a Cartesian formulation of an individual thinking mind.

Conversely, I do not mean to imply that the authors of the reports intended to appeal directly to dualism; instead, it brings up the questions of disciplinary habits and commitments. As a society that generally practiced scientific "positivism" that defined the era, Dewey says, "this positivism has the advantage of freedom from entanglement with highly dubious psychological theories about sensations, and the involved epistemological

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[41] *Ibid..* Troland p 532.

doctrines concerning particulars."[42] For Dewey, the leftovers of dualism in positive science generally stem from the disciplinary pressure for certainty. Anything less was considered 'substandard' science; thus, Dewey suggests positivism as a scientific practice had a "once-sided grasp of the method of inquiry"[43] This disciplinary practice is also reflected in the Colorimetry report. They define color in divisive subject/object mind/body terms, but it doesn't really develop from there. For instance, in the discussion of nomenclature, they directly move away from referencing stimulus or coming up with meanings for individual sensations; instead, the authors build on how to define color through its attribute of brilliance, hue and saturation, which is now the standard description for color systems[44] So, this brings up important inquiry questions in researching the underpinning influences of the groundbreaking OSA Colorimetry report of 1922, and the follow-up work done by the CIE in 1931. What were the influences in adopting the language of dualism? And, how may have the strict divisions between subject/object, psychological/physical shape the results of the CIE standards and color space?

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[42] *Ibid.* Dewey "Logic", p523
[43] *Ibid.* Dewey "Logic", p523
[44] *Ibid.* Troland, p 534.

4.6 OSA and The Epistemological Review of 'Color Space'

In 1943, over twenty years after the initial report on colorimetry, a succeeding Chairman of the OSA, Loyd Jones, penned a historical background and follow up to the report. While acknowledging the tremendous influence the 1922 and 1934 reports had on colorimetrics, he addressed a few lingering issues from the original report. First, quotes the definition of color as "sensation", stating: "at the time the report was written, sensation was regarded by many psychologists and particularly those concerned with the preparation for the report as a very definite and meaningful element of experience and consciousness, However, even at that time the literature in psychology contained some criticism of the concept represented by the word sensation."[45] The author goes on to cite psychologist William James and the move in psychology to dispense with the word sensation because is refers to something unsubstantiated.

During these years, color was more and more becoming defined by its describable attributes and physical appearances to perceivers rather than its *qualia* or inner-sensations that had traditionally plagued the definition. There is a detailed review in the report of how the word "psychophysical" was

[45] Jones, Loyd A. "The Historical Background and Evolution of the Colorimetry Report" JOSA. Vol 33. No. 10 October, 1943.

becoming a more popular way to define color rather than just purely physical or purely psychological.[46] This evolving understanding of color could be an indicator of the changing practices of science and the interdisciplinary nature that comes from visual 'problems.' It's clear that big changes in the way the society approached the "psychological" aspects of color were happening, and from the report it seems this was due more to a change in the way information was exchanged between members rather than any huge gains of "knowledge." In fact, as the discussions indicate, the society was 'less sure' of the underpinning terminology. It was a period marked by both progress and compromise for the OSA, and as the 1943 report indicates, this stemmed from the diverse membership's openness to challenging basic disciplinary assumptions in a spirit of inquiry and collaboration – and this can be demonstrated just in their framing of the word psychophysical which reflects a 'breaking down' of the subject/object binary.

[46] *Ibid.*. Jones p542. Jones details a productive meeting in Oct. 1939, where a Dr. Judd and others collaborate on a report about the correlations between physical and psychological concepts of color. It was noted the Judd "highly commended for his willingness at all times to appraise without prejudice proposals at variance with his own views, and his willingness to meet more than halfway opinions of others in order to promote progress in the work of the committee."

4.7 Functions of CIE Color Space

Going back to the signal processing of an analog image of a pink flower in a color appearance model, our digital data in this scenario is now on its way to the next general phase of color image processing, the encoding phase. It must be noted that the ways in which the technical conversion of RGB values to XYZ color space enabled *visual matching* and more accurate interactions between systems. While RGB is based on physical measurements of tristimulus wavelengths, the XYZ color space was purely a theoretical model. A theoretical was needed in order to express the tristimulus values in positive terms that would show up on the spectrum. The main achievement if the CIE report in 1931 was figuring out the math to convert tristimulus values based on data from human visual testing into XYZ terms that could be mapped on a 2-D vertical plane. (See Fig. 4.4 and Fig. 4.5)

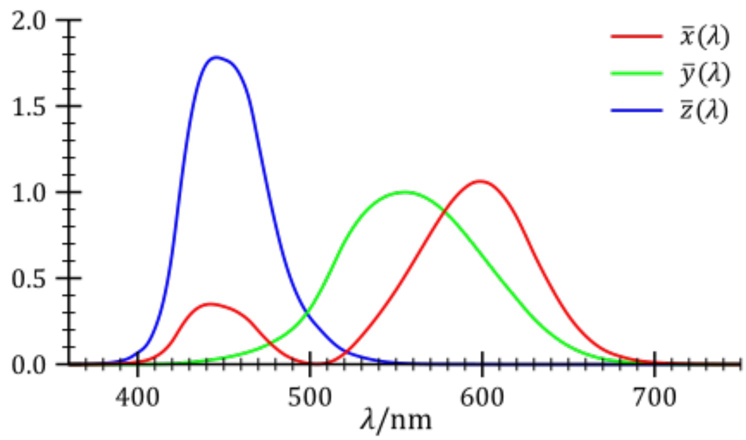

Fig. 4.3 Color Matching Functions of the 1931 CIE/XYZ Color Space – After calculations, values based on stimulus measurements of wavelengths were able to be expressed in positive terms that could account for the visual spectrum of light.

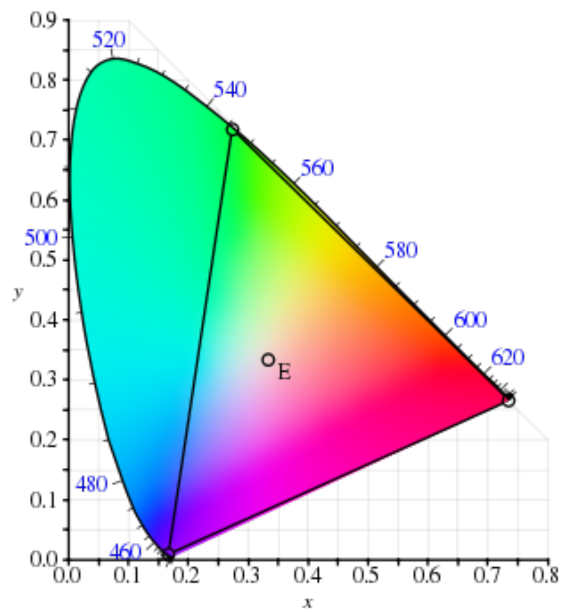

Fig. 4.4 CIE Color Space showing RGB values inside of the visual spectrum on a 2D XY plane.

Essentially, the mathematical conversion allowed analog RGB values viewed in three-dimensional space (3D) to be broken into three separate values of Hue, Saturation (chroma) and Brilliance (aka value, intensity or luminance). The creation of a two dimensional plane (2D) was helpful for people working with color because it separates hue and saturation from the third axis of light intensity, which is on a scale from light to dark.[47] Margaret Livingstone notes that all 2D representations of color, including Newton's color wheel, share the same feature of excluding luminance.[48] So what we see in the 2D CIE space is of functional importance. It standardized the color spectrum by giving it a numerical value, which also worked well with existing imaging technology already designed for the gray scale of light to dark (luminance). The underlying logical importance, then, lies in symbolic operations that makes the calculations reliable, thus knowable.

The 2D representation of color space also addressed another technical limitation, which was that RGB values expressed in this way did not account for all the mixtures of hues between the long and short wavelengths that the standard observer can see. To state this in plain color language, tristimulus

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[47] Livingstone, Margaret *Vision and Art, The Biology of Seeing*. New York, NY: Abrams Books. 2002. Print. pp 87-91.

[48] *Ibid.*. Livingstone, p 87.

values do not account for all the mixtures of blues and reds, including the pinks, many of the purples and violets. The RGB to XYZ conversion, however, was able to account for this because, like Newton's color wheel, it joined the visual spectrum together in both 3D and 2D color space.

To explain the importance of this working model, consider our analog image of the pink patch of light skin. The tristimulus (RGB) system of measurement calculates RGB values into single points of the light wavelengths, but since there is no single spectral wavelength that appears to the standard observer as "pink," it can be inferred that pink must be a mixture of wavelengths. The CIE Color Space allowed a way to more accurately calculate what mixture of two spectral colors (red and blue) it takes to produce a non-spectral color (pink). The calculations for RGB to XYZ conversion becomes critical to digital imagery in the *encoding* phase because in the *reconstruction* phase digital images are once again given RGB values that we see on our display screen. This is a hard concept to imagine, but if you draw a curve between the red and blue through the white pointe on the plane in Fig. 4.5, then cut that part of the spectrum out, that is roughly what one would see if our vision was only a matter of tristimulus values. There is something in the way that we perceive color that must be accounted for, and this is a fact realized in the original OSA and CIE reports on color, and the problem they had to address in order to make a functionally predictive model.

4.8 Color Spaces and Trichromatic Color Vision

From a modern historical perspective, we can easily understand where the gap in these first reports stem from – the reports privileged the Young/Hemholtz theories of trichromatic color vision because it offered them data based on the color vision of human subjects to work with. As I will explain in the next section, trichromatic theory was conceived under the Cartesian 'reflex arc' understanding of perception, with a sharp division between the physical and the psychological; additionally, this theory ignored the other explanations based on the physiological understanding of the visual system. Most notably, the original OSA and CIE reports didn't mention a competing theory of color opponency first described by Edward Hering. Color Opponent Theory, however, was a big part in the evolution of the CIE color space and was eventually reflected in almost all color model we use today.

What I would like to point out here are the different ways 'technology' can be defined in this epistemological case study. If we view the CIE color space as just a technological artifact (an object) used in the practice of color management (phronesis*)*, which is disconnected from theoretical knowledge (episteme). Then the object can be determined as useful or not useful without the theoretical underpinnings being questioned. On the other hand, if we define the CIE color space within a system of technology (an artifact, a methodology, and sociotechnical systems of manufacture and uses), then CIE color space can be considered a technology (techne) that bridged the theory/practice divide. I contend that the historical record demonstrates this point. The original CIE model worked, but only because the engineers and scientists were open to questions that stemmed directly from the technical application of the model. As I stated before, the model was built for the purpose of visually matching analog color to a technical system that could be applied to an accurate reproduction of the color that is based on the vision of a standard observer. The continual application of this technology led to a change in definition of color, and it is through the mode of inquiry that led to these changes.[49] Through the technical model of the CIE color space, a system of classifying color based on appearance challenged the theory of 'color as sensation' and this was due to the focus on evidence, and more importantly, reconfiguring our color perceptions as part of a psychophysical phenomenon rather than a purely mental sensation. Thus, the newly developed terminology for color appearance was based on bridging the mind/body dualism embedded in earlier definitions. The scientific view of color, then, shifted from 'sensations perceived by an individual thinking mind' to a growing set of 'visual appearance' classifications, such hue, value, chroma,

[49] *Ibid.* Jones.

aperture colors, illuminant colors, volume colors and surface colors.[50] There was something predictable about human physiology and perception that wasn't 'individual'; although, much about the psychophysical aspects of vision were not yet understood, this shift in terminology reflects a focus on the interconnecting ways that light interacts with material objects and with our physical bodies, which together we perceive as reality. As we shall see, the evolving view of color represented by a practical technical application of a color space represents a synthesis of the Trichromatic and Color Opponent theories for the CIE and OSA.

4.9 A Synthesis of Trichromatic and Opponent Theories of Vision.

My intent with this narrative history is to explain how color theory, and by proxy, how color technologies shaped our views on the paradigms of science, but also opened up pathways to connect the sets of possibilities and constraints imposed by cultural, technical and biophysical understandings of color. I argue that focusing on the interactions of applied technology within the epistemological accounts of color theory will provide insight into some of the major divisions between the cultural and scientific accounts of color theory. I'd like to emphasize that these divisions are not one, but many, because neither scientific nor cultural color epistemologies are monolithic. As

[50] Ibid. Jones, p 539.

the classic example of Newton's misinterpretation of color categories reinforces, scientific interpretation of visual phenomenon is also run through a cultural lens, with different mechanisms of evaluating the evidence.[51] What I intended to establish at the beginning of the chapter is a framework for evaluating the quality of evidence that supports logical coherence of knowledge. As Dewey suggests, the move away from a 'quest for certainty' that defined logical positivism, to a 'model of inquiry' that embraces uncertainty, is required for a coherentist model to work. This inquiry involves continually addressing cultural and disciplinary biases that affect the way 'knowledge' of a topic is understood. Therefore, a big part of understanding the way "color space" and the "color appearance model" was established stems from examining how disciplinary biases informed the interpretation of knowledge, and the questions that were asked. The way two competing theories of Trichromatic Color Vision and Opponent Color theory were synthesized is great example to study in this regard.

4.10 Trichromatic Color Theory and The CIE Color Space

[51] Historian Robert Findlay (2007) notes that Newton's *Optiks* (1704) is the first experiment to describe how the light spectrum consists of wavelengths, thus "unweaving the rainbow" represented a paradigm shift for optical science. However, Newton categorized the seven primary colors that he saw in the light spectrum by matching it to the seven notes of the musical scale. His color wheel was widely criticized as a result due to categorical errors of color language.

Trichromatic color theory is often traced back to English polymath, Thomas Young and his "Bakerian Lecture" published in 1802.[52] The idea of that just three color primaries could account for the spectrum of colors that we see was not a new idea, but Young's theory was much different in that he assigned the primary photoreceptors to the retina of the eye, and by adopting a wave theory of light, he theorized that light waves were responsible for "vibrations" of color receptors.[53] This is an important moment for theories of color vision, because it expanded the post-Newtonian experimental focus away from just physical investigation towards physiological mechanisms.[54] As Mollon notes, Young also distinguished between the "sensation nerve fibers" and the "phenomenal experience" of color, and although he did not know the actual spectral sensitivities of the three light receptors in the retina, he concluded that color was "not in the nature of light, but in the constitution of man."[55] This concept, also, was not new. Both Descartes and Newton has suggested that the eye works by light exciting the retina and causing it to vibrate, thus the new wave theory of light already had a fitting

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[52] Young, Thomas "The Bakerian Lecture: On the Theory of Light and Colours" Philosophical Transactions of the Royal Society. London. 1802. V92. Pp12-48 (January 1, 1802).

[53] *Ibid.* Young, p20

[54] Mollon, J.D (2003) "The Origins of Modern Color Science". In Shevell, S. (Ed) Color Science,

Optical Society of America, Washington D.C. The Science of Color

[55] *Ibid.* Mollon, p 14.

model in neo-Cartesian and post-Newtonian mechanics of the human subject.[56] Waves causing vibrations in the retina, that then excited three primary color receptors and allowed the subject experience color describes a model that fits into Dewey's definition of the "reflex arc." However, because observing the physiology of the eye was a secondary focus, Young pursued physics instead and never developed his trichromatic color theory through experimentation.

In 1855, two scientists, Herman von Helmholtz and James Clerk Maxwell independently gave trichromatic theory some experimental robustness with tests on 'color mixing'. Helmholtz had already errantly rejected the Young's three primary color theory in his early work on the subject of additive and subtractive color mixing several years earlier, but from discussions with mathematician Herman Grassman on the three dimensions of color (hue, brightness and saturation), Helmholtz reversed his original idea and came to accept the trichromatic color theory.[57] The problem Helmholtz encountered I define as a transactional or practical one. He argued that he could find only two primaries to make white light, yellow and blue,

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[56] Heesen, Remco (2015) The Young-(Helmholtz)-Maxwell Theory of Color Vision. [Preprint] URL:
http://philsci-archive.pitt.edu/id/eprint/11279 (accessed 2015-09-20).

[57] *Ibid.* Mollon, p 27.

thus the green primary was not necessary and seemingly did not have a harmonious compliment. He also argued that spectral yellow was indistinguishable from a mixture of spectral green and red, and that somehow didn't fit with trichromatic theory. Today, we can look back and see that opponent color theory can explain this conceptual error; but, instead of pursuing the specific inquiry of differences in a pure spectral yellow, or a mixed yellow, Helmholtz was eventually persuaded to accept trichromatic color theory by way of Grassman's geometrical equations of the three primaries we are familiar with, red, green and blue.[58] [59]

James Clerk Maxwell would become best known for his electromagnetic theory of light, but in 1855 he was experimenting with color mixing.[60] Lee explains that Maxwell's carefully devised experiment for mixing three spectral lights to produce white light (daylight) "gave trichromatic color mixing the best evidence for Young's trichromatic color theory so far produced."[61] Maxwell added extensively to the creation of "color space" by plotting R, G and B primaries onto a 2D graph that "visually matched" wavelengths.[62] Additionally, he graphed the same data into a 3D

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[58] *Ibid.* Mollon pp. 26-27.

[59] *Ibid.* Lee, p 8.

[60] It's also important to note that out of this series of experiments Maxwell used his primary color scheme to create the first color photographs.

[61] *Ibid.* Lee, p 8

[62] *Ibid.* Mollon, p 29

model to determine chromaticity. Both these models were very useful in many applications of color research, including converting values between trichromats and dichromats; but Maxwell's contribution to the theory of trichromatic color built upon the work of Young and Helmholtz, can be directly linked to the creation of CIE color space and the CAM model used today.[63]

To summarize, a synthesis of the Young - Helmholtz - Maxwell trichromatic color theories state that electromagnetic light waves stimulate three primary light sensitive receptors in the retina. Three receptors correlate to three known primary color, red, green and blue which, to the theorists, provide a basis for explaining the color spectrum that we see. The experimental models thus far focused on either physical experimentation, or on physiological theorizing from known studies on optics. The missing data to test this theory more accurately would be to measure the individual light sensitivities of the eye that are predicted by the theory. In separate experiments in the late 1920s, researchers David Wright and John Guild devised a way a measuring device that could observe tristimulus responses of the retina by placing the device close to the fovea (Wright, 1928, 1928; Guild, 1932). They carefully measured a small number of subjects based on the

[63] *Ibid.* Lee, p 8

spectral primaries established by Maxwell, and their stated goal was to accurately define the spectral sensitivities of visual receptors.[64] With the 'standard observer' already defined in the 1922 OSA report on colorimetry, Wright and Guild's data was used to create the CIE XYZ color space that could be used to 'visually match' RGB trichromatic values representing the 'standard observer.'[65]

4.11 Opponent Color Theory and the CIE Color Space

In 1874, physiologist Edwald Hering proposed an alternative to the Young-Helmholtz trichromatic theory called the opponent process theory. Hering noticed that when blue and yellow are mixed, the human observer doesn't perceive a mixture of yellow and blue but an entirely different color (white), he also noted the red and green had the similar opposite relationship, these colors didn't produce a reddish-green or a greenish-red, but instead produced a new color – yellow. From his observations, Hering suggested "there were two pairs of opponent processing underlying human color vision."[66] While Hering was correct about the opponent pairs of B/Y and R/G, he was incorrect about these relationships being located in the visual

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[64] *Ibid.* Lee, p8.

[65] *Ibid.* Jones, p545.

[66] Gouras, Peter "Color Vision". Eds Kolb et al. Webvision: The Organization of the Retina in the Visual System. http://webvision.med.utah.edu/ Open Web Text. Accessed: 9/20/15

receptors.[67] Neuroscience has since been able to partially explain how color opponent cells in both the ganglion cells of the retina and the opponent cells in the visual pathway (LGN), process color opponents to enable visual perception of color, but this is still very much on the frontier of neuroscience today.[68] However, in 1957, Leo Hurvich and Dorothea Jameson provided the empirical data needed to support color opponent theory and provided a schema for how the L,M,S photoreceptors are dispersed into color three pairs – blue/yellow, green/red, and black/white.[69] (Fig. 4.6)

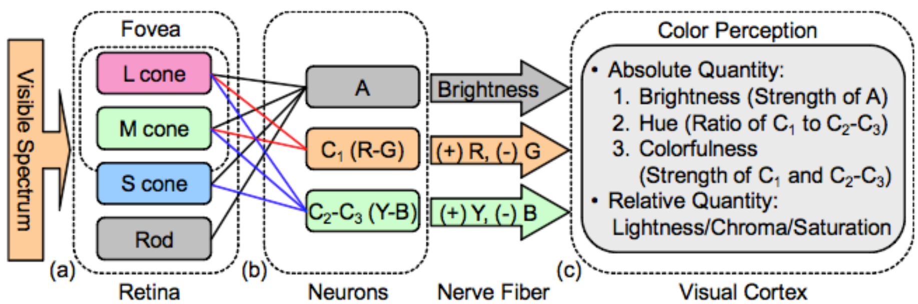

Fig 4.5. Representation of Hurvich and Jameson's *Color Opponent Schema*, showing how three short, medium and long retina receptors can transduce signals into opponent cells that organized by opponent responses to blue/yellow and green/red in addition to light/dark responses.

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[67] Gouras "Color Vision"; Hubel's "Eye, Brain and Vision" 1995.

[68] Conway (2010) provides a great summary on neural color pathway The Neuroscience of color will be part of a later discussion in a different chapter.

[69] Hurvich, Leo M.; Jameson, Dorothea Psychological Review, Vol 64(6, Pt.1), Nov 1957, 384-404

Hurvich and Jameson's calculations were based on neural responses and brought considerable evidence to the connection between physiological and neurophysiological understanding of color vision.

Because the evidence for Hering's color opponent theory was not fully tested until 80 years after he proposed it, the trichromatic color theory was more widely accepted dues to the experimental underpinnings by Young, Maxwell and Helmholtz that all published extensively on their findings. Still, in 1976, the CIE report revealed the updated CIELAB color space that was also compatible with the XYZ and RGB values. L stands for luminance, A represents the red/green axis, and B represents the yellow/blue axis. The development of this space, then, synthesized the trichromatic and color opponent understandings of color vision. The adaption of the CIELAB space allowed color differences "to be perceptually uniform throughout the space."[70] The CIELAB color space is still effectively used to this day but many difference color models with visual matching functions, designed for specific purposes and industrial uses have been created using the same basic methods. The development of the XYZ dimensional space that allowed color to be mapped on a two dimensional plane is the basis for all color spaces used in color appearance model; additionally, if you have the 3D values of any

[70] Ibid. Fairchild p, 81

color space, analog or digital, the XYZ space can be used to convert data into any other color space. All of this computing, now, takes place in the computer with minimal input from the user, but this is how visual data is transferred between most input/output systems today.

It is interesting to point out how well these two theories work together in spite of being considered rival ideas ever since Hering challenged trichromatic color vision with his proposal. As we can see from the narrative of these models for color vision, there were conceptual shifts in the study of color from the *physical* (material) via Newton, to *physiological* (biophysical) via Young, to the *psychological* (psychophysical) via many theorists. And this offers a way to categorize the underpinning concept in some of these theories. For instance, Hurvich and Jameson's work provided the physiological basis for color opponent theory, although they fully recognized the psychophysical effects of opponent colors, just as Hering did. The famous neuroscientist, David Hubel, offers another insight into this organizing structure for understanding color. Hubel states:

> In thinking about color, it is useful to keep separate in our minds these different components: physics and biology. The physics that we need to know is limited to a few facts about lightwaves. The biology consists of psychophysics, a discipline

> concerned with examining capabilities as instruments for detecting information from the outside world, and physiology, which examines the detecting instrument, our visual system, by looking inside of it to learn how it works. We know a lot about the physics and the psychophysics of color, but the physiology is still in a relatively primitive state, largely because the necessary tools have been available for only a few decades.
>
> David Hubel "Color Vision" 1995

As Hubel's careful words imply, the study of physiological mechanisms represent some of the hardest problems in color research, and should be considered under its own definition due the nascent 'tools' of neuroscience. However, his use of the psychophysical terminology indicates a unity of body and mind. All of these paradigms, even if studied separately with different sets of material and conceptual tools, all make up the gamut of our understanding of color; but the idea is that the paradigm divisions are on their own trajectory. This brings up a question - How does 'knowledge' of color advance under these divisions? How do we get knowledge to logically cohere with our experiences? The case of the CIE color space provides a wider lesson for the coherence of knowledge as well.

4.12 Logical Inquiries and A System of Constraints

When the inventors of the OSA Standard Observer and the first CIE Color Space were constructing their technology to allow enable visual matching for color applications, they were privileging the work of the Young, Helmholtz and Maxwell. Obviously, Wright and Guild derived their technology and gathered their data largely based on the strengths of trichromatic color theory to empirically explain part of color vision as well. Additionally, the OSA borrowed heavily from the terminology of Helmholtz and Maxwell to 'standardize' the field of colorimetry. Hering's rival theory wasn't completely ignored, however. In the OSA report (1922) it mentions Hering's experiments on the "color constancy of visual object" which, like color opponency, predicts an underlying visual process not explained by the physiology of the eye, let alone trichromatic theory. Yet, this issue was not further addressed in the report.

Another example that illustrates the privileging of trichromatic theory is from the omission of Abney's synthesis of Hering's color opponent theory in his work on vision and color blindness for the Royal Society. In his report on colored vision as part of the Tyndall Lectures in 1894, Abney gave extensive attention in comparing Young' theory to Hering's. Although he favored Young's theory for the most part, he did acknowledge the merits of Hering's theory in that it opened the door to inquiry. Abney says Hering's theory "has already pointed out the question of extent of fields requires further investigation beyond which it has received."[71] Again, at the end of the section, he acknowledges the limited view of both physiologists and physicist perspectives because of the bias they accrue from the complexities of the eye.[72] Abney's synthesis of Hering, then, is that he challenges Young's theory as it was gaining in acceptance and popularity due to its promotion by Helmholtz and Maxwell.

In the language of Dewey's *Logic,* the acknowledgement of Hering's color opponent theory speaks to a new set of postulates set by the theory. Specific color phenomenon of afterimages and impossible color mixture introduced a rational and logical uncertainty to color vision not explained by trichromatic theory. However, Abney's lecture and the OSA report both invoke a logic of progressive and social disciplines. On one hand, the OSA and the CIE are autonomously and purposefully evaluating the best evidence with logical inquiry. On the other hand, Abney's lecture, the OSA and the CIE reports demonstrate how social expectations for certainty effect the logic of inquiry by asking for more certain knowledge.

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[71] Abney, Cpt. W. "Colour Vision – The Tyndall Lectures" London, EN: Sampson Low and Marston CO. 1895.

[72] Ibid. Abney, p200.

4.13 Color Vision and the Coherentist Framework

Through a coherentist structure for evidence based inquiry we can see how both Abney, OSA and the CIE reports focused generally on the amount and quality of evidence. As documented, Hering's theories wouldn't receive strong evidence for another 80 years. Even then, the opponent color cells retinal ganglion region and the neural pathway (LGN), would have significantly falsify Hering's theory. Still, his observations and systematic inquiry into the phenomenon of color constancy, afterimages and impossible colors led him to question the certainty of the trichromatic model. And it was enough to be acknowledged, but not justified, or falsified due to the lack of data.

We can also see how a coherentist framework may have influenced the formation of the standard observer and the CIE color space. Enough evidence was accrued to justify a working model for color space, even with its technical limitations. The mathematical calculation needed to make the XYZ color space facilitate 'visual matching' turned out to be a line of inquiry that proved trichromatic color theory was only a partial explanation of color vision. Yet the original model worked fairly well in spite of the gap in understanding the physiology, and it provided a basis for verification and falsification later on. As the eventual adoption of CIELAB color space implies, the technology of the color space had a significant impact in bridging the subject/object divide. It is a true psychophysical model that coheres with together with the established physiological record.

As we can see from the history of this color space, we can conclude there are some obvious constraints within each of the paradigms of physiological, physical, and psychological perspectives of color research. The vestiges of old dualisms are reflected in many of texts that recorded the construction of color space. Consider the way the 1922 OSA report describes color in the summary:

> The color of an object, considered as an impression which the object produces on the observer, is determined by at least three general sets of factors: (1) the physical characteristics of the object, (2) the physical characteristics of the radiant energy falling upon or emitted by it, and (3) the nature and condition of the observer's visual apparatus.
>
> "Report on Colorimetry" (1922)

In spite of the lack of physiological evidence for color opponent cells that were later found throughout the visual system downstream from the retinal cones, there were still enough anomalies to bring the strongest evidence for trichromatic color theory into question. What we see in the language of the reports is a bias towards the 'reflex arc' model of perception, where the psychological is treated as distinctly separate from the other problems. This was an issue for Descartes and Newton, and it's an issue for Young and Helmholtz as well. The above description of color exemplifies the commitment to mind/body dualist explanation of vision almost no inquiry involving the psychophysical aspects of color. However, the CIE color space also marked a time technological changes that were followed by conceptual changes for using the CIE color space.

4.14 A Discussion of Bonjour's 'Observational Requirement' and The CIE Color Space

In this chapter, I argued that the visual matching function of the CIE color space technology can be viewed as a mode of inquiry. In conclusion, I would like to clarify this view. As demonstrated in the review of historical literature above, this technology has continually found new applications since being engineered in 1931, and its central function visual matching of color intended for production has largely remained the same. As emphasized, one of the everyday uses of this technology is in the input/output process of digital images, which is largely an automated process. However, theories of visual perception, biological understandings of vision, and knowledge of light physics that underpin the logical coherence of how the CIE color space works has changed drastically since its inception, and this brings up interesting questions about the nature of coherent theories that justified the CIE Color Space.

To summarize how I define this technology, the CIE color space can be viewed as an example of physical hardware, or artifact, because of the components involved in signal processing, but this technology also is defined by its sociotechnical applications and the evolving technical know-how to use the technology. These different definitions of technology demonstrate how the CIE color space works well with other technical systems in a way that isn't necessarily tied to the technical hardware used to manufacture the CIE, but rather to its algorithmic nature which is both analog and digital, theoretical and physical. In this way, the CIE technology works on a logic that is in accordance with Dewey's terminology for logical inquiry which is progressive, operational, postulational, social and autonomous.

An argument can also be made that the initial epistemological justification for CIE color space in 1931 fits into the first four points of Bonjour's *coherence criteria*, but maybe susceptible to the fifth criteria. As the early OSA reports indicated, a synthesis of Young, Helmholtz and Maxwell's Trichromatic theories offered coherent logical consistency to explain the technology, and because the technology worked adequately and found a variety of applications this demonstrated coherence through its probabilistic consistency and its inferential connections to with other systems of technology (such as industrial applications and cameras). Conversely, Bonjour states in his fifth criteria that "the coherence of a system of beliefs is decreased in proportion to the presence of unexplained anomalies in the believed content of the system," and as the historical record indicates there were plenty of anomalies with both the CIE technology and trichromatic theory that explained it.[73] Most notably there was the gap in knowledge of how trichromatic theory with three color values could account for all the colors that we can see, and this was also reflected in measurements of the human retina taken by Wright and Guild that were eventually used to construct the CIE color space. The engineers of the CIE addressed this anomaly by creating a theoretical model used to visually match colors that person with normal vision can see to colors created using the CIE color space. With current knowledge of opponent color theory, the neuro-physical process involved in vision and a better understanding of the way we perceive physical light, it's easy to see how these advances have modified a CTEK for the CIE color space using Bonjour's same criteria that better addresses the anomalies

[73] Ibid. 4. pp. 95-99

of its previous justification; however, this does little to explain how such a significant shift in CTEK could take place while the technology mostly remained constant.

To address 'how' such a change could occur, I would like to point back to Bonjour's additional class of *cognitively spontaneous beliefs* that he also included to be an observational requirement for CTEK. Since the central function of the CIE Color Space was engineered around a 'standard observer' that was initially described the Optical Society of America, and then constructed with the measurements taken by Wright and Guild, I argue that the CIE Color Space enables the observational requirement for a coherent theory of empirical knowledge to be fulfilled. If the output of digital images using the CIE Color Space is justified to be consistent with our biological visual system, this also allows for cognitively spontaneous beliefs to occur in the perception of these digital images, only these beliefs are technically mediated vie the logic of the CIE technology. The non-inferential knowledge gained from a digital image is also made possible by the automated and hidden algorithmic nature of signal processing in the input/output system. Simply put, when we see an image of a red book on a desk (to use Bonjour's example), the technological mediation of the CIE Color Space is not present to the perceiver to the point where the experience of perceiving digital imagery allows of cognitively spontaneous beliefs to be possible. This is also the case for digital images of pinkish human skin, where the CIE technology theoretically predicts our human perception of pink based upon criteria for a standard observer. Of course, even a brief introspection on the technology that produces the image of human skin can shift this observational mode to what Bonjour refers to as a "deliberative or ratiocinative" process which is relies on "language entry inferences."[74] And it is the shift from non-inferential/experiential knowledge from outside the system to inferential/introspective knowledge within a coherent system that allows for a CTEK to change. Thus, we can view the embodied experience of perceiving images produced by the CIE color space as a way to inquire about the logical coherence of the technology.

4.15 Conclusion

I would like to reflect back upon the twin descriptions of skin at the start of the chapter. Both passages present flaws in the semantics of visual observation by assuming that 'white' (or lightly pigmented, or pinkish) skin is the "superior" coloration in the early text, and the "desired" baseline skin tone in the later text. Even though the methodologies, technologies, sociotechnical applications and disciplinary commitments are completely

[74] Ibid. 4 p117.

different, the nomenclature and descriptions of their human subject's skin carries these assumptions. The appearance of skin matters, but the historical record has shown there is high amount of diversity in why it matters. In these historical artifacts I have put together, the visual appearance of skin served as the catalyst for investigation, but as we see in this case of modern digital measurement and cosmetic production, a desired color skin appearance can also be the outcome for measurement. I'm thinking here of products designed around skin appearance such as cosmetics, skin tanning, and skin whitening, but can be extended out to entire visual cultures that concern the appearance of skin.

As some of the other case studies in my research suggest, the legacy of visual observation has effected the practices and applications of skin diagnostics in diverse ways, but one way to address this diversity to compare the language of visual observation to the language of light and skin interactions. The development of the CIE color space plays a functional role in this comparative method because it bridges the era of linguistic matching to the era of diagnostic digital imaging. While the diversity principle predicts that CIE technology used in skin diagnostic applications will have a narrowing effect on the terminology and categories used for skin, the wide variety of applications that use the CIE demonstrate there is no unifying standards for the ethics or results of skin diagnostic studies. With such wide applicability for this measurement tool, it seems there is a dearth of disciplinary constraints placed in sociotechnical applications. As we can see from this most recent description of skin as a turbid medium, the changes in technology, terminology and methodology do not necessarily reflect changes in how old standards of visual observation are applied. The observational requirements the observers of that study depended on pre-existing language and cultural beliefs about human skin, and this insight keeps the problems found in long history of visual theories relevant to today's diagnostic technologies

Chapter 5

The Human Body, Big Data and Skin Measurement: Diverse Applications in a New Era of Digital Biometrics

"By bringing instruments front and center, we get a different history, a history awkwardly classed under the old rubrics "internal intellectual history" and "external sociological history." Of course, the history of instruments must be a technical history... But the history of instruments is also part labor history, part sociology, and part epistemology. It is the history that is inseparable from individuals' search for a way of working in laboratories sited squarely in a particular culture."

Peter Galison – "Image and Logic: A Material Culture of Microphysics"

5.1 Digital Imaging Analysis and The Instruments of Skin Measurement

Digital imaging analysis is a growing set of procedures that use image processing techniques to make useful information from the pixel information of digital images. The applications of digital imaging analysis used to assess biomedical images have been traditionally produced using widely different methods and such as CT scans (X-rays), ultrasounds (sound waves), fMRI brain scans (magnetic waves) and PET (radioactive measurement). Further, digital imaging technologies are being used to produce visual 3-D models and even to produce image based diagnostic tools using digital information directly from the images made from consumer quality digital cameras. For the purposes of this dissertation, I will focus and just a few of the ways digital imaging analysis techniques have been incorporated into the diagnostic measurement of human skin. In particular, a few of my collected artifacts demonstrate the confluence of skin measurement technologies that merge the techniques spectrometry and digital imaging analysis, and through these emergent applications new ethical questions regarding the data and skin diagnostic imaging become clear, while some of the older problems of skin measurement I have described in earlier chapters are still present as well.

Since digital imaging analysis is a growing field in medicine (and many other areas), theories of computational vision and digital imaging are then increasingly being used in biomedical applications with an alarming amount of potential for the medical industry.[1] This marks a shift in the way technology interacts with the body, and the way biometric data is collected, produced and represented. The IEEE Medicine and Biology Society (EMBS)

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[1] " Lecture Notes in Computational Vison and Biomechanics" *Color Medical Image Analysis eds. M. Emre Celebi & Gerald Schaefer.* New York, NY: Springer Science Media. 2013. Print.

states purposefully on their website that these new digital image processing technologies allow for researchers to explore "the theoretical potential of data and technology' by moving the question from 'how does it work?' to 'how and what can we use it for?'[2] One often repeated claim is that image analysis techniques are inherently more non-invasive to the body, fulfilling the medical ethic of "first do no harm."[3] The EMBS sums this up with the statement: "New imaging techniques bring new means for peering into the human body, helping to reduce the need for more invasive diagnostic and treatment procedures."[4] Therefore, much of the research in this area operates with excitement about the potential that digital imaging and software tools brings to the medical imaging analysis, with little risk to the human body during technical exploration.

Another important feature of biomedical imaging and image analysis is the idea of 'digital enhancement' - which is where the advantages of using digital imaging technology are found. Software and computational processing (aka algorithms) allow biomedical images to be probed and analyzed for data beyond what the human eye can see. Bringing biomedical images to the

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[2] *IEEE* Engineering in Medicine and Biology Society (EMBS) *nDiagnostic and Therapeutic Systems.* http://www.embs.org/about-biomedical-engineering/our-areas-of-research/diagnostic-a-therapeutic-systems *Accessed: 12/5/14*

[3] Ibid. 2

[4] Ibid. 2. http://www.embs.org/about-biomedical-engineering/our-areas-of-research/biomedical-imaging-a-image-processing Accessed: 12/5/14

digital realm aids researchers in “a spatial and temporal analysis to detect patterns” in the body that would not otherwise be visible.[5] Thus, these processes produce images that are quantitative and visual displays of biological mechanisms, using digital processes to visually enhance the body for diagnostic detection purposes.

There are many examples of imaging technology that fit the above simple description of modern biomedical imagery, including consumer level cameras and open source software; additionally, it is the interpretation and explanation of these growing and diverse applications that my inquiry seeks to address. But for the purposes of narrowing my case studies to a manageable inquiry, I have chosen to focus on just a few developing technologies from the history of skin diagnostics that exemplify digital imaging technology that operates under the ‘great potential/low risk’ ethic, and features a component of ‘digital enhancement’ that significantly adds to the visual interpretation of the images of human skin.

5.2 The Algorithm and The Database - Two “New” Directions in the History of Skin Diagnostics

[5] Ibid. 7.

To summarize one of the main arguments of this dissertation, the diversity principle historically predicts that diversity in skin measurement technologies, methods of measurement, and disciplinary applications will increase over time, while the diversity of terminology for skin, the categorizations of skin and the sociotechnical applications will decrease. Further, it seems that advances in technological hardware and technical know-how act as organizing mechanisms for the rationalization of disciplinary logic that follow the use of the technology, even as applications become more diverse. For example, Sheard's use of a spectrophotometer built to analyze the reflectance properties of soil was crossed a disciplinary line when it was used to measure the reflectance properties of human skin; however, the logic and rationalization for using the technology remained the same in that both soil and skin share complex technical conditions for measuring light reflectance (see Artifact 31). Another example of this principle is demonstrated in the combined rationalization and disciplinary logic behind Jablonski's use of the Von Luschan Chromatic Scale and the CIE Color Space (see Artifact 53). Both technologies follow the logic that our human perception limits our ability to distinguish between hue and luminosity and instead both visualize a spectrum of colors based on 'normal' human trichromatic vision. Since the CIE Color Space covers the spectrum of human visual perception, this technology accommodates the chromatic spectrum of human skin colors represented by the Von Luschan Chromatic Scale. The combination of these technologies allowed for new and diverse applications for the old data gathered by Von Luschan Chromatic Scale, while narrowing the terminology for skin to the quantified logic of the CIE Color Space that is based on a 'standard' of human perception.

In general, the sociotechnical applications that employ digital imaging analysis biometric purposes have been focused on medical diagnostics of human skin, or in the case of Jablonski's research, to the field of physical anthropology and the understanding the relationship between evolution, human health and the environment (see Chapter 3). The progression of measurement technologies that narrowed our scientific understandings of human skin into terms of reflectance properties based on human perception of light was, and is, crucial to understanding how disciplinary logic and rationalizations of the scientific enterprise that applies these technologies work. I argue that there are specific reasons that some of the old sociotechnical applications of skin measurement studies have disappeared in the age of digital imaging analysis. Specifically, skin color measurement is not used to make claims about 'racial categories' or to claim some human groups as innately different based on skin type. Instead, the technology used today for skin diagnostics reinforces the perspective of a universal human category and the diversity of chromatic skin colors found in human population. In summation, the digital technology used to measure skin and skin color variations today works within a collective of scientific knowledge that has falsified many of the diverse understandings and claims made by scientists of the past, while standardizing the more accurate 'knowledge' of human skin as well as the conditions that lead to skin color variance in all human populations. This shift within the scientific enterprise has led to a focus on human health for skin diagnostic technologies. However, because digital technologies are adaptable to large range of disciplinary applications, there are certain features of digital imaging technologies with the potential to extend the past the boundaries of the scientific enterprise, and break from the systems of coherent logic maintained by scientific disciplines.

Artifact 51: "Eulerian Video Magnification"

One example of a boundary crossing technology comes from computer scientists at MIT who have developed digital video algorithms that amplify color changes on the body, thus giving doctors a non-invasive way to visibly monitor breathing and heart rates through digital color monitors (see Artifact 51). The digital video algorithms rely on a set of computational visual theories, and analysis of the color information received from a camera.[6]

[6] Wu et al.(2012)"012)012)(2012)5/14/Sussman and Jablonski covered in Ch.3pplication is th. ACM Transactions on Graphics. v.31 n.4

Although there's also many potential applications for this technology, the basic idea here is that the average consumer digital camera can become a diagnostic tool for measuring blood changes underneath the by capturing reflected light that the human eye cannot see. These video images look normal when viewed on a computer screen, but using the algorithm developed for the Matlab software that is also widely available to anyone, the reflectance data can detect micro changes of blood flow, and then the data can be enhanced by a digital algorithm before being reconstructed for a visual display. The result is a real time video that potentially monitors heart rate, and visually tracks blood changes on the body.[7][8]Additionally, I point out the importance of technological access to these applications. The MIT lab that created this algorithm posted the Matlab code and instructions on how to reproduce the results, and they even have a online application that computes your video for you.[9]

The potential of this technology for biomedical applications can be immediately realized, and the fact that it was built and released on an open-access platform means that consumer products, such as the iPhone or other

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[7] to see the full report and process: http://people.csail.mit.edu/mrub/vidmag/

[8] See the full report and the Matlab code here: http://people.csail.mit.edu/mrub/vidmag/

[9] See my results using the Matlab algorithm here: https://vimeo.com/103024111.

personal internet devices, will potentially be able to produce these diagnostic images for use in everyday applications. To sum up the article, the potential uses, digital enhancement, non-invasive techniques are the core justifications used for the development of the study. They do a great job of explaining how the technology works and provide concrete examples for the 'what can it be used for' question. What is omitted, though, is an explanation of the question 'why' is this important to produce on an open access platform, and 'how' could it may affect the users of the technology? I call these type of questions 'practical problems' and if you show a dozen people a video of this technology, you will get a dozen 'practical problem' questions. I can speak to this as I have incorporated this example into several presentations on digital color; perhaps the most surprising question that inevitably comes up in the audience is: *Does this technology work for dark skinned people?* And it's a question like that, in a public setting, that knowing 'how the technology works' falls short in addressing, and often becomes oversimplified in answering. Therefore, while this technology can have a positive outcome in applications where trained professionals are interpreting the image and can explain the technical aspects of imaging a range of the skin color spectrum, the wide accessibility to the technology could potentially create problems of uniformed speculation. Poor communication could lead to a misinterpretation that is divorced from the coherent logic of a specialize scientific discipline. In other words, the digital algorithm functions as an expedient tool that serves usability and allows for wider access, but it also hides the intricate understanding how light interacts with the properties of human skin by allowing for an instant 'real' time analysis of skin color changes, rather than track the 'know how' through an analog process.

Artifact 54: "Skin Reflectance Signatures"

Another example of how the techniques of digital imaging analysis can exceed the boundaries of discipline in unpredictable ways comes from a National Institute of Standards and Technology project that is collecting data for a hyper-spectral imaging database (see Artifact 54). The goal of this project is to collect images of human soft tissue, from a wide spectrum of skin pigments, tissue density, blood cell content and volume, with the purpose of supporting non-invasive diagnostic technologies used to assess a variety of soft tissue injuries and conditions.[10] The project relies on the capabilities of a digital camera and the digital enhancement of the images to capture the distinct spectral features of a variety of substances, including skin. Because of the variability and diversity of skin properties in the human population, this technique requires a large database of images that organizes different

[10] Catherine C. Cooksey, Benjamin K. Tsai, and David W. Allen. 2014. "A collection and statistical analysis of skin reflectance signatures" Cooksey et al. Proc. of SPIE Vol. 9082 908206-2

images of tissue samples with a wide variety of variable conditions in both the environment and the tissue itself. The accumulation of data from a diverse population is key to this project because with a wider the range of informative data from the spectrum of the population, the more accurate a researcher can account for variabilities between subjects.

In general, the article describes the sociotechnical application of this database of images to be intended for medical applications such as wound diagnosis, of skin cancer diagnosis using the "reflectance signatures" of skin properties. However, in the article, list other potential applications for the database that are left unexplained. The article says: "Some examples [of applications] include medical imaging, security, biometrics and safety" (Cooksey *et al.*). While the disciplinary logic of medical imaging for diagnostic purposes is for the most part understood, "security, biometrics and safety" carry a tremendous amount of uncertainty and vagueness that are not expounded on, yet are central to the rationalization for the technology. It's these alternative and diverse sociotechnical applications for digital imaging analysis that once again can be detached from the scientific enterprise that developed the methodology.

Additional articles written by this team of researchers for NIST describe these alternative applications for hyperspectral imaging databases to include "person-born threat objects" (Human bombs!), as well as other reflectance signatures on the skin and body that are undetectable to the naked eye, but could be identified using digital imaging analysis and a database of images.[11] [12] Again, the method of hyper-reflectance imaging build off the disciplinary logic of skin diagnostics derived from advances in spectrophotometry, the CIE color space and accumulated scientific knowledge about the biological properties of human skin. The additional implementation of the 'database' of images introduces a component to the technology that allows for uncertainty in regards to its disciplinary function and application, and this uncertainty encompasses an undefined socio-political function for the technology, and more specifically, the database of images that are being collected under the medical science logic of 'first do no harm', but with the potential for being applied to a set of undefined 'security' or 'safety' applications, including surveillance and wartime scenarios.

5.3 Old Questions Made New: Risk and Diversity in the Communication of Skin Diagnostics

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[11] Cooksey, C. C., Neira, J. E., and Allen, D.W., "The evaluation of hyperspectral imaging for the detection of person-borne threat objects over the 400nm to 1700 nm spectral region," Proc. SPIE 8357, 83570O (2012).

[12] Cooksey, C.C. and Allen, D. W., "Investigation of the potential use of hyperspectral imaging for stand-off detection of person-borne IEDs," Proc. SPIE. 8017, 80171W (2011).

I have chosen to emphasize examples of the database and the algorithm in this chapter as these are added components to the historical view of the technological system of skin diagnostics that both alter the communication of the science and introduce potential risk in the sociotechnical applications of the skin diagnostic technology. Much like the CIE color space was found useful to a wide range of disciplinary applications in the measurement of skin, and brought with it both the logic physical light and the language of the way light is perceived by humans, both databases and algorithms in used in these case studies introduce their own logic, language and unforeseen potential into the developing methods of digital imaging analysis.

For example, as stated in the NIST literature on the hyperspectral imaging database, a database of spectral signatures from a range of human skin signatures would likely benefit future applications and the building of imaging systems.[13] The groundwork for this research comes from several diverse disciplines. First, the skin samples were collected with a spectrophotometer with its technological roots in anthropology, dermatology, biomedicine and this history is partially described in earlier chapters of this dissertation. However, the implementation and the benefits of database

[13] Catherine C. Cooksey and David W. Allen (2013) "Reflectance measurements of human skin from the ultraviolet to the shortwave infrared (250 nm to 2500 nm)" Proc. of SPIE Vol. 8734 87340N-1.

imagery were developed for a remote sensing application called the Advanced Spaceborn Thermal Emission and Reflection Radiometer (ASTER) which works by matching recorded reflectance data to a database of spectral signatures of a specific object. ASTER was originally developed in part by NASA for environmental objects like minerals and vegetation images captured from satellites or planes; however, the instrumental use of an image database developed specifically for reflectance signatures of human skin (using human subjects) is new application for this technology, and this project being actively developed by this team of NIST researchers. Furthermore, the logic for collecting, archiving and distributing this database to researchers is not just limited to medical and health related projects that could benefit from more accurate data of skin signatures; conversely, 'security applications' are foregrounded throughout the literature of this research, and yet the applications remain only as a suggestion with no ethical considerations considered. Therefore, the scientific ethic for non-invasive imaging technology is lost when disconnected from medical applications and provided for unspecified 'security' application that could very well be invasive and used for unethical socio-political ends.

A similar shift in the ethics of applied digital imaging technology can be found in the algorithm of MIT's Eulerian Video Magnification code. While the researchers suggest positive uses for this technology such a "non-invasive" method to detect blood flow and heart rates of a human subject, there is an added element of risk in the way the algorithm is being distributed on an open access platform. From the outset of the project, the research team at MIT has provided the data and the technical knowledge they have developed that enables users to visualize subtle motions captured by consumer grade cameras, including motion caused my undetectable color changes, physical vibrations and even soundwaves. This allows users of the code to visually re-construct motion related information captured by the camera that is not detectable by our senses alone, and this can be done remotely, from a digital camera, with minimal lighting restrictions.[14]

While non-invasive imaging of human skin is only a small component of this developing technology, the researchers rationalized the technology with the medical science ethic of 'non-invasive' monitoring. Their original examples show videos of monitoring the heartbeat of a baby, and the face and wrist of other human subjects with obvious implications for medical applications. This ethic is quickly abandoned in later research developments of the technology, and the potential risk that comes with surveillance technology is foregrounded by the open-access algorithm provided for the

[14] MIT researcher Abe Davis summarizes the potential of this technology in his 2015 TED talk: http://www.ted.com/talks/abe_davis_new_video_technology_that_reveals_an_object_s_hidden_properties?language=en

general public to use. In fact, in a 2015 TED talk on MIT's research on Eulerian Video Magnification, researcher Abe Davis, addresses the concern over the potential surveillance usage of their technology.[15] Curiously, however, he demonstrates how it 'could' be used for this end, but then immediately shifts focus back to more positive uses. Again, security and surveillance are listed as potential uses of the technology by the researchers along with the other biomedical applications; however, the underpinning ethics that coincide with the technology are omitted from these potential uses that are divorced from the scientific enterprise of medical diagnostics.

One of the key understandings that my collection of primary texts reveals is how the technology of skin diagnostics (technical hardware, technical know-how, technical applications and technical systems) was influenced by a scientific enterprise that eventually developed correcting mechanisms to refine technology and the science underpinning the technology. Part of the coherent epistemological structure of science that developed during this history was benefitted not only by the way evidence was tested with inquiry and experimentation, but also from the way technical data was collected, accumulated, stored and accessed. Beginning with the

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[15] "Abe Davis on Eulerian Video Amplification" www.ted.com. Web. Mach 2015. http://www.ted.com/talks/abe_davis_new_video_technology_that_reveals_an_object_s_hidden_properties/transcript?language=en

Von Luschan Chromatic Scale, the history of skin diagnostics demonstrates the risks involved with quantifying the color of human skin and developing methods to collect and use skin samples as data for a variety of future purposes. Nina Jablonski's work further exemplifies the unpredictable directions that technology can afford by developing a method to recover old data from this abandoned technology, and using the CIE color space to convert it into a more modern language of comparative data. In this case, too, both the algorithm and a database are crucial to new applications for the technology, which was to make old skin color data useful for theorizing how skin color variation evolved in different parts of the human population over and extended period of time. Jablonski's work is clear in its purposes as well, and maintains a strong sense of disciplinary ethics developed in the modern practices of anthropology. I argue this represents a strong form of ethics within a coherent logical and technical system, within a scientific enterprise, and this is a strong example of how the diversity principle explains how the ethic choices of an individual researcher shape the ethics and application of a technology.

Conversely, in the case studies of Eulerian video magnification" and the Skin reflectance signatures, we can see how the algorithm and the database also contribute to a coherent and logical system of knowledge, as demonstrated by the expanding applications for these technology. However, it is easy to see the great uncertainty and risk involved in the way the algorithm and database are constructed and distributed in these cases. The principle researchers in both cases both promote uses of the technology that go way beyond a scientific enterprise regulated by disciplinary ethics, and the historical, philosophical and ethical underpinnings that informed their development and intended usage. Of course, a deeper look at this history of skin diagnostics reveal that risk and compromised ethics have always been present, but it also shows how concerns over ethics and risk could be addressed in the communication of science as well as in its technical developments. Thus, questions about how researchers and technical users from diverse scientific understandings, disciplines and backgrounds form a system of communication practices can help address the diversity found in the sociotechnical applications for skin diagnostic technologies that have proved to be unpredictable at different times throughout its history.

5.4 Epistemology and The Logical Coherence of Digital Imaging Analysis.

In conclusion to this chapter on the era of digital imaging analysis of human skin, I would like to outline some specific implications for this research in three disciplinary areas that I think could benefit from this project. In general, these areas are:

- Science and Technology Studies
- Scientific and Technical Communication
- Philosophy and History of Technology (Epistemology)

Although the greatest potential for the future of this research is in the areas of digital imaging analysis, biomedical imagery, human skin diagnostics and biometrics, the bulk of this dissertation focuses on the diverse historical and theoretical underpinnings of skin diagnostics. This history, in part, coincides with the development of natural philosophy into modern disciplines of science, and I sought to trace just a few of the threads of understanding that have informed the development and use of the skin diagnostic technology. In particular, I made a conscious effort to build a narrative bridge that connects the era of analog skin measurement to the era of the digital. My hope for this project is that I can contribute to the history and philosophy of technology by demonstrating how the diverse epistemologies from different eras, disciplines and cultures have converged in this digital era, and also add to the complexities of our understanding and uses of technology and scientific practices today. My argument builds off the philosophy of Stephen Toulmin in exploring the ways diversity arises from the concerns of individual practitioner and the network of disciplinary influences that make up the scientific enterprise and a technological system of knowledge and practices.

What I think this particular focus on skin diagnostic technologies can offer is a particular way to examine the philosophical questions being asked in these case studies and inquire into how it may have shaped the historical threads of science.

The field of scientific and technical communication concerns itself with the communication practices within a wide range of professional, public, educational and intra-disciplinary settings. Many of the primary texts I have covered in this dissertation are not only are examples of technical communication, they also reveal some of the history of scientific and technical communication practices. As I explained in the introductory chapter, the roots of science and rhetoric converge in our understanding and uses of techne and eventually our understanding of technology. Throughout this work I have tried to draw specific correlations between scientific theory and scientific communication and demonstrate how our understanding of technology both complicates and unifies the diverse practices of science. I think my work adds to the field of STC by demonstrating how technical communication practices, genres, theories have contributed to the development of a technical system, and how it offers a way of understanding the complex rhetorical situations found in science. In particular, I see digital imaging analysis as an emergent field of study for technical communication theories as digital tools like algorithms, databases and computational visualizations of human skin create new ways of communicating information that requires rhetorical and multimodal literacy that is also one of the strengths of the STC discipline.

Lastly, I see the potential of this work addressing some of the major concerns found in the current scholarship of science and technology studies. The broad scope STS scholarship addresses how enterprises of science and technology interact within society, and this includes articulating its social context. Therefore, when I referenced Stephen J Gould's definition of science as a 'socially embedded activity', I am also opening the historical threads of these scientific practices and technologies to consider their social dimension. For example, the focus in Chapter 3 on the murky history of scientific racism is a perfect example of how this research fits into the mold of STS scholarship. This history demonstrates explicitly how science influences our language, our culture, and our socio-political landscape in lasting and important ways, sometime with brutal and inhumane consequences. A big part of my argument in this dissertation was about the nuances of scientific diversity and technology's role in helping scientific practices find a correcting mechanism within their system of knowledge. Yet this system, based on the logic of science, has limits and should always be under carefully scrutiny because of the uncertainty that come with living in a technological society.

I can envision the future of this research exhaustively exploring how diagnostic technologies that measure human skin, skin color and the human body will find its way into new socio-technical applications. Even though I highlighted and argued for specific patterns found in my research of skin diagnostics, I also demonstrated how converging technologies have a way of taking new and unexpected directions. This work, then, can be used as both a predictive model and a basis for comparison in which to theorize the potential risks of digital imaging diagnostics of human skin.

The era of digital imaging analysis, with its databases, algorithms and complicated imaging techniques are changing the way we can view human bodies in the digital realm, but also how we categorize and archive that information. Most of the history of skin diagnostics was developed without the key understandings in biology, genetics and evolutionary processes, but in this new era of digital imaging analysis, humans are once again at risk of being classified, surveilled, and placed into hierarchical categories just through the interpretation of their body as digital data. I argue that this era of imaging technology and digital biometrics demands that we re-examine not only how science and technology is being communicated and applied in social frameworks, but we need to critically question how the technology of skin measurement is being constructed and developed within an increasingly diverse scientific enterprise.

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Appendix: A History of Skin Diagnostics and Measurement

Note: This Appendix is a collection of 55 artifacts, organized by year, from earliest to most recent. The collection of primary texts presented here is by no means a complete history of skin measurement; instead, I intended to build around key moments in the history of measurement, and show key changes and relationships between the interrelated concepts, methods, techniques and technologies that are applied in diverse scientific settings and practices. Together, this collection demonstrates some salient historical arcs in the history of skin measurement, along with changes/differences in epistemologies, technologies, methods and applications. Additionally, I have made several inferences about the logic and rationalization of skin diagnostic studies in this dissertation based on this collection of historical data, and even suggest a few predictions for the future of biometrics as well.

Table 1: Collection of Primary Documents Related to the History of Skin Measurement

Appendix – A History of Skin Diagnostics and Measurement		
1	**Artifact**	"Aristotle: Generation of Animals" Translated by A.L. Peck (July 5, 1949) Cambridge, MA: Harvard University Press.
A	**Date**	c. 336 B.C.E.
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Observation - Analog
D	**Results of Data or Illustration**	Medical Philosophy/Records
E	**Sociotechnical Application**	Theory on zoological and biological processes
F	**Terminology for Skin**	Black/White
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	*Disputed. Aristotle Scholars say he mentioned both "environmental theories" and "biological/social" theories of "race." He used the word "Blackmoor" to describe the Greek Woman from Elis

H	**Disciplinary Commitments**	This work was used in a Comparative Study in the heredity of animals and living things.
I	**Additional Notes**	Aristotle's method is described as Inductive/Deductive in the preface. Case study referenced is on P. 55
2	**Artifact**	Galen, "On the Natural Faculties" (1952) Translated by Brock, A.J.
A	**Date**	170 A.D.
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Observation - Four Humors Theory
D	**Results of Data or Illustration**	Medical Philosophy
E	**Sociotechnical Application**	To diagnose Jaundice, Dysentery, Cholera and Intestinal Disorders,as well as to explain differences in individual temperaments.
F	**Terminology for Skin**	Warm, Dry, Cold, Moist, Choleric - Yellow Phlegmatic - White Melancholic - Black Bile Sanguine - Red Blood
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Environmental Theory of Human Intellectual and Behavioral Differences
H	**Disciplinary Commitments**	Medical Observation method to explain differences in character
I	**Additional Notes**	
3	**Artifact**	(Italian) *De Statica Medicina*. Santorio Santorio
A	**Date**	1614
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Observation - Four Humours Theory

D	**Results of Data or Illustration**	Medical Philosophy. Attempted to measure changes in skin color along with changes in bodily fluids.
E	**Sociotechnical Application**	Medicinal - Physiology Practices
F	**Terminology for Skin**	Black Bile
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	*Undefined. Santorio questioned whether skin color was biologically inherited (innate nature), or a reaction to environment (nurture).
H	**Disciplinary Commitments**	To measure and record bodily changes as an Anatomist.
I	**Additional Notes**	Santorio Santorio is attributed to introducing mathematics to physiology.
4	**Artifact**	Boyle, Robert *Experiments and Considerations of Touching Colours*.
A	**Date**	1644
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Observation - Comparative Observation
D	**Results of Data or Illustration**	Natural Philosophy report on human anatomy.
E	**Sociotechnical Application**	Theorized about the physics of color and colored objects
F	**Terminology for Skin**	Black/White/Tawny/Olive/Ash Colored. Lighter/Darker Skin; Skin Colour is a matter of complexion
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Monogenist - All humans are Descendants of Adam and Eve.
H	**Disciplinary Commitments**	To give skin color measurement an experimental platform.
I	**Additional Notes**	He put the environmental theories into question with his "experiments"

5	**Artifact**	Browne, Thomas. *Pseudodoxia Epidemica*: *Enquiries into Received Tenants and Commonly Presumed Truths*.
A	**Date**	1646
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Observation
D	**Results of Data or Illustration**	Book on the Philosophy of Science and Medicine
E	**Sociotechnical Application**	Tried to reconcile Greek observations of dark skinned people to that of contemporary observations.
F	**Terminology for Skin**	Black, Darker or Fairer Complexion.
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Skin Color was solely attributed to reaction from to the sun, and permanent to one's lineage. He is one of the first users of the word "Indigenous" and "Native" which is attached to climate theories of race.
H	**Disciplinary Commitments**	A Christian Polymath committed to tolerance and goodwill of all as a medical doctor. He was also committed to advancing knowledge (described as Baconian Science)
I	**Additional Notes**	Brown questioned the 'Noah' theory of mongenism and labeled it as "Improbable" - so he must have been a monogenist, but not a biblical literalist.
6	**Artifact**	Malpighi, Marcello. (Italian) *De externo tactus organo anatomica observatio*
A	**Date**	1665
B	**Measurement Method**	Linguistic Matching.
C	**Measurement Technology**	Visual Observation, Anatomical Separation of Skin Layers.

D	**Results of Data or Illustration**	Report on Layers of Skin and Human anatomy.
E	**Sociotechnical Application**	Malpighi's main contribution was naming the different layers of skin of human anatomy.
F	**Terminology for Skin**	Black/White – Correlated Blackness and Black Bile. He identified layers of the skin as the *stratum corneum* and the *dermis.*
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Environmental Theory - The dark skin color of "Ethiopian" subject was derived from black bile between layers.
H	**Disciplinary Commitments**	He reported that he "discovered the seat of color in Ethiopian skin" (Malpighian Layer)
I	**Additional Notes**	Anotomists following Malpighi named the layer of mucous in the skin after him. Still, claiming it as "black bile."
7	**Artifact**	"An Extract of a Letter of Mr. Lister Containing some Observations Made at Barbados" Mr. Lister. Phil. Trans. Jan. 1, 1675, 10, 399-400.
A	**Date**	1675
B	**Measurement Method**	Linguistic Matching.
C	**Measurement Technology**	Visual Comparison/Observation
D	**Results of Data or Illustration**	Report (letter) to the Royal Society.
E	**Sociotechnical Application**	"Experiment on Negros Blood" To refute climate theory and correlate black skin with black blood.
F	**Terminology for Skin**	Black/Negro.
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Polygenist. Blackness was inherent to the person and not a result of climate.

H	**Disciplinary Commitments**	Report was in response to Dr. Thomas Townes of the Royal Society who was an anatomist that tried to establish racial differences between European and African bodies through blood.
I	**Additional Notes**	Leeuwenhoek's refutation of his finding is discussed in detail Cristina Malcolmson's book, *Studies of Skin Color in the Early Royal Society* (2013) (pp67-68).
8	**Artifact**	Berneir, Francois "A New Division of the Earth According to the Different Species or Races of Men Who Inhabit It."
A	**Date**	1684
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Observation
D	**Results of Data or Illustration**	Report on Bernier's lengthy travels.
E	**Sociotechnical Application**	A report on Human Geography
F	**Terminology for Skin**	light, dark, very dark, sunburnt, oily, polished, olive. fair, black, brown, livid parlor, yellowishness, bright, sparkling, white.
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Polygenist (inferred) He mentioned distinct "races" according to phenotype traits. European (Type I), African, Asian Kingdoms, Lapps, American Indians.
H	**Disciplinary Commitments**	Human Geographer/Physician. Bernier's work is considered the first to develop a racial classification system to compare different human groups. He used skin color, facial features and shape, but Graves says Bernier concluded that skin color was not sufficient enough to classify human groups into races.
I	**Additional Notes**	Bernier is significant because of the wide scope of his travels, and his comparative

		methods without a prior lexicon of terminology.
9	**Artifact**	Byrd, William "An Account of a Negro Boy with White Spots"
A	**Date**	1695
B	**Measurement Method**	Linguistic Matching.
C	**Measurement Technology**	Visual Observation
D	**Results of Data or Illustration**	Report of Skin Conditions.
E	**Sociotechnical Application**	Medical Report of examination of "white spots" appearing on a child's body.
F	**Terminology for Skin**	Black, White Pale Spots, "Paler than skin of White People"– "Not Tanned" – Thick Skinned.
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Unknown - Mentions Distempered Skin, Wooly Hair, describes the subject as "like other black children" and describes parents as "perfect negros" (I interpret this doctor to mean that there are biological differences between Europeans and "negros")
H	**Disciplinary Commitments**	To offer a Medical Report of an unusual skin condition, he felt the need to write about the unusual condition to the Royal Society.
I	**Additional Notes**	Although this report is an anomaly, it does represent the growing collective disciplinary structure that the Royal Society was building as a time when skin color variance was a growing question. Also, correspondence between American Physicians and the Royal Society is notable on this topic.

10	**Artifact**	John Mitchell and Peter Collinson. "An Essay upon the Causes of the Different Colours of People in Different Climates"
A	**Date**	1744
B	**Measurement Method**	Linguistic Matching.
C	**Measurement Technology**	Visual Observation of Color, However, they used measurements of skin thickness and compared the opacity capabilities of dark and light skin. Also, they made a theoretical calculation of skin "pores."
D	**Results of Data or Illustration**	Study was a response to the to the "Prize Problem" put forth by the Academy of Bourdeaux, that climate and mode of life is sufficient to account for skin color differences.
E	**Sociotechnical Application**	In the introduction the author's stated the study as an enquiry into "the strange phenomenon on nature – the cause of the Colour of Negroes"
F	**Terminology for Skin**	Skin color is discussed in terms of anatomy and light reflectance: Redness and Blueness of Blood changes. Epidermis layers. Reflecting Rays of light. Color of "juices", the yellowness of "jaundiced skin", Describes "skin of negros" as thicker, coarser, dryer.
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Environmental Theory: Explains whiteness and blackness of skin according to Newton's "Doctrine of Light and Colors" Refutes the Four Humor Theory, yet maintains the ethnic categories of Negro, European, Indian, Moors, Also, they considered habits like indoors/outdoor lifestyle and exposure to the sun. Claim that original color was red or brown, and rules out the "black fluid" or Black bile theory.

H	**Disciplinary Commitments**	Mitchell was a Botanist - but conducted this study as a special investigation and submitted it to the Royal Society. Culture and Lifestyle was placed into the report as important factors along with physical exposure to sunlight.
I	**Additional Notes**	This study seems to be another anomaly with little purpose except to answer a “Prize Problem”. It is the most detailed discussion of light exposure, and that cultural habits may result in more or less exposure to sun light, and how this may effect skin color along with hot/cold and environmental adaptions. The authors make a rhetorical argument against the four humor theory and the explanations of Malpighi.
11	**Artifact**	Parsons, James “Account of the White Negro”.
A	**Date**	1765
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Observation
D	**Results of Data or Illustration**	Report to Royal Society.
E	**Sociotechnical Application**	A Case Study report on the anomaly of “white negro” and trying to uncover the cause.
F	**Terminology for Skin**	White/ Black/Copper/ “White like a horse rather than Fair Skinned like White Europeans”.
G	**Author’s Nomenclature or Viewpoint of Human Categorizations**	The Author is comparing case studies of race mixing and seem to be describing Albinoism.
H	**Disciplinary Commitments**	Medical Doctor.
I	**Additional Notes**	The use of the word “copper” as a skin color is significant to this history because

		of its frequent use. Especially in American contexts.
12	**Artifact**	"An Account of the Remarkable Alteration of Colour in a Negro Woman" James Bate and Alexander Russel. Philosophical Transactions (1683-1775), Vol. 51 (1759 - 1760), pp. 175-178
A	**Date**	1759
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Observation - Four Humors Diagnostics (colored bile, wet/dry, hot/cold are mentioned)
D	**Results of Data or Illustration**	Description of cutaneous condition in a patient.
E	**Sociotechnical Application**	Report on a Investigation of a "piece of physical history" - Professional Letter/Medical Transactions
F	**Terminology for Skin**	"Dark as Swarthy African" "Fair European" "White"
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Unknown, Used the word "Negroes" Worked as a physician to treat "Slaves"
H	**Disciplinary Commitments**	Patient Examination by a Physician attempting to describe the "whitening" of a patient's skin.
I	**Additional Notes**	The "negro woman" in question was a 40 year old "cookmaid" (slave) from Virginia.
13	**Artifact**	George Louis Leclerc Comte de Buffon. *Histoire Naturelle*
A	**Date**	1753
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Observation

D	**Results of Data or Illustration**	Natural History including Race Categories
E	**Sociotechnical Application**	A naturalistic philosophy adopted by many naturalists - a creation of taxonomy and human categories a la Linnaeus.
F	**Terminology for Skin**	White, Yellow Brown Black and Red Races. Correlated to Caucasian, Mongolian, Malayan, Ethiopian and American.
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Monogenism - Degenerated from Adam and Eve, other races were caused by poor health and environmental exposure.
H	**Disciplinary Commitments**	Naturalist
I	**Additional Notes**	
14	**Artifact**	Linnaeus, Carl *Systema Naturae*
A	**Date**	1767
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Observation
D	**Results of Data or Illustration**	Natural History - Taxonomy of animals.
E	**Sociotechnical Application**	To describe and categorize varieties of species of animals found in nature.
F	**Terminology for Skin**	Americanus - Red Choleric Europeanus - White Sanguine Asiaticus - Yellow Melancholic Africanus - Black Phlegmatic Monstrosus - color unknown, hairy.
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Monogenism - geographically based, also based on four humors theory. (its been argued that Linnaeus had viewed ethnicity as culturally different, not as biological races.
H	**Disciplinary Commitments**	biologist, zoologist and a physician.

I	**Additional Notes**	Stephen J. Gould and others have defended Linnaeus because he created a nonhierarchical taxonomy of species that had been adapted to modern classification systems.
15	**Artifact**	Blumenbach, Johann Friedrich “On the Natural Variety of Mankind
A	**Date**	1779
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Observation / Comparative Anatomy / Cranial Measurement
D	**Results of Data or Illustration**	Taxonomy of Race Categories.
E	**Sociotechnical Application**	A naturalistic philosophy - a creation of taxonomy a la Linnaeus.
F	**Terminology for Skin**	White, Yellow Brown Black and Red Races. Correlated to Caucasian, Mongolian, Malayan, Ethiopian and American.
G	**Author’s Nomenclature or Viewpoint of Human Categorizations**	Monogenism - Degenerated from Adam and Eve, other races were caused by poor health and environmental exposure.
H	**Disciplinary Commitments**	Naturalist
I	**Additional Notes**	
16	**Artifact**	Kant, Immanuel. *Anthropology from a Pragmatic Point of View*
A	**Date**	1798
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Four Humours Diagnostic
D	**Results of Data or Illustration**	Comparative Data, Graphed Numerically
E	**Sociotechnical Application**	Essays and Lectures on Human Philosophy, and Human Geography

F	**Terminology for Skin**	A mixture of black, red, yellow white
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Naturalism - Climate Theory Uses the word "Negro" repeatedly.
H	**Disciplinary Commitments**	To explore Human characteristics, behaviors, in terms of how a "human being makes himself" Kant taught Geography and taught in that area, even though his moral and aesthetic philosophies were picked up later in other contexts.
I	**Additional Notes**	Kant also wrote an essay called "On the Different Races of Men" 1775 where he described four fundamental races and attributed each to climate theory, and contended that men could change back and forth according to climate reactions. This line of reasoning can be distinguished from the four humors diagnostic used in Anthropologie, however.
17	**Artifact**	Rush, Benjamin. "Observations Intended to Favour a Supposition That the Black Color (As It Is Called) of the Negroes Is Derived from the Leprosy"
A	**Date**	1799
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Observation - Medical Examinations
D	**Results of Data or Illustration**	Philosophical Report
E	**Sociotechnical Application**	His "scientific argument" seemed to align with his position as an abolitionist, and a founding signer of the U.S. Constitution. He wanted social reform for blacks, and argued that leprosy had made them dark

		and gave them ill health, so they should be given care.
F	**Terminology for Skin**	Negroidism (A Hereditary Skin Disease) White=Beautiful Black = Ugly
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Claimed Blacks were not morally or intellectually inferior. He was against slavery. He also thought blackness was a disorder and that every dark person was white underneath; thus he was against whites mixing with blacks.
H	**Disciplinary Commitments**	Rush was a medical physician, but he was also an active civic leader and politician. As an abolitionist, and a critic of history and the predominate mindset, he wrote this letter to the Royal Society.
I	**Additional Notes**	
18	**Artifact**	Smith, Samuel Stanhope*. Essay on the Causes of the Variety if Complexion and Figure in the Human Species*
A	**Date**	1810
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Matching
D	**Results of Data or Illustration**	Natural Philosophy
E	**Sociotechnical Application**	First to attribute climate zones to specific skin color, and also first to theorize about geographical patterns of human globalization and relation to skin color in the populations. (Jablonski)
F	**Terminology for Skin**	Dark to light Pigmentation - Skin changed due to the suns intensity. Dark Skin. Attributed dark skin to being a "big freckle"

G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Dark Skin was a combo of sun exposure and excess bile due to extreme heat. Explains human variation in terms of geographical movements and adaptions to climate.
H	**Disciplinary Commitments**	argued against racism, and opposed racial classifications Thought that philosophy and religion must align.
I	**Additional Notes**	Jablonski attribute Smith as the first to correlate 'latitude' and skin pigment variation. Thus, reflectance measurements have refines his observations.
19	**Artifact**	Home, Everard "Scorching Effect of the Sun's Rays"
A	**Date**	1821
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Matching Color Changes in Tanning experiments with both light and dark skin in extreme temperatures at different times.
D	**Results of Data or Illustration**	Physical Anatomy / Illustrated Data - Drawings of Skin Reactions.
E	**Sociotechnical Application**	Essay Addressed an "Ongoing problem" of skin color differences that were being discussed in the Royal Society.
F	**Terminology for Skin**	*rete mucosum* , lighter and darker skin, *nigrum pigmentum*, (a pigment in every human, presumably melanin)
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Biological Inheritance - defines subjects as European and Negro, but describes both having the same anatomy with different levels of pigmentation.
H	**Disciplinary Commitments**	To Ascertain the use of the black color of the *rete mucosum* in the "Negro"
I	**Additional Notes**	

20	**Artifact**	Cartwright, Dr. Samuel. “Report on the Diseases and Physical Peculiarities of the Negro Race” New Orleans Medical and Surgical Journal. (May, 1851).
A	**Date**	1851
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Observation using Four Humours Diagnostic, along with “Folk Knowledge” of the disease “Dysaethesia”
D	**Results of Data or Illustration**	Medical Report
E	**Sociotechnical Application**	Medical diagnosis and therapy of “medical” conditions particular to “negro slaves”
F	**Terminology for Skin**	“Black Skin that is Dry, Thick and Harsh to the touch.”
G	**Author’s Nomenclature or Viewpoint of Human Categorizations**	Mongenism - Decendents of Noah. “Negroes are a different species”
H	**Disciplinary Commitments**	To describe “biological” differences of human slaves and make recommendations to “awaken intellectual faculties” and improve “moral culture” through religious instruction and physical stimulation to improve “slave conditions.”
I	**Additional Notes**	
21	**Artifact**	Morton, Samuel; Agassiz, L. “Types of Mankind” (1854)
A	**Date**	1854
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Linguistic/Visual Observation
D	**Results of Data or Illustration**	Illustration (Ancient Primitive Divisions)

E	**Sociotechnical Application**	To argue for different types of races according to Interpretation of “the Sons of Noah” story.
F	**Terminology for Skin**	Red, Yellow, Black, White - Biblical Interpretation of skin categories.
G	**Author’s Nomenclature or Viewpoint of Human Categorizations**	Polygenism - Negroid Caucasian, Mongolian, Egyptian Races.
H	**Disciplinary Commitments**	Ethnography, Race Classifications.
I	**Additional Notes**	Agassiz believed in “zones” in creation.
22	**Artifact**	Gould, B. A. *Investigations in the military and anthropological statistics of American soldiers.*
A	**Date**	1869
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Observation and Matching to Reported “Nativity” information of Soldiers.
D	**Results of Data or Illustration**	Graphical Data – Military Report
E	**Sociotechnical Application**	This specific data on phenotype was used to reinforce demographic and measurement data for military purposes. The state goals for this report was to gather evidence of a volunteer army, versus an immigrant army paid in bounties.
F	**Terminology for Skin**	Complexion: Dark, Light Medium was assigned to geographical populations as well as “nativity”
G	**Author’s Nomenclature or Viewpoint of Human Categorizations**	Monogenism - Mentions Buffon’s Classification of Races. Races are biologically different. Races of “White, Negro, Australian, and Indian” are mentioned in the report, but not in terms of skin color.

H	**Disciplinary Commitments**	Anthropometric measurements were specifically for military purposes in order to determine health and vitality and correlate it to ethnicity and “nativity”
I	**Additional Notes**	This report mentioned specifically that phenotype data is to be taken lightly, as the variance of complexion alone doesn’t indicate anything. This information only serves as a marker for separations of “race” and “nativity” to specific geographical regions. Also, this report is footnoted in Darwin’s *The Descent of Man*
23	**Artifact**	Darwin, Charles. *The Descent of Man* by Charles (Ch. VII: The Races of Man)
A	**Date**	1871
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Observation
D	**Results of Data or Illustration**	Natural Philosophy
E	**Sociotechnical Application**	Darwin’s philosophy in Descent of Man was a continuation of his Theory of Natural Selection that became the dominate viewpoint in the natural sciences. His aim was to give a testable theory that can explain the variation in the human species.
F	**Terminology for Skin**	Dark and Light Tints, Skin Tones and “strongly marked differences between races of men” Speaks of phenotypic differences in “color” between human groups rather than inherent classifications.
G	**Author’s Nomenclature or Viewpoint of Human Categorizations**	Biological Inheritance through Natural Selection. Darwin speaks directly against the theories of monogenism and polygenism. He discusses many theories on race and tends to use the

		nomenclature of the study under discussion, while not truly forming his own.
H	**Disciplinary Commitments**	Biologist. Naturalist.
I	**Additional Notes**	Darwin argues directly against assigning specific biological identities for the races given in his tradition of naturalistic biology.
24	**Artifact**	Broca, Paul *Instructiones Anthropologiques Générales* (1879)
A	**Date**	1879
B	**Measurement Method**	Visual Matching
C	**Measurement Technology**	Visual Observation – Broca's Scale
D	**Results of Data or Illustration**	Anthropometry Measurement Manual
E	**Sociotechnical Application**	Color standard scale (similar to Von Luschan Scale) Published in a field manual.
F	**Terminology for Skin**	Dark to Light
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Biological Inheritance
H	**Disciplinary Commitments**	Recognized skin measurement as important, so the scale was developed by Broca to complete the measurement tool kit.
I	**Additional Notes**	Broca's skin color scale was developed further by his student Topinard.
25	**Artifact**	Abel, John; Davis, Walter; "On The Pigment of the Negro's Skin and Hair" Journ. of Exp. Medicine. (1896).
A	**Date**	1896
B	**Measurement Method**	Chemical Analysis

C	**Measurement Technology**	Microscopic Observation of removed and treated human skin samples from a cadaver. Used a Chemical Process to isolate dark pigment molecules from keratin molecules in the skin and hair and the measure quantity.
D	**Results of Data or Illustration**	Chemical analysis of isolated pigments.
E	**Sociotechnical Application**	Journal Article - Abel and Davis's analysis concluded that pigmentation in hair and skin were of the same composition, and differ only in amount in all human beings, and not in "kind"
F	**Terminology for Skin**	light and dark pigment, physiological differences in skin color, "straw colored" "ruby Red" "Brown Granules" "Black Sediment" Black Skin.
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Refers to subject as Negro, indicating social or ethnic group, with no mention of "race"
H	**Disciplinary Commitments**	Chemical Composition of Skin and Hair Pigment.
I	**Additional Notes**	
26	**Artifact**	Thomas, N.W. "Hautfarbentafel. by von Luschan" *Man*, Vol. 5 (1905), p. 160
A	**Date**	1905
B	**Measurement Method**	Visual Matching
C	**Measurement Technology**	Von Luschan Chromatic Skin Scale
D	**Results of Data or Illustration**	N/A
E	**Sociotechnical Application**	Reporting on the development of a skin color measurement standard for fieldwork in anthropology.
F	**Terminology for Skin**	All shades of Human Skin pigmentation - represented by 36 colored tiles.

G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Biological Inheritance - classified human groups by ethnographic region.
H	**Disciplinary Commitments**	To measure all human subject on a single skin color chromatic scale.
I	**Additional Notes**	
27	**Artifact**	Pearson, Karl "Note on the Skin-Colour of the Crosses Between Negro and White" *Biometrika*, Vol. 6, No. 4 (Mar., 1909), pp. 348-353
A	**Date**	1909
B	**Measurement Method**	Visual Matching and Linguistic Matching
C	**Measurement Technology**	Visual Observation – Mathematical statistics based on linguistic categories.
D	**Results of Data or Illustration**	Mathematical formula
E	**Sociotechnical Application**	Journal Article in a social medicine publication to critique the correlation between a Mendelism formula and skin color gradations in the classification of biological "race"
F	**Terminology for Skin**	"Blondes, Brunnettes" Darker and Paler Mahogany, black, white, yellow, dark chocolate, brown,
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Monogenism - Assumes "race purity" - Terminology reflects "Mixtures" of races. Uses the terms "Negro" "Negress" "Mulatto" "Sambo" "pure white" "black" "octoroon" "quadroon"
H	**Disciplinary Commitments**	Biostatician - Social Darwinism - Eugenics.

I	**Additional Notes**	Assumes that races are biologically distinct, and places them as inferior/superior to each other.
28	**Artifact**	Gortner, Ross Aiken "Studies on Melanin" J. Biol. Chem. 1910, 8:341-363.
A	**Date**	1910
B	**Measurement Method**	Chemical Analysis
C	**Measurement Technology**	Chemical Process Isolation
D	**Results of Data or Illustration**	Chemical Analysis Data
E	**Sociotechnical Application**	Lab Study and Comparative Analysis between many data sets of Melanin from different living Species, Sheep Wool, Horse Hair, Human Hair.
F	**Terminology for Skin**	"Melanin is jet black granular mass powdering to a very dark brown dust"
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	N/A
H	**Disciplinary Commitments**	To study how Melanin is similar in chemical form, but bonds and decomposes differently in different samples.
I	**Additional Notes**	
29	**Artifact**	Davenport, Gertrude; Davenport, Charles. "Heredity of Skin Pigment in Man Part I & Part II".
A	**Date**	1910
B	**Measurement Method**	Visual Matching
C	**Measurement Technology**	Milton Bradley Color Top
D	**Results of Data or Illustration**	"Complexion Chart" of different families and individual subjects.

E	**Sociotechnical Application**	Davenport wanted to use this data to create a heuristic chart to figure out race mixture based on heredity and skin color, along with other phenotype measurements.
F	**Terminology for Skin**	Blond, Brunet, intermediate, yellowish-white, olive yellow, dark-yellow-brown, dark olive, copper colored, chocolate, sooty black, full black, three-fourths black, one half black, one fourth black.
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Used human categories: Caucasian, Mullato, American Indian, Negro,
H	**Disciplinary Commitments**	Davenport understood part of the chemical composition of skin pigments and layers of the *stratum mucosum*, and this study was designed through the lens of Mendelian Genetics. Davenport was trying to devise a predictable model of skin color based heredity, including predicting Albinism.
I	**Additional Notes**	
30	**Artifact**	Lyde, Lionel W. *Proceedings of the First Universal Race Congress* "Climatic Control of Skin Color"
A	**Date**	1911
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Observation
D	**Results of Data or Illustration**	n/a
E	**Sociotechnical Application**	To argue for the climate theory of evolutionary natural selection.
F	**Terminology for Skin**	Black, brown, yellow, white - tonal scale.
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Skin color is correlated to climate and heredity.

H	**Disciplinary Commitments**	Human Geography, thus he was invited to speak at the congress to explain the influence of climatic origin on skin color, based on observational data.
I	**Additional Notes**	He makes the comparative analogy of how light and chlorophyll are in an evolutionary relationship with plant that influence its color just as light and skin are.
31	**Artifact**	Sheard, Charles "Analysis of the Color of the Skin and its Significance" *Science, New Series*, Vol. 64, No. 1646 (Jul. 16, 1926), pp. 70-72
A	**Date**	1926
B	**Measurement Method**	Spectrophotometry (Spectrohpotometric analysis)
C	**Measurement Technology**	Keuffel and Esser color analyzer
D	**Results of Data or Illustration**	Spectral Wavelengths, graphical RGB data
E	**Sociotechnical Application**	Health applications - technological testing for "jaundice, cyanosis, polycythemia vera, Addison's disease, hemochromatosis, anemia"
F	**Terminology for Skin**	Pigmentation spectrum, blood flow changes and tanning.
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Biological Inheritance - Human Universal
H	**Disciplinary Commitments**	To develop method of "Accurate determinations of skin color" in terms of spectral wavelengths Sheard was a medical researcher for the Mayo Clinic in Rochester, MN.
I	**Additional Notes**	Original technical diagram was found: Keuffel and Esser Color Analyzer: Journal of Oil & Fat Industries January 1925, Volume 2, Issue 1, pp 14-20

32	**Artifact**	Mead, Margret The Methodology of Racial Testing. *American Journal of Sociology*. V.31 N.5 1926.
A	**Date**	1926
B	**Measurement Method**	Visual Matching
C	**Measurement Technology**	Ferguson's Observations (1916)
D	**Results of Data or Illustration**	A refutation of Ferguson's study on "racial admixture"
E	**Sociotechnical Application**	Public rebuttal of skin color measurement studies as a means to determine racial mixing.
F	**Terminology for Skin**	Darker to Lighter Negro Skin
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Biological Inheritance (defined against cultural inheritance)
H	**Disciplinary Commitments**	Margaret Mead is making a rhetorical argument here to dismantle the notion of using skin color measurement as a way to calculate "racial mixing." Very similar to Darwin's in Descent of Man.
I	**Additional Notes**	Mead Strongly points out the circular reading of Ferguson and others anthropologists that assume skin color is a valid index of innate differences. (such as intelligence)
33	**Artifact**	Shaxby; Bonell. "On Skin Colour " Man, Vol. 28 (Apr., 1928), pp. 60-64
A	**Date**	1928
B	**Measurement Method**	Spectrophotometry (Spectrohpotometric analysis)
C	**Measurement Technology**	Trotter Photometer
D	**Results of Data or Illustration**	Coefficient data - "foot candles" that contrast skin reflectance to white, green and red light reflectance.

E	**Sociotechnical Application**	Technological and methodological testing.
F	**Terminology for Skin**	Spectrum of melanin pigmentation.
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Naturalism European Whites, Negroes and Half-Castes
H	**Disciplinary Commitments**	To understand and quantify exact differences between skin colors of different "races"
I	**Additional Notes**	"There appears to be no difference in type between the reflection of "white" and "coloured" skins, negroes in this respect differing from Europeans only in the amount of melanin pigment in the skin."
34	**Artifact**	Blackwood, Beatrice "Racial Differences Is Skin-Colour as Recorded by the Colour Top" *The Journal of the Royal Anthropological Institute of Great Britain and Ireland*, Vol. 60 (Jan. - Jun., 1930), pp. 137-168
A	**Date**	1930
B	**Measurement Method**	Visual Matching
C	**Measurement Technology**	Spinning Color Tops - Milton Bradley, Constructed of Disc of Black, Yellow, Red and White sections. Visual comparison of skin and assigned a correlating number for each colored disc.
D	**Results of Data or Illustration**	Data, graphic,
E	**Sociotechnical Application**	To study "the effect of sunshine and other climatic, conditions; changes in pigmentation from birth through childhood to puberty, and in old age; or the results of racial mixture, in studies of heredity." health applications, rickets, tuberculosis.

F	**Terminology for Skin**	pigmentation due to melanin. light to dark bronzing, red to yellow, tanned,
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Monogenism - "Grouped by Social Group" Negro Full bloods, Negro Hybrids, Southern Indian Fullbloods, Pueblo Indian Fullbloods, Navajo mainly, Fullbloods, Mexicans, Pueblo Indian Hybrids, Northern Indian Fullbloods, Northern Indian Hybrids, Chinese, Whites
H	**Disciplinary Commitments**	Correlation between environment, skin color, and ethnographic background. States that "the field-worker's problem is to find the best means available to aid him in making his observations as accurately as possible, and in recording them in such a manner as to render them useful for subsequent study"
I	**Additional Notes**	Discusses "mixture" of races,
35	**Artifact**	Edwards, Edward; Duntley, S. Quimby "The Pigments and Color of Living Skin The American Journal of Anatomy" V. 65 No. 1, July 1939.
A	**Date**	1939
B	**Measurement Method**	Spectrophotometry
C	**Measurement Technology**	Spectrophotometer. Developed by: (Hardy, J. D., 'The Radiation of Heat from the Human Body: III, The Human Skin as a Black-Body Radiator,' J. Clin. Invest., Vol. XIII (1934), p. 6I5.)
D	**Results of Data or Illustration**	diagnostic measurement standards, and techniques
E	**Sociotechnical Application**	A comprehensive study on skin pigments including tanning.

F	**Terminology for Skin**	Pigments - melanin/carotene Dark/Light Variation.
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Biological Inheritance, negro, white (ethinic)
H	**Disciplinary Commitments**	examine the complex factors of skin color variation.
I	**Additional Notes**	The study was widely reported in other science journals, and ethnic "races' terms we're still used, Japanese, Mulatto, negro, Hindu, even though light/dark and pigmentation terms were in use also.
36	**Artifact**	Luckiesh, Holladay & Taylor "Reaction of Untanned Skin to Ultraviolet Radiation"*JOSA* August, 1930 Vol 20 No 8.
A	**Date**	1938
B	**Measurement Method**	Spectrophotometry (Spectrohpotometric analysis)
C	**Measurement Technology**	Taylor Reflectometer
D	**Results of Data or Illustration**	Graphic/Reflectance Data
E	**Sociotechnical Application**	Maintenance of health and treatment of disease related to UV light radiation.
F	**Terminology for Skin**	"Blondes, Brunette and Intermediate"
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Naturalism / Climate Theory - Three members of the "White Race" from the "North Temperate Zone"
H	**Disciplinary Commitments**	To "increase the need of knowledge concerning the spectral reflectance of the skin and relative effectiveness per unit of energy of various wave lengths in promoting various physiological actions"

I	**Additional Notes**	The omission of any other ethnic groups is curious, as is the use of the "climate" words - blondes brunettes and other words tied to the Euro-centric theory.
37	**Artifact**	Derksen, Willard L.; Monahan, Thomas I. "A Reflectometer for Measuring Diffuse Reflectance in the Visible and Infrared Regions" *JOSA*. Vol 42, No 4. April, 1952.
A	**Date**	1952
B	**Measurement Method**	Spectrophotometry (Spectrohpotometric analysis)
C	**Measurement Technology**	G. E. Recording Spectrophotometer
D	**Results of Data or Illustration**	Graphic/Reflectance Data
E	**Sociotechnical Application**	Technical Recommendation for further calibration of spectrometer machines.
F	**Terminology for Skin**	Medium Negro Skin Fair Caucasian Skin
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Naturalism/ Mongenism Differentiate between Caucasians and Negro "Races"
H	**Disciplinary Commitments**	Engineering, contribution to technical calibration
I	**Additional Notes**	
38	**Artifact**	Sociology Study - "Black Metropolis - A Study of Negro Life in a Northern City" Drake and Cayton. New York, NY Harper Torchbooks 1945.
A	**Date**	1945
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Observation - Self Reported Ethnography.

D	**Results of Data or Illustration**	Social groups classified by color/ethnography and correlated to socio-economic data
E	**Sociotechnical Application**	To demonstrate the job ceiling among "negroes" in a negro/white society. Recognizes Social Class / Color Caste divides.
F	**Terminology for Skin**	White/Black , light skinned, dark skinned, light-brown, blue-vein, dark, dark-brown, browned-skinned,
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Monogenism - "Biological Aggregate" of Social Categories of Race "Negro" "White" - subjects also referred to as Mongoloid, Negroid, Asiatic.
H	**Disciplinary Commitments**	Part of an ongoing Sociological Impact Study To examine social relations among races and social groups.
I	**Additional Notes**	Studied color castes within social groups and between social groups as well.
39	**Artifact**	Barnicot , N.A. "Human Pigmentation" *Man*. V. 57 (Aug. 1957)
A	**Date**	1957
B	**Measurement Method**	Spectrophotometry
C	**Measurement Technology**	Evans Elpctroselenium Spectrometer
D	**Results of Data or Illustration**	Compared spectrometry data between "white" and "negroe" skin pigments.
E	**Sociotechnical Application**	Study designed to assess the geographical distribution of skin, hair and eye colors. To study human variation within individual and populations., Argues for the biological significance of Skin Color.
F	**Terminology for Skin**	Melanin - dark to light pigmentation.
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Distinguished between skin variation, and ethnic "types" White, Europeans, Hybrids Negroes,

H	**Disciplinary Commitments**	Anthropological Study of different groups in Nigeria.
I	**Additional Notes**	Definition of Skin color: The skin colour is due to two pigments in the main, melanin and hemoglobin. The optical properties of the skin are very complicated in detail, the pigments being distributed non-uniformly and embedded in tissues such as epidermis and the collagen of the dermis which reflect and scatter light. In addition, some light reaches the subcutane-ous fat and the absorption bands of carotene may be de-tected in some subjects
40	**Artifact**	Loomis, W. Farnsworth "Skin Pigment Regulation of Vitamin D Biosynthesis in Man", Science, Vol 157, No. 3788.
A	**Date**	1967
B	**Measurement Method**	Spectrophotometry (Comparative Analysis between reflectance data, pigmentation and vitamin D synthesis)
C	**Measurement Technology**	Microscope, Quantitative Analysis. Spectrophotometer
D	**Results of Data or Illustration**	Comparable data of Vitamin D synthesis, pigmentation and reaction to UV light.
E	**Sociotechnical Application**	Theory of how uv radiation, globalization and adaption through Vitamin D synthesis explain human pigmentation regulation, and variation.
F	**Terminology for Skin**	Lightest to darkest skin. Scale of white, yellow, black pigmentations, A blend of pigmentation and keratinization "activated" by UV radiation.
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Biological Inheritance skin pigment of a universal man with African Origins that lost pigmentation as they adapted to new climates. We are all Hominids.

H	**Disciplinary Commitments**	To expand on the "known correlation between human skin and latitude" and explanation of how the bod protected against the "twin dangers" of rockets and vitamin d toxins.
I	**Additional Notes**	
41	**Artifact**	Biasutti, Renatos "Le Razze E I Popoli Della Terra" 1967. UTET, Torino.
A	**Date**	1967
B	**Measurement Method**	Visual Matching/Spectrometry
C	**Measurement Technology**	von Luschan Color Scale/Photospectrometer
D	**Results of Data or Illustration**	Human Geographic Data Map base don skin tones
E	**Sociotechnical Application**	Four Volume Book on Human Geography and Culture - Includes Maps and Illustration that visualizes anthropometric data. (Maps still widely used)
F	**Terminology for Skin**	ligher to darker, variation in pigmentation
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Biological Inheritance - Environmental Adaption UV spectrum. Ethnic groups/ tribal affiliations.
H	**Disciplinary Commitments**	Human Geographer (Italy)
I	**Additional Notes**	Collected all accessible data using the Von Luschan Chromatic Scale in order to make his map.
42	**Artifact**	"Skin Color Measurements in Terms of CIELAB Color Space Values" Weatherill, *Coombs Journal of Investigative Dermatology* (1992) V 99 pp 468-473.
A	**Date**	1992
B	**Measurement Method**	Spectrophotometry
C	**Measurement Technology**	Labscan 6000 Spectrophotmeter

D	**Results of Data or Illustration**	CIELAB Color Matching Values for Hue and Chroma.
E	**Sociotechnical Application**	Medical Journal Article - Technical Report: Open Medical and Clinical Applications, and Scientific Applications
F	**Terminology for Skin**	Spectrum of “color attributes” pigmentation
G	**Author’s Nomenclature or Viewpoint of Human Categorizations**	Biological Inheritance - socially identified races
H	**Disciplinary Commitments**	To develop a quantitative and unambiguous method of Skin Color Communication that directly matches visual observation.
I	**Additional Notes**	All human subjects involved self identified their “race” (Key Problem for Today’s Studies - Un-Defined Self Identification procedure)
43	**Artifact**	Aoki, K. “Sexual Selection as a cause of human colour variation” *Annals of Human Biology*.(2002)
A	**Date**	2002
B	**Measurement Method**	Linguistic Matching (compared to biological data)
C	**Measurement Technology**	Visual Observation.
D	**Results of Data or Illustration**	Statistical data that studied the percentage of males and females preferences for verbally described skin colors.
E	**Sociotechnical Application**	Study and overview of literature on genetic makeup of skin color in a population.
F	**Terminology for Skin**	Black, Brown, Red Brown, Dark White, Medium White, that tans gold, Medium White that tans red-brown. Very light that freckles. Very light that doesn’t freckle.

G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Biological Inheritance – Evolution by sexual selection.
H	**Disciplinary Commitments**	Study was designed to revisit Darwin' s idea of sexual selection's role as a basis of skin color evolution within populations.
I	**Additional Notes**	Study uses a mixed method approach from chemistry, biology, physical anthropology, and statistics. It's interesting that they conducted a study of sexual attraction preferences based on verbal skin color categories.
44	**Artifact**	Lynn, Richard "Skin Color and Intelligence in African Americans" (2002) Population and Environment. March 2002, pp 365-375.
A	**Date**	2002
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Observation *based on self reported data from test subjects.
D	**Results of Data or Illustration**	Statistical Data attempting to compare/correlate Skin Color to Genetically Inherited Intelligence through "Vocabulary Test Scores".
E	**Sociotechnical Application**	Research Article using 20 year old data that continues a series of articles promoting eugenics, and intelligence differences based on race
F	**Terminology for Skin**	Subjects were asked if they identify as Whites or Black. Then asked to describe their skin color as Very Dark, Dark brown, Medium brown, Light brown, Very Light
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Monogenism, "Distinct Races" Mongoloid, Causoid, Negroid. Lynn is using Philip Rushton's theory that African ancestors is predisposed to "lower intelligence" and

		that race mixing with caucasians increases intelligence
H	**Disciplinary Commitments**	Lynn's article is another attempt to correlate "intelligence" to skin color and "race", and is part of a research program that promotes a theory of white nationalist superiority based on genetic "races".
I	**Additional Notes**	Lynn's data has been used by the defamed research of Hernstein and Murry's "The Bell Curve" and Ruston's "Race Evolution an Behavior", He's also listed as a "white nationalist" by the SPLC and his research is funded by "The Pioneer Fund" which is a racist organization.
45	**Artifact**	"Skin Color and Intelligence in African Americans: A Reanalysis of Lynn's Data" (2002) *Population and Environment* Nov. 2002, pp 209-214.
A	**Date**	2002
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Observation
D	**Results of Data or Illustration**	Criticism of the same statistical data used by Lynn that correlates skin color to intelligence through vocabulary scores.
E	**Sociotechnical Application**	A peer review/ critical response to Lynn's article and methods. Concludes that there's no basis to Lynn's claims .
F	**Terminology for Skin**	Lighter to Darker Skin tones.
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Biological Inheritance - Human Universal - Uses the words "African American" as a cultural identity.
H	**Disciplinary Commitments**	Hill points out Lynn's omission of early childhood development, family background, education factors and socio economic status that have all been

		proven influences on cognitive development. Thus, concludes that skin color and genetics is a false correlation in Lynn's data.
I	**Additional Notes**	Nisbett and others have conducted studies on color based discrimination in education, especially the effects on dark-skinned African Americans.
46	**Artifact**	Chaplin, George "Geographic Distribution of Environmental Factors Influencing Human Skin Coloration" *American Journal of Physical Anthropology* 125:292–302 (2004)
A	**Date**	2004
B	**Measurement Method**	Spectrophotometry (Spectrohpotometric analysis)
C	**Measurement Technology**	Evans Electroselenium Company Ltd. (EEL) or Photovolt Reflectometer
D	**Results of Data or Illustration**	Graphic/Geographical Map correlating UVR climate data and skin pigmentation data.
E	**Sociotechnical Application**	Human Geography, Health, Human Population, Human Evolution, Environmental adaption.
F	**Terminology for Skin**	Spectrum of pigmentations - Melanin, Blood and Tissue variables
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Biological Inheritance - Human Universal
H	**Disciplinary Commitments**	To test the hypothesis that skin color of populations correlates strongly to environmental adaption to UV radiation present in the environment.
I	**Additional Notes**	

47	Artifact	Mark Changizi, Qiong Zhang, Shinsuke Shimojo "Bare Skin, Blood and the Evolution of Primate Color Vision" *Bio. Lett* 2006. 2, 217-221.
A	Date	2006
B	Measurement Method	Spectrophotometry
C	Measurement Technology	Gathered Data from the NSCU Spectral Database.
D	Results of Data or Illustration	Data demonstrating how trichromatic color vision is attuned to changes in blood oxygen and blood flow levels that affect skin color on skin surface. Developed a color tone chart designed to heuristically determine blood modulations by observing the skin.
E	Sociotechnical Application	Changizi used this data to make better optics technologies for medical doctors that optimize trichromatic color vision to observe skin.
F	Terminology for Skin	Recognizes the variance in Baseline reflectance spectrum of human skin (dark to light phenotypes). Discuss skin in terms of changing modulation due to hemoglobin oxygenation and concentration,
G	Author's Nomenclature or Viewpoint of Human Categorizations	Biological Inheritance - Evolution through natural selection.
H	Disciplinary Commitments	Changizi is a theoretical evolutionary biologist, so he challenges the current paradigm of evolutionary biology to explain selection pressures for primate trichromatic vision was actually to observe changes in skin color, not discriminate fruits from foliage.
I	Additional Notes	

48	**Artifact**	Hoschild, Jennifer; Weaver, Velsa "The Skin Color Paradox and the American Racial Order" *Social Forces*, Vol. 86, No. 2 (Dec. 2007) pp 643-670.
A	**Date**	2007
B	**Measurement Method**	Linguistic Matching
C	**Measurement Technology**	Visual Observation
D	**Results of Data or Illustration**	Statistical Data Correlation Skin color to certain Socioeconomic Statuses such as income, political representation, jobs,
E	**Sociotechnical Application**	Study was conducted to address the reasons behind racial prejudice, and social status based on skin tone. Focused on differential treatment of African Americans with different skin tones.
F	**Terminology for Skin**	Skin Tones/ Skin Colors Very Dark, Dark, Medium, Light, Very Light.
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Biological Inheritance - Human Universal - Uses the words "African American" and "Black" as a cultural identity.
H	**Disciplinary Commitments**	To show that "colorism" - which is the idea that lighter tone African Americans are given more advantages - is an issue in society that needs to be addressed. And just another form of racial prejudice.
I	**Additional Notes**	The study brings up many interesting questions - the authors suggest this 'paradox' is a legacy of 'one drop politics' or the fear of blood mixture as a driving force behind inequality.
49	**Artifact**	Pershing *et al*. "Reflectance Spectrophotometer: The Dermatologist's 'Sphygmomanometer for Skin Phototyping?" *Journal of Investigative Dermatology* (2008) 128, 1633–1640
A	**Date**	2008

B	**Measurement Method**	Spectrophotometry (Spectrohpotometric analysis)
C	**Measurement Technology**	Portable Reflectance Spectrometer (model S2000; Ocean Optics Inc).
D	**Results of Data or Illustration**	Skin Phototype (SPT) Data/Chart
E	**Sociotechnical Application**	Dermatology, and the Health/Treatment of Human Skin.
F	**Terminology for Skin**	in vitro and in vivo measures of pigmentation, and quantification of cutaneous *eumelanin* and *pheomelamin*
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Biological Inheritance - Human Universal Subject. - Recognizes Social "Races"
H	**Disciplinary Commitments**	To develop a single/ non-invasive method that can differentiate between all six SPTs -
I	**Additional Notes**	Human subject of the study filled out an Institutional Review Board-approved questionnaire containing phenotypic descriptions of constitutive skin color (very fair, fair, light brown, medium brown, dark brown, black),
50	**Artifact**	Chaplin, George; Jablonski, Nina. "Physical Anthropology/ Evolution: Human skin pigmentation as an adaptation to UV radiation" *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 107, Supplement 2: In the Light of Evolution IV: The Human Condition (May 11, 2010),pp. 8962-8968
A	**Date**	2010
B	**Measurement Method**	Spectrophotometry (Spectrohpotometric analysis)

C	**Measurement Technology**	Evans Electroselenium Company Ltd. (EEL) or Photovolt Reflectometers
D	**Results of Data or Illustration**	Geographic Data, Mapping Human Variation/ Skin Color Adaptions.
E	**Sociotechnical Application**	Theorize of human evolution and adaption to local climates and UV light levels. Claim the important of UV light's role in natural selection.
F	**Terminology for Skin**	Spectrum of Human Pigments Dark/Light Pigmentation
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Biological Inheritance - Evolution through natural selection
H	**Disciplinary Commitments**	Establish skin color adaption model as an exemplary model for evolution through natural selection. Also, explain certain disease frequencies related to Vitamin D production.
I	**Additional Notes**	
51	**Artifact**	"Eulerian Video Magnification for Revealing Subtle Changes in the World" *ACM Transactions on Graphics*, Volume 31, Number 4, 2012"
A	**Date**	2012
B	**Measurement Method**	Digital: Eulerian Video Magnification: Amplifies Skin Color Variation/Motion due pulse rate.
C	**Measurement Technology**	Digital Video Camera (DSLR) Spatial decomposition and temporal filtering through computation processing of a sequence of images.
D	**Results of Data or Illustration**	Output Video that visualizes heart rate through amplification of skin color changes.

E	**Sociotechnical Application**	Technical Report on Non-Invasive Heart Rate Monitoring, Experimental applications.
F	**Terminology for Skin**	N/A
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	N/A
H	**Disciplinary Commitments**	"This Eulerian based method, which temporally processes pixels in a fixed spatial region, successfully reveals informative signals and amplifies small motions in real-world videos."
I	**Additional Notes**	This technology isn't just for skin, and does not really measure it, however, it uses light sensing to capture not color changes and motion to reveal motion of blood reflected in changing skin color.
52	**Artifact**	Chengjun, Liu "New Color Features for Pattern Recognition" Eds. Liu , Mago *Cross Disciplinary Biometric Systems* (2012)
A	**Date**	2012
B	**Measurement Method**	Digital: Discrete Cosine Transform (DCT) "The DCS utilizes discriminant analysis [4] to acquire three new color component images that are most discriminatory in terms of class separatability."
C	**Measurement Technology**	Digital Camera, RGB Color Space and Cosine Analysis/Photo Filtering Software
D	**Results of Data or Illustration**	Testing Images for Biometric Identification
E	**Sociotechnical Application**	Biometric Identification Technology.
F	**Terminology for Skin**	N/A – "Color Data" "RGB color space values"

G	**Author's Nomenclature or Viewpoint of Human Categorizations**	N/A - Images are all close ups of lighter skinned faces
H	**Disciplinary Commitments**	Improve Facial Recognition Performance that improves upon existing facial recognition biometric methods.
I	**Additional Notes**	
53	**Artifact**	Swiatoniowski et al. (2013) "Technical Note: Comparing von Luschan Color Tiles to Modern Spectrophotometry for Measuring Human Skin Pigmentation" *American Journal of Physical Anthropology* 151:325–330 (2013)
A	**Date**	2013
B	**Measurement Method**	Visual Matching Scale to Spectrophotometry Conversion Using the CIELab Color Space
C	**Measurement Technology**	Von Luschan Scale and The Dermaspectrometer (DermaSpec)
D	**Results of Data or Illustration**	Graphed data,
E	**Sociotechnical Application**	Created a predictable conversation chart in order to make all skin color data collected with von Luschan's scale to convert to the M-index measurements.
F	**Terminology for Skin**	Spectrum of Skin Pigmentations
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Biological Inheritance - Groups in the study were named by ethnic origin. Changes were made group names, "Negro" in von Luschan's study was changed to "African American" in recent study.
H	**Disciplinary Commitments**	"To make historical and Contemporary Skin Color Data Comparable" - Physical Anthropology application, as well as a

		variety of other fields that find the data useful.
I	**Additional Notes**	Human Subject Self Reported Ethnic Data in the later studies. African American/ Black, Asian/Asian American European American/ White, and Hispanic/Latino
54	**Artifact**	Technical Report: NIST Report "A collection and statistical analysis of skin reflectance signatures" Cooksey et al. Proc. of SPIE Vol. 9082 908206-2
A	**Date**	2014
B	**Measurement Method**	Spectrophotometry to Digital Image Conversion
C	**Measurement Technology**	NIST Spectral Trifunction Automated Reference Reflectometer
D	**Results of Data or Illustration**	Spectral Imaging - Photographic Database of Skin Reflectance Profiles.
E	**Sociotechnical Application**	Large Database of Skin Reflectance Data to be used for "emerging imaging applications, medical imaging, security, biometrics, and safety"
F	**Terminology for Skin**	Optical Properties: cells, fibers, and chromophores, as well as its surface features, which include hair, freckles, wrinkles, and contours
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Biological Inheritance - Human Universal
H	**Disciplinary Commitments**	"to establish the range and distribution of spectral signatures in a population rather than define an average spectral signature"
I	**Additional Notes**	

55	**Artifact**	Han, J. Y., Kim, E. J., Lee, H. K., Kim, M. J. and Nam, G. W. (2015), "Analysis of yellowish skin color from an optical image and the development of 3D Skin Chroma Diagram™" *Skin Research and Technology*, 21: 313–318.
A	**Date**	2015
B	**Measurement Method**	Spectrophotometry And Optical Imaging – Digital Color Separation Analysis
C	**Measurement Technology**	Spectrophotometer and digital software
D	**Results of Data or Illustration**	3D Skin Chroma Diagram (tm) specifally for Asian women.
E	**Sociotechnical Application**	This study was conducted to define yellowish skin color, which is a major concern of Asian women, and to develop a 3D skin-pigment color model
F	**Terminology for Skin**	"We decompose the skin color into four components (Fig. 2); skin base color, shading effect by lightening and pigmentation by hemoglobin and melanin."
G	**Author's Nomenclature or Viewpoint of Human Categorizations**	Biological Inheritance - Human Universal
H	**Disciplinary Commitments**	Skin Color Cosmetics - It became possible to diagnose yellowish color on human skin and to analyze the improvement in skin tone both quantitatively and visually.