Philosophy's Movement Toward Cognitive Science

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Chapter 3
Galen, Euclid, and the March Towards the 20th Century

3.1 Introduction

In the first chapter I outline the concept of an ontological framework and discuss how ontological frameworks function in cooperative investigation and theorizing. In the second chapter I discuss how the Greek notion of the soul evolves from the pre-Socratic philosophers through Plato and Aristotle. That second chapter ends with a discussion of three hypotheses that characterize the evolution of the Greek notion of the soul. The domain hypothesis refers to the often tacit theoretical supposition that a *prima facie* diverse set of phenomena form a common set of interrelated phenomena (i.e., a domain). The common locus hypothesis refers to the often tacit supposition that a set of interrelated processes and properties have a common locus—a single kind of thing that possesses the properties and in which the processes occur. Finally, insofar as the process of property accretion proceeds in an indirect and somewhat indiscriminate fashion, theorists often must tacitly or explicitly formulate and affirm what I call the mental distillation hypothesis. Thus, Aristotle and the stoics begin to conceive of mental phenomenon as comprising a simple integrated domain, associated with a single kind of ontological entity.

In this chapter, I discuss three developments shape much of the thinking about the mind and its relationship to the physical world from the time of Aristotle through the beginning of the 20th century. First, thinkers begin to develop an increasingly sophisticated understanding of human physiology[1] and anatomy.[2] Anatomists study the structure of organisms, including cells, organs, and organ systems (e.x., the digestive system includes several organs) and organisms. In contrast, physiologists study the functions of cells, organs, organ systems, and organisms (e.x., the digestive tract functions to breakdown food and absorb the nutrients). The slow but steady development and refinement of human physiological and anatomical knowledge ultimately acts to render the tensions between alternative ontological frameworks with ever-increasing starkness and rigor. In particular, greater familiarity with the structures and functions of the human nervous system begins approximately around 300 BCE and continues throughout this time period. Improvements in physiological and anatomical knowledge result in increasingly sophisticated mechanistic theories of mind/body interaction. Second, the publication and subsequent influence of Euclid's geometric text, *The Elements*,[3] exerts a profound influence upon, not just mathematics, but conceptions of knowledge, inference, and psychological functioning. Third, the advent of the European Renaissance[4] (c14th to 17th centuries) and the scientific revolution[5] (c15th to 18th centuries) fuel ever more sophisticated theoretical approaches to the mind and its relationship to the physical world. Ultimately, these three elements combine to produce two general results. First, within philosophy one sees an ever increasing intensity of debate regarding ontological frameworks. For the most part the philosophical debate centers on monistic physicalism versus oppositional substance dualism. This philosophical debate continues throughout the 20th century. Second, an increasing body of empirical evidence, improvements in investigative methodology, and greater theoretical sophistication gives rise to empirical science as well as the doctrine of mechanistic determinism.[6] In essence, mechanistic determinism asserts that each prior state of the world determines exactly and completely the

next state of the world in accordance with universal and necessary physical laws. Throughout this period, the scope, pace, and sophistication of scientific theories accelerates. Investigations into psychology and neuroscience lag significantly behind work in physics, chemistry, and even biology until well into the 20th century. Nevertheless, one sees an increase in the amount of intersubjective empirical data available in psychology and neuroscience. Moreover, the progress in such disciplines as physics and chemistry inspire monistic physicalists and provide analogical support for continued investigations into neurophysiology and neuroanatomy as well as psychology.

3.2 Galen and the Beginnings of Neurophysiology

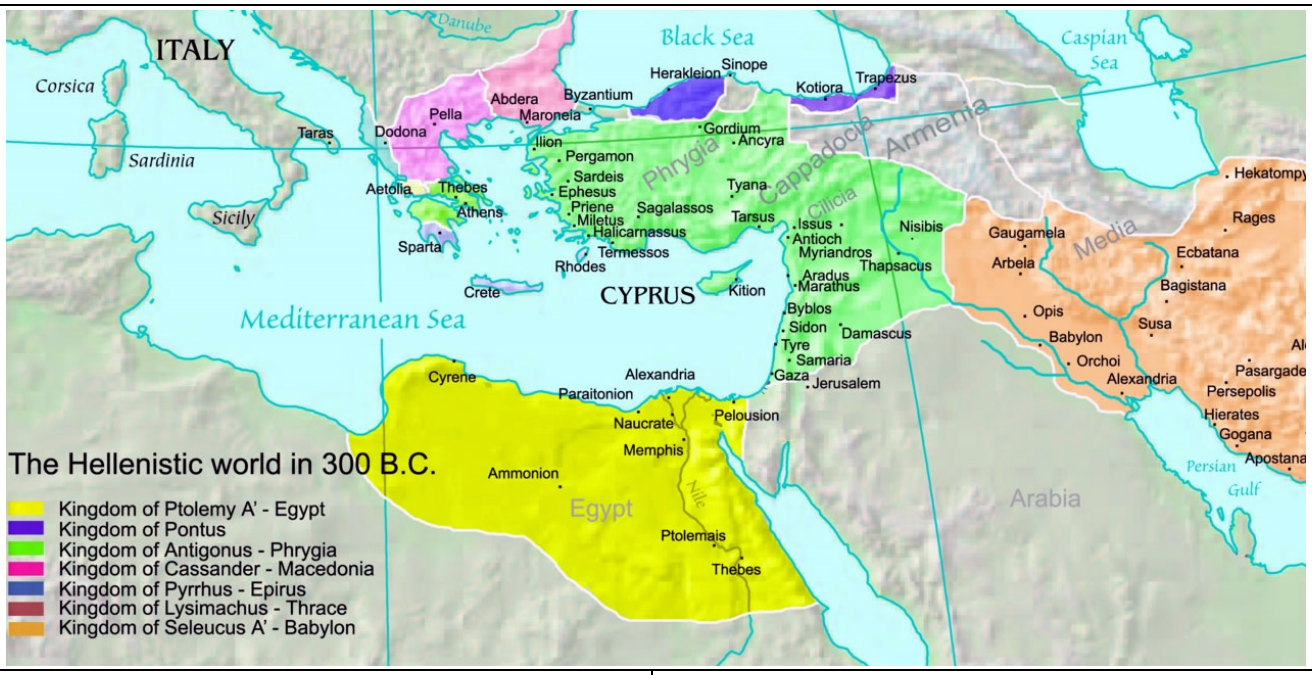
The slow accumulation of knowledge regarding the anatomy and physiology of the human nervous system contributes to the rise of well-articulated ontological frameworks and ultimately the leads to the beginnings of the scientific study of the mind. As we'll see, knowledge of even the gross anatomical structures of the nervous system and their function eludes theorists throughout most of history. This ignorance has two sources. First, prohibitions and/or stigma around the dissection of human corpses prevent systematic empirical investigation, rendering the scant documentation of even the gross human anatomical structures incomplete and inaccurate for a significant part of the history of western civilization. Second, a lack of valid empirical and experimental methodology provides for only a very limited understanding of the corresponding functions and functional organization of gross anatomical structures. For example, it isn't until William Harvey's publication in 1623 of his *Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus*[7] that systematic experimental evidence supports a widespread acceptance of the hypothesis of the circulation of blood.

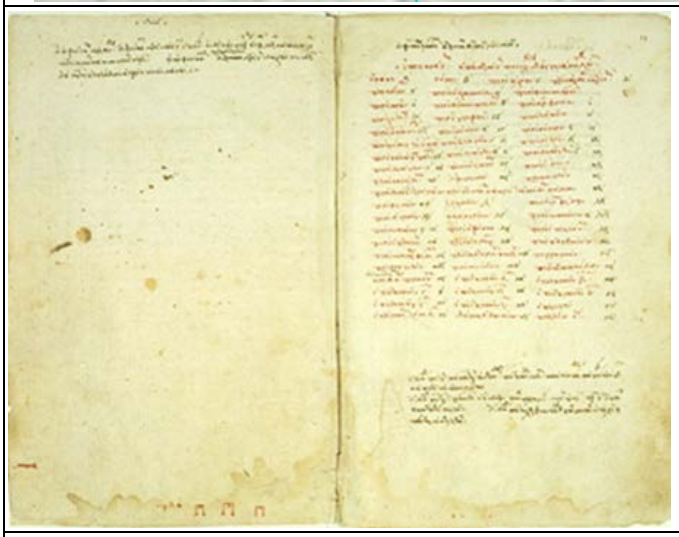
Many discussions of the history of human physiology and anatomy refer to Hippocrates of Cos[8] (c460BCE–c370 BCE) as the earliest human anatomist. Researchers often make this attribution on the basis of a collection of ancient Greek medical manuscripts called *The Hippocratic Corpus*.[9] Some of the texts included in *The Hippocratic Corpus* show a basic familiarity with musculoskeletal anatomy as well as with a few organs. However, none of the texts in the corpus have a demonstrable origin with Hippocrates himself. Researchers have speculated that as many as 19 different authors contribute to the collection (none of whom are actually Hippocrates) over a time period ranging from the end of the 5th century BCE to the 2nd century CE.[10, 11] The earliest known work dealing with human physiology and anatomy dates to 1600 BCE. The Edwin Smith Surgical Papyrus[12] discusses the structure of the heart, liver, spleen, kidneys, hypothalamus, uterus, and bladder along with the blood vessels that emanate from the heart. The Ebers Papyrus[13] dating back to approximately 1550 BCE also discusses the heart.[12-14] However, much of the Egyptian knowledge of human anatomy and physiology appears to have faded from the flow of historical knowledge.

The widespread legal and moral barriers to the dissection of human cadavers further compound the loss of Egyptian physiological and anatomical knowledge. Even in the most enlightened areas during the most enlightened period of Greek civilization the practice of dissecting human cadavers to study human anatomy and physiology carries a significant stigma. In most areas of the Macedonian and Hellenistic Greek world such practices remain illegal. For the most part, during the periods between 300 BCE and the 16th century physicians look primarily to the dissection of animals to gain knowledge of the human anatomy. Indeed, over 1200 years after the Egyptians and their anatomical works, Aristotle relies primarily upon dissections of animals to gain anatomical knowledge. His anatomical studies lead him to view the brain primarily as a radiator for the heart, with the later generating sensations and emotions in 335 BCE. In *Parts of Animals*[15]

Aristotle claims that "...the brain cannot be the cause of any of the sensations, seeing that it is itself as utterly without feeling as any one of the excretions." (Part 10, ¶2)

The Egyptian toleration of human anatomical study and dissection does seem to have continued into the rise of the Greek civilization. The Greek physicians Herophilus of Chalcedon[16] and Erasistratus of Chios[17] perform relatively systematic human dissections around 300 BCE in the Egyptian city of Alexandria (then under Greek control). Herophilus, for example, earns a reputation for his careful anatomical studies. Herophilus distinguishes between motor and sensory nerves, describes many of the cranial nerves, and recognizes the division between the cerebellum and the cerebrum. Herophilus also appears as the first anatomists to suggest that the seat of mentality resides in the ventricles of the human brain. Specifically, Herophilus identifies the *calamus scriptorius* (the floor of the fourth ventricle) as the seat of the human soul.[16, 18, 19]





(Top Left) Plates vi & vii of the Edwin Smith Surgical Papyrus at the Rare Book Room, New York Academy of Medicine. Image and description from: Wikipedia **(Bottom Left)** Vaticanus graecus 277, 10v-11r: Table of contents in a fourteenth-century Hippocratic Corpus manuscript. Marcus Fabius Calvus owned this manuscript, transcribed it in his own hand, and used it in the preparation of his 1525 Latin translation. Image and description from: Wikipedia **(Bottom Right)** Map of the Kingdoms of the Hellenistic Period. Adapted from: Greek Thesaurus

Little of note occurs in human physiology and anatomy for nearly 500 years. The Greek-born Roman physician Galen of Pergamum, also known as Claudius Galenus or simply as Galen[20](129BCE-c200-217CE), delivers a series of lectures in 177CE arguing that the brain--not the ventricles-- serves as the seat of human mentality.

Galen lives in in the city of Pergamon[21] located in Asia Minor. Scholars often describe Galen as the greatest

(Above) Claudius Galenus (129BCE-c200-217CE) From: Listverse **(Right)** Map of the Roman Empire showing Pergamum circa 117CE. Modified from: Fragments and Reflections

medical researcher of the Roman period. Galen makes significant contributions to medicine, anatomy, and physiology as well as logic and philosophy. He continues to shape thought in these areas for centuries. Roman law, like Greek law before it, forbids dissection and autopsy of the human body, so Galen is unable learn from the dissection of human cadavers. Galen does dissect the bodies of the Barbary Macaque and other primates, transferring what he learns on the assumption that primate and human anatomies are basically the same. However, Galen does have an advantage that most anatomists do not--as a physician to gladiators Galen has many occasions to view the internal organs of their bodies. In his work, *On the Usefulness of the Parts of the Body*,[22] Galen describes the ventricles and pineal gland. He argues against the idea--apparently widely espoused at the time--that the ventricles are filled with "psychic pneuma," the airy or vaporous substance supposed to interact with both body and mind. He also argues against the idea that the movements of the pineal gland act to regulate the flow of these pneuma within the ventricle. Despite Galen's singular status, his arguments fail to prevent such theories from continuing to dominate thinking about the nature of the mind throughout the middle ages.

3.3 Euclid's Axiomatic Treatment of Geometry as a Model for Knowledge and Reason

Euclid of Alexandria (325-265 BCE) stands out as one of the most underappreciated figures considered in this text. Euclid's one text shapes the western notions of mathematics, philosophy, science, rationality and mentality for literally thousands of years after its creation. Euclid is a Greek mathematician, who likely receives his training in geometry in Athens from students of Plato before moving to Alexandria. In *The Elements* [23](approximately 300BCE), Euclid's only known work, he systematically and rigorously organizes geometrical knowledge in terms of indubitable axioms from which he deduces all other known truths by careful proof. *The Elements* also includes a treatment of basic number theory. *The Elements* provides readers

with a comprehensive collection of geometrical theorems and proofs developed by earlier mathematicians such as Thales, Pythagoras, Plato, Eudoxus,[24] Aristotle, and Menaechmus.[25] Euclid's accomplishment in *The Elements* is not its content, per se, but the organization and rigor of its presentation. Indeed, academics use Euclid's book as a mathematics text as late as the beginning of the 20th century. Euclid's rigorous (for the time) axiomatization creates a model for mathematics that remains influential today. Moreover, its influence extends to other disciplines such as philosophy and science, where it comes to serve as the dominant model for rational thought and knowledge for many, many thinkers.

Indeed, Euclid's geometry influences great thinkers holding very different theories about the nature of the mind. For instance, Thomas Hobbes (1588–1679) advocates a hard-bitten mechanistic monistic physicalism. Hobbes views all things, including politics and the mind, in terms of mechanistic operations upon physical matter. Hobbes speculates in his *Elements of Philosophy* [26] that

> PHILOSOPHY is such knowledge of effects or appearances, as we acquire by true ratiocination from the knowledge we have first of their causes or generation: And again, of such causes or generations as may be from knowing first their effects. … By ratiocination [reasoning], I mean computation. (pp. 6-7)

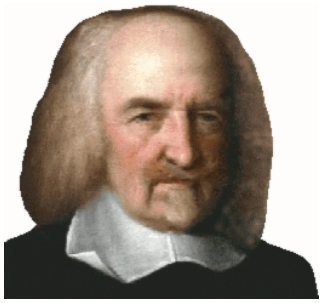
Hobbes views computation as analogous to simple arithmetical operations upon words, where words come to signify the objects of our experiences stored memory. As we will see below, René Descartes[27] (1596–1650) models both his epistemology and his scientific method on Euclid, though he famously holds--in contrast to Hobbes--that the mind is immaterial. Baruch de Spinoza[28] (1632–1677) writes his famous, posthumously published work, *Ethics (or Ethica Ordine Geometrico Demonstrata*)[29] in an axiomatic format. In the *Ethics* Spinoza argues that the universe consists of one infinite, necessary, and deterministic substance that he seems to equate with both God and nature as well as with both mind and body. So, despite the diverse nature of their views, all these thinkers portray one's knowledge--and one's rationale belief corpus--as having (or as needing) an organizational structure and genesis comparable to the Euclidian geometry of *The Elements*. Specifically, all of one's knowledge flows from careful arguments based upon premises (axioms), where one's evidence for the truth of those premises (axioms) consists in their manifest intuitive obviousness—i.e., one's inability to doubt them. Deductive reasoning transmits the certainty and truth of one's initial principles—these axioms--to all other beliefs one forms.

Thus, the impact of Euclid consists in providing a paradigmatic instance of intellectual synthesis and accomplishment. Eucild's work serves as a model for the nature and structure of knowledge, for reasoning, and for the nature and operations of the mind. In this Euclidian-inspired vision of the mind thought consists in deductive operations on statements. Each statement traces its origin back either to the certainty of immediate experience, to a set of statements held to be certain and indubitable, or some combination of the two. That is, one explains one's beliefs in terms of logical operations on truth-functional representations (i.e., representations that can be true or false). One cannot underestimate the impact of this conception of reason, knowledge, and mentality upon our theoretical musings regarding rational inquiry, reason, and the mind.

Whereas the increasing anatomical and physiological knowledge fuels mechanistic theories of mind-body interaction, the theoretical structure of axiomatic geometry fuel theories of scientific methodology, knowledge, and human reasoning processes. However, the increase in wealth and commerce resulting from

European Renaissance proves the crucial factor that gives rise to the scientific revolution and to an explosion of empirical research and theory.

Euclid of Alexandria
(325BCE-265BCE)



Thomas Hobbes
(1588–1679)

Baruch de Spinoza
(1632–1677)

René Descartes
(1596-1650)

Euclid's Axioms

1.) To draw a straight line from any point to any other.
2.) To produce a finite straight line continuously in a straight line.
3.) To describe a circle with any centre and distance.
4.) That all right angles are equal to each other.
5.) That, if a straight line falling on two straight lines make the interior angles on the same side less than two right angles, if produced indefinitely, meet on that side on which are the angles less than the two right angles.

One of the oldest surviving fragments of Euclid's *Elements*, found at Oxyrhynchus and dated to circa AD 100. The diagram accompanies Book II, Proposition 5. From Wikipedia http://en.wikipedia.org/wiki/Euclid

3.4 Descartes and Substance Dualism

Descartes' life and work provide a microcosm of the changes and challenges wrought by the important intellectual, social, and economic developments that characterize the European Renaissance and the Scientific Revolution. Scholars generally hold that the European Renaissance began in the 14th century city state of Florence located in Tuscany, Italy. The increase in commerce, artistic, and religious activity associated with the period from the 14th to the 17th century also brought increased scientific activity that eventually lead to what historians call the Scientific Revolution. Historians generally associate the beginning of the scientific revolution with the publication of two important works: After Nicolaus Copernicus'[30] (1474-1543) death in 1543, Johannes Petreis, a German publishing firm in Nuremburg, publishes Copernicus' privately circulated manuscript called *Commentariolus* (Little Commentary) under the title *De Revolutionibus Orbium Coelestium* (*On the Revolutions of the Heavenly Spheres*, published in 1543)[31]. The physician Andreas Vesalius[32](1514-

1564) publishes his seven volume text on anatomy called *De Humani Corporis Fabrica* (*On the Fabric of the Human body*) in 1555.[33] Both works challenge traditional theories and authority figures in their respective areas. Copernicus forwards the heliocentric conception of the universe in contrast to Ptolemy. Vesalius challenges many aspects of the anatomical teachings of the famous physician Galen[20](129BCE-c200-217CE).

Nicolaus Copernicus (1474-1543)
From: CNS News

Andreas Vesalius (1474-1543)
From: Compton History

The works of Copernicus and Vesalius as well as many others serve to create a tradition of mechanistic determinism in science. This growing tradition of mechanistic determinism increasingly moves scientists to seek a unified understanding of all phenomena--mental and physical. Such an account of the scientific enterprise envisages a set of universal and necessary physical laws discovered through controlled empirical experimentation through which scientists could explain and predict all of the workings of the universe--even those phenomena definitive of life and the mind.

Thus, the tension between the religious or immaterial worldview and this hard-bitten deterministic physicalism builds as the European Renaissance and Scientific revolution gain momentum. But, it is not until one hundred years later that a scientist, René Descartes[27] (1596-1650)brings these tensions into clear relief with his publication of his *Meditations on First Philosophy* (or *Meditationes de prima philosophia, in qua Dei existentia et animæ immortalitas demonstratur*) [34] in 1641. Like all thinkers of the time, the French philosopher, physicist, mathematician, and anatomist ascribes to a mind-body dualism. However, Descartes' work represents perhaps the clearest, most systematic presentation of what philosophers now understand as mind-body or substance dualism and what I call oppositional substance dualism. Indeed, Descartes' mediations prove profoundly influential in philosophy and science--in part because Descartes paints the tension between the spiritual (or immaterial) world view and the mechanistic physical world view in explicit and stark terms.

3.5 Descartes' Early Life

Descartes comes to science rather indirectly: He attends a Jesuit school located at La Flèche, France called Collège Royal Henry-Le-Grand in 1607. His graduation from Henry-Le-Grand sees him earn his degree and license in Law at the University of Poitiers in 1616. However, Descartes chafes under the yoke of an academia dominated by the scholastic approach to intellectual research. Descartes joins the army of the Dutch Republic for a brief time in 1618. During his time in the Dutch army, Descartes meets the Dutch philosopher and scientist Isaac Beeckman.[35] Beeckman reignites Descartes' interest in physics and mathematics. Descartes claims to have dreams shortly thereafter which he interprets as a divine sign that he should found a unified science of nature based upon mathematics. Most of Descartes's work from the time between 1618 and 1637 remains unpublished until after his death. These works articulate Descartes' theory of scientific method and contain Descartes' earliest theoretical tracks on music, terrestrial mechanics, and the nature of the mind. The period between 1637 and 1641, in contrast, results in the publication of *Discours de la méthode*[36](*Discourse on the Method*, 1637),[37] *La Géométrie* (*Geometry*, 1637),[38] *Meditationes de prima philosophia*[39] (*Meditations on First Philosophy*,[34] 1641). Each of these works represents a highly influential contribution to their respective areas.

3.6 The *Meditiations* and Their Impact

The *Meditations on First Philosophy*, proves important in the development of the philosophy of mind for many reasons. For instance, Descartes' view proves important, in part, because it and Descartes himself become very influential in the intellectual circles of Europe. However, the discussion in this chapter focuses upon two ideological reasons for the influence of Cartesianism: First, Descartes brings his scientific and mathematical interests to philosophical speculation regarding the mind. More precisely, Descartes brings the goal of scientific explanation together with an emphasis on rigorous methodology to philosophical ruminations regarding the mind. One ought not to suppose that these features are exclusive to Descartes' works. Rather, he exemplifies a growing movement. Importantly, his emphasis on rigorous methodology in the development of theories and explanations leads Descartes to seek an account of why only some kinds of physical entities appear to have minds or the potential for mentality.

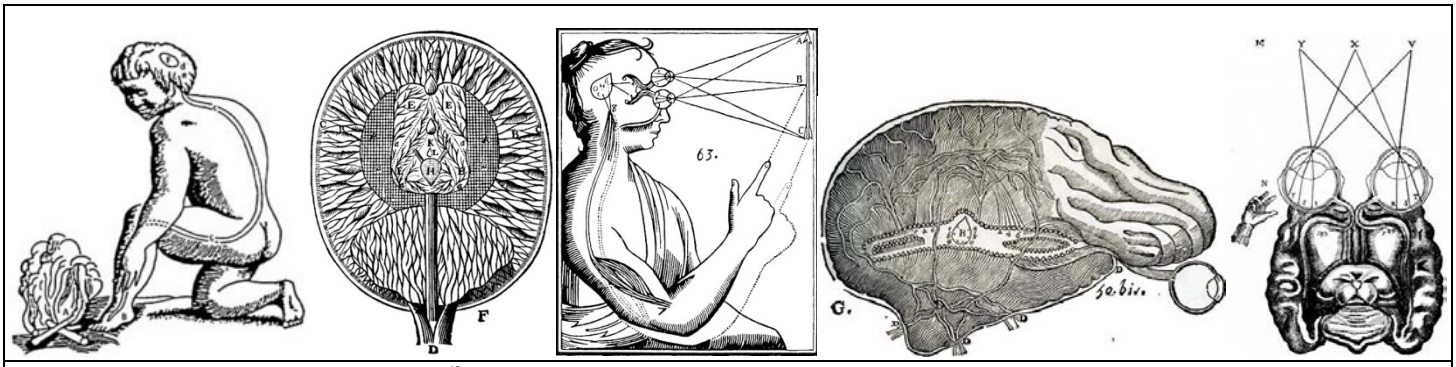
Though a substance and property dualist, Descartes makes some of the first steps towards a materialistic, scientific psychology and neuroscience. Descartes maintains a very strong, long-term interest in the workings of the physical body, and spends a great deal of time dissecting cadavers. In 1637 Descartes publishes *La Dioptrique*[40] as one of three appendices to his *Discourse on Method*.[37] In each appendix, Descartes offers an example illustrating the method he outlines in *Discourse on Method*. *Dioptrique* is a treatise on optics. Though not particularly original in its results from optics, it articulates the corpuscular theory of light and suggests for the first time that the retina projects directly onto brain (in Descartes view, onto the walls of the ventricles). Though *Dioptrique* represents Descartes first publication on the topic of mind-body interaction, Descartes' exposition in *Dioptrique* reflects theoretical speculation from a work he began long before, *Traite de l'homme*[41] (Treatise on Man, published 1648, written 1637).

Descartes bases his theory of mind-body interaction upon his knowledge of gross neuroanatomy. Specifically, (A) Descartes posits the pineal gland as the "seat" of mind-body interaction. As early as his first work, *Treatise of Man* (written 1637, published 1662) Descartes hypothesizes, contra Galen, that the pineal gland plays a role in sensation, imagination, memory and the causation of bodily movements.[42] Thus, the pineal gland serves as the principle organ for *sensus communis*--the communication between the body and the soul. Both the soul and the body's animal spirits can affect the pineal gland by literally moving it, thereby allowing each to act on the other. Additionally, (B) Descartes adopts Galen's hypothesis that the nerves are hollow tubes that contain "…a certain very subtle wind, or rather a very lively and pure flame, which is called 'animal spirits'."[42](p.19) Ironically, though Descartes advocates a substance dualism, he actually furthers the mechanistic picture in that he views the body as an elaborate machine. Moreover, he takes pride in his claim to have furthered mechanistic explanation of human and animal behaviors.

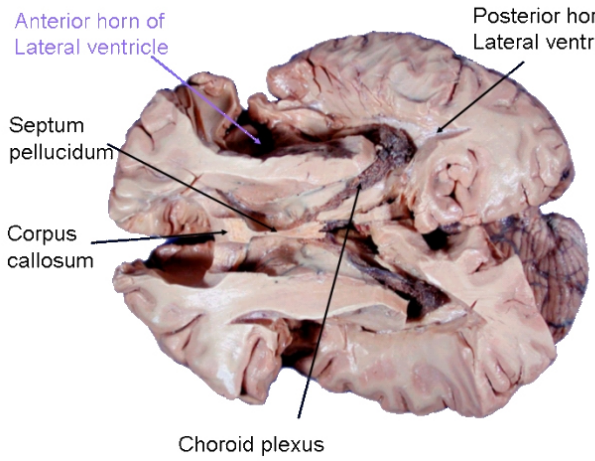
So, the *Meditations*' importance in the development of science and the evolution of philosophical theories of mind results, in part, from its basis in physiology and anatomy. Though Descartes' account of the pineal gland and related neuroanatomy and neurophysiology suffers from numerous inaccuracies, he articulates and argues for a view of the body as a machine capable of autonomous action. Descartes thereby indirectly furthers physical explanations of the mind and mental processes. Indeed, Descartes notes that,[42]

> …it is not necessary to conceive of this machine as having any vegetative or sensitive soul or other principle of movement and life, apart from its blood and its spirits, which are agitated by the heat of the fire burning continuously in its heart—a fire which has the same nature as all the fires that

occur in inanimate bodies. (p.113)



Left to Right: From *L'homme de René Descartes*[43] Transmission of painful stimuli **(p.25);** Diagram section of brain **(p.52);** Diagram of the pineal gland facilitating visual-motor function **(p.72);** Diagram of optic nerve running directly to the ventricles. **(p.95);** Diagram depicting visual processing from *La Dioptrique*[44] **(p.128).**



Annotated picture indicating the position of the ventricles in a cross-section of a human brain. From: Medlearn

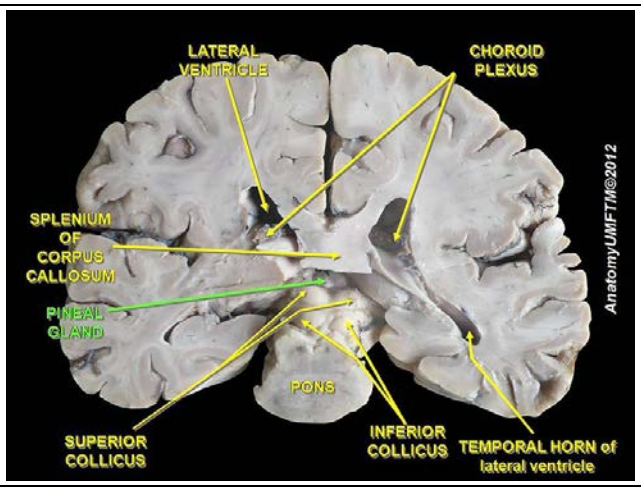
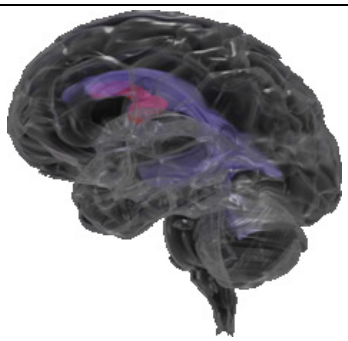
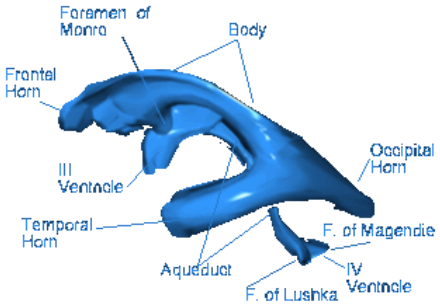


Diagram indicating the position of the pineal gland in a cross-section of a human brain. Modified From: Wikipedia





(Above Left) Computer generated graphic showing the relative position of the ventricles in the human brain. **(Above Right)** Computer generated graphic depicting the shape of the overall ventricle system. Both diagrams from: Neuroanimations.com

In addition to the goal of understanding the mental and its relationship to the physical, the same epistemic concerns that motivate Plato also drive Descartes' theorizing. For instance, in the *Mediations* Descartes asks readers to [34]

> Take, for example, this piece of wax; it is quite fresh, having been but recently taken from the beehive; it has not yet lost the sweetness of the honey it contained; it still retains somewhat of the odor of the flowers from which it was gathered; its color, figure, size, are apparent (to the sight); it is hard, cold, easily handled; and sounds when struck upon with the finger. In fine, all that contributes to make a body as distinctly known as possible, is found in the one before us. But, while I am speaking, let it be placed near the fire--what remained of the taste exhales, the smell evaporates, the color changes, its figure is destroyed, its size increases, it becomes liquid, it grows hot, it can hardly be handled, and,

> although struck upon, it emits no sound. Does the same wax still remain after this change? It must be admitted that it does remain; no one doubts it, or judges otherwise. What, then, was it I knew with so much distinctness in the piece of wax? Assuredly, it could be nothing of all that I observed by means of the senses, since all the things that fell under taste, smell, sight, touch, and hearing are changed, and yet the same wax remains. (M II, ¶12)

As a result, Descartes seeks to explain both how people can come to know (and fail to know) about the world in the face of perceptual flux as well as how there could be a distinction of kind between physical objects and minds. To explain these facts, Descartes sketches an explicit and clear oppositional substance dualism. Specifically, Descartes hypothesizes that the mental and the physical constitute distinct substances having opposing essential properties. Indeed, both Plato's form vs sensible object dualism and Descartes' substance vs matter dualism rely essentially upon the supposition of irreducible differences between their respective ontological posits. Like Plato, Descartes defines mental and physical substance through a cluster of essential properties. Unlike Plato, however, Descartes frames his oppositional substance dualism with the specific goal of further articulating the sorts of properties and causal connections that ought to underlie any explanation of the mental. Descartes characterizes mental substance as a non-extended, thinking substance manifesting mental properties like consciousness and belief. As Descartes tells his readers, mental substance "…is a thing that doubts, understands, [conceives], affirms, denies, wills, refuses; that imagines also, and perceives." (M2, ¶8) [34] In other words, Descartes rejects the tenuous dualism of earlier thinkers. Unlike Plato and Aristotle, Descartes crafts his ontological framework with the specific goal of unambiguously subsuming mental phenomena within its categories, properties, and relations. Unlike most thinkers from Herophilus through the scholastic scholars, Descartes defines the category of mental substance so that it shares none of the properties of physical substance, thereby avoiding the tenuous dualism whereby such thinkers imbue the mental with quasi-physical properties. For Descartes, mental substance constitutes an ontological category characterized exclusively by mental properties. Descartes sees his oppositional substance dualism as providing the best explanation—both for mental phenomena and for the seeming irreducibility between the mental and the physical. In contrast, Descartes defines physical substance as essentially extended, having properties of shape, size, position, and number. Thus, for Descartes physical substance has no mental properties either. In effect, Descartes' ontological categories explain the perceived difference between mental and physical phenomena through stipulative definition. However, Descartes does not wish to simply dispel theoretical problems with arbitrary stipulative definitions. He views his ontological categories as having, intuitive, methodological, and empirical motivations.

Like Plato, Descartes locates knowledge—not in the physical object or sensations caused by physical objects—but in mental judgment regarding sensations. Error occurs because sensation cannot provide knowledge without the proper exercise of judgment. Knowledge occurs in so far as the mind judges properly regarding the import of sensations. In short, Descartes explains the seeming difference between physical bodies that can have minds and bodies that cannot have minds by proposing that the world has two ontological kinds. He adopts Plato's solution to Plato's epistemic dilemma. Descartes explains the limitations of human knowledge and human failures to know by reference to the speculative nature of inferences. Indeed, thinkers must judge the import of sensations with regard to the physical, nothing intrinsic to the interaction between these two fundamentally different sorts of ontological kinds provides a guarantee that sensations of physical objects,

properties, and events resemble their causes. Descartes explains human knowledge by appealing to the innate, God given reliability of human judgment abilities when properly employed.

So, Descartes' *Mediations* proves influential in that it brings his scientific and mathematical interests to philosophical speculation regarding the mind. Ironically, the second reason for the influence of Descartes' *Mediations* lies in its failure to offer an adequate scientific explanation of the relationship between the mind and the body. Descartes oppositional substance dualism paints mental and physical substance as utterly unlike one another. Thus, his dilemma regarding their interaction again illustrates the daunting challenges of understanding and explaining mind/body interaction. In everyday life humans experience a seamless interaction between physical events and mental events. When one hits one's thumb, instead of a nail, that physical event immediately and predictably results in the mental phenomenon of pain. The challenge for Descartes's oppositional substance dualism lies in articulating a plausible theoretical account whereby these two opposite ontological kinds, mental substance and physical substance, could possibly interact in the seemingly fluid and highly integrated way one observes in one's everyday life. Thus, because of his dualist conception of the mind, and because of his scientific slant on philosophy, the *Meditations* together with his *Les Passions De L'ame* (Passions of the Soul) [45] and *Traite de l'homme* (Treatise on Man) [42] lay the groundwork for a switch in emphasis in the philosophy of mind. Whereas philosophical speculation regarding the mind exhibits a stronger epistemic and functional emphasis before Descartes, the emphasis turns somewhat away from epistemology and towards ontology after Descartes. That is, philosophers become increasing interested one of two theoretic projects: (1) Some thinkers seek to understand if/how the mind could be physical in nature and explained through science. (2) Other thinkers seek to explain the apparent seamless integration of the mental and the physical within an oppositional dualist framework. These interests, at least the former, continue today and lead to the explicit formulation of a variety of theories regarding the nature of the mind and its relationship to the physical world.

3.7 Science, Representations, and Ideas

Ironically, the increasing emphasis science, observation, and physicalism inspires still another tenuous dualistic posit—the idea. John Locke (1632-1704) writes his *An Essay Concerning Human Understanding* [46](1690) to flush out the corpuscularian philosophy[47] (essentially the hypothesis that the physical world is composed of atoms and "the void"—a doctrine he learns from the great chemist Robert Boyle) with regard to the mind. Like all British Empiricists, Locke seeks to understand the mind in order to more accurately understand and theorize about the nature, limits, and sources of knowledge.

David Hume (1711-1776), shares Locke's project of understanding the nature of the mind in order to understand the nature, sources, and limits of knowledge. However, reflection upon observational evidence--as opposed to a particular ontological picture--drive Hume's theorizing in works like, *A Treatise of Human Nature* [48] (1739-40) and *An Enquiry concerning Human Understanding* [49] (1748). Hume's speculations famously lead him to the conclusion that empiricist theories of mind undermine one's claim to knowledge of physical objects and causality. Locke and Hume both outline theories of mind that have representations and operations on those representations. Unlike Hobbes--but like Descartes--Locke's and Hume's model for ideas, the medium of mental representations, is pictures. Locke and Hume both seek to explain the functioning of mental processes underlying thought and reasoning in terms of ideas and operations upon ideas. Of particular significance, Hume views human reasoning about experience as resulting from operations of association

rather than by deduction. Hume proposes that cause and effect reasoning results from habitual associations between ideas because of their constant conjunction in experience. In the work, *An Abstract of a Book lately Published: Entitled A Treatise of Human Nature etc.* [50] tells readers that,

> Tis evident that all reasonings concerning matter of fact are founded on the relation of cause and effect, and that we can never infer the existence of one object from another, unless they be connected together, either mediately or immediately... Here is a billiard ball lying on the table, and another ball moving toward it with rapidity. They strike; and the ball which was formerly at rest now acquires a motion. This is as perfect an instance of the relation of cause and effect as any which we know, either by sensation or reflection. (¶8-9)

The third famous British Empiricist, George Berkeley (1685-1753), differs from Locke and Hume in that his work emphasizes ontological issues. Indeed, in his works, *A Treatise Concerning the Principles of Human Knowledge, Part I* (1710) [51] and *Three Dialogues Between Hylas and Philonous* (1713) [52], Berkeley argues against monistic physicalism and in favor of monistic idealism. For Berkeley, nothing exists but minds, God, and ideas. All phenomena--mental and physical--consist exclusively of a series of ideas coming into in passing from one's mind.


John Locke (1632-1704)

David Hume (1711-1776)

George Berkeley (1685-1753)

Immanuel Kant (1724-1804)

Thomas Reid (1710-1796)

Thus, with Berkeley one sees the third of three major ontological frameworks regarding the nature of the mind and body. First, monistic physicalism (reductive materialism or materialism) posits only one type of substance, material substance. The mind and all mental properties result from modifications of the same substance--physical substance, i.e., the mind = the body. Second, oppositional substance dualism (substance dualism or mind-body dualism) posits two distinct kinds of substance, mental substance and physical substance. The mental substance underlies minds and mental properties, while physical substance underlies all physical objects and physical properties. Finally, monistic idealism (idealism or mentalism) posits only one kind of substance, mental substance. All seemingly physical objects and physical properties actually consist of ideas and their properties. These basic ontological frameworks have many permutations.

Similarly, the line of development outlined in this text does not exhaust the rich theoretic permutations in the historical record. For instance, Thomas Reid (1710-1796) rigorously rejects the notion of a representational mind at about the same time that people read Hume's and Locke's representational theories. Another sort of objection, this time to scientific psychology comes from Immanuel Kant (1724-1804). Kant, a physicist and philosopher, adopts the same general project as Hume--understanding the nature of the mind in order to further epistemological theorizing. However, in his book, *The Critique of Pure Reason* [53](Kemp Smith's English

translation 1929), Kant wants to counter Hume's skeptical conclusions. Kant argues that much of our knowledge flows from the innate presuppositions necessary for experience itself. Interestingly, though Kant rejects the notion of a scientific psychology, he nevertheless develops and draws heavily upon a theory of the mind in his work. These two positions are not necessarily at odds with one another; Kant argues for the impossibility of a science of the mind, i.e., he argues against a particular conception of scientific psychology, because the field cannot be mathematized.

3.8 Substance Dualism in the Twentieth Century

Despite Kant's skepticism scientific psychology eventually begins to develop. From Descartes through the first part of 20th century, philosophers focus primarily on the debate over ontological frameworks. By the second half of the twentieth century, concerns over how best to understand and explain the mind's physical origins drive a significant portion of philosophical speculation regarding the mind. Additionally, concerns arising from philosophical interests in language and mathematics begin to pervade the philosophy of mind. It is, therefore, convenient to use this section to outline the standard positions in the philosophy of mind, including those that developed prior to the second half of the 20th century, before turning to the second half of the 20th century in the next chapters.

As noted above, each view--materialism, dualism, and idealism constitute classes of ontological frameworks in which multiple theoretical permutations exist. For instance, in the case of dualism philosophers commonly note three distinct positions: Descartes holds the most common position--interactive dualism. Interactive dualism holds that mental substance and physical substance causally interact with one another. Interactive dualism might seem like the only possibility. However, two other possibilities emerge if one denies that mental and physical substances interact. Such a denial might seem ridiculous given the apparent connection between mental phenomena and physical phenomena. For instance, if someone steps on your foot (a physical phenomenon) you will likely experience a feeling of discomfort in your foot (a mental phenomenon). However, Descartes' clarity and rigor in differentiating mental and physical substance raises, ironically, a significant challenge to interactionism.

Recall that mental substance is essentially non-spatial, lacking all physical properties. Likewise, physical substance is essentially spatial, lacking all mental properties. If the mind and the body are fundamentally different sorts of stuff, one must ask, "How could these two substances possibly causally interact with one another?" For that matter, given that the mind is non-spatial, where could they possibly causally interact? Experience renders mind-body interaction *prima facie* indubitable, so interactive dualism must explain how such causal interaction could possibly occur. Philosophers articulate many difficulties with interactive dualism, but most agree that the difficulties with causal interaction rank very high. In addition to difficulties with the very idea of inter-substance causation, another serious difficulty emerges almost immediately from dualistic interactionism. In a mechanistic, deterministic physical science, all changes in the physical world should be explicable (at least in principle) by universally applicable purely mechanistic, deterministic physical laws. But, if mental substances and causal substances causally interact, mental causation renders universal purely mechanistic, deterministic physical laws impossible. Mental to physical causation will always fall outside of these purely physical laws, thereby violating those laws.

One possible solution to this last worry involves denying causal interactionism--at least in one direction. Epiphenomenalism asserts that changes in physical substances and properties can cause changes in mental substances and properties, but that changes in mental substances and properties cannot cause changes in physical substances or their properties. Thus, one still retains causal connections between the mental and the physical, without mental causation violating universally applicable purely mechanistic, deterministic physical laws. While epiphenomenalism might allow for deterministic physical laws, it implies that mental phenomena never cause physical phenomena--violating the seeming obvious nature of mind-body interactions. Worse still, it must explain why causation only runs from the physical to the mental, and not vice versa. Indeed, why the

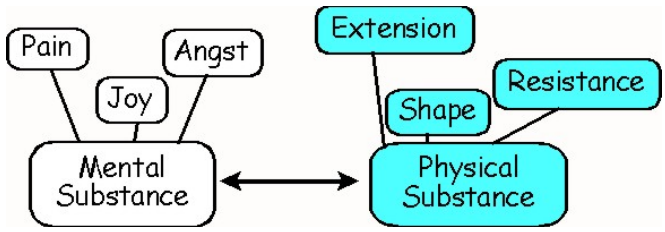
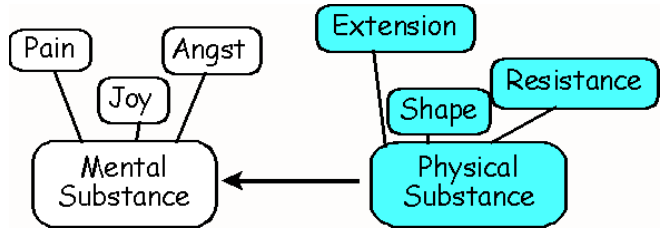
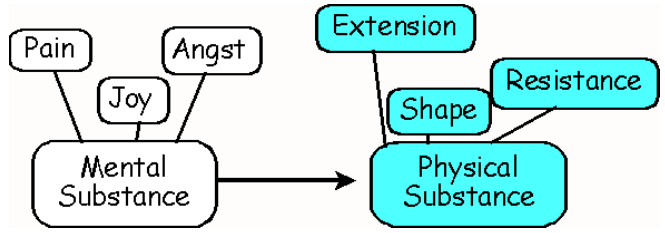
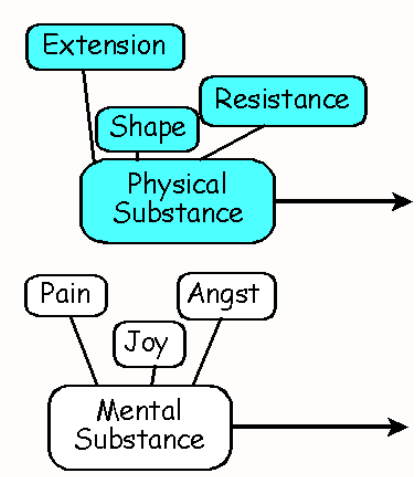
Possible Substance Dualisms			
Name of Position	Mental to Physical Causation	Physical to Mental Causation	Illustrative Diagram
Interactionism	Yes	Yes	
Epiphenomenalism (mental)	No	Yes	
Epiphenomenalism (physical)	Yes	No	
Parallelism	No	No	

Table of the possible substance dualisms with diagrams depicting each variety. Substance dualisms posit two fundamental types of substances, physical and mental. Each substance has distinct properties. Here conveniently yet inaccurately modeled by bubbles.

universe would exhibit such a causal asymmetry seems as daunting an explanatory target as explaining interaction itself—particularly given that experience does not lend support to an asymmetrical causation between the mental and the physical.

The third dualist position also seeks to solve to the problem of interaction by denying interactions. Parallelism asserts that mental and physical substances only appear to causally interact. Instead of causal interaction between the two substances, parallelism holds that mentally generated mental changes and physically generated physical changes merely mirror one another, creating the illusion of interaction. One might find one version of anti-interactionism less plausible than the next. However, considering the difference between causation and correlation might make parallelism seem somewhat more plausible. The time on Bill's watch may always correlate with the time on Tom's watch, but no one supposes that the two watches causally interact with each other. The above table summarizes the various substance dualistic positions.

Each of the modern substance dualist positions illustrates the tensions inherent in the oppositional substance dualism framework. Recall that early in the first chapter I noted that the development of the Greek notion of the soul also illustrates a common dilemma that theorists have faced throughout the historical development of theories of mind: (D1) Physicalist theories face the difficulty of formulating physical mechanisms that plausibly explain various mental properties and processes. In contrast, (D2) Dualist oppositional theories face the difficulty of formulating accounts of how two fundamentally different types of objects could possibly interact in such a seemingly continuous and seamless fashion. Advocates of oppositional substance dualism generally face still more difficulties: Indeed, given the nature of mental substance, oppositional substance dualist often provide little insight into how one might explain mental functioning within their ontological framework. Mental substance, by its very nature, and does not offer theorists these sort of properties with which one can explain mechanistic and causal changes in physical substance. For instance, mental substances do not exist in particular places, nor do mental substances have parts.

3.9 Arguments for Mind-Body Dualism

At various points throughout this text I suggest motivations and challenges for the various ontological frameworks. For oppositional substance dualists--dualists who assert a fundamental and irreconcilable difference between the kinds posited in their ontological frameworks (e.x., mental and physical substance) the most salient challenge lies in explaining (or explaining away) the seeming seamless and perpetual integration of mind and body. Thus, one might well ask, "Why would someone advocate dualism?" Descartes and other theorists present three mainlines of argumentation for their ontological framework; (1) Arguments based upon the apparent inimical differences between mental and physical phenomena, (2) Arguments based upon knowledge claims linked to mentality, and (3) Arguments alleging the physicalist cannot explain various mental phenomena.

3.9a The Argument From Leibniz's Law/Identity of Indiscernibles (Descartes)

Descartes gives readers a version of the first kind of argument in the *Mediations VI:*[34]

> … I here remark, in the first place, that there is a vast difference between mind and body, in respect that body, from its nature, is always divisible, and that mind is entirely indivisible. For in truth, when I consider the mind, that is, when I consider myself in so far only as I am a thinking thing, I can distinguish in myself no parts, but I very clearly discern that I am somewhat absolutely one and entire;

> and although the whole mind seems to be united to the whole body, yet, when a foot, an arm, or any other part is cut off, I am conscious that nothing has been taken from my mind; nor can the faculties of willing, perceiving, conceiving, etc., properly be called its parts, for it is the same mind that is exercised [all entire] in willing, in perceiving, and in conceiving, etc. But quite the opposite holds in corporeal or extended things; for I cannot imagine any one of them [how small soever it may be], which I cannot easily sunder in thought, and which, therefore, I do not know to be divisible. This would be sufficient to teach me that the mind or soul of man is entirely different from the body, if I had not already been apprised of it on other grounds. (M VI, ¶19)

Contemporary writers often update Descartes argument it as follows:

3.9b Modern Argument From Leibniz's Law/Identity of Indiscernibles (Descartes)

> (L1) I can easily imagine my body being chopped-up, placed into garbage bags, and scattered about town. Hence, my body is divisible.
>
> (L2) I cannot imagine my mind being chopped-up. Hence, my mind is not divisible.
>
> (L3) If my mind was just my body, by Leibniz's Law, I should be able to imagine my mind being chopped-up. That is, identical things must have all and only the same properties. [i.e., if (x)(y)((x=y) then (P)(Px if and only if Py))]
>
> (L4) Hence, my mind is not my body.

Theorists criticize such Leibniz law arguments on the basis that the seeming differences between the properties associated with the mind or mental substance and the properties associated with the body of physical substance might well only appear to differ because of referential opacity. Theorists assert the referential opacity of two categories, concepts, or terms whenever the exact nature of their reference (or possibly co-reference) remains indeterminate. For instance, suppose that you have no experience of ice whatsoever, but you do know and have experience with water. In this context, ice and water will likely prove referentially opaque to you. That is, if someone holds up a piece of ice and announces that they are holding water you will likely deny the truth of their assertion. On the other hand, if they hold up a glass of water you will likely agree with their assertion. Thus, your context--your knowledge and your situation—prevents you from clearly determining the reference of the two categories, concepts, or terms. As a result, those terms, concepts, or categories are referentially opaque to you. In the case of the above Leibniz Law argument, the arguer asserts that mental and physical substance are distinct because one, physical substance, can be divided while the other, mental substance, cannot. But the premise does not provide direct evidence that the two substances differ. Instead, the argument relies upon one's ability to imagine division of each substance. Logicians have long known that in contexts like imagining, knowing, and and believing one cannot necessarily substitute co-referential, but opaque terms *salva veritate* (i.e. without changing the truth value of the statement). Thus, it may be true that Bob believes that Richard Bachman wrote *Thinner*, and yet deny that Stephen King wrote *Thinner* (despite the fact that King did write *Thinner* under the pen name Richard Bachman). In short, seeming differences in properties may result for non-identity or they may result from referential opacity.

3.10 The Argument from Introspection

In the case of arguments from introspection, the arguer infers the differences between mental and physical substance on the basis of differences between one's sensory experiences of one's body and one's introspective perceptions of one's mental states and processes. Readers can find something like an argument from introspection in Descartes' *Mediation VI*: [34]

> …because I know with certitude that I exist, and because, in the meantime, I do not observe that aught necessarily belongs to my nature or essence beyond my being a thinking thing, I rightly conclude that my essence consists only in my being a thinking thing [or a substance whose whole essence or nature is merely thinking]. And although I may, or rather, as I will shortly say, although I certainly do possess a body with which I am very closely conjoined; nevertheless, because, on the one hand, I have a clear and distinct idea of myself, in as far as I am only a thinking and unextended thing, and as, on the other hand, I possess a distinct idea of body, in as far as it is only an extended and unthinking thing, it is certain that I, [that is, my mind, by which I am what I am], is entirely and truly distinct from my body, and may exist without it. (M VI, ¶9)

Putting this argument in a more generic and contemporary format gives one something like this:

3.10a The Contemporary Argument from Introspection

> (I1) Introspection reveals mental states and properties to the introspector in much the same way that vision reveals objects in the visual world.
>
> (I2) Introspection reveals that mental states have none of the properties of brains or brain states.
>
> (I3) Thus, direct observation seems to belie the claim that mental states and processes are simply physical states and properties.

Writers like Paul Churchland [54-56] as well as psychological researchers [57-66] note the pitfalls of introspection as a means for accurately accessing mental states and processes. The lectures later in the course discuss the difficulties with introspection in more detail.

3.11 The Argument From Special Abilities/Inabilities (Descartes)

Logicians often refer to form of this current class of arguments as an appeal to ignorance. Arguments from special abilities or inabilities point to a lack of current ability and/or knowledge and attempt to infer an in principle claim to the effect that the ability can never exist or that some fact or facts can never be known. Part of the appeal of these arguments stems from our tendency to see mental creatures as fundamentally different from other entities. Not everything acts in a manner people recognize as, for example, intelligent. Arguments from special abilities infer from the fact that theorists do not fully understand some mental property or ability to the claim that such a property or ability can never be fully understood or realized in purely physical entities. Such arguments lose their efficacy insofar as viable physicalist explanations emerge for various aspects of mentality. For instance, in part five of his *Discourse on Method* Descartes suggests such and argument from disability:

> The second test is, that although such machines might execute many things with equal or perhaps greater perfection than any of us, they would, without doubt, fail in certain others from which it could be discovered that they did not act from knowledge, but solely from the disposition of their organs: for while reason is an universal instrument that is alike available on every occasion, these organs, on the contrary, need a particular arrangement for each particular action; whence it must be morally impossible that there should exist in any machine a diversity of organs sufficient to enable it to act in all the occurrences of life, in the way in which our reason enables us to act. Again, by means of these two tests we may likewise know the difference between men and brutes. For it is highly deserving of remark, that there are no men so dull and stupid, not even idiots, as to be incapable of joining together different words, and thereby constructing a declaration by which to make their thoughts understood; and that on the other hand, there is no other animal, however perfect or happily circumstanced, which can do the like. Nor does this inability arise from want of organs: for we observe that magpies and parrots can utter words like ourselves, and are yet unable to speak as we do, that is, so as to show that they understand what they say; in place of which men born deaf and dumb, and thus not less, but rather more than the brutes, destitute of the organs which others use in speaking, are in the habit of spontaneously inventing certain signs by which they discover their thoughts to those who, being usually in their company, have leisure to learn their language. (Part 5, ¶7)

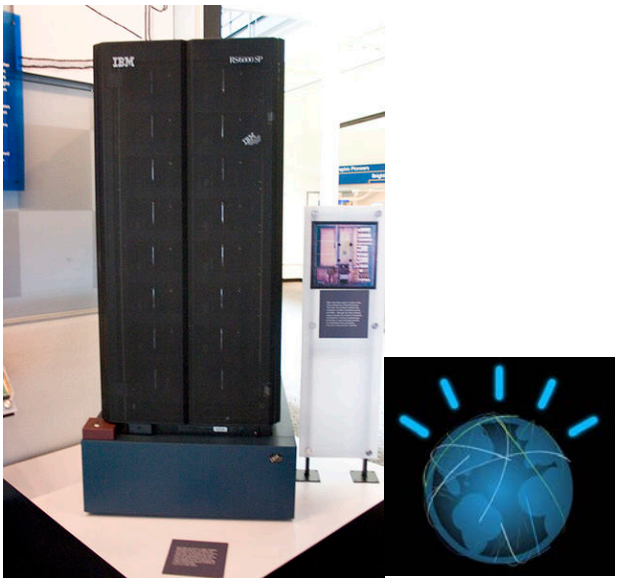
3.11a The Contemporary Schema of the Argument From Special Abilities/Inabilities

> (SA1) Only humans can _____.
>
> (SA2) If mental properties and abilities where just physical properties and abilities, then one would expect to find or to be able to create other physical systems with that can _____.
>
> (SA3) Since we do not, humans must be mental in virtue of some other, nonphysical substance having some other, nonphysical properties.

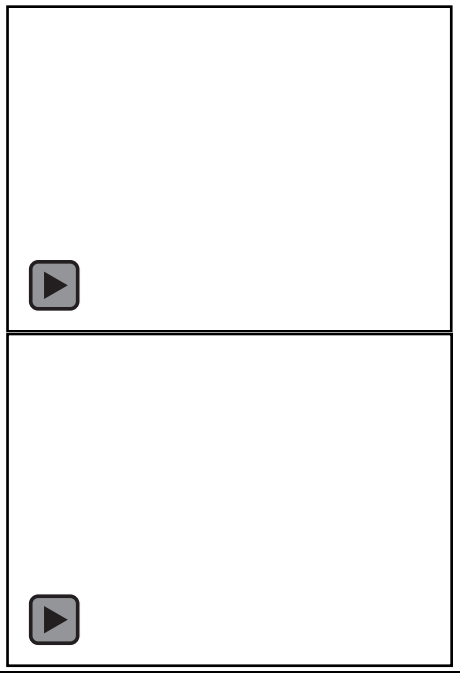
Over time the greatest difficulty with the argument from special abilities/inabilities lies in the slow march of human understanding and ingenuity. For instance, in the case of computers, many abilities once claimed as beyond the possible abilities of computers have been realized in computers. Computers have beaten the best chess players in the world.[67] In similarly spectacular fashion, computers have controlled vehicles in urban and off-road races without the intervention of human drivers.[68] Most recently a computer beat all of the best past contestants in the game Jeopardy.[69]

Similar problems emerge for the inability argument in light of the discoveries of scientists tying various mental abilities very strongly to specific neuronal structures. For instance, psychologists have long known that extensive bilateral (both sides) damage to a structure of the brain called the hippocampus results in the inability an to form long-term declarative memories. Declarative memories are memories of facts and events. Specifically, declarative memory systems share a common functional characterization and a significantly overlapping neural substrate. At the functional level, researchers consider declarative memory systems to be representational and to encode factual information (i.e., people, places, things, and times) as well as the significance of such information. Though not necessarily propositionally encoded, normal subjects can express information stored in declarative memory through linguistic and/or graphic mediums with sufficient precision to warrant its evaluation for veridicality--most often truth-functionality. Insight into the crucial role of the

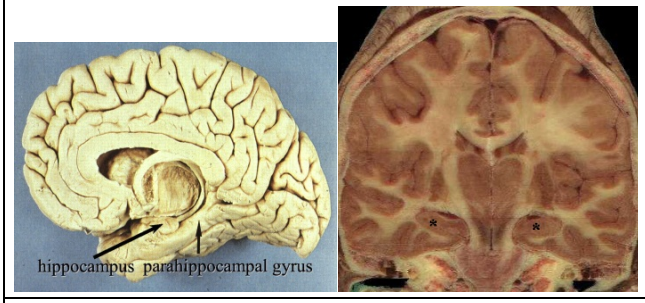
hippocampus in long-term declarative memory has been dramatically advanced by the selfless contributions made by Henry Gustav Molaison, known as HM in the literature and a musicologist and conductor, Clive Wearing. Each man suffered drastic bilateral (both sides) damage to their hippocampus. This damage resulted Mr. Molaison and Mr. Wearing losing their ability to create long-term declarative memories. Each man had to function exclusively using their working-memories, their procedural memories, and their previously stored long-term memories. Worse still, each man's working memory limited his ability to consciously attend to activities and environments to continuous periods ranging between seven seconds and about one and one-half minutes. Nevertheless, both men volunteered for countless psychological studies and upon his death in 2008 Mr. Molaison donated his brain to science.



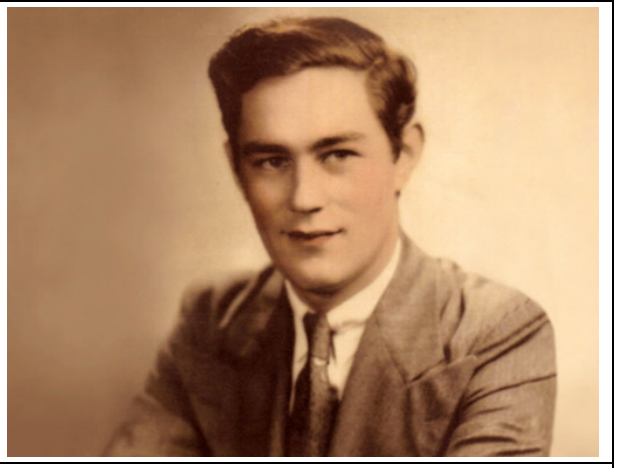
(Above left) Picture of deep blue. From Wikipedia (Above right) A Picture Watson's avatar—the Jeopardy Champion computer. From: Wikipedia



Two videos of memory patient Clive Wearing. After massive bilateral (both sides) damage to his hippocampus Mr. Wearing lost the ability to form long-term memories or to function for more than between 7-90 seconds without exhausting his working memory and "rebooting." Both videos are from Youtube. Click on the images to play the videos.



(Above left) A sagittal cut of the right hemisphere of the human brain revealing the hippocampus labeled in the picture. From: PNAS **(Above right)** A coronal bisection of a human brain revealing the hippocampal structures in each hemisphere. From: The Center for Neural Informatics, Neural Structures, and Neural Plasticity



Picture of the late Henry Gustav Molaison (1926-2008) who furthered research into long-term declarative memory after an epilepsy operation resulted in bilateral hippocampal damage. Mr. Molaison also donated his brain to science. Picture from Wikipedia

3.12 Arguments Against Dualism

Most theorists rely upon two kinds of arguments against an oppositional mind-body dualistic framework. On the one hand, theorists note that dualism by its very nature posits entities and properties that provide no obvious means of causal interaction. How does the pin-prick one gets (a physical event caused by physical entities and processes), cause the pain that one feels (a mental event supposedly caused by mental entities and processes)? How does something with no location in space provide one with a perspective from a location in space? Such problems regarding the interaction of mental and physical substances seem insurmountable to most theorists. This line of argumentation usually goes under the moniker of the problem of interaction.

More recently Paul Churchland [54, 70] argues that oppositional mind-body dualistic frameworks do not actually provide plausible explanations for seemingly mental phenomena. For instance, why do humans sleep? Why do humans dream when they sleep? Why do humans develop mental disorders like schizophrenia? Substance dualism tends merely to posit a substance together with a set of properties corresponding to mental attributes such as fear, belief, desire, etc.. However, the nothing about such entities or their proposed properties provides one with any dynamical mechanisms to explain how mental phenomena occur or lead one to the next. For this reason, substance dualisms seem to suffer from the same difficulties faced by physicalistic theories. As noted in the beginning of this chapter, (D1) Physicalist theories face the difficulty of formulating physical mechanisms that plausibly explain various mental functions and properties. Churchland argues forcefully that substance dualisms face the same difficulties in explaining various mental functions and properties. Thus, in contemporary times many researchers allege that, qualitative consciousness, viz., conscious experiences of red, represent a mental function that seems to resist explanation by known physical mechanisms. Churchland suggests that dualist theories likewise face the difficulty of formulating dualistic mechanisms that plausibly explain various mental functions like sleep, dreaming, etc..

Bibliography

1. Wikipedia. Physiology. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
2. Wikipedia. Anatomy. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
3. Euclid. *The Elements of Euclid*. London: William Pickering; 1847 (300 BCE).
4. Wikipedia. Renaissance. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
5. Wikipedia. Scientific Revolution. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
6. Wikipedia. Determinism. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
7. Harvey W. *Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus (An Anatomical Exercise on the Motion of the Heart and Blood in Living Beings)* Frankfort 1623.
8. Wikipedia. Hippocrates. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
9. Wikipedia. Hippocratic Corpus. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
10. Hippocrates L, Geoffrey E.R, . *Hippocratic Writings* New York, NY: Penguin Classics; 1978.
11. Ermerins FZ. *Specimen Historico-Medicum Inaugurale de Hippocratis Doctrina a Prognostice Oriunda (The Origins of Hippocrates' Diagnostics)*. Lugduni Batavorum: Van der Hoek; 1832.
12. Wikipedia. Edwin Smith Papyrus. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
13. Wikipedia. Ebers Papyrus. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
14. Porter R. *The Greatest Benefit to Mankind: A Medical History of Humanity from Antiquity to the Present*. New York, NY: W. W. Norton & Company; 1999.
15. Aristotle. *On the Parts of Animals*: MIT Internet Classics Archive; 350 BCE.
16. Wikipedia. Herophilos. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
17. Wikipedia. Erasistratus. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.

18. Von Staden H, ed. *Herophilus: The Art of Medicine in Early Alexandria*. Cambridge, England: Cambridge University Press; 1989.
19. Wills A. Herophilus, Erasistratus, and the Birth of Neuroscience. *The Lancet.* 1999;354(9191):1719-1720.
20. Wikipedia. Galen. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
21. Wikipedia. Pergamon. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
22. Galen, Helmreich G. Galeni De usu partium libri XVII: Internet Archive; 1907.
23. Euclid. The Thirteen Books of Euclid's Elements. In: Joyce DE, Heath (translator) STL, eds. Boston, MA: Perseus Digital Library Project; 1956.
24. Wikipedia. Eudoxus of Cnidus. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
25. Wikipedia. Menaechmus. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
26. Hobbes T. Leviathan or the Matter, Forme, & Power of a Common-wealth Ecclesiastical and Civill In: White E, Widger D, eds: Project Gutenberg Literary Archive Foundation 1671.
27. Wikipedia. René Descartes. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
28. Wikipedia. Baruch Spinoza. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
29. Spinoza Bd. Ethics. In: Sharpe T, Haines A, Elwes (translator) RHM, eds. *Ethica Ordine Geometrico Demonstrata*: Project Gutenberg Literary Archive Foundation; 1677.
30. Wikipedia. Nicolaus Copernicus. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
31. Copernici N. *De Revolutionibus Orbium Coelestium*: Wikipedia.org; 2007.
32. Wikipedia. Andreas Vesalius. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
33. Vesalius A. *De Humani Corporis Fabrica (On the Fabric of the Human Body)*. Evanston, IL: Northwestern University; 1543.
34. Descartes R. Meditations on First Philosophy: In Which the Existence of God and the Immortality of the Soul are Demonstrated. In: Manley DB, Taylor CS, Veitch (Translator) J, eds. *Meditationes de prima philosophia, in qua Dei existentia et animæ immortalitas demonstratur*; 1901.
35. Wikipedia. Isaac Beeckman. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
36. Wikipedia. Discourse on Method. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
37. Descartes R. Discourse on the Method of Rightly Conducting One's Reason and of Seeking Truth in the Sciences: Project Gutenberg; 1649.
38. Wikipedia. La Géométrie. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
39. Wikipedia. Meditations on First Philosophy. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
40. Descartes R. La Dioptrique. Nice, France: Philosophy Department, University of Nice; 1637.
41. Descartes R. Traite de l'homme Quebec, Canada: Universite Du Quebec, Les Classiques Des Sciences Sociales; 1648.
42. Descartes R. *Traite de l'homme (Treatise on Man)*. Amherst. NY: Prometheus Books; 2003.
43. Descartes R. L'homme, et la formation du foetus Ottowa, Canada: Internet Archive; 1677 (2010).
44. Descartes R. Oeuvres de Descartes. Storrs-Mansfield, CT: Internet Archive; 1902 (2010).
45. Descartes R. *Les Passions De L'ame (Passions of the Soul)*. Indianapolis, IN: Hackett; 1989.
46. Locke J. *An Essay Concerning Human Understanding*. Oxford: Oxford University Press; 1979.
47. Wikipedia. Corpuscularianism. *Wikipedia*. San Francisco, CA: The Wikimedia Foundation; 2013.
48. Hume D. *A Treatise of Human Nature*. New York, NY: Barnes & Noble; 2005.
49. Hume D. *An Enquiry Concerning Human Understanding*. Cambridge: Cambridge University Press; 2007.
50. Hume D. *An Abstract of a Book lately Published: Entitled A Treatise of Human Nature etc.*; 1740.
51. Berkeley G. A Treatise Concerning The Principles Of Human Knowledge: The Project Gutenberg; 2002.
52. Berkeley G. Three Dialogues between Hylas and Philonous in Opposition to Sceptics and Atheists. In: Bennett J, ed: Early Modern Texts; 2010.
53. Kant E. *Critique of Pure Reason*. New York, NY: Palgrave Macmillan; 2003.
54. Churchland PM. *Matter and Consciousness*. Boston, MA: MIT/Bradford Books; 1988.
55. Churchland P. *Neurophilosophy: Toward a Unified Science of the Mind-Brain*; 1986.
56. Churchland PM. Reduction, Qualia, and the Direct Introspection of Brain States. *Journal of Philosophy.* 1985;82(1):8-28.
57. Berry DC, Broadbent DE. On the Relationship Between Task Performance and Associated Verbalizable Knowledge. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology.* 1984;36A(2):209-231.

58. Crutcher RJ. Telling What We Know: The Use of Verbal Report Methodologies in Psychological Research. *Psychological Science.* 1994;5(5):241-244.
59. Evans JSB, Wason PC. Rationalization in a Reasoning Task. *British Journal of Psychology.* 1976;67(4):479-486.
60. Nisbett RE, Wilson TD. Telling More than We can Know: Verbal Reports on Mental Processes. *Psychological Review.* 1977;84(3):231-259.
61. Nisbett RE, Wilson TD. The Halo Effect: Evidence for Unconscious Alteration of Judgments. *Journal of Personality and Social Psychology.* 1977;35(4):250-256.
62. Williams EF, Gilovich T. Do People Really Believe they are above Average? *Journal of Experimental Social Psychology.* 07 2008;44(4):1121-1128.
63. Wilson TD, Dunn EW. Self-Knowledge: Its Limits, Value and Potential for Improvement. *Annual Review of Psychology.* 02 2004;55:493-518.
64. Wilson TD, LaFleur SJ, Anderson DE, Schwarz N, Sudman S. The Validity and Consequences of Verbal Reports About Attitudes. *Answering questions: Methodology for determining cognitive and communicative processes in survey research.* San Francisco, CA US: Jossey-Bass; 1996:91-114.
65. Wilson TD, Nisbett RE. The Accuracy of Verbal Reports about the Effects of Stimuli on Evaluations and Behavior. *Social Psychology.* 06 1978;41(2):118-131.
66. Wilson TD, Schooler JW, Fazio RH, Petty RE. Thinking Too Much: Introspection Can Reduce the Quality of Preferences and Decisions. *Attitudes: Their structure, function, and consequences.* New York, NY US: Psychology Press; 2008:299-317.
67. Wikipedia. Deep Blue (chess computer). *Wikipedia*. San Francisco, CA: Wikimedia Foundation; 2012.
68. Wikipedia. DARPA Grand Challenge. *Wikipedia*. San Francsico, CA: Wikimedia Foundation; 2012.
69. Markoff J. Computer Wins on 'Jeopardy!': Trivial, It's Not. *The New York Times.* Vol February 16, 2011. New york, NY: The New York Times Company; 2011.
70. Churchland PM. *The Engine of Reason, The Seat of the Soul: A Philosophical Journey into the Brain*. 1 ed. Boston, MA: MIT Press; 1996.