

**Tools of Thinking:  
Understanding the World through  
Experience and Reason**

**Part I**

**Professor James Hall**



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Born in Weimar, Texas, in 1933, I spent my early childhood there and in New Orleans, Louisiana. Just before World War II, my family moved to Washington, D.C. I lived in that city and received my education from its public schools, museums, and newspapers, until I went off to college in Baltimore, Maryland, in the fall of 1951.

I knew *that* I wanted to teach by the time I graduated from high school, but I didn't know *what* I wanted to teach until much later. So I made a career of being a student for 12 more years (at Johns Hopkins University, Southeastern Theological Seminary, and the University of North Carolina at Chapel Hill), before trying to earn a living full time.

I had discovered my discipline by 1959, but it was 1965 before I found my school and my city. Each of the 40 years since then has confirmed my good fortune in joining the University of Richmond community and putting my roots down.

Teaching is my calling and first professional priority. I am especially gratified to have been declared "Outstanding Faculty Member of the Year" by both Omicron Delta Kappa and the Student Government of the University of Richmond at the end of my last year in the classroom. With 44 years at the blackboard, I have taught most of the standard undergraduate philosophy curriculum, including *Symbolic Logic*, *Moral Issues*, and *Philosophical Problems* to thousands of beginners and advanced courses and seminars on *Analytic Philosophy* (especially the works of Russell, Ayer, Wittgenstein, Ryle, and Austin), *Philosophy of Religion*, and *Epistemology* to hundreds of philosophy majors and minors. I have also pursued a number of issues beyond the boundaries of philosophy per se, in interdisciplinary courses as varied as *Science and Values*; *The Ideological Roots of the American Revolution*; and *Science, Pseudoscience and the Paranormal*. My research has produced an adult education series for The Teaching Company (*Philosophy of Religion*) and three published books (*Knowledge, Belief and Transcendence*; *Logic Problems*; and *Practically Profound*), with another in progress (*Taking the Dark Side Seriously*).

A life totally confined to the ivied tower would be truncated and precarious. My own is constantly expanded and kept in balance by ongoing involvements in church (Episcopal), politics (Democratic), and choral music (from Bach to Durafle, with just a dash of Ralph Vaughan Williams) and by travel (Wales or the Pacific northwest for preference) and a daily bout with the *New York Times* crossword. Many people outside of the academy have enriched my life by their work—Herblock and Harry Truman, John D. MacDonald and David Lodge, to name four—and others by their friendship and character—chief among them my wife, Myfanwy, and my sons, Christopher, Jonathan, and Trevor.

My complete track record, academic and otherwise, can be seen on the Web at: <http://www.richmond.edu/~jhall/>.

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## Tools of Thinking: Understanding the World through Experience and Reason

### Scope:

Whenever we decide to do a little thinking, a variety of tools are available for the enterprise. Perhaps we will try to remember what we already know or believe (regardless of how we came by it). Perhaps we will try to deduce something from what we already know or believe. Perhaps we will engage in the give and take of dialectic. Perhaps we will try to identify patterns in what we already know or believe (and remember) that would allow us to generalize it or extrapolate from it to claims of broad (or even universal) scope. Perhaps we will give free rein to the flow of our ideas, allowing them to call one another before the mind's eye in some pattern of association. Perhaps we will turn to sense experience and experimentation to provide the raw materials for some belief or knowing. Perhaps we will invent a model, hypothesis, metaphor, or rule to try to hang all or part of what we believe or know together in some systematic way. Or perhaps we will engage in a vigorous round of hypothesis and counterexample. Whatever tools we use, it is likely that we will, at some point, appeal to "intuition" to back up the general enterprise or some particular foundational piece of it. Whatever tools we use, of course, will involve some risks.

The purpose of this course is to trace out in a semi-historical way how modern rational empiricism has arrived at its tool kit for thinking (a tool kit particularly well modeled by modern natural science but also employed in a wide variety of other, everyday, enterprises). We will look at some of the ideas of Plato, Aristotle, Descartes, Hume, and Newton, interspersed with some representative attention to the methods and limitations of classical syllogistic logic, modern sentential and predicate logic, and Mill's theory of induction. We will also note the necessity of making room for conceptual invention when setting up general principles to organize our thoughts and give close attention to the crucial roles of hypothesis construction and experimentation in the thinking of modern rational empiricists.

As we work through these matters, we will note the frequent occurrence of broadly skeptical ideas about the very possibility of thinking reliably. These include Plato's mistrust of appearances, Descartes' mistrust of sense experience, Hume's mistrust of all general claims, the logical empiricists' mistrust of any claim that is untestable, and postmodern concerns about paradigms and paradigm shifts and the extent to which our thinking is controlled by the culture in which we find ourselves. The purpose of this course, however, is not the refutation of general or systematic skepticism. I have dealt with that in another work— see my *Practically Profound* (Lanham: Roman and Littlefield, 2005), Part I (Belief) and Part II (Knowledge). The present concern, rather, is to show how the various tools that we use in our thinking can lead us to generally reliable (not perfect) beliefs and useful (not certain) knowledge. Further, while any number of thinkers would add revelation and faith to the items set out in the first paragraph here, the purpose of this course does not include the systematic examination of such matters. (I have dealt with them in my Teaching Company course of 2003, *Philosophy of Religion*). The present concern, rather, is to explore the tools that are appropriate to more mundane matters, such as science, history, and navigating the everyday vicissitudes of life.

One thing will emerge from these reflections: There is no *one* tool for thinking. Experience by itself begets chaos in the absence of pattern recognition, memory, association, and some form of reasoning. Reason by itself is sterile absent some practically reliable bases from which to draw our inferences, explanations, and generalizations. Intuition by itself offers no decision procedure. Invention by itself is dangerously speculative. The magic is in the mix.

Because this course is a broad and rapid survey of vast and complex matters, it will not answer all (or even most) of the questions that will occur to you along the way about the mind, our sensory apparatus, belief, knowledge, reasoning, and logic, much less about mathematics, science, philosophy, ethics, and all the other great systematic ventures of the mind. It will, however, deal with some of the important ones and provide references to works where many of the others can be explored. It is a starting point, not a destination.

# Lecture One

## What Are “Tools of Thinking”?

**Scope:** If achieving knowledge (justified true beliefs) is the goal of thinking, then *effective* thinking will use tools that achieve that goal reliably. Our minds and our senses are our most obvious thinking tools, but we use a number of others as well. First, there is the conceptual apparatus of language itself, both verbal and mathematical. Without a rich vocabulary and a complex syntax, there is only truncated thought. Also, especially obvious today, there are the physical instruments and devices that we employ: microscopes, Geiger counters, computers, and the like. These serve as extensions of our bodies and minds and are every bit as important as the conceptual apparatuses we employ. But our languages and our devices are things that we create through thought. Thus, the tools of thought that we use to create them are more basic. These include memory, association, pattern discernment and recognition, and reason (including dialectic and the construction of hypotheses and counterexamples) for *processing* data and experience, invention, experimentation, and (perhaps) intuition for *generating* the data to be processed.

### Outline

- I. In this course, we will examine some of the tools that people use in thinking. The use of these tools is well modeled in the practice of modern science, but scientists do not have exclusive rights. Everyone has to think in order to function in the world. Biologists and physicists may need to do it especially well, but truck drivers, bakers, and parents do, too.
  - A. Thinking involves making sense of what we observe, figuring out the consequences of what we do, and weighing our opinions (and those of others) to see which ones are reasonable and well grounded. These are universal human tasks.
  - B. How we think about things should not be confused with how we feel about them or our attitudes or appraisals of them. Thinking is a matter of the mind, not of the emotions or will. For this reason, we will not explore ethics as such. But what we discover about reliable thought processes will apply just as readily to evaluation statements as to descriptions.
  - C. Philosophers have given a lot of attention to how thinking works and to what makes it reliable. Thus, in this course, we will look at some of the ideas about thinking from such philosophers as Plato, Aristotle, Descartes, Hume, and Mill.
  - D. Many scientists, too, have given a lot of attention to how thinking works. But we will not explore neuroscience or psychology here. Our interest is in how we make sense of things, not in the mechanics of the body and its central nervous system.
- II. Achieving knowledge (that is, justified true beliefs) is the usual point of thinking. The “tools of thinking,” then, are the devices and processes we use in that enterprise. It stands to reason that *effective thinking* relies on *dependable tools*—ones that “get us there” reliably.
  - A. Beliefs amount to expectations about what is, or is likely, to happen.
  - B. True beliefs are expectations that are fulfilled.
  - C. Effective thinking is the primary way to arrive at true beliefs.
  - D. The techniques and devices that we use to arrive at true beliefs are the “tools of thinking” that concern us.
- III. Apart from the brain and the central nervous system connected to it (without which we could not think at all), there are several kinds of tools that we employ in thought.
  - A. Language itself, both verbal and mathematical, is crucial.
    1. The languages we use shape the way we think.
    2. Without a rich vocabulary and a complex syntax, there is only truncated thought.
    3. We need the same things in a mathematical language.
    4. But this is not to be a course in linguistics or even in philosophy of language.
    5. Instead, we shall examine the tools that we use to create our languages and that we employ when we use our languages once we have created them.

- B. Our instruments are crucial, too: microscopes, Geiger counters, computers, and so on.
  - 1. Such instruments play roles in our thought as crucial as those played by language itself: Consider the role of computers, for example.
  - 2. Such instruments serve as extensions of our selves, but they are, in fact, *artifacts* that we have created with our minds (and hands).
  - 3. But this is not to be a course about the machinery we use to expedite our thought.
  - 4. Instead, we will focus on the tools we use to gather data and draw inferences from it—tools we use to produce the machinery and utilize it once we’ve produced it.
- IV. The kinds of tools of interest in this course include:
  - A. *Memory* (or recall) is an essential element in all thought. Without it there would be no possibility of “seeing” patterns in non-simultaneous phenomena.
  - B. *Experiential input*—whether from the senses what we see, and taste, and smell, and feel, and hear—or from some other sources is necessary in order for us to have data to work with.
  - C. *Pattern discernment and pattern recognition* are built on memory, but involve more than simple recall. Not only visual patterns, such as face recognition, but also cause-and-effect patterns and structural patterns, are crucial to any effective problem-solving.
  - D. *Hypothesis construction* (offering possible reasons for a pattern) and *experimentation* (looking for *counterexamples*) work together to process the patterns we remember.
  - E. “*Intuition*” is often a label for those thoughts that appear to be immediately, necessarily, or self-evidently true. Such thoughts are rare and problematic as a source of input for reaching conclusions, as we shall see in Lecture Five. Less relevant here, the label is also used for connections made (or insights had) where we simply do not know what process is at work.
- V. There are at least eight such tools. In Lecture Two, I will give an overview of all eight tools and their uses and prioritize them as a foundation for the detailed work to come in Lectures Three through Twenty-four.

**Essential Reading:**

James Hall, *Practically Profound*, chapter 1, “Are Some Beliefs Better than Others?” pp. 3–8.

**Recommended Reading:**

A. M. Turing, “Computing Machinery and Intelligence,” *Mind*, Vol. LIX, No. 236 (1950).

**Questions to Consider:**

- 1. It is clear enough that we use computers to do some of our thinking for us. Do you think that computers are (or ever will be) able to do any thinking of their own?
- 2. Why do I think of my grandmother every time I drive downwind of the Interbake cookie factory in Richmond?

## Lecture Two

### Which Tools of Thinking Are Basic?

**Scope:** As noted in Lecture One, we employ many tools in effective thinking. We spoke in that lecture of our languages and our instruments and then turned our attention to a more basic set of tools—the processes we use to gather input and draw inferences from it (and to generate our languages and construct our instruments). I named eight such tools: memory, association, pattern discernment and recognition, reason, experience, invention, experimentation, and intuition. In this lecture, I shall describe, note the relationships between, and roughly prioritize these eight. I shall also note the varying emphases that have been placed on them historically. In the 22 lectures to come, we will examine the ways in which they contribute to the thinking tool-box of modern rational empiricism.

### Outline

- I. There are at least eight basic tools that we use in effective thinking. Four have more to do with **processing** data: *memory, association, pattern discernment and recognition*, and *reason* (including dialectic and the construction of hypotheses and counterexamples). Four have more to do with **generating** the data to be processed: *experience, invention, experimentation*, and perhaps, *intuition*.
  - A. *Memory* (or recall) is an essential element of all thought. It is also fallible. This fallibility is a perpetually recurring problem in all kinds of data processing.
  - B. The *association* of one idea with another, or one experience with another, is a key component in thinking our way from A to B.
  - C. *Pattern discernment and pattern recognition*, not only of visual patterns, but also of cause-and-effect patterns and structural patterns, are crucial to any effective problem-solving but are not always reliable. We can think that we see a pattern that isn't there, or we can think we recognize a pattern that is different from the pattern that we see.
  - D. *Reason* is the tool we use to move from one idea or belief to another, not merely by association, but by "logical inference." It comes in many forms (traditionally labeled deductive, inductive, analogical, and so on), always begins with presumptions, and will be one of the primary subjects examined in the lectures to come (especially Lectures Three and Four, Six through Ten, Twelve through Fourteen, and Twenty through Twenty-Two). Reason includes *dialectic*, a device as old as the Socratic method but still vital in the volleying of hypotheses and counterexamples. It can be practiced in two-person dialogues or in soliloquy. Its "give and take" can check our flights of fancy but also stimulate us to get us out of our ruts.
  - E. *Experience* is the primary source of the raw material from which we draw our inferences and about which we construct our explanations. It comes in many forms and is sometimes quite unreliable but is the main (if not the only) thing that ties our thinking to anything "outside our heads." It will be another primary subject examined in the lectures to come (especially in Lectures Five, Eleven, Twelve, and Seventeen).
  - F. *Invention* is the venue of creativity—not only of devices but of ideas. In thought, invention is particularly important in the construction of hypotheses, interpretations, and explanations. Alongside of reason and experience, it is the third important target for us here (especially in Lectures Fifteen through Eighteen).
  - G. *Experimentation* puts reins on our thought but also stimulates us to think in new directions. It is the fourth leg of modern rational empiricism (as will be seen in Lectures Sixteen and Eighteen). When experimentation generates counterexamples for our hypotheses, it is a form of dialectical reasoning.
  - H. "*Intuition*," as discussed in the previous lecture, has several senses, including as a label for those thoughts that appear to be immediately, necessarily, or self-evidently true. Such thoughts are rare and problematic, as we shall see in Lecture Five. We shall keep intuition on our list, though there is not very much to say about it other than (a) those who have it are lucky and (b) when there's work to be done, the work is going to be done in the laboratory, in the field, in experience, in reasoning, and not simply in waiting on an "aha!" moment.



- II. These eight (especially reason, experience, invention, and experimentation) are our fundamental thinking tools—the ones we use to create our languages and make our instruments.
- A. There is a “chicken-and-egg question” about thought and language. Even though our languages are our (or our forebears’) constructions, we have so made them our own that they seem part of us, and they shape all the thoughts that occur once they are in place.
  - B. It is clear enough, however, that our instruments and devices are wholly contingent on us. We invented the telescopes and computers, and—however much our thought employs them and is influenced by them—they remain clearly derivative.
- III. Different tools have been emphasized by different historical thinkers, as we shall see in our examination of the ways in which the basic tools of thought can best be used—working toward an understanding of what I call *modern rational empiricism*.
- A. In ancient times, Plato emphasized intuition, recollection, and reason (especially dialectical reason) (see Lectures Three and Four). In contrast, Aristotle made room for experiential data, but still kept reason at the center of things as he mapped out the beginnings of logic (see Lectures Six, Seven, and Eight).
  - B. In early modern times, Descartes made deductive reasoning from “self-evident” truths central, mistrusting sense experience altogether (see Lecture Ten). In contrast, Hume emphasized sense experience and underscored the crucial role of association in inductive thought (see Lecture Eleven).
  - C. In more recent times, Mill gave special attention to how we can properly generalize the experiences that we have (see Lecture Fourteen). Following Newton, modern scientists have emphasized experimentation and the importance of hypothesis construction (see Lectures Fifteen through Nineteen), and inferential reasoning has been given more secure foundations in the form of modern logic (see Lectures Twenty through Twenty-Two).

Tools for Processing Input		Tools for Generating Input	
	Lectures		Lectures
Memory	3, 4	*Experience	5, 11, 12, 17
Association	11, 14	*Invention	15–18
Pattern discernment and recognition	11, 14	*Experimentation	16, 18
*Reason	3–4, 6–10, 12–14, 20–22	Intuition	3–5, 10

\*Reason, experience, invention, and experimentation are the four legs of modern rational empiricism.

- D. It is no accident that development of these tools coincided with the time when Western science was coming into flower with a combination of observation, hypothesis construction, and testing.

**Essential Reading:**

James Hall, *Practically Profound*, chapter 1, “Are Some Beliefs Better than Others?” pp. 8–20.

**Recommended Reading:**

Jay F. Rosenberg, *Handbook*, chapter 2, “Arguments,” pp. 13ff.

**Questions to Consider:**

1. Can we reason our way to conclusions about the world without using some sort of experiential data as the raw material for the process? Can we learn stuff by “reason alone”?
2. Where do brilliant hypotheses (such as Darwin’s idea of evolution or Einstein’s notion of relativity) come from?

## Lecture Three

### Platonic Intuition, Memory, and Reason

**Scope:** Plato subordinated sense experience to intuition, memory, and reason for at least three reasons. First, sense experience is corporeal, not mental, which makes it “lower” in his metaphysical scheme of things. Second, the objects of sense experience (appearances) are ephemeral in contrast to the unchanging objects (Eternal Forms) of reason, memory, and intuition. Third, sense experience is subjective and perspectival in contrast (he held) to the objective and fixed processes of reason, memory, and intuition. Thus, he postulated the world of eternal “Forms” or “Ideas,” hypothesized that they were intuitively accessible to the mind in its pre-corporeal existence, and concluded that human knowledge, when it occurs, amounts to rationally uncovering what the mind already knows intuitively and remembers. In this lecture, we shall examine how this scheme is supposed to work. In the next, we shall examine some of its gaps and problems.

### Outline

- I. Plato thought well of the mind and its processes (such as intuition, memory, and reason) and not so well of the body and its processes (such as sense experience).
  - A. This is nicely illustrated in the *Meno*, where Plato offers an amazing account of how a slave boy “learns” geometry—the boy’s apparent experiential learning being explained away as the recovery of preexisting intuitive knowledge, buried in memory until it is unearthed by dialectical reasoning.
  - B. While we may wonder whether people have preexisting intuitions to remember, we should note that thinking always presupposes the occurrence of *some* sort of data to work with and never proceeds without *some* sort of memory coming into play.
- II. Why are the mind and its processes held in such comparatively high esteem?
  - A. In part, it is because Plato held the mind’s *substance* to be closer to that of the Forms or that of God—bodily experience, in contrast, being subject to all the limitations of the flesh. Plato is not alone, of course, in marking such a dichotomy.
    1. St. Paul elevated the soul (*pneuma*) over the flesh (*sarx*). That soul was not the same thing as Plato’s cognitive soul (*psyche*), of course, and cognition was of less interest to Paul than salvation, but the maneuvers are congruent.
    2. Descartes’ mind/body dualism is another parallel.
  - B. In part, it is because Plato held the mind’s *objects* (Ideas) to be more stable, permanent, absolute, or universal than those of sense experience (appearances).
    1. The cave myth in *The Republic* shows how ephemeral Plato took appearances to be.
    2. The features of the cave are an allegory for the world and our place in it: the flickering shadows on the wall (appearance), bondage (our embodiment), objects (reality) that cast the shadows, and fire—and, ultimately, the Sun—behind it all.
  - C. In part, it is because Plato held the mind’s *processes* (intuition, memory, and reason) to be relatively error free when compared to the process of sense experience.
- III. Here is Plato’s argument in a nutshell. Note his metaphysical proposal (J) and its dependent hypotheses (K and L).
  - A. **Premise:** The appearances of things do change.
  - B. **Premise:** The essences of things don’t change.
  - C. **Inference:** So the essences and the appearances of things are not the same.
  - D. **Premise:** The reality of things resides in their essences, not in their appearances.
  - E. **Inference:** So reality is unchanging, or (the same thing) what *does* change is *not* reality.
  - F. **Premise:** Appearances are all that we have sensory access to.
  - G. **Inference:** So we do not have sensory access to reality.
  - H. **Inference:** So the senses cannot supply the content for our thoughts about reality.

- I. **Inference:** So the content of our thoughts about reality must be supplied in some other way.
  - J. **Metaphysical proposal or inference:** Perhaps reality lies in the world of the Forms and is directly and intuitively accessible to cognitive souls that are free of bodily encumbrances and distractions.
  - K. **Inference:** If so, then preexisting, non-embodied intellects would do the trick.
  - L. **Inference:** If that is the case, then embodied humans' thoughts about reality, when and if they occur, could rely on their remembering and using what their minds already know.
- IV. This package raises many questions. Six of them will be addressed in Lecture Four. Here are the first three (to think about):
- A. The premises of the argument (A, B, D, and F) are insecure for various reasons; thus, the inferences based on them (C, E, G, H, and I) are not secure either.
  - B. The metaphysical proposal (J) and its dependent hypotheses (K and L) presuppose a great many facts not in evidence. But if these presuppositions are insecure, so are the proposal and its dependent hypotheses.
  - C. Plato's mistrust of sense experience and reliance on suppositional recollections leaves gaps in the input that reason needs in order to do its work.

**Essential Reading:**

Plato, *Meno*.

**Recommended Reading:**

Plato, *Republic*, Book VII, ¶514ff.

**Questions to Consider:**

1. If experience yields only more or less *probable* beliefs (rather than *certain* ones), why should that be a problem? Are actuarial tables unreliable as a guide to profit and loss for insurance companies because they show only probabilities, not certainties?
2. Isn't it just as easy to *reason* badly as is to *perceive* incorrectly? What (or who) could guarantee the reasoning process in such a way as to make it foolproof?

## Lecture Four

### Intuition, Memory, and Reason—Problems

**Scope:** There are problems with Plato’s reliance on intuition, memory, and reason. First, the four assumptions behind it are insecure. Second, there is no particular reason to think the metaphysical proposal and its dependent hypotheses are true. Third, although reason does require some content to process, it is not at all clear that putative recollections from a past life are the kind of content it needs. Fourth, intuition, memory, and reason are often unreliable themselves. Fifth, like all dualisms, this one generates a *methexis* problem. Sixth, this view encourages us to extrapolate from how we think about mathematical truths to how we think about contingent matters of fact, but in so doing, it does not take into account the possible sterility of purely formal reason. So even though Plato’s position makes good use of some basic tools of thinking, it is inadequate.

### Outline

- I. Plato’s four premises (A, B, D, and F) are insecure for various reasons.
  - Premise A:** The appearances of things do change.
    1. Is *every* change equally significant here? Is there a difference between adjustments, growth, cycles, and flip-flops?
    2. Couldn’t a change be part of a permanent (or semi-permanent) pattern?
  - Premise B:** The essences of things don’t change.
    1. Do things (or even kinds of things) actually have “essences”?
    2. Why should what *changes* be necessarily inferior to what doesn’t? Unless something is perfect, why couldn’t it change for the better?
    3. Why couldn’t *change* be part of the essence of some things?
  - Premise D:** The reality of things resides in their essences, not in their appearances.
    1. If this (as well as premise B) is so, then only unchangeable things are “real.”
    2. But if we have any reason to think that something is real (say an ocean wave) that does change (as ocean waves do), then we have reason to think this premise (or premise B, or both) is *not* so.
  - Premise F:** Appearances are all that we have sensory access to.
    1. This may be so, but (in fact) many things to which we have sensory access are remarkably constant, such as the effects (appearances) of gravity, for example.
    2. Thus, if this premise is so, we have some reason to dispute premise A.
- II. Plato’s metaphysical proposal (J) and its dependent hypotheses (K and L) constitute a nice exercise in hypothesis construction and modeling. But this particular construction presupposes that there *are* Forms, that the mind *is* substantially different from the body, that the mind *does* preexist the body, that in that preexistence the mind *has* access to the Forms, and that what it intuits directly there, it *can* remember here.
  - A. What reasons are there, if any, for thinking that any of these presuppositions is true?
  - B. What grounds are there for determining the merits of such a hypothesis and model?
    1. Can we directly discover what the world itself is like?
    2. If so, can we lay this model up against the world and see whether it is accurate?
    3. If we can’t do that, are there pragmatic advantages or disadvantages in using this model rather than some other model? (We shall return to this complex issue in Lectures Sixteen and Eighteen.)
- III. Although reason does require content to process, it is not clear that suppositional recollections from a past life (that we may not have had and, *a fortiori*, may not have any recollections of) are the kind of content it needs. To fill in the gaps in that needed content, sensory experience is positively attractive, for all its alleged fallibility.
- IV. In any case, intuition, memory, and reason are often unreliable themselves.
  - A. Every intuition has a rival. There are even rival geometrical axioms.
  - B. I misremember things all the time, and I don’t think I am unique in this.
  - C. One has to *learn* to reason accurately. It is uncommon and *not* innate.

- D. If all these things *and* sense experience are *fatally* unreliable, then the door is open to systematic skepticism of the sort Peter Unger advocates (unless we can find some external guarantor, as Descartes claimed to find in God).
- V. Furthermore, like all dualisms, this scheme generates a *methexis* problem.
- A. *Methexis* means “interaction” or “participation.” Descartes has a methexis problem about the interaction of the mind and the body. The ancient Greeks had a methexis problem about the interaction of the good and humans. Traditional Christians have a methexis problem about the incarnation.
  - B. The methexis problem here is that if we (now) live in the world of appearances, *not* in the world of the Forms, how can memory “bridge the gap”? Where does *memory* live?
- VI. Finally, this view encourages us to extrapolate mathematical thinking beyond its bounds.
- A. Plato’s view suggests a rather “geometrical” model for belief and knowledge. (In geometry, self-evident assumptions are said to yield deductively certain conclusions.)
  - B. In so doing, it does not take into account the possible sterility of purely formal truths and the availability of alternative “axioms.”
  - C. It ignores the difference between what is formally true within a system and what is descriptively true of the world.
  - D. Even Euclidean geometry is contingent. The work of Lobachevsky and other mathematicians in the 20<sup>th</sup> century showed that alternative geometries are possible.
  - E. Although this model may work nicely for figuring out the properties of Euclidean triangles, it is problematic if we try to extrapolate it to wider realms (see Lecture Ten).
- VII. In spite of the fact that Plato’s view makes good use of three basic tools of thinking—intuition to provide input, memory to provide continuity, and reason (to uncover and manipulate what we intuit and remember)—it is inadequate. Perhaps readmitting sense experience will help.

**Essential Reading:**

James Hall, *Practically Profound*, Chapter 3, “Two Kinds of Evidence,” Part B, “Is ‘reason alone’ enough?”

**Recommended Reading:**

Peter Unger, *Ignorance, A Case for Skepticism*. Chapter I, “A Classical Form of Skeptical Argument.”

**Questions to Consider:**

1. If a person (while trying to remember a tune, say) suddenly “gets” it and “knows” that it is right, *is* he or she always correct?
2. Is it theoretically conservative or profligate to explain something as simple as a child’s being taught the Pythagorean Theorem with the hypothesis that there is, hidden in the child, an inner being that has existed forever and has known the Pythagorean Theorem “all along”?

## Lecture Five

### Sense Experience—A More Modern Take

**Scope:** Sense experience provides much of the data that we manipulate with reason, even though there are difficulties with some of it that diminish its usefulness. What we see, taste, smell, feel, hear, and read (and what we remember of such things, for that matter) can be unreliable. That means that we must exercise great caution when we use such input as a basis for our thoughts. Standard tests and benchmarks, however, provide ways to exercise that caution. So sense experience need not be banished altogether. The need for testing the bases of our reasoning is not limited to sensory input. Indeed, is *any* sort of input self-guaranteeing, transparent, intuitively obvious, or in any other way exempt from standard tests?

### Outline

- I. Experiences of one sort or another provide most of the data that we manipulate with reason.
  - A. These include the following, at least:
    1. Sense experience (see, taste, smell, feel, hear) contributes new firsthand data.
    2. What we read and what we are told contribute secondhand data.
    3. What we remember keeps old firsthand and secondhand data in play.
  - B. Experiences might also include dreams, imaginings, visions, and transports.
- II. There are difficulties, however, that may prevent some experiences from doing the job.
  - A. What we sense, read, are told, and/or remember can be unreliable for a wide variety of reasons. Some experiences are ambiguous, vague, and/or indistinct. Even clear and distinct ones can suffer from the effects of many factors.
    1. Perspective shapes (and may even distort) the input.
    2. Bias (a kind of “attitude perspective”) can do the same things.
    3. Defective equipment (our own body parts, as well as our instruments) can alter the input or even block it altogether.
    4. Intruding illusions, delusions, and dreams can make it difficult to distinguish between “real” input and that which is internally generated.
  - B. For these reasons, we must exercise great caution when we use experiences as a basis for our thoughts.
- III. Standard tests, benchmarks, and helpers provide ways to exercise that caution and to work around the difficulties.
  - A. Public accessibility mitigates the risks of entirely “private” data.
  - B. Repeatability mitigates the risks of “one-off” data.
  - C. Various *aides-mémoire* (such as notes, diagrams, recordings, and so on) can help us work around memory failures.
  - D. Specifying “standard conditions” (for example, temperature or pressure) can help us avoid input distorted by circumstances.
  - E. Cross-checking experiences (and experience modes) against each other can help isolate defects or distortions that are unique to a particular experience episode or channel.
  - F. Becoming aware of (and then either eliminating or at least controlling for) “limiting conditions” in ourselves and our sources is crucial to the establishment of reliable data. Such limiting conditions include bias, faulty equipment, unnoticed or uncontrolled variables, lack of due care, and lack of expertise.
  - G. We also need to be sure that the theoretical framework or paradigm in which we are construing our sources is “viable.”
    1. A viable framework is coherent.
    2. A viable “local” framework meshes smoothly with other local frameworks and keeps the global framework coherent.
    3. A viable framework is fertile.
    4. A viable framework is broad in scope.

5. A viable framework has the capacity for self-correction.
6. A viable framework minimizes *ad hoc* “adjustments after the fact.”

IV. We can never avoid the need for testing the bases of our reasoning.

- A. Some bases are said to be self-guaranteeing, transparent, or intuitively secure.
  1. Perhaps some human insights are “self-evident” or “necessary.”
  2. Perhaps we can have direct “extrasensory” perceptions of how things are.
  3. Perhaps religious experiences are guaranteed by their divine source.
  4. Perhaps we can defer to the pronouncements of authorities as being beyond question.
  5. Perhaps we can rely on common sense—what “everyone knows.”
- B. Actually, we need to take *more* care in these special venues, not *less*, and special pleadings (such as tests that are “cut to fit”) are out.
  1. While analytic claims may be necessary (*a priori*), they are empty, and while synthetic claims are rich in content, they are contingent (*a posteriori*).
  2. ESP is notoriously unreliable and frequently fraudulent.
  3. Religious experiences have rivals and have to be interpreted.
  4. Pronouncements by authorities also have rivals that we must choose between.
  5. It is easily demonstrable that what “everyone knows” is local and changeable. Common sense is frequently wrong.

**Essential Reading:**

James Hall, *Practically Profound*, Chapter 2, “Evidence Standards,” pp 29–40.

**Recommended Reading:**

Peter Unger, *Ignorance, A Case for Skepticism*. Chapter III, “An Argument for Universal Ignorance.”

**Questions to Consider:**

1. If we read about demons from hell crawling up out of the ground fissures that resulted from a California earthquake and carrying survivors off to perdition, what precautions should we take before incorporating this account into our data banks for serious thought?
2. What are the odds that any given piece of data for thought would pass each and every test for reliability? Put another way, is data reliability an “all-or-nothing” affair?

## Lecture Six

### Observation and Immediate Inferences

**Scope:** Aristotle recognized the importance of observation. But his primary concern was still with what one can rationally *infer*. This generated a sharp interest in the processes and patterns of reason itself, and that motivated his systematic mapping of what we call *logic*. His ideas suggested a vision of a logical system where all knowledge is deducible from a set of indubitable axioms. Aristotle's logic focused on what we can directly infer from individual assertions (by *immediate inference*) and on what we can figure out from pairs of assertion (by using *categorical syllogisms*). In this lecture and next, we shall focus on the former. We shall examine the latter in Lectures Eight and Nine.

#### Outline

- I. Aristotle makes room for the important role that observation plays in thinking—providing data for our contemplation and raw material for our inferring.
  - A. His work on biological taxonomy illustrates this nicely.
  - B. Alexander the Great is said to have been so impressed with Aristotle's interest in observing and understanding the natural world that he regularly sent samples to his former teacher.
- II. But Aristotle's primary concern was still with what one can rationally *infer*.
  - A. For Aristotle, the bases of our inferences are observations and generalizations of them, rather than our memories or intuitions of the Forms.
  - B. But he is still working with a vision (that started with Plato and culminates with Descartes) that all general knowledge is deducible from foundations that are (or nearly are) indubitable and directly apprehended in one way or another.
- III. This generated his sharp interest in the processes and patterns of reasoning itself, and that motivated his systematic mapping of what we call *logic*.
  - A. Logic is not necessarily a map of how we, in fact, think. It is, rather, a rational reconstruction of what constitutes reliable thought.
  - B. The use of logic presupposes that every statement that we use in our reasoning is either true or false, never both and never neither, and that the denial of a true statement is false and the denial of a false statement is true. These "laws of thought" are often summarized as the *Law of Contradiction*, the *Law of Identity*, and the *Law of Excluded Middle*.
  - C. Although we are confining our attention to logic with two values (true or false), with no *tertium quid* available, contemporary logicians have discovered logical systems that can work with three values or more.
- IV. Aristotle's logic focused on what we can directly infer from individual *categorical propositions* and on what we can infer from pairs of them in *categorical syllogisms*.
- V. Categorical propositions declare what is or is not the case.
  - A. Every categorical statement has a subject term and a predicate term and asserts something about the relationship between the sets (categories) named by those terms.
  - B. A categorical proposition can be *analytic* or *synthetic*. The meaning of the predicate of an analytic categorical proposition is "contained" in its subject's meaning. The meaning of the predicate of a synthetic categorical proposition "adds to" its subject's meaning.
  - C. Categorical statements with the same subject and predicate terms can differ in quality (affirmative or negative) and quantity (universal or particular).
  - D. The standard forms for categorical propositions are:

Universal affirmative	(called an <i>A proposition</i> ):	All S are P.
Universal negative	(called an <i>E proposition</i> ):	No S are P.
Particular affirmative	(called an <i>I proposition</i> ):	Some S are P.



Particular negative (called an *O proposition*): Some S are not P.

- E. Why are the propositions labeled A, E, I, and O?
1. The A and O propositions are both affirmative, and the letters A and O are the vowels in the Latin (and English) word AFFIRM.
  2. The E and O propositions are both negative, and E and O are the vowels in the Latin word NEGO (meaning “I deny”).

VI. Immediate inferences from standard-form categorical propositions include obversion, conversion, and contraposition.

- A. Note that the complement of a class name is the name of the class comprised of everything not in the class named by the term itself. For example, the complement of the term *heroes* is *non-heroes* (not *cowards*!). Note also that *not* is an indicator of a proposition’s quality, but *non-* is part of the class name.
- B. *Obversion* is changing the quality of a categorical proposition (affirmative to negative or negative to affirmative) and replacing the predicate term with its complement. Obversion works reliably for A, E, I, and O propositions.

OBVERSION

A: All S are P.	Obverse: No S are non-P.	(reliable)
E: No S are P.	Obverse: All S are non-P.	(reliable)
I: Some S are P.	Obverse: Some S are not non-P.	(reliable)
O: Some S are not P.	Obverse: Some S are non-P.	(reliable)

- C. *Conversion* amounts to swapping the subject and predicate terms of a categorical proposition. Conversion works reliably only with E and I propositions.

CONVERSION

A: All S are P.	Converse: All P are S.	(unreliable)
E: No S are P.	Converse: No P are S.	(reliable)
I: Some S are P.	Converse: Some P are S.	(reliable)
O: Some S are not P.	Converse: Some P are not S.	(unreliable)

- D. *Contraposition* amounts to replacing the subject of a categorical proposition with the complement of its predicate and replacing the predicate with the complement of the subject. Contraposition works reliably only with A and O propositions.

CONTRAPOSITION

A: All S are P.	Contrapositive: All non-P are non-S.	(reliable)
E: No S are P.	Contrapositive: No non-P are non-S.	(unreliable)
I: Some S are P.	Contrapositive: Some non-P are non-S.	(unreliable)
O: Some S are not P.	Contrapositive: Some non-P are not non-S.	(reliable)

**Essential Reading:**

Irving Copi, *Introduction to Logic*, chapter 5, “Categorical Propositions,” pp. 181–187, 193–199.

**Recommended Reading:**

W. T. Jones, *A History of Western Philosophy*, Volume II, “The Classical Mind,” pp. 244–254.

**Questions to Consider:**

1. If every logical proof must start with premises, is there any such thing as a *complete* logical proof that is not infinite in length?
2. Is there any reason to think that the world itself is logical?

## Lecture Seven

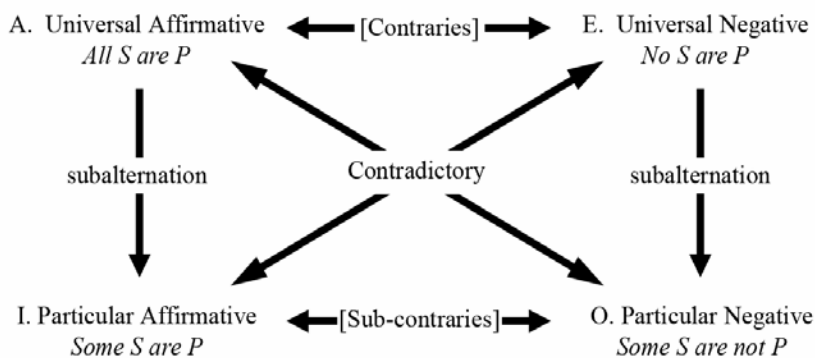
### Further Immediate Inferences

**Scope:** Standard-form categorical propositions with the same subject and predicate terms can be aligned in a traditional *square of opposition* that shows certain immediate inferences that can be drawn from the truth or falsity of one of them, based on such intuitive relationships as *contradiction*, *contrariness*, *subcontrariness*, and *subalternation*. Statements about empty classes, however, generate problems with this traditional square. All of the legitimate immediate inferences can be used to manipulate the various propositions in an extended argument so as to help put the argument itself in standard form.

### Outline

- I. Standard-form categorical propositions with the same subject and predicate terms can be aligned in a traditional *square of opposition*.

#### The Traditional Square of Opposition



- II. Recall the inferences discussed in the last lecture.
- A. Each of the four corners can be obverted (change quality and replace predicate with its complement).
  - B. The I and E corners can be converted (switch subject and predicate).
  - C. The A and O corners can be contraposed (replace subject and predicate with their complements).

PROPOSITION	PROPERTIES			IMMEDIATE INFERENCE		
	<i>quantity</i>	<i>quality</i>	<i>distrib-utes</i>	<i>obverse</i>	<i>converse</i>	<i>contra-positive</i>
<b>A: All S are P.</b>	universal	affirmative	subject	reliable	unreliable	reliable
<b>E: No S are P.</b>	universal	negative	subject, predicate	reliable	reliable	unreliable
<b>I: Some S are P.</b>	particular	affirmative	neither	reliable	reliable	unreliable
<b>O: Some S are not P.</b>	particular	negative	predicate	reliable	unreliable	reliable

III. The square of opposition highlights relationships between standard-form categorical propositions with the same subject and predicate terms that enable certain further immediate inferences to be drawn from the truth or falsity of one of them, as long as none of the classes mentioned is empty (null).

- A. *Contradictories* (A and O, E and I) differ from each other in both quality and quantity, with the result that contradictories always have opposite truth values. If a statement is true, then its contradictory is false (and vice versa, this being a two-way street).

- B. *Contraries* (A and E) are universal claims that differ from each other in quality but not in quantity, with the result that while they can both be false, they cannot both be true. However, null classes—those that do not have any members at all, for example, round squares—lead to problems.
  - C. *Subcontraries* (I and O) are particular claims that differ from each other in quality but not in quantity, with the result that while they can both be true, they cannot both be false. Null classes, however, present problems.
  - D. *Subalternation* is the relationship between a universal claim and its dependent or hanging particular claim. Thus, a statement and its subalternate differ from each other in quantity but not in quality, with the result that if a statement is true, its subalternate is also true (but not vice versa, this being a one-way street).
    1. However, null classes again present problems.
    2. The view of ancient logicians that you could convert a universal proposition “by limitation”—by moving to the subalternate of the universal proposition—does not hold if the class is empty.
    3. For example, “All round squares are truly remarkable,” seems true, but “There is at least one truly remarkable round square” is clearly false.
- IV. The various immediate inferences can be used to modify the propositions in an argument so as to (a) have each one begin properly with its quantity indicator and (b) reduce the number of terms that occur in it to the three that a syllogism can handle.
- A. If one of the statements in an argument amounts to the denial of a standard-form proposition (e.g., “Not all Greeks are Athenians”), one may appeal to the rule of contradiction to replace that denial with the assertion of its contradictory (in this case, “Some Greeks are not Athenians”).
  - B. If two of the statements in an argument employ complementary terms (e.g., heroes and non-heroes), one may obvert one of them, thus ensuring that both propositions are about the same set.
  - C. If one of the statements in an argument amounts to the denial of an I proposition (e.g., “It is not the case that some wolves are strict vegetarians”), one may appeal to the rule of subcontraries (or to the rules of contradiction and subalternation) to replace that denial with the assertion of its corresponding O proposition (“Some wolves are not strict vegetarians”). This is highly problematic, however, if the subject term names a null class (as in “It is not the case that some unicorns are carnivores”). We shall examine this problem in Lecture Eight.
  - D. The same thing can be done with the denial of an O proposition, to replace it with the assertion of its corresponding I, but this is also problematic when null classes are in play.
  - E. Once the statements in an argument are cleaned up, the argument itself can be put in standard form and assessed for validity in terms of formal rules, as we shall see in Lecture Eight.

**Essential Reading:**

Irving Copi, *Introduction to Logic*, chapter 5, “Categorical Propositions,” pp. 188–192.

**Recommended Reading:**

Aristotle, *Prior Analytics*.

**Questions to Consider:**

1. “Opposites” are not always complementary. For instance, heroes and cowards are certainly opposites, but since non-hero  $\neq$  coward, they are not complements. Thus, care is required when obverting. Can you think of other examples of “non-complementary opposites”?
2. Is it really always the case that subcontraries cannot both be false? How about “Some unicorns are blue-eyed” and “Some unicorns are not blue-eyed”? If these are both false (because there are no unicorns at all, blue-eyed or not), is immediate inference in irreparable trouble?

## Lecture Eight

### Categorical Syllogisms

**Scope:** A categorical syllogism consists of three categorical propositions—two premises and a conclusion. To be tested for validity, it must be stated in *standard form*. Standard-form categorical syllogisms can be sorted in terms of *mood* and *figure* into 256 possible arrangements, only some of which pass muster as valid in the system. To be valid (that is, for its conclusion to “follow” from its premises), it must satisfy certain formal restrictions on the number of terms that may occur in it; on the positions in which those terms may occur; on the “distribution” of the middle, major, and minor terms; and on the occurrence of negative statements.

### Outline

I. A categorical syllogism consists of three standard-form categorical statements: two serving as premises and the third as the conclusion.

A. Each of the individual statements must be unambiguous.

**Example:** “All undergraduates aren’t philosophy majors” might be either a universal negative claim that “No undergraduate students are philosophy majors” or a much less sweeping particular negative that “Some undergraduates are not philosophy majors.”

B. To be in standard form, a syllogism must have exactly three terms, each of which occurs in two of its three propositions.

1. The predicate term of the conclusion (called the *major term*) will also occur as either the subject or predicate of the premise that is stated first (hence, the *major premise*).
2. The subject term of the conclusion (called the *minor term*) will also occur as either the subject or predicate of the premise that is stated second (hence, the *minor premise*).
3. The third term (called the *middle term*) will occur in both of the premises (it can be the subject or the predicate term of either one) and will not occur in the conclusion.

Major premise:	middle term, major term (in either order)
Minor premise:	middle term, minor term (in either order)
Conclusion:	minor term, major term (in this order only)

C. Some nonstandard-form syllogisms can be reduced to standard form by reducing their number of terms to three—for example, if the syllogism seems to have more than three terms because of synonymy or because of the use of complementary terms—by manipulating their constituent propositions by means of immediate inferences, or by placing their premises and conclusion in proper order.

**Example:** The argument “All Athenians are mortal because they are all Greeks and no Greeks are immortal” can be reduced to standard form by obverting “No Greeks are immortal” to “All Greeks are mortal,” by specifying the reference of “they,” and by placing the statements in proper order (major premise, minor premise, conclusion):

All Greeks are mortal.  
All Athenians are Greeks.  
Therefore, all Athenians are mortal.

D. A syllogism with irreducibly more than three terms is not valid in this system.

II. For a standard-form categorical syllogism to be valid, it must comply with rules that restrict its structure in terms of (a) the “distribution” of the middle, major, and minor terms and (b) the occurrence of negative statements.

A. Restrictions on distribution: The distribution of a term has to do with whether or not the proposition in which it occurs conveys some information about all, or only part of, the class it names. No term can be

distributed in the conclusion that is not distributed in the premise in which it occurs; that is, a conclusion cannot say more than the premises support.

1. If the major term is distributed in the conclusion but not in the major premise, the argument fails due to “illicit process of the major term.” If the minor term is distributed in the conclusion but not in the minor premise, the argument fails due to “illicit process of the minor term.”
2. The middle term must be distributed in at least one of the two premises. If it is not, the argument fails due to “undistributed middle.”

B. There are also restrictions on negative propositions.

1. If one of the premises is negative, the conclusion must be negative.
2. If both of the premises are negative, no valid conclusion can be drawn.

C. Again, there must be exactly three terms and exactly three propositions, not four or more.

### III. Standard-form categorical syllogisms display both *mood* and *figure*.

A. The *mood* of a syllogism is captured by listing the quality/quantity of each of its propositions in order (AAA, AEO, EIA, and so on).

#### 64 Possible Moods of a Syllogism

AAA	AIA	EAA	EIA	IAA	IIA	OAA	OIA
AAE	AIE	EAE	EIE	IAE	IIE	OAE	OIE
AAI	AII	EAI	EII	IAI	III	OAI	OII
AAO	AIO	EAO	EIO	IAO	IIO	OAQ	OIO
AEA	AOA	EEA	EOA	IEA	IOA	OEA	OOA
AEI	AOE	EEI	EOE	IEI	IOE	OEI	OOE
AEO	AOI	EEO	EOI	IEO	IOI	OEO	OOI
AEE	AOO	EEE	EOO	IEE	IOO	OEE	OOO

A = universal affirmative

E = universal negative

I = particular affirmative

O = particular negative

B. The *figure* of a syllogism depends on where its middle term resides.

**Figure One:** The middle term (M) is the subject of the major premise and predicate of the minor.

**Figure Two:** The middle term (M) is the predicate of both premises.

**Figure Three:** The middle term (M) is the subject of both premises.

**Figure Four:** The middle term (M) is the predicate of the major premise and subject of the minor.

#### Four Figures of a Syllogism

(mnemonic: shape of shirt collar for the middle term M's)

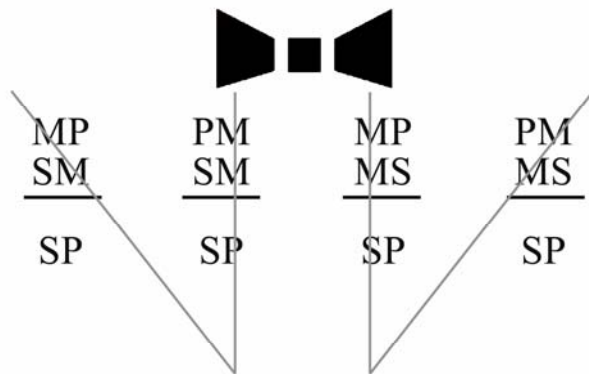


Fig. 1. Fig. 2. Fig. 3. Fig. 4.

In all four figures, the subject of the conclusion (S) appears in the minor premise (the second premise) of the syllogism and is known as the minor term. The predicate of the conclusion (P) appears in the major premise (the first premise) of the syllogism and is known as the major term.

- C. There are 256 possible moods and figures for standard form syllogisms, from AAA-1 to OOO-4. Very few are valid.

**Example:** AAA-1 (Valid).

All Greeks are mortal.

All Athenians are Greeks

Therefore, all Athenians are mortal.

**Example:** AAA-2 (Invalid, undistributed middle).

All Rastafarians are bearded.

All billy goats are bearded.

Therefore, all billy goats are Rastafarians.

- D. By Aristotelian standards, 24 of the 256 possible categorical syllogisms are valid.

IV. Problems with null classes remain, as will be seen.

**Essential Reading:**

Irving Copi, *Introduction to Logic*, chapter 6, “Categorical Syllogisms,” pp. 217–223, 232–235.

**Recommended Reading:**

Irving Copi, *Introduction to Logic*, chapter 6, “Categorical Syllogisms,” pp. 236–246.

**Questions to Consider:**

1. How likely do you think it is that all valid arguments can be stated as categorical syllogisms?
2. An A proposition distributes its subject term but not its predicate term. An I proposition does not distribute either term. Can you figure out which terms, if any, E and O propositions distribute? Does the rule of contradictories help?

## Lecture Nine

### Ancient Logic in Modern Dress

**Scope:** Does every claim assert that its subject class has members? If so, what is a claim's truth value when its subject class is empty? For instance, are all claims about my daughters false if I have no daughters? If so, then the rules of contradictories and subcontraries fail, and any attempt to maintain the rule of contradictories succeeds only if we abandon contraries and subalternation along with subcontraries. Modern syllogistic logic, following George Boole, adopts a different interpretation of A and E statements to deal with this. Graphically represented in Venn diagrams, this interpretation provides a convenient way to determine the validity of three-term syllogistic arguments, but is still severely limited in its scope of application.

### Outline

- I. Some classes have no members. For instance, the class of unicorns, the class of round squares, and the class of my daughters are all null. This creates problems because we don't always know whether the classes we are discussing are populated or not. We need a logical apparatus that can be relied on, either way.
  - A. Since any particular (I or O) claim about a null class clearly asserts that its subject class is populated, then they must all be false—for example, “Some of my daughters are blonde” and “Some of my daughters are not blonde.” But then, if we insist that the law of contradictions holds, their contradictory universals (A and E) must both be true—for example, “All of my daughters are blonde” and “None of my daughters is blonde.”
  - B. Modern syllogistic logic, following the 19<sup>th</sup>-century mathematician/logician George Boole, recognizes that particular (I and O) claims assert that their subject classes are populated but reads universal (A and E) claims differently, so as to preserve the law of contradiction.
    1. *All S are P* is read in obverse—*No S are ~P*, or *S outside of P is null*—which is clearly true when *Some S are not P* is false.
    2. *No S are P* is read straightforwardly as asserting that the intersection of S and P is null, which is clearly true when *Some S are P* is false.
    3. In this analysis, both of the “contraries” are true of a null class *because they truly assert that certain sets are empty*, and both of the “subcontraries” are false *because they falsely assert something to exist that does not*.
    4. Consequently, the rules of contraries, subcontraries, and subalternation disappear from the modern square of opposition, and a further syllogistic rule is established: No valid categorical syllogism can have a *particular* conclusion (I or O) unless it has at least one *particular* premise.
    5. A convenient way to represent categorical propositions, so interpreted, is in terms of *null forms*. Here, we represent the intersection or overlap of two classes by placing the class names side by side. Every class S has a complement, written  $\sim S$ , and read “curl S” or “tilde S.” For example, the intersection of S and P is written SP, and the intersection of S and  $\sim P$  is written  $S\sim P$ , and whether that intersection is populated or null is indicated by saying it is, or is not, equal to zero. Thus, “All S are P” can be represented with “ $S\sim P = 0$ ,” which is read as “The intersection of S and non-P is empty” or “S outside of P is empty.”

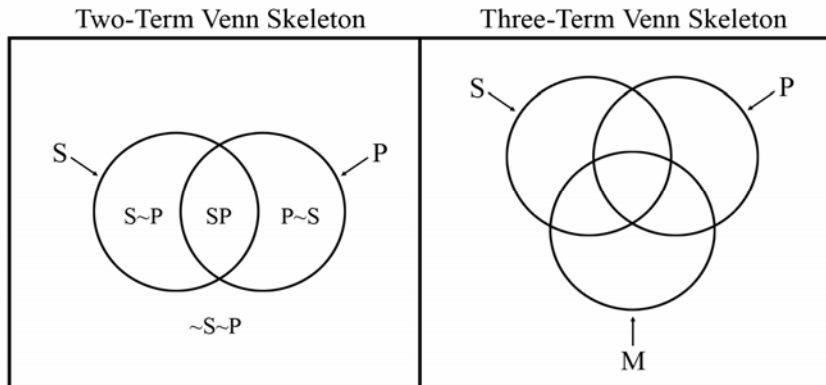
#### Null Forms of Categorical Propositions

<i>Proposition</i>	<i>Notation (reading of notation)</i>
A. All S are P	$S\sim P = 0$ (“S outside P is empty”)
E. No S are P	$SP = 0$ (“intersection of S and P is empty”)
I. Some S are P	$SP \neq 0$ (“intersection of S and P is not empty”)
O. Some S are not P	$S\sim P \neq 0$ (“S outside P is not empty”)

6. Null forms help us work with Venn diagrams.



II. Venn diagrams provide a graphic way to test the validity of three-term syllogistic arguments, by shading out empty areas and placing an X in populated areas. We know that a syllogism is valid if, upon inspection, it is evident that diagramming its premises is all it takes to provide a complete diagram for its conclusion.

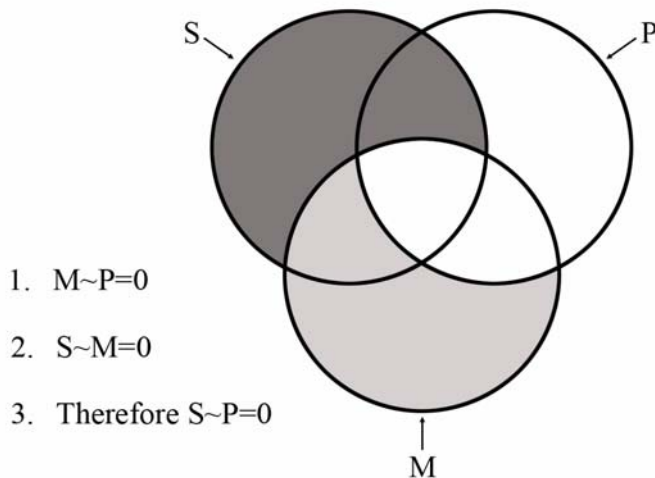


B. A valid AAA-1 syllogism.

Anything meritorious (M) is praiseworthy (P).

All scholarship winners (S) are meritorious (M).

Therefore, all scholarship winners (S) are praiseworthy (P).

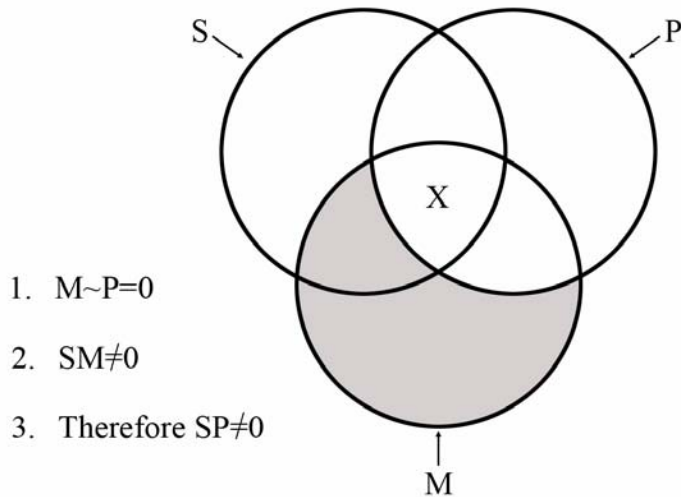


C. A valid AII-1 syllogism.

Everyone who is meek (M) is polite (P).

Some sophomores (S) are meek (M).

Therefore, some sophomores (S) are polite (P).

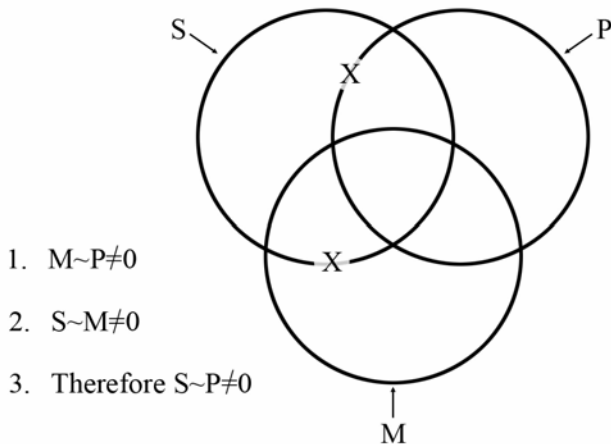


**D.** An invalid OOO-1 syllogism.

Some moderates (M) are not politically savvy (P).

Some Senators (S) are not moderates (M).

Therefore, some Senators (S) are not politically savvy (P).



**III.** Using diagrams to show graphically that a categorical syllogism is valid—or that it’s not—was a wonderful advance over the more traditional ways of handling syllogisms but perfectly consistent with that ancient system.

(*Note to readers:* Even with these embellishments, however, the logic of categorical syllogisms is still severely limited in its scope of application. It will not comfortably handle categorical arguments with more than three terms, and it does not reveal the relationship between syllogistic logic—which is part of a larger realm known as predicate logic—and sentential logic. Those gaps will be partly filled in Lectures Twenty through Twenty-two.)

**Essential Reading:**

Irving Copi, *Introduction to Logic*, chapter 6, “Categorical Syllogisms,” pp. 224–231.

**Recommended Reading:**

Irving Copi, *Introduction to Logic*, chapter 7, “Arguments in Ordinary Language,” pp. 249–271.

**Questions to Consider:**

1. Do we need a separate syllogistic rule to ban all arguments that have particular premises and a universal conclusion, or will the distribution rules take care of that?
2. By Aristotelian standards, twenty-four of the 256 possible categorical syllogisms are valid. This, however, assumes that universal propositions (As and Es) assert the existence of individuals in the classes they name. If so, however, then an A proposition about a null class is false and an O proposition with the same terms is also false, which demolishes the law of contradiction. So, on the Boolean interpretation, universal propositions are interpreted as *not* asserting the existence of individuals in the classes they name, and all categorical syllogisms with universal premises and a particular conclusion are ruled invalid (being said to commit the “existential fallacy”). There are only nine syllogisms that fail due exclusively to the existential fallacy, as enumerated in the table below.

**Valid Categorical Syllogisms**

	<b>Valid for Aristotle and Boole</b>	<b>Valid for Aristotle but Invalid for Boole due to the Existential Fallacy</b>
<b>Figure 1</b>	AAA, AAI, EAE, EIO	AAI, EAO
<b>Figure 2</b>	AEE, AOO, EAE, EIO	AEO, EAO
<b>Figure 3</b>	IAI, AII, OAO, EIO	AAI, EAO
<b>Figure 4</b>	AEE, IAI, EIO	AEO, EAO, AAI

The other thirteen of the thirty-two existentially fallacious syllogisms are already invalid because they violate other rules as well. For example AAI-2 is invalid on both Aristotelian and Boolean interpretations because of undistributed middle. Can you identify some others of these thirteen and what is wrong with them besides the existential fallacy?

## Lecture Ten

### Systematic Doubt and Rational Certainty

**Scope:** The early moderns elevated human reason, downplaying the epistemic role of revelation. Some also questioned the safety of relying on sense experience. In the 17<sup>th</sup> century, René Descartes proposed a method of *systematic doubt* to clear away every basis for thought that could be called into question. His aim was to find an *a priori* basis for it instead. Although we may question the certainty of the foundation that he claimed to find (the famous *cogito ergo sum*), we can recognize the cogency of his demand for reliable foundations for thinking. Here, we will recapitulate some of the reasons for calling sense experience into question, examine the alleged need for “certain” foundations for thought, and show how that quest for certainty can have radically skeptical results.

### Outline

- I. Many early modern Western thinkers elevated the epistemic role of reason over revelation.
  - A. Modern rationalism, a part of the Enlightenment, is identified with such thinkers as Descartes, Leibniz, and Spinoza.
  - B. The Enlightenment was not “new.” It came from a genuine renaissance and harked back to an ancient Greek epistemic model that the medieval “era of faith” had subordinated.
- II. Some early moderns also questioned the safety of relying on sense experience as a basis for our rational exercises.
  - A. This kept a good “Christian” mistrust of fleshly things center stage.
  - B. However, it also made this aspect of the Greek revival more Platonic than Aristotelian.
  - C. Nevertheless, revelation was not the thing either.
  - D. But if a reliable basis for thought is not provided by revelation or by sensation, where can it come from?
  - E. Early modern rationalists, such as Descartes, were foundationalists who believed that there are basic or foundational items of knowledge that we have from which we can reason to the full array of knowledge that we seek.
- III. In the 17<sup>th</sup> century, René Descartes proposed a method of *systematic doubt* to clear away every basis for thought (every sort of content source) that could be called into question.
  - A. His aim was to find an *a priori* basis for it instead.
  - B. What he arrived at is the famous *cogito ergo sum* (which he wrote in French—*je pense, donc je suis*).
    1. The *cogito* is supposed to be *beyond doubt*. Doubt itself is a form of thought, and whatever thinks *is*.
    2. Everything else can be doubted. Sense experience, as we have seen, *is* notoriously unreliable. Revelation, by the same token, is also unreliable, because what may seem to be a revelation from God might be the result of the interference of an “evil genius.”
    3. Even if we agree with Descartes in believing that the occurrence of doubt entails the occurrence of thought and that the occurrence of thought entails the occurrence of a thinker, his claim that “*I think*” entails “*I am*” does not necessarily follow. As Bishop George Berkeley later showed, alternatives to the “*I*” (the substantial ego) are readily available (for example, the mind of God).
    4. Although we may question the self-evidence, certainty, or intuitive necessity of the *cogito*, we can understand Descartes’ mistrust of sensation and recognize the cogency of his demand for an unshakable foundation for thinking.
- IV. There is a mathematical model at work here again: Conclusions are to be rationally derived from necessarily true axioms (emulating Euclid’s theorems that were said to be grounded in the necessarily true axioms of geometry).
  - A. This model is, once again, strongly reminiscent of Plato.
  - B. The model is put directly in play when Descartes uses Euclidian geometry to show how his ontological proof of the existence of God works (which proof, please note, appeals directly to reason, not to religious

experience and/or revelation, however “theological” its topic). The proof of God, if it works, eliminates the possibility that our reasoning is being manipulated by an “evil genius.”

- C. This model requires that its axioms (starting points) actually be self-evident, necessary, or logically true.
  - D. But are statements about matters of fact (for example, the statements of applied geometry) ever self-evident, necessary, or logically true? Or, conversely, do logically true statements (for example, the statements of formal geometry) necessarily have any *factual content* or *application*? Isn't their applicability to the world contingent?
  - E. Non-Euclidean geometries—in which the interior angles of a triangle don't add up to  $180^\circ$ —apply very well in an area of intense gravitation where, according to Einstein's theories of relativity, space itself is distorted or bent, and triangles drawn there are not Euclidian.
- V. Descartes' rational reconstruction of knowledge is based on what he takes to be a self-evident and necessary truth from which he aims to reconstruct a full understanding of the world around us, but the self-evident truth that he starts with is not necessarily self-evident. The model that he follows is based on a conventional and arbitrary starting point, and its applicability is a contingent matter of fact, not a matter of logical necessity.

**Essential Reading:**

René Descartes, *Meditations*.

**Recommended Reading:**

John Dewey, *The Quest for Certainty*, pp. 3–39.

**Questions to Consider:**

1. What is the best way to understand the relationship between reason and the “revelations” that are so often important in religious thought? Could reason ever *independently establish* the contents of a revelation, or do revelations (when and if they occur) always “transcend” what reason can accomplish?
2. If logical certainty is a necessary condition of knowledge and, in addition, all matters of fact are contingent rather than logically certain, how much knowledge can we have about matters of fact?

## Lecture Eleven

### The Limits of Sense Experience

**Scope:** What content for thought does sense experience, by itself, provide? Do we sense the structure or pattern of events or just unconnected bits? As cases in support of the latter view, David Hume argued that we have no sensations of causation as such (with the result that all of our causal claims amount to *interpretations* of what we sense), that every generalization of particular experiences relies on the notion that nature is uniform (a notion that cannot be demonstrated without circularity), and that our accounts of experience involve the association of ideas according to principles that are habitual and not justificatory. In his view, experiencing is more than “picking berries off the bush” with our senses. Put my own way, it involves “construals” of our sensations at the very least, and construals are a contribution of the *subject*, not part of the *object out there*. Should this lead us in the Cartesian direction of demanding necessary truths as the basis for our ratiocination, or can we achieve something more reliable than “naïve realism” without taking that poison pill?

### Outline

- I. If we set the benchmark for knowledge too high, we may conclude that we never have any knowledge at all.
  - A. Many philosophers now think that only analytic truths are *a priori* and that the search for synthetic *a priori* truths is doomed to fail.
  - B. If so, the Cartesian “quest for certainty” may, in fact, open the door to radical skepticism rather than the door to solid knowledge.
- II. What does sense experience—taken by itself—actually provide as fodder for thought?
  - A. Do we sense the structure or pattern of events or just “blooming buzzing confusion”?
    1. What would sense experience be like if we could take it “neat”—that is, without the contributions of the following:
      - a. Memory takes us from sensation to sensation.
      - b. Patterns, whether discerned or imposed by us, are an essential part of the usable content of the experience that we have.
      - c. Associations have enormous implications, for example, in how we classify and react to people we meet.
      - d. Habits channel and shape what we discern.
      - e. Presumptions, too, channel and shape what we discern.
      - f. Vast established mind sets (bicks, theoretical frameworks, paradigms) provide ways of thinking for whole cultures.
    2. Absent such contributions, sense experience amounts to unconnected bits.
  - B. As cases in support of the view that experiencing does *not* amount just to “picking berries off the bush” with our senses, David Hume argued (in the 18<sup>th</sup> century) that:
    1. We have no experience of causation as such; consequently, our notions that one thing is caused by another and that all explanations should be governed by some causal version of a “principle of sufficient reason” (the principle that nothing just happens) presume relationships that are not evident to the senses;
    2. Every generalization of particular experiences relies on the notion that nature is uniform—a notion that cannot itself be demonstrated without circularity; and
    3. Such generalizations involve the association of ideas according to principles that are habitual rather than justificatory.
      - a. We habitually “associate” ideas in terms of similarity, contrast, proximity of one sort or another, inertia, mimicry, and so on.
      - b. Such principles are not “justificatory” because there are examples of each and every one of them that are obviously false or misleading. As we have learned from the *post hoc, ergo propter hoc* fallacy, there are many observable regularities that are not causal.

**Example:** Mark Twain joked that his perfect teeth after a lifetime of drinking whiskey proved the teeth-preserving properties of whiskey.

4. Experience is not passive. We make contributions to it and hence to our experiential understanding of the world.
    - a. The presumption of the uniformity of nature is something that we cannot generalize from the experiences we've already had. We supply it.
    - b. The principle of causation is a way of making sense of the patterns that we discern through the filters that we bring to the actual sensory experiences as they occur.
    - c. Gestalt or field experiences—which are something more than what we merely *sense*—are another contribution that we bring to experience
  - C. My own way of putting this point is to note that experience (as opposed to sensation) always involves “construal,” and that construal is a contribution by the *subject who construes*, not by the *object that is construed*.
    1. This means that experience is inevitably “subjective,” that is, it includes a contribution made by a subject or involves a transaction between a subject and object.
    2. This also means that its content is *not* “logically certain” or “necessarily accurate.”
- III. Should this lead us in the Cartesian direction of demanding *a priori* truths as the basis for our ratiocination, or can we achieve something more reliable than “naïve realism” without taking that (possibly) poison pill?
- A. The Cartesian offer of “certainty” is attractive, but perfect and indubitable truths are a will-o'-the-wisp.
  - B. Naïve realism simply takes things “at face value,” and we all know the cost of saying “who cares?” or simply giving up.
  - C. As we shall see in the lectures ahead, modern rational empiricism offers us a third route.

**Essential Reading:**

David Hume, *An Enquiry Concerning Human Understanding*, Section VII, “Of the Idea of Necessary Connection.”

**Recommended Reading:**

James Hall, *Practically Profound*, Chapter 3, Part IB, “Is experience enough by itself?” pp. 42ff.

**Questions to Consider:**

1. Some states of affairs, such as being offside in soccer, involve what are called *institutional facts*. Here, the institutional fact is the offside rule—a convention of that particular game. Although we can *see* the offside player, we certainly do not see, taste, smell, feel, or hear the offside rule. Does this make being offside any less “objective”?
2. How many different ways might one construe the fact that one had a flat tire, a screen freeze, and an attack of gout all in the same day?

## Lecture Twelve

### Inferences Demand Relevant Evidence

**Scope:** If we rely on experiences as evidence for our inferences and explanations, we must sift through those that offer themselves so as to focus on ones that are *relevant* to the conclusions that we seek to draw. Inferences that rely on irrelevant “evidence” fail, being guilty of the fallacy of *non sequitur*. Several representative types of *non sequitur* are explained in this lecture, and examples are provided. Examining them will help us avoid egregious errors in our own thinking. For, while thinking that is based on such fallacies is common, it is always misleading.

### Outline

- I. There’s another kind of logic, usually called *informal logic*, commonly covered in books or courses about *critical thinking*.
  - A. Although it’s less technical and less demanding, it is no less important than the formal matters of logical inference.
  - B. Informal logic concerns the standards that need to be satisfied in order for us to get formal reasoning underway.
- II. If we rely on experiences (or anything else, for that matter) as evidence for our inferences and explanations, we must sift through those that offer themselves and focus on the ones that are *relevant* to our enterprise.
  - A. Evidential relevance is a prerequisite for useful inference drawing.
  - B. Unless our purported evidence is relevant to the inferences we are trying to draw, we are not even in the ballpark, much less in the game.
- III. Inferences that rely on irrelevant “evidence” commit *non sequitur* in one form or another. Here are descriptions and examples of seven forms that such bad reasoning can take:
  - A. *Ad vericundium*. This fallacy amounts to an appeal to an improper authority (often due to some equivocation over the notion of authority itself).

**Example:** “Don’t question the President. He is the highest authority in the land.”
  - B. *Post hoc ergo propter hoc*. This fallacy amounts to the inference that because one thing follows another in time, the later of the two must have been caused by its predecessor.

**Example:** Keeping Mark Twain’s story in mind, any wino with good teeth will serve.
  - C. *Ad populum*. This fallacy amounts to inferring that a point of view or opinion must be true on the grounds that it is widely held.

**Example:** “Fifty million Frenchmen can’t be wrong!” “Join the swing to Dodge!”
  - D. *Ad baculum*. This fallacy amounts to inferring that a point of view or opinion is true (or false) on the grounds that the one who holds it has (or lacks) the power to impose it on others.

**Positive Example:** “You do exactly what I said, young man, or else!”  
**Negative Example:** “And exactly how many tanks does the pope have?”
  - E. *Ad misericordiam*. This fallacy amounts to inferring that a point of view or opinion must be true on the grounds that those who hold it deserve (or are, at least, natural targets for) our sympathy.

**Example** (a defense lawyer at the sentencing hearing after a conviction for matricide): “Please be lenient with my client. He is, after all, a motherless child.”
  - F. *Ad hominem*. This fallacy amounts to inferring that a point of view or opinion must be true (or false) because of the character and/or the position of those who hold it.

**Positive Example:** Teresa must have been right about her visions coming directly from God. She was a good and virtuous person.  
**Negative Example:** Bill Clinton’s improper liaisons prove the illegitimacy of his political policies.



- G.** *Accident* and *converse accident* (hasty generalization). These fallacies amount to inferring that a member of a group has certain characteristics on the grounds that they are common to the members of the group or that all the members of a group must have certain characteristics on the grounds that some of its members do.

**Example:** Any case of stereotyping will do for the accident fallacy: “White men can’t jump.” Any case of jumping to conclusions will do for the converse accident fallacy. Where, after all, do the stereotypes come from?

- IV.** We should not be misled by the fact that such fallacies are common, by the fact that some of them “sound OK” to careless ears, or by the fact that contrived examples of them can be amusing. They are *always* dangerous. They *never* settle an issue.

**Essential Reading:**

Irving Copi, *Introduction to Logic*, Chapter 4, Section 2 (“Fallacies of Relevance”), pp. 139ff.

**Recommended Reading:**

Jamie White, *Crimes Against Logic*.

**Questions to Consider:**

1. Why do you suppose that more hospitals dispense Tylenol than any other brand of pain reliever (presuming that they actually do)? Is it necessarily because it is more effective or safer? Why do you suppose that Tylenol television ads emphasize the claim that more hospitals dispense Tylenol than any other brand of pain reliever? Is it because the ad writers think that the viewers will infer that the product is more effective or safer?
2. Why do shoe companies spend so much money on sports celebrity endorsements?

## Timeline

c. –1300	Decimal system in use in China
c. –500	Early logic in India and China
–470 to –399	<b>Socrates</b> ; Socratic dialectic introduced, sophistry refuted
–427 to –347	<b>Plato</b> ; foundations laid for classical metaphysical idealism in such dialogues as <i>Republic</i>
–384 to –322	<b>Aristotle</b> ; foundations laid for classical logic in the <i>Analytics</i> and for empirical investigation in <i>History of Animals</i>
–325 to –265	<b>Euclid of Alexandria</b>
c. –300	Publication of Euclid’s <i>Elements</i> ; Babylonian Salamis (origin of the abacus) in use; zero comes into use in Babylon and India
25	Christianity founded
622	Muslim Calendar Year 1
c. 900	Zero introduced in West by Arab traders
c. 1000	Decimal system appears in West
1066	Battle of Hastings
1095	Crusades begin
<b>1126–1198</b>	<b>Averroës</b> ; preservation of Aristotelian rationalism and logic
1215	Magna Carta
<b>1225–1274</b>	<b>Thomas Aquinas</b> ; reclaiming of Aristotelian rationalism and logic in the Christian West
1240	Roger Bacon reintroduces Aristotle to the University of Paris
<b>1280–1349</b>	<b>William of Ockham</b> ; introduction of Ockham’s Razor
1291	Crusades end
<b>1473–1543</b>	<b>Nicolas Copernicus</b> ; modern rational empiricism begins to define “science”
1492	Columbus sailed the ocean blue
1519–1522	Ferdinand Magellan circumnavigates the globe
1531	Erasmus publishes first complete edition of Aristotle
<b>1561–1626</b>	<b>Francis Bacon</b>
<b>1564–1642</b>	<b>Galilei Galileo</b> ; refutation of Aristotelian astronomy
<b>1571–1630</b>	<b>Johannes Kepler</b>
<b>1596–1650</b>	<b>René Descartes</b>
1609	Publication of Kepler’s <i>Astronomica Nova</i> , including his first two laws of planetary motion, gives a solid foundation for the modern scientific method
1614	John Napier invents logarithms
1620	Publication of Bacon’s <i>Novum Organum</i>
1633	William Oughtred invents the slide rule

1637	Publication of Descartes’ <i>Discourse on Method</i> , including the introduction of analytic geometry
1642–1660	English Revolution, Civil War, and Protectorate
<b>1642–1727</b>	<b>Isaac Newton</b>
1643	Blaise Pascal’s “Pascaline” calculating device introduced
<b>1646–1716</b>	<b>Gottfried Leibniz</b>
1662	Publication of <i>Port Royal Logic</i>
c. 1665	Newton and Gottfried Leibniz simultaneously invent the calculus
c. 1670	Anton van Leeuwenhoek’s lenses makes microbiology possible
1674	Leibniz invents the “stepped rocker” calculating device (the basis of the Monroe Calculator of 1912)
1687	Publication of Newton’s <i>Principia</i> : Newton’s laws of motion, the foundation of modern physics
1698	Thomas Severy steam engine
<b>1711–1776</b>	<b>David Hume</b>
1712	Thomas Newcomen steam engine
<b>1724–1804</b>	<b>Immanuel Kant</b>
1735	Carl Linnaeus’s <i>Systema Naturae</i> published (biological taxonomy)
1748	Publication of Hume’s <i>Philosophical Essays</i> (aka <i>An Enquiry Concerning Human Understanding</i> )—quintessential early modern empiricism, rejection of “sophistry and illusion”
1769	James Watt’s steam engine
1776–1783	American Revolution
1781	Publication of Kant’s <i>Critique of Pure Reason</i> ; reason and experience differentiated, the analytic/synthetic distinction triumphant; the search for the synthetic <i>a priori</i>
1789–1795	French Revolution
1798	Edward Jenner publishes report on cowpox and smallpox
<b>1798–1857</b>	<b>Auguste Comte</b>
<b>1806–1871</b>	<b>Augustus DeMorgan</b>
<b>1806–1873</b>	<b>John Stuart Mill</b>
1812–1814	War of 1812
1815	Waterloo
<b>1815–1864</b>	<b>George Boole</b>
1821	Michael Faraday’s electric motor
1822	Publication of Comte’s <i>Plan de travaux scientifiques necessaries pour réorganiser la société</i> ; the application of observation and experimentation to sociology (and a foundation for logical positivism in the 20 <sup>th</sup> century)
<b>1822–1895</b>	<b>Louis Pasteur</b>

c. 1825 .....	Charles Babbage’s “Difference Engine” (developed from an idea of J. H. Miller of 1786); the idea behind computers
1830 .....	Joseph Henry’s telegraph (made commercial in 1844 by Morse)
<b>1834–1923 .....</b>	<b>John Venn</b>
1835 .....	James Woodward’s and Matthew Evans’s electric light bulb
<b>1839–1914 .....</b>	<b>Charles Sanders Peirce</b>
<b>1842–1910 .....</b>	<b>William James</b>
1847 .....	Publication of DeMorgan’s <i>Formal Logic</i> ; one beginning for modern symbolic logic, especially DeMorgan’s theorems
1847 .....	Publication of Boole’s <i>The Mathematical Analysis of Logic</i> ; another beginning for modern symbolic logic, especially set theory
<b>1848–1925 .....</b>	<b>Gottlob Frege</b>
1856 .....	Charles Babbage’s “Analytical Engine”
<b>1858–1932 .....</b>	<b>Giuseppe Peano</b>
<b>1858–1947 .....</b>	<b>Max Planck</b>
1859 .....	Charles Darwin’s <i>On the Origin of Species</i> published
1861 .....	Ignatz Semmelweis published explanation of childbed fever; confirmed by Lister in 1865
1861–1865 .....	American Civil War
1866 .....	Gregor Mendel explains inheritance in peas
<b>1872–1970 .....</b>	<b>Bertrand Russell</b>
1873 .....	Publication of Peirce’s “Description of a Notation for the Logic of Relatives” (the predicate logic of relations)
1878 .....	Ramon Varea invents a partial-product calculating device (basis of the Burroughs Calculating Machine of the 1920s)
<b>1879–1955 .....</b>	<b>Albert Einstein</b>
1881 .....	Introduction of Venn diagrams
1887 .....	Michelson-Morley experiment; aether rejected
1889 .....	Publication of Frege’s <i>Begriffsschrift</i> , an apparatus, including truth tables, for the formal analysis of logical arguments
1889 .....	Publication of Peano’s <i>Geometrical Calculus</i> , including a chapter on mathematical logic with the basics of what has become “Peano-Russell Notation” for modern logic
1889 .....	Publication of Peano’s <i>Arithmetices Principia</i> , defining natural numbers in terms of sets
<b>1889–1951 .....</b>	<b>Ludwig Wittgenstein</b>
1891 .....	Publication of Mill’s <i>A System of Logic</i> , the classical formulation of inductive reasoning
1899 .....	Guglielmo Marconi’s radio telegraph
<b>1901–1976 .....</b>	<b>Werner Heisenberg</b>

<b>1902–1994</b> .....	<b>Karl Popper</b>
1903 .....	Ivan Pavlov confirms conditioned reflexes in dogs
1905 .....	Einstein’s special theory of relativity
1905 .....	X and Y chromosomes described
1906 .....	Mechanical television
1907 .....	Publication of James’s <i>Pragmatism</i> , notable for its influence on Bertrand Russell and Ludwig Wittgenstein
<b>1908–2000</b> .....	<b>W. V. O. Quine</b>
1910 .....	Publication of Russell’s <i>Principia Mathematica</i> , Vol. 1
<b>1910–1989</b> .....	<b>Alfred Jules Ayer</b>
1912 .....	Publication of Russell’s <i>Principia Mathematica</i> , Vol. 2
1912 .....	Publication of James’s <i>Essays in Radical Empiricism</i>
1913 .....	Publication of Russell’s <i>Principia Mathematica</i> , Vol. 3
1913 .....	J. B. Watson’s “Psychology as a Behaviorist Views It” published
1914–1918 .....	World War I
1915 .....	Einstein’s general theory of relativity
1921 .....	Publication of Wittgenstein’s <i>Tractatus Logico-Philosophicus</i>
<b>1922–1996</b> .....	<b>Thomas Kuhn</b>
1924 .....	J. B. Watson’s <i>Behaviorism</i> published
1926 .....	Proof of Planck’s Quantum Theory by Paul Dirac
1927 .....	Publication of Heisenberg’s Uncertainty Principle
1927 .....	Philo Farnsworth files patent for electronic television
1929 .....	Karl Mannheim publishes <i>Ideologie und Utopie</i> , setting out the “sociology of knowledge”—the roots of postmodern epistemic relativism
1936 .....	Publication of Ayer’s <i>Language, Truth and Logic</i> , bringing logical positivism to the English-speaking world
1938 .....	B. F. Skinner’s <i>The Behavior of Organisms</i> published
1938 .....	Otto Hahn and Fritz Strassman; first fission of uranium
1938–1945 .....	World War II
1942 .....	First controlled nuclear reaction (Chicago)
1945 .....	ENIAC; computers arrive for military use
c. 1950 .....	First nuclear fusion weapons
1951 .....	UNIVAC; computers arrive for civilian use (Census Bureau)
1951 .....	Publication of Quine’s “Two Dogmas of Empiricism,” disputing the traditional empiricists’ bright-line analytic/synthetic distinction
1953 .....	The double helix: Francis Crick and James Watson explain the molecular structure of DNA
1953 .....	Publication of Wittgenstein’s <i>Philosophical Investigations</i>

- 1953 ..... Publication of Popper’s *Conjectures and Refutations*, including the article “Science as Falsification,” putting a different twist on the logical positivists’ verificationism
- 1960 ..... TIROS photos of Earth from space
- 1962 ..... Publication of Kuhn’s *The Structure of Scientific Revolutions*, introducing the notion of “paradigm shifts” and sharply contextualizing the notion of scientific knowledge
- 1963 ..... First electronic calculating device (the Sumlock)
- 1971 ..... First pocket electronic calculator
- 1973 ..... Internet conceived and designed
- 1974 ..... First PC kit: Altair
- 1977 ..... First working PCs: Apple II and Tandy
- 1983 ..... Internet rollout
- 1989 ..... The Web
- 1990 ..... First gene replacement therapy

## Glossary

**A Posteriori:** Known or knowable on the basis of experience of some sort.

**A Priori:** Known or knowable independent of experience of any sort.

**Analytic:** Traditionally, the character of a statement that can be shown to be true or false by logical analysis; logically necessary. See **Synthetic**.

**Analytic Falsehood:** Traditionally, a statement whose predicate denies what is contained in its subject; a self-contradiction or necessary falsehood.

**Analytic/Synthetic Distinction:** An alleged “dogma” of empiricism (see Biographical Note for **Quine, W. V. O.**) in terms of which statements can be neatly sorted into necessary and contingent categories.

**Analytic Truth:** Traditionally, a statement whose predicate is contained in its subject; a tautology or necessary truth. See **Tautology**.

**Argument:** An arrangement of statements in which one or more (premises or assumptions) are presented as evidence or support for the truth of another (the conclusion).

**Association:** A key classificatory operation of the mind, connecting words, ideas, or experiences based on similarity, proximity in time or place, habit, and so on. According to Hume, our idea of causation is rooted in our habitual association of contiguous events. According to Freud, our psyche is revealed in our patterns of word association.

**Behaviorism:** The theory that mental phenomena, states, and processes can be reduced to, or explained in terms of, observable behavior and/or dispositions to behave.

**Belief:** An experiential expectation, usually based on mental processing of experiences that have already occurred or are occurring.

**Bifurcate:** To radically divide, as Descartes divided mind and body, Plato divided ideas and appearances, and transcendentalists divide the divine and the mundane.

**Blick:** A distinctive way of taking things, a picture of, or perspective on reality. More basic (and less considered than a *weltanschauung*), a blick is rather like a paradigm.

**Boolean Algebra:** Two-valued logic where the operators are based on negation and the logical AND or the logical OR.

**Ceteris Paribus:** All things held equal.

**Circumstantial:** Accidental, contingent.

**Common Sense:** Whatever beliefs are held by consensus in a community but usually focused on beliefs that are directly supported by everyday experience.

**Complement:** Every set (or term naming a set) has its complement, which (unlike an opposite) is whatever is not included in the set itself. Thus, the sum of any set and its complement is *everything*.

**Connotation:** See **Sense**.

**Consensus:** Common agreement, considerably more than majority opinion but not necessarily unanimous.

**Contingent:** Circumstantial or accidental, depending on external factors.

**Covering Law:** A scientific (descriptive) law of very general scope and application and of great explanatory power, thought to be universally true. Covering laws may subsume many particular laws of narrower scope under their aegis, entailing this one or that one in various specific natural circumstances. Example: *Universal gravitation*. See **Hypothesis, Theory, and Law**.

**Cultural Relativism:** The view that value (moral cultural relativism) and/or truth (epistemic cultural relativism) are local to a culture, being produced by the culture itself rather than found in the external world.

**Deduction:** Argument (or reasoning) is called *deductive* when its grounds offer ironclad support for its conclusion; that is, if it is said to give “closure.” Traditionally, the paradigm for deduction was Euclidian proof, typified by inference from general truths to particular outcomes (cf. **Induction**).

**Definition:**

**Essential:** Defining a term or phrase in terms of the “essence” of its referents, that is, the universal necessary and sufficient conditions of its use.

**Family Resemblance:** Defining a term or phrase in terms of overlapping similarities that may be observed in its referents.

**Operational:** Defining an abstract term or phrase in terms of observable phenomena or operations; for example, defining *gravity* as the acceleration of objects toward one another.

**Ostensive:** Defining a term or phrase by pointing to its referent.

**Paradigm Case:** Defining a term or phrase by reference to a stipulated model.

**Denotation:** See **Reference**.

**Dialectic:** A process for discovering first principles through probing the presuppositions of common sense beliefs, usually carried out in a question-and-answer dialogue. *Socratic dialectic* aims at debunking false opinions. *Platonic dialectic* seeks underlying reality. *Hegelian dialectic* is the alleged historical process of mind through thesis and antithesis toward synthesis. *Marxian dialectic* sees this historical process as material and economic, not mental.

**Distribution:** To say that a proposition “distributes” its subject term is say that it makes a claim about each and every member of class named by that term. A term is “undistributed” in a proposition (or “fails to distribute”) when the proposition does not make so inclusive a claim. Thus, for example, the proposition “All Athenians are Greeks” distributes “Athenians” (that is, it says something about each and every Athenian) but does not distribute “Greeks” (that is, it does not say something about each and every Greek).

**Empiricism:** The view that experience (sometimes limited to sense experience) is the primary (or even the exclusive) source of human knowledge (cf. **Modern Rational Empiricism**).

**Enlightenment:** An age of humanism, naturalism (and some deism), broadly associated with the 18<sup>th</sup> century.

**Epistemic Relativism:** The view that the knowable and known vary independently of what is the case, as a function of one’s culture, paradigm, mind set, or circumstances; a variety of collective subjectivism.

**Epistemology:** Knowledge theory, one of the main traditional branches of philosophy.

**Evidence:** That which is offered as a basis for inferences. It may amount to observations, recollections, axioms of one sort or another, or even revelations. Some kinds evidence are much more reliable than others.

**Experience:** A covering term for the source of any external data for thought. Usually, sense experience (seeing, tasting, smelling, feeling, hearing), but other input can be included (encounters, visions, and the like). Experience can be objective or subjective, private or public, one-off or replicable.

**Experiments:** Organized work to test hypotheses, discover new facts, establish connections, and so on. Often done in a lab or in the field and, sometimes (as in the case of *thought experiments*), done in one’s head.

**Explanation:** The rendering intelligible of a state of affairs by carefully noting how it came about and how it relates to other states of affairs (causal), why or for what purpose it occurred (teleological), or the use that it serves (functional).

**Extension:** Contrasts with **Intension**. See **Reference** and **Sense**.

**Felicity Conditions:** The circumstances in which a locution is “happy,” (for example, a description is felicitous if it is true, a promise is felicitous if it is sincere, a joke is felicitous if it is funny).

**Foundationalism:** The view that only some states of affairs are directly known and that all other knowledge is derived from that foundation. Different schools of thought pick different foundations.



**Hypothesis:** A descriptive proposition, not known to be true, that is entertained provisionally in an attempt to explain observed phenomena. It may be narrow or broad in scope and, ideally, will be open to testing in terms of whether or not its various implications are confirmed experientially. Example: *That acquired characteristics can be passed on to one's offspring.* See **Theory, Law, and Covering Law.**

**Idealism:** The metaphysical view that there is a non-physical reality “behind” or “above” the apparent reality of everyday events.

**Imply, Entail:** To provide sufficient grounds for the truth of, as a premise implies a conclusion. If an implication is logically necessary, it is called an entailment.

**Incommensurable:** Of two or more statements, theories, or paradigms, not measurable or assessable on a common standard.

**Induction:** Argument (or reasoning) is called *inductive* when its grounds offer probable support for its conclusion but do not give “closure.” Traditionally, the paradigm for induction was generalization, typified by inference from particular truths to universal outcomes (cf. **Deduction**).

**Inference:** That process of thought by which we move from some grounds or evidence to a thought or opinion said to be based on it or to follow from it. People infer; statements imply. (See **Deduction** and **Induction**.)

**In principle:** By definition, not accidental.

**Intension:** See **Sense.**

**Intuition:** Direct (unmediated) understanding, knowledge, or insight; also unexplained understanding, knowledge, or insight. Often, to say something is intuited is only to say we don't know how we got it.

**Invention:** Creation. People invent devices, such as telescopes. They also invent ideas, such as the general theory of relativity. Sometimes, invention involves only the synthesis of preexisting bits. Occasionally, however, it involves a *de novo* “leap.”

**Knowledge:** Justified true belief, at least, but more than that according to skeptics who deny its occurrence.

**Law:** A law is either a prescriptive statement that is desired to be exceptionless (prescriptive law), or a descriptive statement that is thought to be exceptionless (descriptive law). Prescriptive laws (whether common laws or statute laws) are in the realm of social control and are aimed at influencing and directing things in one way or another. Descriptive laws are in the realm of explanation and are aimed at accurately capturing things the way they are. Prescriptive laws may be good or bad, and can be revised when the interests of the law maker change. Descriptive laws may be true or false, and are open to revision in the light of new data. Descriptive laws have *no* prescriptive force. In science, the term ‘law’ is descriptive and is commonly used as an honorific for a theory that has repeatedly passed rigorous tests across a range of applications. Example: *That for every action, there is an equal and opposite reaction.* See **Hypothesis, Theory, and Covering Law.**

**Logic:** A system of rules of inference to determine whether or not (and, if so, to what extent) the premises of an argument support its conclusion. A rational reconstruction of effective thinking. (See also **Modal, Predicate, and Sentential Logic**; also **Boolean Algebra**.)

**Logical Empiricism:** A philosophical position identified with the Vienna Circle that insisted that all cognitively meaningful language is, in principle, either empirically or formally verifiable; logical positivism.

**Logical Form:** The syntactical structure of an argument, such as *modus ponens* (that is, “If P, then Q; P, therefore Q”) and *modus tollens* (that is, “If P, then Q; Not-P, therefore Not-Q”).

**Logical Positivism:** See **Logical Empiricism.**

**Meaning:** The sense or the reference (or both) of a word, phrase, or other representation or the intention of one who uses such.

**Meaning, Theory of:** An account, such as the use theory or the naming theory, of how a word, phrase, or other representation conveys a sense and picks out a reference.

**Memory:** Recollection or recall or the mental faculty by means of which we recollect or recall. Accurate memory presupposes that what is remembered actually happened the way it is remembered to happen. Not all memory is accurate.

**Metaphysics:** In Aristotle's collected works, what comes after *Physics*. To logical positivists, nonsense. To the ambitious, speculative "theories of everything." More generally, abstract inquiry about "the furniture of the world." Ontology.

**Methexis:** Interaction or, in the case of Plato's Forms and the appearances, "participation." Usually occurs in the locution *methexis problem*, as in: "We have no idea how the Cartesian minds and bodies interact. His dualism causes a real *methexis problem*."

**Modal Logic:** Logic applied to the notions of possibility and necessity (in contrast to the ordinary logic of contingent statements).

**Modern Rational Empiricism:** The typical epistemological stance of Western science: reason and experience working together to discover, understand, and anticipate facts.

**Moral Relativism:** The view that what is good, moral, or right varies independently of what is factually the case, as a function of one's culture, paradigm, mind set, or circumstances; a variety of collective subjectivism.

**Naming Theory of Meaning:** A still common view that words and phrases mean by naming something. It encounters difficulty with such words as *nothing* and such phrases as *the present king of France* (which are meaningful but don't name anything),

**Natural Law:** "Natural law" may be used as a synonym for "scientific law," in which case the label denotes a strictly descriptive proposition. In many contexts, however, "natural law" is taken to denote one or another *prescriptive* principle of nature. In the latter sense, it has everything to do with religion and metaphysics and nothing to do with science. See **Law**.

**Nominalism and Realism:** Metaphysical positions on the status of abstract nouns. Realism insists that they name actual entities (such as the Good), while nominalism allows that they express only notions.

**Ockham's Razor:** The primary tool of theoretical economy; hypothesizing no more than is necessary to save the appearances.

**Operationalism:** Metaphysical position that abstract nouns must be given operational definitions (see **Definition**).

**Opposite:** see **Complement**.

**Paradigm:** Generally, a model, template, or pattern. In recent usage, the frame of reference or perspective in which one operates that determines how things appear and, hence, how one describes or explains them.

**Pattern Discernment:** Picking out (usually visually but other sense modes can be used) some similarity, structure, organization, or recurrence in occurring experiences; for example, noticing that most of the native residents of Spanish Wells have reddish hair.

**Pattern Recognition:** Connecting a discerned pattern to a remembered one.

**Positivism:** The philosophical position of Auguste Comte, typified by the rejection of myth, magic, and metaphysics and the affirmation of "positive science." A precursor of logical positivism.

**Post Hoc Ergo Propter Hoc:** "After, therefore because of"—a common fallacy.

**Postmodernism:** A point of view that rejects "modern" rationalism and empiricism, usually focused on Descartes. It is notably committed to both epistemic and normative cultural relativism, trades heavily on such notions as the "sociology of knowledge" and "paradigm shifts," and suggests that *everything* is a text open to interpretation.

**Predicate Logic:** Logic that involves the analysis of the internal structure of subject/predicate sentences (in contrast to sentential logic, which treats simple sentences as unanalyzed units). The logic of syllogisms and of set theory.

**Premise:** An assumption or starting point for argument; the basis from which an argument's conclusion is inferred.

**Rationalism:** The view that genuine knowledge (perhaps all of it) must be achieved through the exercise of the mind rather than through experience (cf. **Modern Rational Empiricism**).

**Realism:** See **Nominalism and Realism**.

**Reason:** (1) Cognitive processing, including deductive and inductive inference, classification, hypothesis construction, and the like. Not to be confused with affective processing (the emotions) or conative processing (the will). (2) The basis or grounds for a belief or act. (3) The goal of an act.

**Reductionism:** A philosophical enterprise that consists of translating accounts of one sort of phenomena into the vocabulary of an allegedly simpler and more inclusive sort of phenomena. Behaviorism, for example, is a reductionist theory of mind.

**Reference:** Denotation or extension; that which is referred to or picked out by the sense of a word or phrase.

**Scholasticism:** High medieval thought.

**Semantic:** Having to do with the sense and reference of language, as opposed to its internal structure or logic. See **Syntactic**.

**Sense:** The connotation or intension of a word or phrase; the set of characteristics or properties so invoked in terms of which one can pick out the reference.

**Sentence, Compound:** A sentence composed of two or more simple sentences, joined together (such as “It’s 5 o’clock, and I’m ready to quit for the day” and “If I quit now, then I will be home before sundown.”) Some compound sentences are truth functions of their components (such as the examples just given), but others are not (such as “John believes that Mary loves Bill”).

**Sentence, Simple:** A sentence no part of which is a sentence in its own right (such as “Today is Friday” and “Grass is green”). See **Sentence, Compound**.

**Sentence, Truth-Functional:** A compound sentence, the truth or falsity of which is a function of the truth or falsity of its component parts and the meaning of the connector with which those parts are joined. Simple sentences joined by verbal connectors, such as “and,” “or,” and “if...then,” produce truth-functional compound sentences.

**Sentential Logic:** Logic that examines the implications of simple and truth-functional compound sentences but does not involve the analysis of the internal structure of the simple sentences themselves (as is the case with **Predicate Logic**).

**Sociology of Knowledge:** The idea, sometimes associated with Karl Mannheim, that what is known is always a function of the culture in which one operates. *Epistemic cultural relativism* is the more common label now.

**Sound:** The quality of an argument that is valid and has true premises.

**State Description:** In Newtonian physics, the precise specification of the location and vector of all the bits in a closed physical system. A map of a reality slice.

**Syllogism:** An argument in predicate logic composed of two premises and a conclusion, each of which has exactly two terms (subject and predicate), each of which occurs twice (one in the first premise and the conclusion, one in both premises, and one in the second premise and the conclusion). See **Predicate Logic**.

**Syntactic:** Having to do with the internal structure or logic of language (as opposed to its meaning). See **Semantic**.

**Synthetic:** The character of a statement that cannot be shown to be true or false by logical analysis alone. See **Analytic**.

**Theory:** A hypothesis that has been well confirmed and, generally, is of sufficiently broad scope to have wide application and utility. Example: *That the physical characteristics of biological organisms are, for the most part, genetically determined*. See **Hypothesis, Law, and Covering Law**.

**Thinking:** The contemplation of an idea, the holding of a belief, or (most notably) using your mind to get from A to B.

**Tautology:** A statement that is necessarily true, true by virtue of its form, or analytically true (for example, “In base-10 arithmetic,  $2 + 2 = 4$ ,” and “If P, then if Q then P”).

**Truth Conditions:** Circumstances in which a statement will be true or false. These may be experiential or logical, at least.

**Truth Criteria (Tests):** Ideas about how we can ascertain whether a statement is true or not, such as *correspondence* (seeing if it “matches” the way things really are), *coherence* (seeing if it is consistent with other statements that are held to be true), and *pragmatic* (seeing if it works in use).

**Truth Theories:** Ideas about what makes a statement true, such as *correspondence* (actually matching the ways things are), *coherence* (meshing with other statements that are true themselves), and *pragmatic* (being reliable in use).

**Use Theory of Meaning:** The theory, associated with Wittgenstein, that the meaning of a statement amounts to nothing more than the uses to which the statement can be put.

**Valid:** The quality of an argument with a logical form such that the truth of its premises assures the truth of its conclusion.

**Venn Diagrams:** Graphics used to represent sets, set membership, and the relations between sets by means of overlapping circles, shading, and the placement of Xs. They are used to evaluate syllogisms.

**Verification:** Testing a statement for truth.

**Verificationism:** The notion, associated with logical empiricism, that a statement can be meaningful only if it is testable by either experience or logic.



became proficient in Latin, Greek, German and French without formal training. Boole began correspondence with De Morgan in 1842 and wrote a paper applying algebraic methods to differential equations that was published in 1844. In November 1849 Boole became the first Professor of Mathematics at Queen's College, Cork, where he taught the rest of his life. In 1854 he published *An investigation into the Laws of Thought, on Which are founded the Mathematical Theories of Logic and Probabilities*. This began the development of “Boolean algebra,” now an important component of the “languages” of computers and switching circuits.

**Comte, Auguste (1798–1857).** A French thinker, the inventor of sociology and the founder of classical positivism, Comte argued that science has emerged from theological and metaphysical stages into its modern “positive” (operational or experiential) posture, and that human reverence should be for humanity itself. His works include six volumes on *Positive Philosophy* and four on *Positive Polity*. He is said to have practiced what he called “mental hygiene” by avoiding reading the works of others.

**Copernicus, Nicholas (1473–1543).** The son of a Polish copper trader and educated at the University of Krakow, Copernicus studied Latin, mathematics, astronomy, geography and philosophy. Astronomy then consisted of mathematics courses which introduced Aristotle’s and Ptolemy’s view of the universe so that students could understand the calendar, calculate the dates of holy days, and navigate at sea. While a student, Copernicus also became familiar with Euclid’s *Elements*, the Alfonsine Tables (planetary theory and eclipses) and spherical astronomy. Notable as the author of what we now call the “Copernican Revolution,” he brought three tools of thinking to the table: painstaking observation, mathematical/logical skill and the creative capacity to reconceptualize what we observe under a new paradigm.

**DeMorgan, Augustus (1806–1871).** Born in India, DeMorgan was educated at Trinity College, Cambridge, where he matriculated at the age of 16 in 1823. He began the use of a slash to represent fractions, perfected the principle of Mathematical Induction (1838), and made many contributions to the development of symbolic logic, including “DeMorgan’s laws.” He held the chair in mathematics at University College, London, from which he resigned (twice) on issues of principle. Not a warm person, he is remembered for his devotion to abstract reasoning.

**Descartes, René (1596–1650).** A French rationalist philosopher and mathematician, Descartes was Jesuit trained and strictly Catholic, but no Scholastic. He was notable for his reconstruction of rational knowledge by way of systematic doubt. Apart from the “cogito” and everything built on it, he is also noted for the invention of analytic geometry. His notable works include *Discourse on Method* and *Meditations on First Philosophy*. The model Cartesian tool of thinking is precise deduction. The bases of that deduction are to be found in those indubitable truths that are available to us (such as, allegedly, the axioms of geometry). If such “necessary” truths are not available, of course, there will be issues about the output of our thinking, however fool-proof the tool we use to process our data.

**Einstein, Albert (1879–1955).** Born in Germany, Einstein had a lackluster record in his early schooling there. He continued his education at the Zurich Technical High School, and after becoming a Swiss citizen in 1901 found temporary employment as a secondary school mathematics and physics teacher in Winterthur. While employed at the Bern Patent Office (1902–1905), Einstein wrote numerous articles on topics in theoretical physics in his spare time and completed a Ph.D. at Zurich in 1905. In the years that followed, Einstein contributed to his own “Scientific Revolution” by way of his Special and General theories of relativity and his reconceptualization of space and time. He also contributed to the philosophical revolution from genetic to confirmational empiricism. Not only at the forefront of all things theoretical (though he did not share the general enthusiasm for Quantum Mechanics), he was also influential in international affairs. Eventually a citizen of both Switzerland and the United States, he was an unflinching advocate of world peace.

**Euclid of Alexandria (circa 325 BC–circa 265 BC).** Euclid is best known for his treatise *The Elements*. Little is known of his life except that he taught at Alexandria. There is even argument about whether he actually existed. Most likely, he was a student of Plato and lived during the reign of Ptolemy I. Whether the content of *The Elements* is wholly (or even in part) his own, that work set the pattern for “axiomatizing” bodies of knowledge. We are also in Euclid’s debt for the pattern of “*reductio ad absurdum*” proof (where we assume the falsehood of an hypothesis and, by showing that this leads to absurdity, infer that the hypothesis is true).

**Frege, Gottlob (1848–1925).** Son of a schoolmaster in Wismar, Frege entered the University of Jena shortly after the Seven Years’ War, and completed his doctorate at Göttingen in 1873. He returned permanently to Jena in 1874 where he taught all branches of math; but his works on the philosophy of logic, mathematics and language are key.

In 1879 his *Begriffsschrift*, a book on “conceptual notation,” laid out a logical system with negation, implication, universal quantification, and the essential idea of truth tables. His *Foundations of Arithmetic* (1884) attempted to axiomatize it, in keeping with his belief that it is reducible to logic. In 1902, Frege received a letter from Bertrand Russell pointing out a contradiction in his system of axioms. This generated lengthy correspondence and a revision to an axiom, but the system remained inconsistent.

**Galileo (1564–1642).** Born near Pisa, the son of a musician and teacher, Galileo seemed destined for a career in medicine but was seduced by mathematics. An early reader of Euclid and Archimedes, he abandoned his medical studies altogether by 1585. A student of the theory of motion, he worked out many important ideas (such as the parabolic path of a projectile), but they were not published until the 1630s. In 1609 he came into possession of a spyglass, took up lens making, made telescopes, and turn his gaze skyward. This serendipitous combination of intellect and artifact (creative thinking and a telescope) opened the door to a thorough reconceptualization of the universe and our place in it.

**Heisenberg, Werner (1901–1976).** Born in Würzburg, Germany and educated at the University of Munich, Heisenberg is remembered for his contributions to physics in the form of matrix mechanics, quantum mechanics, atomic structure and the indeterminacy principle. Calling Newtonian notions about causation and predictability in question, he contributed heavily to the twentieth century “revolution” in theoretical physics. While there may be no questions about accuracy of quantum mechanics, there are questions about its implications. Heisenberg’s own interpretations of them, in *Physics and Philosophy* (1962), are controversial.

**Hume, David (1711–1776).** A Scottish philosopher and historian, Hume studied at Edinburgh, but was denied professorships there and at Glasgow for religious reasons. His many important works include *An Inquiry Concerning Human Understanding*, *A Treatise of Human Nature*, and *Essays Moral and Political*. He was the definitive British Empiricist, noted for his views on causation, the association of ideas and the roots of induction in habit rather than in demonstrable truth. He is notably credited for awakening Kant from his “dogmatic slumbers” and for his aversion to “sophistry and illusion.” His long-term influence on British Analytic philosophy is unmistakable at every turn, but is especially evident in the works of Russell, Ryle, Wittgenstein, Austin and your present lecturer.

**Kant, Immanuel. (1724–1804).** A German philosopher, perhaps the first *professional* philosopher, Kant was a career academic. His three *Critiques* (of *Pure Reason*, *Practical Reason* and *Judgment*) are landmarks in modern philosophical history, responding to Hume’s empiricism and permanently marking out the limits of reason in such a way as to exclude any knowledge whatever of “things in themselves.” Most of the subsequent philosophical discussion of the analytic/synthetic distinction and of the impossibility of synthetic *a priori* knowledge has been influenced for good or ill by his notions of the “transcendental analytic.”

**Kepler, Johannes (1571–1630).** Son of a mercenary soldier who died in war, Kepler began life in Swabia and was raised by his mother in her father’s inn. After school and a regional seminary, he enrolled at the University of Tübingen. Now remembered for the laws of planetary motion named for him, he also worked with optics and made discoveries in solid geometry, demonstrated how logarithms work, and contributed to the eventual development of calculus. Not only a keen mathematician, he was also a painstaking observer. His remarkably precise astronomical tables also helped to establish the truth of heliocentric astronomy.

**Kuhn, Thomas (1922–1996).** An American philosopher and historian of science, Kuhn taught at Harvard, Berkeley, Princeton and MIT. His *The Structure of Scientific Revolution* was published at mid century as a volume in the *International Encyclopedia of Unified Science*—a surprisingly positivistic venue for a non-positivistic treatise. If Kuhn did not invent paradigms and paradigm shifts, he certainly put them on the map for the rest of us. On his view, there is no rational basis for choosing one paradigm over another. Other works include *The Essential Tension: Selected Studies in Scientific Tradition and Change* and *The Road Since Structure: Philosophical Essays, 1970–1993*.

**Mill, John Stuart (1806–1873).** Born in London, the son of the Scottish philosopher James Mill, and the product of an early excursion into home schooling, Mill took on Greek at the age of 3, Latin and arithmetic at 8 and logic at 12. With the security of a nominal career at the India Office, he devoted much time to the Utilitarian Society, the Westminster Review, and the London Debating Society. His first major work, *A System of Logic*, was published in 1843. Later important pieces include *Liberty* (1859), *Utilitarianism* (1863) and *Three Essays on Religion* (1874). His influence on Bertrand Russell and John Maynard Keynes was substantial. The reputation of Mill’s *Logic* was

largely due to his analysis of inductive proof. He sought to provide the empirical sciences with a set of formulas and criteria which might serve the same purpose for them that the formulas of the syllogism had served for classical deductions from general principles.

**Newton, Sir Isaac (1643–1727).** The most famous of English scientists, Newton entered Trinity, Cambridge, to prepare for law in 1661 (after a thoroughly spotty career in school). The slightly non-restrictive atmosphere there allowed him to read widely (including Aristotle, Descartes, Gassendi, Hobbes, Boyle, Galileo and Kepler). He started reading mathematics in 1663, by way of a book on Astrology, but soon progressed to Euclid and to the analytical geometry and algebra of Descartes and Viète. When the plague closed the University in the summer of 1665 Newton returned to Lincolnshire where, in two years time, he began revolutionary advances in optics, physics, and astronomy, and laid the foundations for differential and integral calculus, several years before its independent discovery by Leibniz. Best remembered for the laws of motion constituting “Newtonian Mechanics,” he laid out the basic dimensions of orthodox scientific thinking for the next two centuries, before turning his attentions away from science and mathematics for the last half of his life.

**Peano, Giuseppe (1858–1932).** Son of a farming family in the Piedmont, Peano began his education at a village school but completed it at the University of Turin. He went on to teach there in 1880. In 1887, he published a method for solving systems of linear differential equations, and in 1888, a geometrical calculus including a chapter on mathematical logic. In 1900 he presented at the International Congress of Philosophy in Paris. Of him, Bertrand Russell said, in his *Autobiography*, “this was the turning point of my intellectual life ... In discussions at the Congress I observed that [Peano] was always more precise than anyone else, and that he invariably got the better of any argument on which he embarked. ... I decided that this must be owing to his mathematical logic ... an instrument of logical analysis such as I had been seeking for years.”

**Peirce, Charles Saunders (1839–1914).** A man of notably erratic temperament and son of a Harvard astronomer/mathematician, Peirce was born in Cambridge and educated at Harvard himself. Early research with the U.S. Coastal Survey into geodesy and gravimetrics, and his work on Boolean logic, led to contact with such logicians as W. S. Jevons and Augustus De Morgan. Noted for his essays “The Fixation of Belief” and “How to Make our Ideas Clear,” Peirce was appointed to a position at Johns Hopkins in 1879 where he developed a theory of relatives and quantifiers independently of Frege’s work. His career was beset with difficulties in the wake of his indiscretions; but his influence (particularly by way of Pragmatism, of which he was a primary founder) was substantial in the long run.

**Plato (427–347 BCE).** Student of Socrates, founder of the Athenian Academy, and teacher of Aristotle, Plato exercised the dialectical method not only to discover error but also to lead the way to insight. While we may debate the accuracy of the details of his insights, the broad sweep of the Platonic message remains intriguing. Plato’s notions of the human mind, will and appetites, his fundamental models for social organization, and his basic dualism of appearance and reality, have all found their way (through Aristotle, Descartes and others) into the modern mind set. Of primary interest here is his notion that the mind (in pre-existent circumstances) once had immediate access to reality (the Forms), and that the process of thought that leads to present understanding is essentially one of elucidating (through dialectic) what the mind remembers of what it already knows.

**Popper, Karl (1902–1994).** A very influential Austrian philosopher of science and politics, Popper insisted in *The Logic of Scientific Discovery* (1935) that scientific knowledge never advances by proving the truth of a theory (since that is impossible), but only through the systematic experiential falsification of alternatives to one. His controversy with Wittgenstein is legendary. In the long run, his political philosophy (in *The Open Society and Its Enemies*), has had greater impact than his theory of falsification; but that theory certainly influenced the development of Logical Empiricism, being particularly prominent in A. J. Ayer’s accounts of that movement.

**Port Royal Logic (1662).** Port Royal was a Jansenist convent near Paris, noted by logicians for *The Port Royal Logic*, one of the most widely used philosophical works of the 17th century. This volume dealt with traditional logic with a strong Cartesian flavor, and was in the vernacular. Written by Antoine Arnauld (1612–1694), and Pierre Nicole (1623–1695), and first published anonymously, it was translated into many languages and was widely influential.

**Quine, W. V. O. (1908–2000).** Son of an engineer and a school teacher, Quine was educated at Oberlin and Harvard. Having read James’s *Pragmatism* in school, and Russell and Whitehead’s *Principia Mathematica* as an undergraduate (!), he turned to mathematics and philosophy of mathematics at Harvard where, after his PhD, he was



appointed Junior Fellow in 1933 and instructor in philosophy in 1936. The lines of influence between Quine, the Logical Positivists, Russell and Whitehead were many and mutual. A prolific writer, perhaps his most influential essay was “Two Dogmas of Empiricism” in which he called empirical orthodoxy into serious (pragmatic) question, arguing that “it is folly to seek a boundary between synthetic statements, which hold contingently on experience, and analytic statements, which hold come what may.” Your lecturer had the honor to meet him at Oxford in 1974, finding him terse and more than a little intimidating, but warmly interested in the work of a young philosopher from the provinces.

**Russell, Lord Bertrand (1872–1970).** An English philosopher, logician, mathematician, freethinker and essayist, Russell was a student, fellow and professor at Cambridge, where he influenced the shape of philosophy for generations (by way of “both” Wittgensteins as well as the Vienna Circle), and set the course of all subsequent philosophy of logic and mathematics. His early works included *Principles of Mathematics* and *Principia Mathematica*. Mid-career books included *An Enquiry into Meaning and Truth* and *Human Knowledge*, plus myriad essays and polemics on topics ranging from education and marriage to nuclear disarmament. Social and political issues were his primary focus after 1949.

**Socrates (470–399 BCE).** A legendary, not to say mythic, figure in Western intellectual history, Socrates is remembered as the teacher of Plato, the gadfly of Athens, an alleged corrupter of youth and worshipper of false gods, and the master of what has come to be called “Socratic dialectic.” Convinced that wisdom begins in the realization of ignorance, Socrates committed himself to convincing one and all—in maddening conversations—of just how ignorant we are. Since Socrates appears repeatedly as a major player in the Platonic dialogues, it is not at all easy to know where Socrates leaves off and Plato takes over. It is likely, however, that the dialectical method of inquiry itself is truly Socratic. The notion of dialectic has been corrupted historically in the metaphysical schemes of Hegel and Marx.

**Venn, John (1834–1923).** Grandson of the founder of the Clapham Sect (a socially progressive religious movement) and son of the Secretary of the evangelical Church Missionary Society for Africa and the East, Venn was educated at Gonville and Caius College, Cambridge. Ordained a priest himself, Venn eventually pursued an academic life, with strong interests in both literature and mathematics. He significantly extended Boole's mathematical logic and is remembered for his diagrammatic representations of sets and their relationships with three circle figures. The relationships of these circles nicely represent the structure of all 256 types of classical categorical syllogisms.

**William of Ockham ( c.1280–c.1349).** An English Scholastic, Franciscan and philosophical nominalist, Ockham studied theology at Oxford (perhaps under Duns Scotus) and Paris, where he taught. Charged with heresy, and subsequently a refugee in Bavaria, he denied papal authority over temporal matters. A dogged opponent of metaphysical *largess*, he is more remembered today for his “razor” than for any particular treatise.

**Wittgenstein, Ludwig (1889–1951).** A Viennese/English philosopher, inventor and sometime schoolteacher, Wittgenstein studied engineering at Berlin and Manchester and mathematical logic at Cambridge, where he taught (with lengthy interruptions) between 1929 and 1947. The most influential Western philosopher of the 20th century, Wittgenstein's two major works, *Tractatus Logico-Philosophicus* and *Philosophical Investigations*, laid the foundations for Logical Atomism and Logical Positivism, on the one hand and for “ordinary language analysis” on the other. Neither an easy person nor an easy philosopher, this brilliant and quirky thinker stirs interest even among non-philosophers, as evidenced by the reception of David Edmonds' and John Eidinow's *Wittgenstein's Poker*.

## Bibliography

### Essential Reading:

Asimov, Isaac. *Asimov's Chronology of Science and Discovery*. New York: Harper Resource, 1991, ISBN 0062700367. Asimov's work is notable for its combination of scientific accuracy and accessibility to the general reader. This particular book will give you a good overview of the sweep of scientific progress and, more important, an insight into the methodology by which that progress was won.

Copi, Irving. *Introduction to Logic*. 11<sup>th</sup> ed. Upper Saddle River, NJ: Prentice-Hall, 2002, ISBN 0130337358. This book is clear and meticulous and covers all the bases, from informal logic (critical thinking), through classical and modern treatments of the syllogism and the basics of symbolic deductive logic, to inductive reasoning and probability. It has many useful exercises and has gone through many editions. The 11<sup>th</sup>, cited here, is not the latest, but it is readily (and cheaply) available on the used-book market.

Hempel, Carl. *Philosophy of Science*. Upper Saddle River, NJ: Prentice Hall, 1966, ISBN 0136638236. Not the newest but one of the best presentations of "mainstream" 20<sup>th</sup>-century philosophy of science. The book is short, clear, thorough, and uncompromising. Hempel's posture is empirical, as far as evidence is concerned, but his empiricism is nuanced in terms of the issues laid out in the next citation. Most important for present purposes, Hempel lays out a clear analysis of how hypotheses work in scientific explanations and of how they are formulated and supported.

Kuhn, Thomas S. *The Structure of Scientific Revolutions*. 3<sup>rd</sup> ed. Chicago: University of Chicago Press, 1996, ISBN 0226458083. This is where all the talk of "paradigms" and "paradigm shifts" comes from. As usual, you should have a look at the source of these notions before you make up your mind about the popularizers use (and misuse) of them. Kuhn is trying to show that science is not inevitably progressive and that its movement over time is not linear. Another important idea that crops up here is that scientific claims are "theory laden" and, hence, *not* "value-free." If so, then the tools that scientists use in their thinking are influenced by the immediate scientific milieu and by the larger culture in essentially political ways. This book channels Wittgenstein into postmodernism. It is not easy going.

### Recommended Reading:

Aristotle. *Prior Analytics*. Robin Smith, ed. Indianapolis: Hackett Publishing, 1989, ISBN 0872200647. Here, as with other volumes mentioned below, we are indebted to Hackett for a high-quality edition of a classical text at an affordable price. This part of Aristotle's legacy is devoted to basic logic. It is the wellspring of the enterprise in the west.

Ayer, A. J. *Language, Truth and Logic*. New York: Dover Publications, 1952, ISBN 0486200108. This is the classic manifesto of logical positivism in English. Ayer's skeptical rejection of everything "metaphysical" fairly bristles. It is not for the fainthearted. Even though this sort of aggressive empirical reductionism was reined in by Wittgenstein's move to "ordinary language," this is still a good account of the knowledge/evidence connection.

Beck, Lewis White. "Constructions and Inferred Entities." *Philosophy of Science*, XVII, 1950. Reprinted in *Readings in Philosophy of Science*, Herbert Feigl and May Brodbeck, eds. New York: Appleton-Century-Crofts, 1953. This essay explores the status of the unobservable "bits" that modern science has so much to say about, showing how scientific theory is empirical even though it is not directly about what we see, taste, smell, feel, and hear. It is a classic presentation of the essential role of responsible hypothesis construction in science.

Berlinski, David. *Newton's Gift: How Sir Isaac Newton Unlocked the System of the World*. New York: Free Press, ISBN 0743217764. This work captures the scope and impact of Newton's "revolution" with just enough attention to the technical side to make it useful for non-scientists in getting a handle on the history of science. It also provides useful insights into Newton himself and his era. The style is a little arch but not unbearably so.

Best, Joel. *Damned Lies and Statistics*. Berkeley: University of California Press, 2001, ISBN 0520219783. Evidence is important, but some evidence is much more important than the rest. Written strictly for the popular market, this book is about the difference. It will either teach you how to mislead others with statistics or how to avoid letting them mislead you. It is transparent, important, and funny and should be universally required reading.

Butler, Christopher. *Postmodernism—A Very Short Introduction*. Oxford: Oxford University Press, 2002, ISBN 0192802399. Part of an excellent new series, this (very) little book will help the reader figure out what is going on

when people start talking about *deconstruction* and other things “postmodern.” Much has been said in recent years to suggest that modern philosophy and modern science are hopelessly flawed and that all “knowledge” is local, relative, and agenda- and culture-driven. A few hours with this book will help the reader see the grounds and implications of those allegations and make a judgment about their merit.

De Kruif, Paul. *Microbe Hunters*. New York: Harvest Books (Harcourt), 2002, ISBN 0156027771. This is the original “gee-whiz” book about the heroes of modern medical discovery. Every boy and girl should read it for inspiration. Every adult should read it for increased understanding and appreciation of how hands-on experimental inquiry is done. Medical and scientific progress is not easy or cheap.

Descartes, René. *Meditations*. Indianapolis: Hackett Publishing, 1999, ISBN 0872204200. Rationalism embodied. It has been said that all of modern philosophy amounts to either the embellishment or the repudiation of Descartes. This little book is the nub of the matter. Here, “systematic doubt” allegedly leads to the deductive reconstruction of all knowledge from one necessary truth (*cogito ergo sum*). Empiricists disagree.

Dewey, John. *The Quest for Certainty*. Carbondale, IL: Southern Illinois University Press, 1988, ISBN 0809314932. Too often overlooked (perhaps because of its turgid style), this is a very important presentation of why epistemologies such as Descartes’ rationalism are doomed by their improper inclusion of “certainty” as one of the necessary conditions of knowledge. Dewey’s own pragmatic reconstruction of knowledge makes it provisional, dynamic, and possible (in contrast to Descartes’, which leaves it absolute, static, and unobtainable).

Fearnside, W. Ward. *Fallacy: The Counterfeit of Argument*. Upper Saddle River, NJ: Prentice-Hall, 1959, ISBN 0133017702. Not new, but worth scouting out on the Web for a used copy, this book catalogs (and gives examples of) just about every informal fallacy there is. Somebody needs to do a 21<sup>st</sup>-century update with current examples from the media, but the fallacies themselves haven’t changed, and this is a handy place to learn what they look like.

Hall, James. *Practically Profound*. Lanham, MD: Rowman & Littlefield, 2005, ISBN 0742543277. Modesty prevents me from assessing the quality of this and the next item. Suffice it to say here that most introductions to philosophy don’t take the time to tackle the question of what makes various beliefs and opinions good, bad, or indifferent. This one does.

———. *Logic Problems for Drill and Review*. Washington, DC: University Press of America, 1991, ISBN 0819183792. This little book contains the skeleton of symbolic deductive logic, plus several hundred problems (with solutions). If you want to learn logic from scratch, I recommend Copi. But if you want a quick profile (or a review), this will be useful.

Hawking, Stephen W. *The Illustrated Theory of Everything: The Origin and Fate of the Universe*. Los Angeles: New Millennium Press, 2003, ISBN 1932407073. This book is not cited because it is *true* or even because your lecturer *thinks* that it is true. It is cited because it dramatically illustrates the sweep of mature modern rational empiricism. No one should either dismiss science (whether on postmodern, religious, or other grounds) or pay homage to it without reading this book (alongside Asimov’s *Chronology*, cited above).

Hempel, Carl. “Problems and Changes in the Empiricist Criterion of Meaning.” *Revue Internationale de Philosophie*, Vol. 1, No. 11, 1950. Reprinted in *Classics in Analytic Philosophy*, Robert R. Ammerman, ed. Indianapolis: Hackett Publishing, 1990, ISBN 0872201015. This is the classic account of the core of logical positivism’s “verificationism.” It shows the pitfalls in this brand of rational empiricism and sketches out possible ways to work around them. The book in which this is reprinted is a gem of a collection. Kudos to Hackett for getting it back in print and keeping it there. When you have read Hempel’s essay, read the others.

Huff, Darrell. *How to Lie with Statistics*. New York: W. W. Norton & Co., 1993, ISBN 0393310728. This book is a cousin of Joel Best’s little volume, cited above. It is less a handbook for deceiving others than a manual for avoiding statistical landmines yourself. This is an enjoyable (even amusing) read, but more important, it is a crucial guide to how mathematics can be used and misused in “proofs,” scientific or otherwise.

Hume, David. *An Enquiry Concerning Human Understanding*. Eric Steinberg, ed. Indianapolis: Hackett Publishing, 1993, ISBN 0872202291. Empiricism embodied. This book does for empiricism what Descartes’ *Meditations* did for rationalism (but with greater success). Hume, too, dances with skepticism. As a result, he arrives at a rather startlingly confined profile of what we know. The treatment of induction and causation, the analysis of beliefs in terms of habits of mind, and the dismissal of “sophistry and illusion” are legendary. No serious thinker can ignore this work.

Jones, W. T. *A History of Western Philosophy*, Volume I, “The Classical Mind.” Belmont: Wadsworth Publishing, 1969, ISBN 0155383124. The five-volume series is old, but the presentation is balanced and the commentary is

illuminating. The advantage and the disadvantage of Jones's approach both lie in his reliance on lengthy quotations from the primary sources. This may tempt the reader to avoid tackling the primary sources head on, but it also helps the reader see whether or not Jones's own analysis is responsible to the texts.

Mill, John Stuart. *A System of Logic: Ratiocinative and Inductive*. New York: Harper and Brothers, 1891. Available as a reprint from University Press of the Pacific, ISBN 1410202526. Far too expensive for a casual purchase, this work can be found in any nearby college library. It is the source of "Mill's method," the backbone of inductive reasoning as it is presented in standard logic texts, such as Copi's (cited above).

Okasha, Samir. *Philosophy of Science—A Very Short Introduction*. Oxford: Oxford University Press, 2002, ISBN 0192802836. Short, excellent, and current, if not as systematic and meticulous as Hempel's treatment (cited above). This book will give the reader an idea of what the current issues are among those who try to map and explain what scientists are up to.

Pinker, Steven. *How the Mind Works*. New York: W.W. Norton and Company, 1997, ISBN 0393318486. If there are any tools of thinking, surely the mind is one of them. But the mind has been the subject of more heat than light in philosophical discussions over the last 2,000 years. Pinker brings neuroscience and other modern tools to the analysis of how this tool operates. This is an exciting read and is totally accessible to the layman.

Plato. *Meno*. G. M. A. Grube, trans. Indianapolis: Hackett Publishing, 1980, ISBN 0915144247. Plato's ideas about how the mind works are not like Pinker's. This little dialogue lays out his basic notion that "recollection" is the key to learning, thinking, and understanding. But that presupposes the preexistence of the "soul" and the objective reality of the "Forms." This is the taproot of traditional rationalism and mind/body dualism.

———. *Republic*. G. M. A. Grube, trans. Indianapolis: Hackett Publishing, 1974, ISBN 0915144094. This is Plato's gem. Everyone should read it for its political, social, and moral implications (some of which are chilling, as noted by Karl Popper in his masterpiece, *The Open Society and its Enemies*—a book worth chasing down). What is of interest here, however, is Plato's conceptions of appearance and reality, the mind (cognitive soul), and knowledge. In the Myth of the Cave, Plato lays all that out metaphorically. The point is the same as in the *Meno*, and if the metaphor is supposed to describe reality, then the metaphysical price tags (and their Cartesian legacy) are even more obvious.

Popper, Karl. *The Logic of Scientific Discovery*. New ed. New York: Routledge, 2002, ISBN 0415278449. In this work, Popper disputed one of the initial tenets of logical positivism, viz. that all meaningful propositions are verifiable in principle. Because that would rule out universal claims, however, Popper suggests that all meaningful propositions are falsifiable in principle. This is all explained nicely in Hempel's essay, cited above. The value of this book is not to be found in the details of the arguments over verification and falsification, however. Its value resides in the notion that scientific discovery is hypothesis driven. This, too, is explained well in the Hempel essay, as he discusses scientific *method*.

Quine, W. V. O. "Two Dogmas of Empiricism." In *From a Logical Point of View*. Cambridge: Harvard University Press, 1980, ISBN 0674323513. Reprinted in *Classics in Analytic Philosophy*. Robert R. Ammerman, ed. Indianapolis: Hackett Publishing, 1990, ISBN 0872201015. This essay calls into question the notion that there is a bright-line distinction between analytic and synthetic statements (and, derivatively, between *a priori* and *a posteriori* knowledge). If there is no such bright-line distinction, then the traditional distinctions between deductive and inductive reasoning need to be rethought. This article contributed in a major way to the postmodern relativizing and pragmatizing of secure inference.

Rosenberg, Jay F. *The Practice of Philosophy: Handbook for Beginners*. 3<sup>rd</sup> ed. Upper Saddle River, NJ: Prentice Hall, 1995, ISBN 0132308487. This simple book lays out basic philosophical methods in very attractive and intelligible form. Reading it will help you understand what is going on in the philosophical essays and books that you read.

Schilpp, P. A. *Albert Einstein: Philosopher-Scientist*. Chicago: Open Court Publishing, 1988, ISBN 0875482864. We are indebted to Professor Schilpp for a large set of volumes about 20<sup>th</sup>-century philosophers, of which this is one. Here you will find Einstein's statement of his own philosophical/scientific outlook, numerous essays by his contemporary critics, and his reply to them. It is not a scientifically technical collection. It is about the broad sweep of Einstein's thought.

Turing, A. M. "Computing Machinery and Intelligence." *Mind*, Vol. LIX, No. 236 (1950). Reprinted in *Minds and Machines*. Allen Ross Anderson, ed. Upper Saddle River, NJ: Prentice Hall, 1964. This really is a classic. The point

of bringing it up is that it was one of the first persuasive essays written that suggested the *possibility* of artificial intelligence. This has become very important as the computer has become more and more central as a thinking tool.

Unger, Peter. *Ignorance, A Case for Skepticism*. Oxford: Oxford University Press, 2002, ISBN 0198244177. This is a definitive presentation of modern radical skepticism. You don't have to agree with Unger to see the power of his arguments to the effect that no one ever knows anything. Of course, if he is correct, then it doesn't matter whether you agree with him or not. Your lecturer does not agree with Unger, and I have tried to refute the line of argument he takes in my *Practically Profound*. I bring him up here simply because everything we have explored about *how* we know presupposes the possibility of knowing something—a presumption that we cannot ignore.

White, Jamie. *Crimes Against Logic*. New York: McGraw-Hill, 2004, ISBN 0071446435. This is another treatment of fallacious reasoning. It is less systematic but far more amusing, than Fearnside's work, cited above.

### **Internet Resources**

#### **Critical thinking:**

<http://www.austhink.org/critical/>

<http://www.criticalthinking.org/>

#### **History of logic:**

[http://www.formalontology.it/history\\_of\\_logic.htm](http://www.formalontology.it/history_of_logic.htm)

#### **History of mathematics:**

<http://www.maths.tcd.ie/pub/HistMath/>

#### **History of science:**

<http://www.fordham.edu/halsall/science/sciencesbook.html>

#### **History of science emphasizing chemistry (Chemsoc timeline):**

<http://www.chemsoc.org/timeline/index.html>

#### **History of ideas and inventions:**

<http://www.ideafinder.com/history/index.html>

<http://inventors.about.com/>

#### **History of calculators and computers:**

<http://www.xnumber.com/xnumber/> (click on "vintage calculators")

<http://www.hitmill.com/computers/computerhx1.html>



**Tools of Thinking:  
Understanding the World through  
Experience and Reason**

**Part II**

**Professor James Hall**



**THE TEACHING COMPANY ®**





## James H. Hall, Ph.D.

Thomas Professor of Philosophy, Emeritus, University of Richmond

Born in Weimar, Texas, in 1933, I spent my early childhood there and in New Orleans, Louisiana. Just before World War II, my family moved to Washington, D.C. I lived in that city and received my education from its public schools, museums, and newspapers, until I went off to college in Baltimore, Maryland, in the fall of 1951.

I knew *that* I wanted to teach by the time I graduated from high school, but I didn't know *what* I wanted to teach until much later. So I made a career of being a student for 12 more years (at Johns Hopkins University, Southeastern Theological Seminary, and the University of North Carolina at Chapel Hill), before trying to earn a living full time.

I had discovered my discipline by 1959, but it was 1965 before I found my school and my city. Each of the 40 years since then has confirmed my good fortune in joining the University of Richmond community and putting my roots down.

Teaching is my calling and first professional priority. I am especially gratified to have been declared "Outstanding Faculty Member of the Year" by both Omicron Delta Kappa and the Student Government of the University of Richmond at the end of my last year in the classroom. With 44 years at the blackboard, I have taught most of the standard undergraduate philosophy curriculum, including *Symbolic Logic*, *Moral Issues*, and *Philosophical Problems* to thousands of beginners and advanced courses and seminars on *Analytic Philosophy* (especially the works of Russell, Ayer, Wittgenstein, Ryle, and Austin), *Philosophy of Religion*, and *Epistemology* to hundreds of philosophy majors and minors. I have also pursued a number of issues beyond the boundaries of philosophy per se, in interdisciplinary courses as varied as *Science and Values*; *The Ideological Roots of the American Revolution*; and *Science, Pseudoscience and the Paranormal*. My research has produced an adult education series for The Teaching Company (*Philosophy of Religion*) and three published books (*Knowledge, Belief and Transcendence*; *Logic Problems*; and *Practically Profound*), with another in progress (*Taking the Dark Side Seriously*).

A life totally confined to the ivied tower would be truncated and precarious. My own is constantly expanded and kept in balance by ongoing involvements in church (Episcopal), politics (Democratic), and choral music (from Bach to Durafle, with just a dash of Ralph Vaughan Williams) and by travel (Wales or the Pacific northwest for preference) and a daily bout with the *New York Times* crossword. Many people outside of the academy have enriched my life by their work—Herblock and Harry Truman, John D. MacDonald and David Lodge, to name four—and others by their friendship and character—chief among them my wife, Myfanwy, and my sons, Christopher, Jonathan, and Trevor.

My complete track record, academic and otherwise, can be seen on the Web at: <http://www.richmond.edu/~jhall/>.

E-mail will always reach me at: [jhall@richmond.edu](mailto:jhall@richmond.edu).

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## Tools of Thinking: Understanding the World through Experience and Reason

### Scope:

Whenever we decide to do a little thinking, a variety of tools are available for the enterprise. Perhaps we will try to remember what we already know or believe (regardless of how we came by it). Perhaps we will try to deduce something from what we already know or believe. Perhaps we will engage in the give and take of dialectic. Perhaps we will try to identify patterns in what we already know or believe (and remember) that would allow us to generalize it or extrapolate from it to claims of broad (or even universal) scope. Perhaps we will give free rein to the flow of our ideas, allowing them to call one another before the mind's eye in some pattern of association. Perhaps we will turn to sense experience and experimentation to provide the raw materials for some belief or knowing. Perhaps we will invent a model, hypothesis, metaphor, or rule to try to hang all or part of what we believe or know together in some systematic way. Or perhaps we will engage in a vigorous round of hypothesis and counterexample. Whatever tools we use, it is likely that we will, at some point, appeal to "intuition" to back up the general enterprise or some particular foundational piece of it. Whatever tools we use, of course, will involve some risks.

The purpose of this course is to trace out in a semi-historical way how modern rational empiricism has arrived at its tool kit for thinking (a tool kit particularly well modeled by modern natural science but also employed in a wide variety of other, everyday, enterprises). We will look at some of the ideas of Plato, Aristotle, Descartes, Hume, and Newton, interspersed with some representative attention to the methods and limitations of classical syllogistic logic, modern sentential and predicate logic, and Mill's theory of induction. We will also note the necessity of making room for conceptual invention when setting up general principles to organize our thoughts and give close attention to the crucial roles of hypothesis construction and experimentation in the thinking of modern rational empiricists.

As we work through these matters, we will note the frequent occurrence of broadly skeptical ideas about the very possibility of thinking reliably. These include Plato's mistrust of appearances, Descartes' mistrust of sense experience, Hume's mistrust of all general claims, the logical empiricists' mistrust of any claim that is untestable, and postmodern concerns about paradigms and paradigm shifts and the extent to which our thinking is controlled by the culture in which we find ourselves. The purpose of this course, however, is not the refutation of general or systematic skepticism. I have dealt with that in another work— see my *Practically Profound* (Lanham: Roman and Littlefield, 2005), Part I (Belief) and Part II (Knowledge). The present concern, rather, is to show how the various tools that we use in our thinking can lead us to generally reliable (not perfect) beliefs and useful (not certain) knowledge. Further, while any number of thinkers would add revelation and faith to the items set out in the first paragraph here, the purpose of this course does not include the systematic examination of such matters. (I have dealt with them in my Teaching Company course of 2003, *Philosophy of Religion*). The present concern, rather, is to explore the tools that are appropriate to more mundane matters, such as science, history, and navigating the everyday vicissitudes of life.

One thing will emerge from these reflections: There is no *one* tool for thinking. Experience by itself begets chaos in the absence of pattern recognition, memory, association, and some form of reasoning. Reason by itself is sterile absent some practically reliable bases from which to draw our inferences, explanations, and generalizations. Intuition by itself offers no decision procedure. Invention by itself is dangerously speculative. The magic is in the mix.

Because this course is a broad and rapid survey of vast and complex matters, it will not answer all (or even most) of the questions that will occur to you along the way about the mind, our sensory apparatus, belief, knowledge, reasoning, and logic, much less about mathematics, science, philosophy, ethics, and all the other great systematic ventures of the mind. It will, however, deal with some of the important ones and provide references to works where many of the others can be explored. It is a starting point, not a destination.

## Lecture Thirteen

### Proper Inferences Avoid Equivocation

**Scope:** If we rely on experiences as evidence for our inferences and explanations, we must screen the ways in which we handle those that offer themselves so as to avoid making unwarranted presumptions about them and to avoid exploiting their ambiguity in various tempting ways. Otherwise, we may be guilty of fallacies of presumption and ambiguity in a variety of ways. Several representative types of such fallacies are explained in this lecture, and examples are provided. Examining them will help us avoid egregious errors in our thinking. Although thinking that commits such fallacies is common, it is always misleading.

#### Outline

- I. If we rely on experiences (or anything else for that matter) as evidence for our inferences and explanations, we must screen the ways in which we handle them in order to avoid making unwarranted presumptions about them and equivocating over what they mean.
  - A. These cautions are also prerequisites for useful inference drawing.
  - B. When we presume, in one way or another, facts that are not in evidence, and when we play fast and loose with the meanings of our locutions, we are (once again) “not even in the ballpark, much less in the game.”
- II. Here are descriptions and examples of eight forms that such bad reasoning can take.
  - A. *Petitio principii*. This fallacy amounts to inferring a conclusion from premises that are, in fact, indistinguishable from the conclusion itself. This fallacy is also called *circular reasoning* and *question begging*.

**Example:** I know that God exists because the Bible says so. And I know that everything in the Bible is true because it is God’s word and God wouldn’t lie.
  - B. *Complex question*. This fallacy amounts to presuming without evidence that a certain state of affairs obtains, then shaping one’s inquiry in terms of that presumption.

**Example:** The classic is “Have you stopped beating your wife?” but it is equally clear in “Don’t you want to be a good boy and go to bed?”
  - C. *Equivocation*. This amounts to exploiting ambiguities of words. Some are simple plays on an everyday noun or adjective. Some exploit the subtleties of dispositional and episodic participles.

**Examples:** When mother asks, “Were you good at the party, Susie?” Susie responds, “Well, Miles said I was.” When father asks, “Are you smoking [these days], Fred?” Fred responds, “No I’m not [right this moment].”
  - D. *Amphibole*. This fallacy amounts to exploiting ambiguities of syntax.

**Example:** A subway rider explains why he lit a cigar right next to the sign that said “No Smoking Allowed” by noting the two ways that sign can be read: “Smoking is forbidden” and “Refraining from smoking is permitted.”
  - E. *Accent*. This fallacy amounts to exploiting ambiguities of emphasis, including selective data use.

**Example:** Story positioning in the media, headline writing, and small print on a box of Broccoli Rice Surprise show just what accent can do.
  - F. *Category mistake*. This fallacy amounts to exploiting ambiguities of classification. The term comes from Gilbert Ryle’s *The Concept of Mind*.

**Example:** Not seeing the forest for all the trees, the parade for all the marchers, and the university for all the buildings and greens are all examples of confusing things and systems. “If we have minds, then where are they?” is a more telling case in point.
  - G. *Composition and division*. These fallacies amount to exploiting ambiguities between the properties of individuals and the properties of the sets that they compose.

**Example:** “Everyone in my gymnastics class is *tiny*. There’s no one there over 80 pounds. I can’t see why the instructor is complaining that the class is too big.”

**H. False dilemma.** This fallacy amounts to exploiting ambiguities of complementarity.

**Example:** “Well, Ali was certainly no hero, so he must have been a coward.”

**Essential Reading:**

Irving Copi, *Introduction to Logic*, Chapter 4, Sections 3 and 4 (“Fallacies of Presumption” and “Fallacies of Ambiguity”), pp. 156ff.

**Recommended Reading:**

W. Ward Fearnside, *Fallacy: The Counterfeit of Argument*.

**Questions to Consider:**

1. Why do you suppose that one must swear to tell the truth, the whole truth and nothing but the truth in court? Why isn't it enough just to swear not to lie?
2. Why do you suppose that when Clinton was asked, “Did you have sexual relations with XYZ?” he responded, “Are we talking Arkansas Code here?”

## Lecture Fourteen

### Induction Is Slippery but Unavoidable

**Scope:** Generalizing over particulars is a problematic way to establish universal claims. The first “problem of induction” is the alleged circularity of all such reasoning. Whether that problem can be effectively solved or is simply shelved, other issues remain about the methods to use to reach general truths, about the probabilistic limitations of such methods, and about the reliability of the bases of our inferences. After making a pragmatic assumption about the regularity of nature, we will look at John Stuart Mill’s classic analysis of the inductive methods of *agreement*, *difference*, *residues*, and *concomitant variation*. These are illustrated with examples to help us understand what induction can do and its limitations. Then, after a brief look (in Lecture Fifteen) at a simplified account of Newton’s “hypothesis-free” explanations, the stage will be set for a discussion (in Lecture Sixteen) of how explanatory hypotheses are constructed and used in contemporary science.

### Outline

- I. Even if questions of relevance, ambiguity, and presumption have been satisfactorily taken care of, generalizing over particulars is a problematic way to establish universal claims.
  - A. The first problem of induction is basic.
    1. Predicting that unobserved or future events will be like the events that are or have been observed assumes the uniformity of nature.
    2. But if the only reason to think that nature will remain uniform is that it has done so thus far, then this assumption is clearly circular or question begging, as Hume notes.
    3. Are there any other reasons to think that nature is uniform? An appeal to natural law is equally circular, appeals to divine constancy or the immutability of the Forms lack any experiential grounds, and an appeal to intuition or insight is radically subjective.
    4. If we cannot effectively “prove” induction, we can bite the bullet and beg the question. There is little practical advantage to be gained by *not* presuming the uniformity of nature.
  - B. Even if we simply shelve this problem, however, other issues remain about the methods to use to reach general truths, about the probabilistic limitations of such methods, and about the bases of our inferences.
    1. Something more than simple enumeration of similarities is called for because this takes no notice of disconfirming instances and, hence, provides no effective test for any putative natural law.
    2. Inductive inferences are probabilistic, at best. They don’t provide closure:
      - a. They “affirm the consequent” (if P then Q; Q, therefore P).
      - b. They presume that surprises will not occur in nature.
      - c. They may, in any instance, overlook alternative accounts.
    3. Our inferences are no stronger than their bases. Consequently, all of the difficulties with the reliability of experience, as well as with the reliability of our recall and pattern recognition, come into play.
- II. John Stuart Mill provides a useful analysis of inductive methods in *A System of Logic*, identifying the techniques of agreement, difference, residues, and concomitant variation.
  - A. *Mill’s method of agreement*: “If two or more instances of the phenomenon under investigation have only one circumstance in common, the circumstance in which alone all the instances agree is the cause (or effect) of the given phenomenon.”

**Example:** Looking for an itinerant Typhoid Mary.
  - B. *Mill’s method of difference*: “If an instance in which the phenomenon under investigation occurs and an instance in which it does not occur have every circumstance in common, save one, that one occurring only in the former, the circumstance in which alone the two instances differ is the effect, or the cause, or an indispensable part of the cause of the phenomenon.”

**Example:** Autopsies, hand washing, and childbed fever.
  - C. Mill’s methods of agreement and difference can be used together.

**Example:** Using control groups and switchover testing for pharmaceuticals.

D. *Mill's method of residues*: "Subtract from any phenomenon such part as is known by previous inductions to be the effect of certain antecedents, and the residue of the phenomenon is the effect of the remaining antecedents."

**Example**: Isolating the effect of video gaming on eye-hand coordination.

E. *Mill's method of concomitant variation*: "Whatever phenomenon varies in any manner whenever another phenomenon varies in some particular manner is either a cause of that phenomenon or is connected with it through some fact of causation."

**Example**: Carefully tracking behaviors of ADD children when on and off their meds.

III. These methods and examples help us understand what induction can and cannot do.

A. Induction can suggest hypotheses to "try on for size" and usefully *test* the ones we come up with.

B. Induction can't *prove* a hypothesis.

1. Induction yields only probability.

2. Induction can operate in ignorance of crucial variables.

3. Induction can't rule out alternative hypotheses that haven't been thought of yet.

IV. After a brief look (in Lecture Fifteen) at a simplified account of Newton's "hypothesis-free" explanations, the stage will be set for a discussion (in Lecture Sixteen) of how explanatory hypotheses are constructed and used in contemporary science.

**Essential Reading:**

Irving Copi, *Introduction to Logic*, Chapter 12, Part 2, "Mill's Methods," pp. 455ff.

**Recommended Reading:**

Paul De Kruif, *Microbe Hunters*.

**Questions to Consider:**

1. What is wrong with Mark Twain's famous induction that his lack of dental problems is the result of his predilection for rye whiskey?
2. What is wrong with Erich Von Daniken's inference (in *Chariots of the Gods*) that some artifacts that he observed in the Yucatan jungle were litter from space-alien visitations?

## Lecture Fifteen

### The Scientific Revolution

**Scope:** Early modern scientific thinking depended on powerful mathematical and observational tools and strictly presumed the regularity of nature. For example, using Isaac Newton's concept of reality as "matter in motion" presupposes reliable mathematical techniques for measuring motion, the availability of detailed state descriptions, and the existence of knowable natural laws in terms of which matter's motion can be understood. All three are essential for generating the predictions that are the hallmark of early modern science. Given that Newton denied making hypotheses, one might suppose that the conception of reality, the mathematical apparatus, the natural laws, and the state descriptions that he used must all be reports of, or inferences of one sort or another from, observations. But, as we shall see, this supposition is highly problematic.

### Outline

- I. Early modern scientific thinking depended on powerful mathematical and observational tools and strictly presumed the regularity of nature.
  - A. Isaac Newton conceived of reality as "matter in motion." Making any use of that conception presupposes the availability of a reliable mathematical technique for measuring motion.
    1. Newton himself invented the calculus, and others before him had invented geometry, analytic geometry, and so on.
    2. Contemporary science is strongly mathematical in all its branches, and the mathematical tools involved are not exactly "empirical."
  - B. Newton's science also presupposes the availability of detailed state descriptions. That necessitates the availability of reliable observational instrumentation for obtaining the data to be measured.
    1. What is a *state description* in Newtonian science? A state description is an account of a closed physical system, in which you precisely locate all of the components of that system and precisely identify the direction and momentum of their movement.
    2. Why are state descriptions so important? With a state description of a physical system and an understanding of the natural laws that govern that system, we can predict future state descriptions of that same system or, for that matter, retrodict descriptions of that same system at some earlier time.
    3. What sort of instruments do we need in order to achieve these accounts? Everything from accurate clocks to the apparatus of modern scientific laboratories.
  - C. Newton also strictly affirmed the existence of knowable natural laws in terms of which matter's motion can be understood.
    1. This invokes the uniformity of nature again.
    2. While Newton may have seen natural laws as having a "divine" origin, this is not crucial to the enterprise. They can just as easily be read in "naturalistic" terms.
    3. There is one group within the "intelligent design" family, who for theological reasons, denies the uniformity of nature.
- II. Mathematical apparatus, precise state descriptions, and natural laws make what we call *understanding* possible. All three of these factors are essential for the generation of the predictions that are the hallmark of modern science.
  - A. This uniformity and these laws make prediction and retrodiction possible.
  - B. This all seems to entail (or presume) that "strict causal" determinism is true of the natural order.
  - C. However, Newton's notion of causation, known as *strict causal determinism*, generates problems.
    1. Certain theologians do not want to see divine volitions constrained by anything external.
    2. Certain philosophers see problems in the areas of human free will and determinism, as well as human responsibility.
    3. Many contemporary physicists, following the work of Heisenberg, dispute the Newtonian notion that nature is, in fact, strictly causally determined.



- III. What is the status of “hypotheses” in early modern science? Isaac Newton famously said, “I don’t make hypotheses” (“*hypotheses non fingo*”).
- A. Given that Newton’s didn’t make hypotheses, one might suppose that the conception of reality, the mathematical apparatus, the natural laws that he “discovered,” and the descriptions that he used to generate predictions must all have been direct reports of observations, generalizations of observations, or inferences from those reports and generalizations. Otherwise, where did they come from?
  - B. These suppositions are, however, highly problematic.
- IV. Consider where mathematical tools come from.
- A. We could make a case that traditional Euclidian geometry is just a generalization from observations by farmers, carpenters, and shipwrights, and the like.
  - B. However, for calculus or for Descartes’ invention of analytic geometry, which translated geometry into an algebraic system, nothing from the level of observation seems sufficient to generate these tools.
  - C. If we did not garner mathematical tools from the world of Platonic Forms and if we did not generalize them from specific observations in this world, then I suggest they come in large part from the inventive genius of individuals who say, “What if?” and then work out the implications of their hypotheses and put them to the test experimentally.
- V. Consider where natural laws—or our ideas of natural laws, at least—come from.
- A. Newton’s law of universal gravitation states that everything in the universe is impelled by a gravitational force toward everything else in the universe, according to a very precise mathematical formula.
  - B. Yet we cannot comfortably say that the law of gravity (or, for that matter, gravity itself) is directly observable.
  - C. Natural laws are descriptive, and descriptive laws differ from prescriptive ones.
    1. Descriptive laws are very general, detailed, and inclusive accounts of the way the world works. They are not prescriptions of what will, should, or ought to be.
    2. Descriptive laws are revised constantly to make them more and more accurate. Indeed, Newton’s law of universal gravitation has been revised numerous times in just that way.
- VI. Natural laws, mathematical principles, and state descriptions are not simple observation reports.
- A. Contemporary philosophers of science note the extent to which Newton’s (or anyone’s) tools, laws, and state descriptions are “colored” by theories that are already in place (that is, they are *theory laden*). We shall examine this matter in Lecture Twenty-Three.
  - B. Newton hypothesized his mathematical apparatus and an array of natural laws. Using those hypotheses, he described what he saw in terms of that mathematical and theoretical apparatus.
  - C. Looking at Newton from this vantage point, we can observe that when he said, “I make no hypotheses,” he was saying that he did not make grand, sweeping, metaphysical, untestable, or bizarre ones—that he tried to keep his hypotheses *grounded*.

**Essential Reading:**

Samir Okasha, *Philosophy of Science—A Very Short Introduction*.

**Recommended Reading:**

Irving Copi, *Introduction to Logic*, Chapter 13, “Science and Hypothesis,” pp. 493–503.

**Questions to Consider:**

1. Is it a strength or is it a weakness that scientific explanations are always open to revision in the light of additional data, new hypotheses, and/or refined observations?
2. What do you think is the connection between the various particles, waves, and so on, that physicists talk about and what we can actually observe with our senses?

## Lecture Sixteen

### Hypotheses and Experiments—A First Look

**Scope:** If important theories and laws, and even the existence of the entities and forces they are “about,” can’t be inferred from our observations, then something like hypothesis construction (or invention) will have to have a place in explanatory thinking. *What* place to make for it in science has been disputed, raising issues about whether (and, if so, how) scientific inquiry is genuinely empirical. Irresponsible hypothesis construction, after all, is hard to distinguish from mere speculation. Responsible hypothetical inquiry is grounded in testing and experimentation—a dialectic of hypothesis and counterexample. Hypotheses that are grounded and confirmed in this way generate covering laws. Covering laws provide the building blocks for state descriptions and testable predictions.

#### Outline

- I. If scientific inquiry were limited to describing and trying to explain macro-level observations, then we might be able to make a somewhat plausible case for a methodology that boils down to observation and simple elaboration, or generalization, based on it.
  - A. That might work for certain kinds of biological or botanical classification and taxonomy. It might work for kitchen science.
  - B. However, a great many of the things that scientists have the most to say about are things that we have never in any sense directly observed.
- II. If important theories and laws, and even the existence of the entities and forces they are “about,” can’t be inferred from our observations, then something like the construction or invention of hypotheses will have to have a place in explanatory thinking.
- III. This is equally true of both scientific and “everyday” explanations. But while the need for hypotheses in both venues is obvious, the precise role and status of a hypothesis in a scientific explanation has long been a topic of debate.
  - A. We cannot “infer” that the Sun will rise tomorrow from our observation that it has risen every day that we can remember. We can (and do) expect that it will do so, but that is part habit, part hope, and all hypothetical.
  - B. Nor can we “infer” that atomic nuclei can be fused from any observations of atomic nuclei that we have ever had. Indeed, given that we have never observed even one atomic nucleus, the difficulty here is not just the “problem of induction.”
  - C. Thus, we (somehow) construct or invent hypotheses, entertain the supposition that they are true, and on that supposition, infer the possibility of particular fusions from the hypothesis package itself. The inference is *from* the hypothesis, not *to* it.
- IV. The use of invented hypotheses in constructing a scientific explanation raises an issue: If the hypotheses themselves are not derived from observations, then in what sense is a scientific explanation that employs them “empirical”?
  - A. Irresponsible hypothesis construction is, after all, hard to distinguish from mere speculation.  
**Negative example:** Erich von Daniken’s *Chariots of the Gods*.
  - B. Intemperate hypothesis construction violates Ockham’s Razor.
    1. One should never hypothesize more than is needed.
    2. This is also known as *theoretical economy* or *parsimony*.
  - C. Rational empiricists, consequently, have a healthy mistrust of untested (and especially *untestable*) hypotheses about matters of fact.
  - D. Rational empiricists insist that responsible explanations are always grounded, somehow, in testing and experimentation—a dialectic of hypothesis and counterexample as old as Socrates but still at the core of things.

- E. That testing, however, is *indirect*. We test the *output* of the hypothesis, theory, or explanation, not the thing itself.
- F. Successful testing, then, does not prove a hypothesis true (that is the fallacy of affirming the consequent), but unsuccessful tests can defeat a hypothesis. Accumulated successes are said to “support” a hypothesis or “lend it weight.”
- G. As famously noted by such scientists as Albert Einstein and such philosophers as Karl Popper and Carl Hempel, this *empirical connection* is, curiously, “after the fact.” We will examine some of the implications of this in Lectures Seventeen and Eighteen.
- H. Output testing (that is, experimentation) is not only a check on our idle fancies, but it can also reveal opportunities for new hypotheses and, hence, new avenues of research.
- I. When several hypotheses have been advanced and experimentally confirmed, they can be woven together into progressively more inclusive explanatory tapestries as theories, laws, and covering laws.

**Essential Reading:**

Carl Hempel, *Philosophy of Science*, Chapter 5, “Laws and Their Role in Scientific Explanation,” pp. 47–69.

**Recommended Reading:**

Irving Copi, *Introduction to Logic*, Chapter 13, “Science and Hypothesis,” pp. 504–522.

**Questions to Consider:**

1. If our hypotheses “color” the way in which we perceive the results of our experiments, does this mean that our experiments are irretrievably tainted? How can experimental output help us “correct” a hypothesis if that output is filtered by the hypothesis in question?
2. What are the relative merits of the two following “explanations” of rain in central Virginia?
  - (a) “It rained because the confluence of cold air moving southeastward from Alberta and moist warm air moving westward off the Atlantic caused the ambient temperature of the atmosphere over central Virginia to drop below the dew point.”
  - (b) “It rained because the Chickahominy elders performed a rain dance.”

## Lecture Seventeen

### How Empirical Is Modern Empiricism?

**Scope:** At the macro level, direct observations and inferences from them (that is, generalizations and extrapolations) are possible. Inquiry that is thus *based on* empirical data is *genetically* empirical. At the micro level, however, and at the theoretical and abstract level, a different kind of empirical link is required. Here, that link is to the *testable output* of the hypotheses rather than to their *sources*. Such inquiry is *confirmationally* empirical. One interesting implication of this is that the pedigree of hypotheses becomes epistemically less important than tradition had held. This opens the door to theoretical imagination, creativity, and conceptual invention, but it also keeps our potentially speculative excursions empirically connected in terms of what can demonstrably be done with them.

#### Outline

- I. At the macro level, direct observations and inferences from them are possible, if not foolproof.
  - A. Direct observations are crucial and available when considering such matters as the concomitant variation of fertilizer use and crop yield.
  - B. Generalizations and extrapolations from observations are exactly the thing if we are trying to decide whether to expand an agricultural practice that has been useful.
  - C. Possible problems arise of course. We can mis-see, misconstrue, and mis-infer. Indeed, all of the fallacies are possible, especially hasty generalization.
  - D. Inquiry that is thus *based on* empirical data is *genetically* empirical.
  - E. Through the first third of the 20<sup>th</sup> century, there was a controversy among philosophers of science about whether science had to be *genetically* empirical at every point, that is, about whether every scientific claim must be rooted in observations.
- II. At the micro level, however, where we may have no direct observations to generalize, a different kind of empirical link is required.
  - A. Here, since we have no direct observations, there is nothing to generalize or extrapolate. We can use  $e = mc^2$  to calculate the energy of an atomic reaction, but never having directly observed the reference of  $e$ ,  $m$ , or  $c$ , or any atoms, we don't get that formula inductively.
  - B. Thus, we have to hypothesize general principles, rather than infer them. This is exactly what was done to arrive at  $e = mc^2$ .
  - C. The link here must be to the *testable output* of the hypotheses, not to their *sources*. Such inquiry is *confirmationally* rather than *genetically* empirical.
    1. This amounts to what A. J. Ayer called "indirect verification" in *Language, Truth and Logic*.
    2. With  $e = mc^2$ , of course, that output is *plainly* observable.
  - D. This requires that a hypothesis be in place. You cannot test what you have not hypothesized. But it says *nothing* about where the hypothesis is to be obtained.
    1. Call it inspiration, luck, or genius, we are eternally indebted to the contributions of a Newton or Semmelweis.
    2. Most of us spend our time working out the implications of those insights, testing them, modifying them, working with them, exploring in terms of them.
  - E. The empirical connections of the hypotheses' output may not be obvious without the help of mathematics, complex instrumentation, and very creative "supplementary" or "bridging" hypotheses.
    1. You cannot confirm a hypothesis about radiation by using a Geiger counter unless you have a Geiger counter and all of the subsidiary information, protocols, and theories that make one useful.
    2. It is not just a flash of insight. Perhaps 99 percent of the scientific work comes between the insight and the output.
  - F. Possible problems arise, of course.
    1. For hypotheses-in-hand, the main problems center on how to decide between rivals.

2. This is where coherence, mesh, scope, fertility, capacity for self-correction, the breadth of data covered, mesh with other theories, and the like, as noted in Lecture Nine, come into play (along with Ockham's Razor).
3. Deciding between alternative hypotheses is typically a pragmatic decision procedure—seeking something that works, both in terms of the quality and reliability of the output that comes out of the theory and of the productivity of the theory as compared to its rivals.
4. For scientists, police detectives, and dimwitted spouses, however, the main problem may be in coming up with any hypothesis at all.

III. On this view, as Einstein famously noted, the pedigree of hypotheses is of far less epistemic importance than tradition had held.

- A. Confirmational empiricism opens the door to theoretical imagination, creativity, and conceptual invention. This is the venue not only for creative geniuses but also for ordinary folk who pay very close attention to what they *do* observe and have the ability to *make* connections where connections cannot be seen.
- B. But confirmational empiricism also keeps our potentially speculative excursions empirically connected in terms of what can demonstrably be done with them.
- C. That “connection” is why experimentation in general, and good experimental method in particular, are so important. We shall look at this closely in Lecture Eighteen.

**Essential Reading:**

Carl Hempel, *Philosophy of Science*, Chapter 2, “Scientific Inquiry: Invention and Test.”

**Recommended Reading:**

Lewis White Beck, “Constructions and Inferred Entities.”

Philipp G. Frank, “Einstein, Mach and Logical Positivism.”

**Questions to Consider:**

1. In the model of an atom on my desk, the electrons are green. What color are real electrons?
2. We know that aspirin works for headaches, whether it really prevents heart attacks or not. But we may wonder why it works for headaches. According to a childhood neighbor, it is “because it has something in it.” Is any better account than that available?

## Lecture Eighteen

### Hypotheses and Experiments—A Closer Look

**Scope:** There are at least two epistemic uses for experiments. Some are aimed at *discovering* patterns and relationships that will help generate descriptive and explanatory knowledge. Others are aimed at *testing* the theories or ideas that we entertain so as to *confirm* (not prove) or *disconfirm* them. In either situation, methodological considerations are of supreme importance. These include the identification and control of variables, the interpretation of experimental output, replicability, and the reliability of sampling techniques.

#### Outline

- I. Experiments may take place in laboratories and in the field. They may be contrived or involve only the detailed examination of existing data. However structured and carried out, there are at least two uses for experiments that are of interest to modern rational empiricists.
  - A. Some are aimed at *discovering* patterns and relationships that will help generate descriptive and explanatory knowledge.

**Example:** Running experiments to discover the impact of various chemical compounds on a variety of infectious organisms and on the plants and animals they infect.
  - B. Others are aimed at *testing* the theories or ideas that we entertain so as to *confirm* (not prove) or *disconfirm* them.

**Example:** Running experiments to see whether or not objects of different mass actually accelerate at the same rate in free fall as theory predicts.
- II. In either kind of use, methodological considerations are of supreme importance if we are concerned at all to think our way to a reliable conclusion. These considerations must include such things as the identification and control of variables and the reliability of sampling techniques.
  - A. Identifying relevant variables is not easy.
    1. What factors do we need to take into account when trying to decide whether or not a particular alternative therapy for a particular degenerative disease is, in fact, therapeutic?
      - a. Many factors may be relevant, and some may not be obvious.
      - b. Consider, for instance, whether or not the particular disease is in any way cyclical. Malaria, for example, is one of many diseases in which there is a regular variation between more intense and less intense symptoms.
    2. In addition to all the characteristics of a procedure under investigation and all the characteristics of the contexts in which it is being assessed, we must also take into account all the *limiting conditions* that may apply in the case at hand.
      - a. Prejudice, bias, faulty instrumentation, lack of due care, and the like are always possible. The alleged achievement of “cold fusion” in 1989 was very likely flawed by contaminated equipment.
      - b. Such things are relevant because they affect outcomes.
      - c. Their presence, however, can be very difficult to see. That’s why repeatability, public access, publication in scientific journals, and the like are needed when we want the results of our work to be reliable.
  - B. Controlling relevant variables can be very difficult, particularly when working with human subjects.
    1. It is very difficult to get humans to honestly report the results of experimentation.
    2. There is also a general problem with volunteered information. Consider, for example, the data in the Kinsey Reports on sexual behavior. People who volunteer to talk about their sex lives may or may not be like everyone else in the kind of sex lives they lead.
    3. When relevant variables are controlled, experimental results should be replicable.

**Negative example:** As already noted, the widely publicized production of “cold fusion” in 1989 was not replicable, and it was widely thought at the time that this was because crucial variables had not been controlled in the lab where it was claimed to have occurred. This is why reputable researchers publish the details of their experiments, not just their results.

C. The reliability of the sampling techniques used in gathering data is crucial.

**Example:** It may be quite important to find out such things as whether a political poll was taken by telephone: People who have telephones and people who do not have telephones probably differ in terms of their economic status and their political outlook.

**Essential Reading:**

Darrell Huff, *How to Lie with Statistics*.

**Recommended Reading:**

Joel Best, *Damned Lies and Statistics*.

**Questions to Consider:**

1. The Kinsey Report (a study of human sexual behavior) was widely criticized when it was published because the people included in the study volunteered to participate. Why might one think that this was a relevant criticism?
2. If the proof of the pudding is in the eating, why isn't the proof of a hypothesis in the experimental results? Why doesn't the fact that a cancer went away *prove* that the therapy employed on the patient (Laetril, Krebiozin, or something similar) was "right" (that is, the source of the cure)?

## Lecture Nineteen

### “Normal Science” at Mid-Century

**Scope:** Although the paradigm-shifting ideas of Albert Einstein and Werner Heisenberg had already called the “neatness” of modern science into question, in the middle of the 20<sup>th</sup> century, a stable view of “normal science” was almost universal in the West. This vision was rooted in logical empiricism, with contributions by logicians, mathematicians, scientists, and philosophers. It affirmed the empirical status of scientific descriptions and explanations, establishing “confirmational” empiricism as orthodox and giving free rein to the use of testable hypotheses regardless of their sources. It also insisted that mathematics and logic are purely formal affairs, closing the door on any notion of “synthetic *a priori*” truths. This view has its problems, however; as we will see in Lecture Twenty-Three, it is now severely questioned by both “Postmodern” and “New Age” critics.

### Outline

- I. Although the paradigm-shifting ideas of Albert Einstein and Werner Heisenberg were already calling the “neatness” of modern rational science into question, in the middle of the 20<sup>th</sup> century, a stable view of “normal science” was almost universal in the West.
- II. This vision was rooted in *logical positivism* (also known by the names *logical empiricism* and the *unity of science movement*), with contributions by logicians, mathematicians, scientists, and philosophers.
  - A. Logical positivism amounted to a program with three aims:
    1. The demonstration of the “unity” of all scientific inquiry—an essentially reductionist enterprise;
    2. The separation of scientific discourse from every other kind of discourse in terms of logical and empirical principles; and
    3. The demonstration that all actual or potential knowledge claims (cognitively meaningful claims) fall on the “scientific” side of that divide.
  - B. Logical positivism was historically connected to Comte’s 19<sup>th</sup>-century positivism, British empiricism, and ultimately, to an Aristotelian (rather than a Platonic) philosophical tradition.
  - C. It is “logical” in that its criterion for cognitively meaningful discourse makes provision for mathematical and logical claims to be true or false only insofar as they satisfy (or fail to satisfy) purely *formal* standards.
  - D. It is “empirical” in that its criterion for cognitively meaningful discourse makes provision for descriptive and explanatory claims to be true or false only insofar as they satisfy (or fail to satisfy) purely *experiential* tests.
  - E. It rules a number of things out of the arena of cognitively meaningful discourse, such as ethics, esthetics, metaphysics, and any and all other enterprises that (by its lights) cannot be “reduced to” natural science.
  - F. The positivistic side of this vision fixed the empirical status of science in terms of empirical “verification” or “falsification” (depending on who you read). After considerable debate, it established *confirmationally* empirical theories as orthodox, rejected any exalted status for *genetically* empirical theories, and gave free rein to the use of testable hypotheses regardless of their sources.
  - G. The logical side of this vision insisted that mathematics and logic are purely formal affairs (their claims are necessarily true but empirically empty). This firmly closed the door on any notion of “synthetic *a priori*” truths.
- III. This program has its problems, however. Here are five of them:
  - A. Reductionism was difficult, if not impossible, to demonstrate.
    1. It is easy to say that psychology and economics have the same theoretical and methodological foundations as physics and chemistry.
    2. It is not so easy to show that this is true, as the ragged history of behavioral psychology demonstrates. George Lundberg, a famous or infamous behavioral psychologist of the 20<sup>th</sup> century, once compared a leaf being blown down the street to a man fleeing an angry lynch mob; the only difference between them, he said, was the complexity of the vectors.



- B. The exclusion of ethics, religion, and the like from the arena of actual or potential knowledge seems arbitrary and self-defeating. It is one thing to say that evaluative discourse is “cognitively empty” because its claims are not empirically testable. It is difficult if not impossible to show, however, that this claim is, itself, empirically testable in any way.
  - C. Another, even deeper, problem is that positivism’s central commitment to empirical verifiability is itself not open to empirical testing and verification or falsification.
    - 1. On the other hand, why would we ever expect a rule or a principle to satisfy itself?
    - 2. As Wittgenstein might point out, although you follow the rules of bridge when playing bridge, the rules of bridge do not *themselves* follow the rules of bridge at all.
  - D. The program seems committed to a particular conception of how science itself actually works—gradual cumulative progress, governed by a fully rational decision procedure. The actual history of science, however, is thought by many to reveal a different story—one of revolutions and paradigm shifts, governed by the cultures in which it is practiced.
  - E. There is also widespread mistrust of the scientific enterprise itself as being, perhaps, driven by a program, an ideology, a style, a platform, or a manifesto—in short, not being objective and value-free in the way that it had always claimed itself to be.
- IV. As we will see in Lecture Twenty-Three, the program has been severely questioned, along these and other lines, by both “Postmodern” and “New Age” critics. But first we shall look at the logical tools that are at its disposal.

**Essential Reading:**

Carl Hempel, “Problems and Changes in the Empiricist Criterion of Meaning.”

**Recommended Reading:**

A. J. Ayer, *Language, Truth and Logic*.

**Questions to Consider:**

1. Why should the NIH privilege Western scientific medicine and marginalize traditional non-Western therapeutic practices? Is this just regional chauvinism, or does it have some real and objective bases?
2. Why should we be nervous about Freud’s “unconscious” unless we are equally nervous about muons, black holes, and strings?

## Lecture Twenty

### Modern Logic—Truth Tables

**Scope:** Wherever our mathematical apparatus, natural laws, and state descriptions come from, we draw inferences from them according to the canons of logic. By the beginning of the 20<sup>th</sup> century, logic far surpassed the traditional syllogism. Modern logic still begins with three intuitive (though no longer thought to be *necessarily* true) assumptions about the truth or falsity of indicative sentences, and these are still called the laws of *identity*, *non-contradiction*, and *excluded middle*. These laws are used in constructing truth tables on which basic operators are defined for *negation*, *conjunction*, *disjunction*, and *implication*. These, in turn, provide the tools to determine the truth or falsity of compound sentences of great complexity and to establish rules of inference and standards for validity. Logic also expedites the analysis of sets and switching circuits and the construction of computer languages.

### Outline

- I. Whether we hypothesize, discover, or create the mathematics, covering laws, and state descriptions that we use in explaining what we observe, we need a reliable apparatus for drawing inferences from them. This is provided by modern logic, an adaptation and extension of the syllogistic logic that we examined in Lectures Four through Seven. We shall examine the rudiments of modern logic in this and the following two lectures, but what we cover here only scratches the surface. You can find a thorough treatment of the history of logic in William and Martha Kneale's *The Development of Logic*.
- II. Modern logic is still based on three intuitively attractive (though no longer thought to be *necessarily* true) assumptions about the truth or falsity of indicative sentences; these are usually called the laws of *identity*, *non-contradiction*, and *excluded middle*.
  - A. *Identity*. For any adequately explicit, indicative descriptive sentence  $p$ , if it is true in a given context, it is true throughout that context, and if it is false in a given context, then it is false throughout that context. For example, if "It is raining [here, now]" is true (false) in one line of an argument, it must be true (false) in every line of that argument.
  - B. *Non-contradiction*. For any adequately explicit, indicative descriptive sentence  $p$ , if it is true in a given context, then its denial is false in that context, and if it is false in a given context, then its denial is true in that context. For example, if "It is raining [here, now]" is true (false) in one line of an argument, then its denial must be false (true) in every line of that argument.
  - C. *Excluded middle*. There is no *tertium quid* truth value for any adequately explicit, indicative descriptive sentence  $p$ . "True" and "false" are the only options available.

III. These principles are intuitively attractive, but they are not necessarily true. They are assumptions, or postulates, for the system. They collectively presume that what adequately explicit, indicative descriptive sentences are about is coherent and consistent.

IV. These laws are utilized in constructing truth tables in terms of which basic logical operators are defined for *negation, conjunction, disjunction, implication, and equivalence.*

<i>operation</i>	<i>symbol</i>	<i>read as</i>	<i>meaning of symbol</i>
negation	~	“curl”	it is not the case that
conjunction	•	“dot”	and; but; furthermore; nevertheless
disjunction	∨	“wedge”	or (in an inclusive sense); unless
implication	⊃	“horseshoe”	if...then; implies; causes
equivalence	≡	“triple bar”	are equivalent; if and only if

V. Using ~ for “it is not the case that”; • for such terms as “and,” “but,” “furthermore,” “nevertheless,” etc.; ∨ for such terms as “or,” “unless,” etc.; ⊃ for such terms as “implies,” “causes,” and “if...then”; and ≡ for such expressions as “are equivalent” and “if and only if,” we may define our operators on truth tables as follows:

A. *Negation*: This is simply a graphic representation of the law of non-contradiction.

Guide Column	<i>Negation</i> Statement
<b><i>p</i></b>	<b>~<i>p</i></b>
<b>T</b>	<b>F</b>
<b>F</b>	<b>T</b>

Guide Column	<i>Conjunction</i> Statement
<b><i>p q</i></b>	<b><i>p • q</i></b>
<b>T T</b>	<b>T</b>
<b>T F</b>	<b>F</b>
<b>F T</b>	<b>F</b>
<b>F F</b>	<b>F</b>

B. *Conjunction*: There are contexts in English in which the word *and* not only says that both parts are true but also says something about the sequence in which those events occur. As my mother would have noted, there is all the difference in the world between John and Sue getting married and having a baby, and John and Sue having a baby and getting married. In the logical apparatus, by contrast, the dot does not say anything about sequencing at all. All the dot captures is the claim that both parts are true.

C. *Disjunction*: In some instances in English, when we say *p* or *q*, we mean one or the other but not both. That is called *exclusive disjunction* and is relatively rare. There are other occasions when we clearly mean at least one, possibly both. That is called *inclusive disjunction*. The wedge represents inclusive disjunction.

Guide Column	<i>Disjunction</i> Statement
<b><i>p q</i></b>	<b><i>p ∨ q</i></b>
<b>T T</b>	<b>T</b>
<b>T F</b>	<b>T</b>
<b>F T</b>	<b>T</b>
<b>F F</b>	<b>F</b>

Guide Column	<i>Material Implication</i> Statement
<b><i>p q</i></b>	<b><i>p ⊃ q</i></b>
<b>T T</b>	<b>T</b>
<b>T F</b>	<b>F</b>
<b>F T</b>	<b>T</b>
<b>F F</b>	<b>T</b>

D. *Material implication*: There are dozens of different expressions in English that amount to something like “if...then.” What we want in the logical system is an operator that will represent what all of those different “if...then’s” have in common. That leads to what some call the *paradoxes of material implication*. Namely,

that “ $p$  horseshoe  $q$ ” turns out to be true on the third and fourth lines, where  $p$  itself is false. Still, the common partial meaning of a wide variety of “if...then” expressions is captured rather nicely by the horseshoe—that is, “It is not the case that ( $p$  and not  $q$ ),” or “ $p$  does not occur without  $q$ ” (which is what the horseshoe says without suggestion *why* that is the case).

- E. *Equivalence*: The equivalence connector asserts that  $p$  and  $q$  have the same truth value. But, as can easily be shown on a larger truth table, it also says that  $p$  and  $q$  imply each other (that is,  $p$  implies  $q$  and  $q$  implies  $p$ ).

Guide Column		<i>Equivalence</i> Statement
$p$	$q$	$p \equiv q$
T	T	T
T	F	F
F	T	F
F	F	T

- VI. These operators, in turn, provide the tools needed to determine the truth or falsity of compound sentences of great complexity.
- A. Some of these establish basic replacement or substitution rules and rules of inference, as we shall see in Lecture Twenty-One.
- B. Taken together, these rules underwrite a strict test for validity: *An inference is valid if and only if its conclusion can be derived from its premises in a finite number of steps, each of which is an instance of an established rule of inference or replacement.*
- Thus, the validity of a formal proof depends on the rules that we will look at in the next lecture.
  - The validity of the rules depends on the definitions that we have lined out on the truth table.
  - The legitimacy of the truth table depends on the three laws of thought mentioned at the beginning of this lecture.
- C. The tools established in this way can also be used to expedite the analysis of sets (as we shall see in Lecture Twenty-Two) and, further afield, to expedite the analysis of switching circuits and the construction of computer languages (where T and F are replaced by representations of “on” and “off” in binary arithmetic).

**Essential Reading:**

James Hall, *Logic Problems for Drill and Review*, Chapter 1, “The Apparatus,” pp. 1–2.

**Recommended Reading:**

Irving Copi, *Introduction to Logic*, Chapter 8, “Symbolic Logic,” pp. 299–320.

**Questions to Consider:**

- If a truth table for a compound statement must have a row for every possible combination of truth values for all the compound’s simple constituents ( $p$ ,  $q$ ,  $r$ , etc.), how many rows will be needed in the truth table for the following statement?

$$[(p \supset q) \bullet (q \supset r)] \supset (p \supset r)$$

Can you figure out a formula to determine how many rows are needed in a truth table for a compound statement with  $n$  simple constituents?

- The equivalence symbol  $\equiv$  (“triple bar”) is often defined as follows:

$$p \equiv q \text{ means } (p \supset q) \bullet (q \supset p).$$

Can you construct a truth table for that definition statement?

## Lecture Twenty-One

### Modern Logic—Sentential Arguments

**Scope:** Using the basic logical connectives as defined on truth tables, representations of a statement can often be expressed in alternative equivalent ways. Using truth tables, a number of such equivalences can be justified as *replacement rules* that allow one equivalent statement to replace another. Traditionally, there are 10 or so replacement rules, such as *DeMorgan's theorems*, *transposition*, and *exportation*. *Rules of inference* are demonstrable on truth tables, too. They include *modus ponens*, *hypothetical syllogism*, and 8 or so others. Many of the rules are readily derived from the others as theorems. With both kinds of rules in place, complex logical derivations are possible and secure. It is important to note, however, that these derivations are only "truth preserving." Nothing in the system provides any assurance that the premises of any argument are true.

### Outline

- I. The logical force of statements can often be captured in alternative ways.
  - A. When that is the case, the alternatives are always equivalent to each other in truth value.
  - B. Based on truth table demonstrations, it is easy to show that certain statements are equivalent in this way. Here are two examples:

One of DeMorgan's Two Theorems						
<i>p</i>	<i>q</i>	$\sim(p \vee q) \equiv (\sim p \bullet \sim q)$				
T	T	F	T	T	F	F
T	F	F	T	T	F	T
F	T	F	T	T	T	F
F	F	T	F	T	T	T

"Neither *p* nor *q*, if and only if, not *p* and not *q*."

Material Implication						
<i>p</i>	<i>q</i>	$(p \supset q) \equiv (\sim p \vee q)$				
T	T	T	T	F	T	T
T	F	F	T	F	F	F
F	T	T	T	T	T	T
F	F	T	T	T	T	F

"If *p* then *q*, if and only if, not *p* unless *q*."

- C. On the left-hand side are the guide columns, and there, we find all the possible combinations of true and false values for the two variables *p* and *q*. On the right side are the statements, and we can fill in the values on the right-hand side for all the possible values of *p* and *q* as indicated by the guide columns.
- II. Ten or so such equivalences are traditionally identified as *replacement rules* that allow their equivalent statements to be substituted for each other at will. We shall look at five samples.
    - A. *DeMorgan's two theorems*: Denying a conjunction says that at least one of its parts is false and vice versa, and denying a disjunction says that both of its parts are false and vice versa.
 
$$\sim(p \bullet q) \equiv (\sim p \vee \sim q) \quad \text{and} \quad \sim(p \vee q) \equiv (\sim p \bullet \sim q)$$
    - B. *Exportation*: A sequence of conditionals can be clustered, and a cluster can be sequenced.
 
$$[p \supset (q \supset r)] \equiv [(p \bullet q) \supset r]$$
    - C. *Transposition*: A conditional can be reversed if you change the signs of both terms:
 
$$(p \supset q) \equiv (\sim q \supset \sim p)$$

D. *Material implication*: Saying that P is a sufficient condition of Q is the same as saying that it is not the case that Q occurs in the absence of P or that P does not occur unless Q does.

$$(p \supset q) \equiv \sim(p \bullet \sim q) \quad \text{or} \quad (p \supset q) \equiv (\sim p \vee q)$$

E. *Tautology*: You need not repeat yourself, but you may if you like.

$$p \equiv (p \bullet p) \quad \text{and} \quad p \equiv (p \vee p)$$

III. It is demonstrable on truth tables that certain inference patterns are valid; that is, the conclusion is never false when the premises are true. For example (using  $\therefore$  to mean “therefore”):

<i>Modus Ponens</i> (“powerful method”)					
<i>p</i>	<i>q</i>	$p \supset q$	<i>p</i>	$\therefore$	<i>q</i>
T	T	T	T	T	√
T	F	F	T	F	
F	T	T	F	T	
F	F	T	F	T	

**Example of *modus ponens***: If you love me, you will remember our anniversary. You do love me. Therefore, you will remember our anniversary.

<i>Absorption</i>					
<i>p</i>	<i>q</i>	$p \supset q$	$\therefore$	$p \supset (p \bullet q)$	
T	T	T	T	T	√
T	F	F	F	F	
F	T	T	T	F	√
F	F	T	T	F	√

**Example of *absorption***: If today is Wednesday, then I have an appointment at 4:00. So it follows that if today is Wednesday, then today is Wednesday, and I have an appointment at 4:00.

IV. Ten or so such patterns are traditionally identified as *inference rules*. Here are seven (again using  $\therefore$  to mean “therefore”):

A. *Modus ponens*

$$p \supset q$$

$$p \quad \therefore \quad q$$

B. *Absorption*

$$p \supset q \quad \therefore \quad p \supset (p \bullet q)$$

C. *Simplification*

$$p \bullet q \quad \therefore \quad p$$

D. *Conjunction*

$$p$$

$$q \quad \therefore \quad p \bullet q$$

E. *Hypothetical syllogism (chain argument)*

$$p \supset q$$

$$q \supset r \quad \therefore \quad p \supset r$$

F. *Reductio*

$$p \supset (q \bullet \sim q) \quad \therefore \sim p$$

**G. Conditional proof**

One may assume a hypothesis and infer from it and the premises together. Then, upon discharging the hypothesis, one may infer the conditional: *If this hypothesis is made, this result follows.*

- V. Only a few of the usual rules are essential, the others being readily derived from them as theorems. For instance, hypothetical syllogism can be (laboriously) derived from the others.
- A. Absorption is essential. It cannot be derived from the other rules, and certain valid arguments cannot be proved without it.
  - B. While the traditional rule set is not as parsimonious as it might be, it has the advantage of closely tracking the syntax of many natural languages, including English.
  - C. There is a judgment call involved in deciding how many rules to include. Having lots of rules makes for short proofs but gives us many principles to keep track of. Just a few rules are easy to handle, but the proofs get long. The traditional system is a compromise.
- VI. With replacement and inference rules in place, complex derivations are possible, such as:

- A.  $1. p \supset q$   
 $2. p \supset (q \supset r) \quad \therefore \quad p \supset r$   
 $3. p \supset (p \bullet q) \quad 1 \quad \text{Absorption}$   
 $4. (p \bullet q) \supset r \quad 3 \quad \text{Exportation}$   
 $5. p \supset r \quad 2, 4 \quad \text{Hyp. Syllogism}$
- B.  $1. p \supset (q \bullet r) \quad \therefore \quad p \supset q$   
 $2. p \quad \text{Hypothesis}$   
 $3. q \bullet r \quad 1, 2 \quad \text{Modus Ponens}$   
 $4. q \quad 3 \quad \text{Simplification}$   


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 $5. p \supset q \quad 2-4 \quad \text{Conditional Proof}$

- VII. The inferences sanctioned by these rules are only truth *preserving*—that is, they will safely keep whatever truth we start with, but that is all. Whether the premises with which an argument begins are true is an entirely *extra-logical* matter.
- A. One can construct proofs for one’s premises, but that will require further premises.
  - B. One could hope for “self-evident” premises, but that is a dicey hope.
  - C. The normal way to determine whether a premise is true is to consult experience. That is why this whole approach is called *rational empiricism*, not just *rationalism*.

**Essential Reading:**

James Hall, *Logic Problems for Drill and Review*, Chapter 1, “The Apparatus,” pp. 3–11.

**Recommended Reading:**

Irving Copi, *Introduction to Logic*, Chapter 9, “The Method of Deduction,” pp. 349–371.

**Questions to Consider:**

1. What is the practical advantage of proving an argument by using the rules, as compared to constructing a truth table for the argument as a whole?
2. Does not finding a way to demonstrate an argument by using the rules constitute any sort of proof that the argument is invalid (or even likely to be invalid)? If not, how could you show that a complex argument is invalid (short of constructing *large* truth tables)? After you have thought about this, look at pages 372–375 in Copi's *Introduction to Logic*.
3. See whether you understand the steps in the following argument (the first three statements are premises):

1.	$p \supset q$		
2.	$m \supset \sim q$		
3.	$\sim(p \bullet z)$		
4.	$\sim z \supset m$	$\therefore$	$\sim p$
5.	$\sim p \vee \sim z$	3	DeMorgan's Theorem
6.	$p \supset \sim z$	5	Material Implication
7.	$p \supset m$	6, 4	Hyp. Syllogism
8.	$p \supset \sim q$	7, 2	Hyp. Syllogism
9.	$q \supset \sim p$	8	Transposition
10.	$p \supset \sim p$	1, 10	Hyp. Syllogism
11.	$\sim p \vee \sim p$	10	Material Implication
12.	$\sim p$	11	Tautology



## Lecture Twenty-Two

### Modern Logic—Predicate Arguments

**Scope:** One of the strengths of modern logic is that it clearly establishes the relationship between predicate logic (e.g., syllogisms) and sentential argument forms, such as *modus ponens*. Using simple conventions for representing predication, the Boolean interpretation of universals, two new operators (the universal and particular quantifiers to express general claims), and two new rules for instantiating (applying) general claims to individuals, predicate arguments far beyond the scope of Aristotelian syllogistic can be solved, utilizing all of the power of the apparatus introduced for handling sentential arguments.

#### Outline

- I. *Sentential arguments*, as in the last lecture, depend upon the connections between simple sentences joined with such connectors as “and,” “or,” and “if then.” In *predicate arguments*, everything depends upon the relationship between the subject and predicate terms within a sentence.
- II. Modern logic connects predicate arguments and sentential arguments, such as *modus ponens*. Only a small number of new things have to be added to the apparatus we have been examining in order to handle individuals and their properties (class memberships).
  - A. There are simple conventions for representing predication.
    1. Properties that things have are represented by capital letters. Greek, wise, and mortal might be represented by G, W, and M, for example.
    2. Property holders are represented with lower case letters. Plato, Socrates, and Aristotle might be represented by p, s, and a, for example.
    3. The assertion that a property holder has a property is represented by placing a lowercase letter immediately to the right of a capital letter. Thus, “Socrates is a philosopher” might be represented Ps, “Alcibiades was a politician” might be represented Pa, and “Bucephelus was a horse” might be represented Hb.
    4. Variables can function as place markers for property holders and their properties, typically lowercase Roman letters, such as  $x$  and  $y$ , etc., for the property holders and capital Greek letters, such as  $\Phi$  (phi) and  $\Psi$  (psi), etc., for the properties.
  - B. There are two new symbols to represent the *quantity* of a proposition.
    1.  $(\forall x)$ , called the *universal quantifier*, expresses the quantity of universal propositions:  $(\forall x)\Phi x$  says that every individual has the property  $\Phi$ —*everything Phi*, and  $(\forall x)\sim\Phi x$  says that no individual has it—*nothing Phi*.
    2.  $(\exists x)$ , called the *particular (or existential) quantifier*, expresses the quantity of particular propositions:  $(\exists x)\Phi x$  says that at least one individual has the property  $\Phi$ —*something Phi*, and  $(\exists x)\sim\Phi x$  says that at least one individual does not—*something doesn't Phi*.
    3. In all instances, the universal or particular quantifier binds (applies to) the subsequent instances of the same variable in the same line, as guided by parentheses and other punctuation.
  - C. The interpretation of A and E propositions is strictly Boolean—universal statements do not assert the existence of any members of the subject class at all.
    1. Using our convention of capital Greek letters, we would write  $(\forall x)(\Phi x \supset \Psi x)$ : for any X, if X Phi, then X Psi. However, it may be clearer at the beginning to use S and P for subject and predicate.
    2. “All S are P” is read: *The intersection of S and  $\sim P$  is null*. Using the universal quantifier, we write  $(\forall x)(Sx \supset Px)$ : *For every individual, if it is S, then it is P*.
    3. “No S are P” is read: *The intersection of S and P is null*. Using the universal quantifier, we write  $(\forall x)(Sx \supset \sim Px)$ : *For every individual, if it is S, then it is  $\sim P$* .
    4. “Some S are P” is read: *The intersection of S and P is not null*. Using the particular quantifier, we write  $(\exists x)(Sx \bullet Px)$ : *There is at least one S that is P*.
    5. “Some S are not P” is read: *The intersection of S and  $\sim P$  is not null*. Using the particular quantifier, we write  $(\exists x)(Sx \bullet \sim Px)$ : *There is at least one S that is  $\sim P$* .

6. This recognizes the contradictory relationship of universal affirmatives and particular negatives, and of universal negatives and particular affirmatives. Using quantifiers, we express these relationships as equivalence statements and establish them as replacement rules (called *quantifier negation*):

$\sim(x)\Phi x \equiv (\exists x)\sim\Phi x:$	$\sim(x)\sim\Phi x \equiv (\exists x)\Phi x:$
<i>It is not the case that everything. This if and only if at least one thing does not.</i>	<i>It is not the case that nothing. This if and only if at least one thing does.</i>

- D. Two new inference rules for instantiation (also known as *stripping quantifiers*) allow the application of general claims to individuals.

1. *Universal instantiation*. If everything possesses a property, then that property is possessed by any individual thing we choose.

Using the universal quantifier, we write:

$$(x)\Phi x \quad / \therefore \quad \Phi v \text{ (with no restrictions).}$$

*If everything phis, then nu phis*—the lowercase Greek letter nu representing the name of any individual whatever.

2. *Existential (particular) instantiation*. If at least one thing possesses a property, then that one thing may be given an arbitrary name.

Using the particular quantifier, we write:

$$(\exists x)\Phi x \quad / \therefore \quad \Phi v \text{ (with restrictions).}$$

*If at least one thing phis, then nu phis*—the lowercase Greek letter nu representing any arbitrary name that has no prior use in the context.

- III. With these additions in hand, predicate arguments can be proven utilizing all of the power of the apparatus introduced for handling sentential arguments. For example:

All Greeks are mortals.	$(x)(Gx \supset Mx)$
All Athenians are Greeks.	$(x)(Ax \supset Gx)$
Therefore, All Athenians are mortals.	$/ \therefore (x)(Ax \supset Mx)$

- |     |  |  |
|-----|--|--|
| 1.  | $(x)(Gx \supset Mx)$   | [for any x whatever, if x is Greek, then x is mortal]    |
| 2.  | $(x)(Ax \supset Gx)$   | [for any x whatever, if x is Athenian, then x is Greek]  |
| 3.  | $/ \therefore (x)(Ax \supset Mx)$  | [for any x whatever, if x is Athenian, then x is mortal] |
| 4.  | $\sim(x)(Ax \supset Mx)$   | Hypothesis   |
| 5.  | $(\exists x)\sim(Ax \supset Mx)$   | 3 Quantifier Negation                                    |
| 6.  | $\sim(Aa \supset Ma)$  | 4 Existential Instant.                                   |
| 7.  | $Ga \supset Ma$  | 1 Universal Instant.                                     |
| 8.  | $Aa \supset Ga$  | 2 Universal Instant.                                     |
| 9.  | $Aa \supset Ma$  | 7, 6 Hyp. Syllogism                                      |
| 10. | $(Aa \supset Ma) \bullet \sim(Aa \supset Ma)$                            | 8, 5 Conjunction   |
| 11. | $\sim(x)(Ax \supset Mx) > [(Aa \supset Ma) \bullet \sim(Aa \supset Ma)]$ | 3–9 Conditional Proof                                    |
| 12. | $(x)(Ax \supset Mx)$   | 10 Reductio  |

- IV. With this apparatus, it is also possible to prove predicate arguments beyond the scope of Aristotelian syllogistic.

- A. Arguments with more than three terms, or with complex terms, are easy.

**Example:**

*Any problem with more than three terms violates Aristotelian rules.*

*This very problem has more than three terms and is demonstrably valid.*

*If at least one argument is demonstrably valid and violates Aristotelian rules, then Aristotelian logic is inadequate.*

*Therefore, Aristotelian logic is inadequate.*

- B. With the addition of a few further conventions and rules, relational arguments can also be solved.

**Example:**

*Everybody loves somebody sometime.*

*I am somebody.*

*Therefore, someday, there will be someone for me to love.*

- C. The apparatus of modern logic is large, growing, and dynamic. It is not the easiest thing in the world to learn, but with a little application and a little focus, you can learn it, and you will have in hand the essential rational tool. The applications, which include switching circuits and a binary mathematical apparatus on which to base computer languages, are astounding.

**Essential Reading:**

James Hall, *Logic Problems for Drill and Review*, Chapter 1, “The Apparatus,” pp. 16–20.

**Recommended Reading:**

Irving Copi, *Introduction to Logic*, Chapter 10, “Quantification Theory,” pp. 385–413.

**Questions to Consider:**

1. Not all quantified arguments are valid. How could we prove a quantified argument to be invalid without constructing a truth table of infinite size? After you have thought about this question, look at page 21 in my *Logic Problems* and pages 406–408 in Copi’s *Introduction*.
2. How different would a logic system have to be to accommodate statements that can have three “states” (say, *true*, *false* and *maybe*)? What would replace the law of excluded middle in such a system?

## Lecture Twenty-Three

### Postmodern and New-Age Problems

**Scope:** Modern rational empiricism is not problem-free. For instance, we know that observations themselves are *theory laden*. That means, at the least, that all our experiences are *construals* made in terms of whatever ideas and theories are already “in place” for us. This amounts to *epistemic* relativism. Further, if the general (or scientific) culture determines what those ideas and theories are, then even our simplest descriptions are *culturally* relative. These central themes of what is now called *postmodernism* were in play under the rubric “the sociology of knowledge” long before the mid-century talk of *language games*, *paradigm shifts*, and *scientific revolutions*. Epistemic and cultural relativism are also central themes of many “New Age” and religious objections to rational empiricism. Along with such issues of *relativism*, there are also issues about *uncertainty* and the possibility of *universal error*. Radical skepticism can be propagated from all of these roots.

### Outline

- I. Modern rational empiricism is not problem-free.
  - A. Observations themselves are *theory laden*, as well as being colored by other observations that we have already made and categorized.
    1. An observation is shaped by the theories that we hold and have in use when it is made. You don’t observe gravity until you have a theory of gravity in place.
    2. An observation is shaped by other observations we have already made and categorized. You can only *observe* food on the banana tree if you have some experience indicating that what grows on banana trees can be eaten.
    3. Thus, all our observations are epistemically relative *construals*, made from the perspective of whatever ideas, theories, and hypotheses are already “in place” for us.
    4. This says that we only see what we are *conceptually equipped* to see. It is why a city slicker can starve in a forest full of food and why most of what occurs on *The Simpsons* goes over the head of a four-year-old.
  - B. If the general (or scientific) culture determines what ideas and theories are in place for an observer, then even the simplest descriptions are also *culturally relative*.
    1. This is a main theme of *postmodernism*, which has several roots.
      - a. Karl Mannheim espoused “the sociology of knowledge” in the 1920s (in *Ideologie und Utopie*), arguing that all knowledge is a product of culture.
      - b. Ludwig Wittgenstein talked a great deal about language games in his *Philosophical Investigations*, published in 1953 (though in circulation before that) and insisted that there were different language games that reflected different “forms of life.”
      - c. In the 1960s, Thomas Kuhn’s notions of paradigm shifts and scientific revolutions in *The Structure of Scientific Revolutions* were based on the idea that our very scientific descriptions of what is going on in the world are the product of the favored ideas of those who are in positions of privilege and power within a particular culture at a particular time.
    2. It is very easy to take this epistemic relativism so seriously as to think that we cannot reach any kind of conclusions about anything at all.
      - a. Yet considering whether to dig a latrine uphill or downhill from your water source suggests that some facts are available to all of us (about infant mortality, a contaminated water supply, etc.), that can be rendered intelligible to anyone, and that are commensurable and translatable enough for people to learn very quickly that if they change their cultural tradition of where to dig their latrines, they can alter the infant mortality rate in their community.
      - b. Epistemic and cultural relativism are also central themes of “New Age” and religious objections to rational empiricism.

- II. Along with epistemic and cultural *relativism*, issues about *uncertainty* and the possibility of *universal error* are also problematic for rational empiricists, in that they seem to imply *radical skepticism*.
  - A. *Uncertainty*: Descartes claimed that one cannot know anything that can be doubted.
  - B. *Universal error*: Peter Unger has argued that we could be mistaken all the time.
  - C. *Radical skepticism*: The notion is that we never know anything at all.
- III. While radical skepticism can be propagated from such ideas as cultural relativism and claims and arguments such as those of Descartes and Unger, it need not be terminal.
  - A. Cultural relativism denies the possibility of internal and external culture critique that actually occurs.
  - B. The uncertainty argument defeats itself by equivocating over the word *certain*.
  - C. The universal error argument ignores the idea that making a mistake is always parasitic on getting *something* right. Example: “All money is counterfeit.”
  - D. Consequently, while radical skepticism can make us reflect on how to avoid mistakes, it should not prevent us from moving forward.
  - E. Once you realize that while you don’t get logical certainty about matters of fact, you can get practical reliability, the threats to modern rational empiricism are effectively disarmed.

**Essential Reading:**

Christopher Butler, *Postmodernism—A Very Short Introduction*.

**Recommended Reading:**

James Hall, *Practically Profound*, Chapter 7, “Knowledge and Cultural Relativism.”

**Questions to Consider:**

1. If claims made in different paradigms are mutually “incommensurable and untranslatable,” does it follow that in olden times, the Sun really did revolve around the Earth, even though the Earth now revolves around the Sun?
2. If reality is a “text” that is “open to interpretation,” does it follow that any interpretation of it is just as good as any other, any more than that any interpretation of *Hamlet* is just as good as any other?

## Lecture Twenty-Four

### Rational Empiricism in the 21<sup>st</sup> Century

**Scope:** For modern rational empiricists, the basic tools of thinking are experience, memory, association, pattern discernment and recognition, reason (including the dialectic of hypotheses and counterexamples), and invention and experimentation, working together to reach probable understandings of reality (with as few appeals to intuition as possible). Such tools do not yield logical certainty about matters of fact, but they do yield a network of evidence in terms of which we can pursue truth *as a limit*. Thinking, so seen, is an *open-ended* and *self-corrective* enterprise, the history of which is marked by dead ends, as well as achievements (both of which are highly instructive). The enterprise of thought is far from over. The tools of thinking are available to all. There are useful places for all of us to put them to use, if we will spend the efforts to master them.

### Outline

- I. For modern rational empiricists, the basic tools of thinking are experience, memory, association, pattern discernment and recognition, reason (including dialectic and the construction of hypotheses and counterexamples), invention, and experimentation.
  - A. Experience provides the basic new input for our thinking: what we see, taste, smell, feel, hear. It can be first- or secondhand. It is as reliable as tests show it to be.
  - B. Memory provides a link to data previously collected by whatever means.
  - C. Association functions with both immediate experience and with remembered experiences to group the data we have into clusters and sets.
  - D. Pattern discernment and recognition enable us to make those clusters and sets useful.
  - E. Reason (including dialectic and the construction of hypotheses and counterexamples) is the tool that we use to draw inferences from what we have observed, remembered, and associated. It takes many forms, such as deduction, generalization, extrapolation, and hypothesis construction, and may be linear or dialectical in form.
  - F. Invention supplies us with hypotheses, construals, models, and theories about what we observe and how it can most fruitfully be put to use.
  - G. Experimentation (in our heads, in the field, or in the laboratory) is the tool we use to test our hypotheses, construals, models, and theories to see how well they work and whether they need revision or replacement in order to work better.
  - H. Intuition is a good thing when it happens, but it is rare and (by definition) uncharted.
- II. Things work best when we use these tools together to reach probable understandings of reality (with as few appeals to intuition as we can get by with).
  - A. Experience, memory, association, and pattern discernment and recognition, working together, supply the raw material for our inferences and explanations.
  - B. Reason in all its forms, along with invention and experimentation, utilizes that input, construes it, constructs possible accounts of it, and puts those accounts to the test.
  - C. Intuition is a label that we can use for starting points—those things that seem “basic”—and for the bolder inventive leaps that we make when they happen to succeed. It is no substitute for thought, however.
- III. Such tools do not yield logical certainty about matters of fact, but they do yield a network of evidence in terms of which we can pursue truth *as a limit*.
  - A. Logical certainty about matters of fact is a will-o-the-wisp, but highly reliable conclusions about matters of fact are readily available to those who seek them.
  - B. “Truth” is a label we use for the limit toward which we perpetually strive in our thinking. It is not a label for where we happen to be at any moment in the quest. What we have achieved at any moment in the quest is, at best, an *approximation* of truth.

- IV. There is a shred of truth in the claim that science, in the era of “big science,” has become one more piece of the ideological give and take of a politicized world.
  - A. It is very difficult to do certain kinds of research without massive funding, and funding is tied to the agendas of the federal government, of foundations, or of various philanthropic groups that provide it.
  - B. But the wonderful thing about modern rational empiricism is that it can be practiced by mavericks, even when they do not have massive funding.
- V. Thinking, so seen, is an *open-ended* and *self-corrective* enterprise, the history of which is marked by dead ends, as well as achievements (both of which are highly instructive).
  - A. There is an infinitesimally minimal likelihood that we will ever be able to say, “Well, we don’t need to think anymore; we’ve gotten there.” Indeed, the more we think, the more things to think about we think of. It is a truly open-ended enterprise.
  - B. While it is possible to hare off in our thoughts, disciplined thinking tests itself and corrects itself by putting output up against expectation, always remembering that where we are *now* is only an approximation of where we are trying to go.
  - C. In the process of weighing outputs, we will often find them wanting. But this serves as a spur to further inquiry and permanently marks (for those who remember with care) paths that can be abandoned for more promising alternatives. Once we understand even the basics of biochemistry, for example, we are unlikely to fund any more expeditions to look for the fountain of youth but very likely indeed to fund medical research.
- VI. The enterprise of thought is far from over. The tools of thinking are available to all. There are useful places for all of us to put them to use, if we will spend the efforts to master them.
  - A. The systematic study of logic, science, mathematics, history, and even philosophy are all good places to begin.
  - B. We see before us—even today—a vista, a wide-open horizon, that beckons us forward to press on with the search, to perpetually think in the best ways that we can, and to make better lives for ourselves and for those to come.

**Three Books to Read Next:**

Isaac Asimov, *Asimov’s Chronology of Science and Discovery*.

Stephen W. Hawking, *The Illustrated Theory of Everything: The Origin and Fate of the Universe*.

Steven Pinker, *How the Mind Works*.

**Questions to Consider:**

1. Why should one think that the fact that scientific explanations of things have changed over time is any indication that scientific truth is an oxymoron or a poor second cousin to revealed truth?
2. When we encounter stubborn phenomena that we do not understand and cannot explain, which is better: grooving on the mystery or rolling up our sleeves and getting to work?

## Timeline

c. –1300 .....	Decimal system in use in China
c. –500 .....	Early logic in India and China
–470 to –399 .....	<b>Socrates</b> ; Socratic dialectic introduced, sophistry refuted
–427 to –347 .....	<b>Plato</b> ; foundations laid for classical metaphysical idealism in such dialogues as <i>Republic</i>
–384 to –322 .....	<b>Aristotle</b> ; foundations laid for classical logic in the <i>Analytics</i> and for empirical investigation in <i>History of Animals</i>
–325 to –265 .....	<b>Euclid of Alexandria</b>
c. –300 .....	Publication of Euclid’s <i>Elements</i> ; Babylonian Salamis (origin of the abacus) in use; zero comes into use in Babylon and India
25 .....	Christianity founded
622 .....	Muslim Calendar Year 1
c. 900 .....	Zero introduced in West by Arab traders
c. 1000 .....	Decimal system appears in West
1066 .....	Battle of Hastings
1095 .....	Crusades begin
<b>1126–1198</b> .....	<b>Averroës</b> ; preservation of Aristotelian rationalism and logic
1215 .....	Magna Carta
<b>1225–1274</b> .....	<b>Thomas Aquinas</b> ; reclaiming of Aristotelian rationalism and logic in the Christian West
1240 .....	Roger Bacon reintroduces Aristotle to the University of Paris
<b>1280–1349</b> .....	<b>William of Ockham</b> ; introduction of Ockham’s Razor
1291 .....	Crusades end
<b>1473–1543</b> .....	<b>Nicolas Copernicus</b> ; modern rational empiricism begins to define “science”
1492 .....	Columbus sailed the ocean blue
1519–1522 .....	Ferdinand Magellan circumnavigates the globe
1531 .....	Erasmus publishes first complete edition of Aristotle
<b>1561–1626</b> .....	<b>Francis Bacon</b>
<b>1564–1642</b> .....	<b>Galilei Galileo</b> ; refutation of Aristotelian astronomy
<b>1571–1630</b> .....	<b>Johannes Kepler</b>
<b>1596–1650</b> .....	<b>René Descartes</b>
1609 .....	Publication of Kepler’s <i>Astronomica Nova</i> , including his first two laws of planetary motion, gives a solid foundation for the modern scientific method
1614 .....	John Napier invents logarithms
1620 .....	Publication of Bacon’s <i>Novum Organum</i>
1633 .....	William Oughtred invents the slide rule



1637	Publication of Descartes' <i>Discourse on Method</i> , including the introduction of analytic geometry
1642–1660	English Revolution, Civil War, and Protectorate
<b>1642–1727</b>	<b>Isaac Newton</b>
1643	Blaise Pascal's "Pascaline" calculating device introduced
<b>1646–1716</b>	<b>Gottfried Leibniz</b>
1662	Publication of <i>Port Royal Logic</i>
c. 1665	Newton and Gottfried Leibniz simultaneously invent the calculus
c. 1670	Anton van Leeuwenhoek's lenses makes microbiology possible
1674	Leibniz invents the "stepped rocker" calculating device (the basis of the Monroe Calculator of 1912)
1687	Publication of Newton's <i>Principia</i> : Newton's laws of motion, the foundation of modern physics
1698	Thomas Severy steam engine
<b>1711–1776</b>	<b>David Hume</b>
1712	Thomas Newcomen steam engine
<b>1724–1804</b>	<b>Immanuel Kant</b>
1735	Carl Linnaeus's <i>Systema Naturae</i> published (biological taxonomy)
1748	Publication of Hume's <i>Philosophical Essays</i> (aka <i>An Enquiry Concerning Human Understanding</i> )—quintessential early modern empiricism, rejection of "sophistry and illusion"
1769	James Watt's steam engine
1776–1783	American Revolution
1781	Publication of Kant's <i>Critique of Pure Reason</i> ; reason and experience differentiated, the analytic/synthetic distinction triumphant; the search for the synthetic <i>a priori</i>
1789–1795	French Revolution
1798	Edward Jenner publishes report on cowpox and smallpox
<b>1798–1857</b>	<b>Auguste Comte</b>
<b>1806–1871</b>	<b>Augustus DeMorgan</b>
<b>1806–1873</b>	<b>John Stuart Mill</b>
1812–1814	War of 1812
1815	Waterloo
<b>1815–1864</b>	<b>George Boole</b>
1821	Michael Faraday's electric motor
1822	Publication of Comte's <i>Plan de travaux scientifiques necessaries pour réorganiser la société</i> ; the application of observation and experimentation to sociology (and a foundation for logical positivism in the 20 <sup>th</sup> century)
<b>1822–1895</b>	<b>Louis Pasteur</b>

c. 1825 .....	Charles Babbage’s “Difference Engine” (developed from an idea of J. H. Miller of 1786); the idea behind computers
1830 .....	Joseph Henry’s telegraph (made commercial in 1844 by Morse)
<b>1834–1923 .....</b>	<b>John Venn</b>
1835 .....	James Woodward’s and Matthew Evans’s electric light bulb
<b>1839–1914 .....</b>	<b>Charles Sanders Peirce</b>
<b>1842–1910 .....</b>	<b>William James</b>
1847 .....	Publication of DeMorgan’s <i>Formal Logic</i> ; one beginning for modern symbolic logic, especially DeMorgan’s theorems
1847 .....	Publication of Boole’s <i>The Mathematical Analysis of Logic</i> ; another beginning for modern symbolic logic, especially set theory
<b>1848–1925 .....</b>	<b>Gottlob Frege</b>
1856 .....	Charles Babbage’s “Analytical Engine”
<b>1858–1932 .....</b>	<b>Giuseppe Peano</b>
<b>1858–1947 .....</b>	<b>Max Planck</b>
1859 .....	Charles Darwin’s <i>On the Origin of Species</i> published
1861 .....	Ignatz Semmelweis published explanation of childbed fever; confirmed by Lister in 1865
1861–1865 .....	American Civil War
1866 .....	Gregor Mendel explains inheritance in peas
<b>1872–1970 .....</b>	<b>Bertrand Russell</b>
1873 .....	Publication of Peirce’s “Description of a Notation for the Logic of Relatives” (the predicate logic of relations)
1878 .....	Ramon Varea invents a partial-product calculating device (basis of the Burroughs Calculating Machine of the 1920s)
<b>1879–1955 .....</b>	<b>Albert Einstein</b>
1881 .....	Introduction of Venn diagrams
1887 .....	Michelson-Morley experiment; aether rejected
1889 .....	Publication of Frege’s <i>Begriffsschrift</i> , an apparatus, including truth tables, for the formal analysis of logical arguments
1889 .....	Publication of Peano’s <i>Geometrical Calculus</i> , including a chapter on mathematical logic with the basics of what has become “Peano-Russell Notation” for modern logic
1889 .....	Publication of Peano’s <i>Arithmetices Principia</i> , defining natural numbers in terms of sets
<b>1889–1951 .....</b>	<b>Ludwig Wittgenstein</b>
1891 .....	Publication of Mill’s <i>A System of Logic</i> , the classical formulation of inductive reasoning
1899 .....	Guglielmo Marconi’s radio telegraph
<b>1901–1976 .....</b>	<b>Werner Heisenberg</b>

<b>1902–1994</b> .....	<b>Karl Popper</b>
1903 .....	Ivan Pavlov confirms conditioned reflexes in dogs
1905 .....	Einstein’s special theory of relativity
1905 .....	X and Y chromosomes described
1906 .....	Mechanical television
1907 .....	Publication of James’s <i>Pragmatism</i> , notable for its influence on Bertrand Russell and Ludwig Wittgenstein
<b>1908–2000</b> .....	<b>W. V. O. Quine</b>
1910 .....	Publication of Russell’s <i>Principia Mathematica</i> , Vol. 1
<b>1910–1989</b> .....	<b>Alfred Jules Ayer</b>
1912 .....	Publication of Russell’s <i>Principia Mathematica</i> , Vol. 2
1912 .....	Publication of James’s <i>Essays in Radical Empiricism</i>
1913 .....	Publication of Russell’s <i>Principia Mathematica</i> , Vol. 3
1913 .....	J. B. Watson’s “Psychology as a Behaviorist Views It” published
1914–1918 .....	World War I
1915 .....	Einstein’s general theory of relativity
1921 .....	Publication of Wittgenstein’s <i>Tractatus Logico-Philosophicus</i>
<b>1922–1996</b> .....	<b>Thomas Kuhn</b>
1924 .....	J. B. Watson’s <i>Behaviorism</i> published
1926 .....	Proof of Planck’s Quantum Theory by Paul Dirac
1927 .....	Publication of Heisenberg’s Uncertainty Principle
1927 .....	Philo Farnsworth files patent for electronic television
1929 .....	Karl Mannheim publishes <i>Ideologie und Utopie</i> , setting out the “sociology of knowledge”—the roots of postmodern epistemic relativism
1936 .....	Publication of Ayer’s <i>Language, Truth and Logic</i> , bringing logical positivism to the English-speaking world
1938 .....	B. F. Skinner’s <i>The Behavior of Organisms</i> published
1938 .....	Otto Hahn and Fritz Strassman; first fission of uranium
1938–1945 .....	World War II
1942 .....	First controlled nuclear reaction (Chicago)
1945 .....	ENIAC; computers arrive for military use
c. 1950 .....	First nuclear fusion weapons
1951 .....	UNIVAC; computers arrive for civilian use (Census Bureau)
1951 .....	Publication of Quine’s “Two Dogmas of Empiricism,” disputing the traditional empiricists’ bright-line analytic/synthetic distinction
1953 .....	The double helix: Francis Crick and James Watson explain the molecular structure of DNA
1953 .....	Publication of Wittgenstein’s <i>Philosophical Investigations</i>

- 1953 ..... Publication of Popper’s *Conjectures and Refutations*, including the article “Science as Falsification,” putting a different twist on the logical positivists’ verificationism
- 1960 ..... TIROS photos of Earth from space
- 1962 ..... Publication of Kuhn’s *The Structure of Scientific Revolutions*, introducing the notion of “paradigm shifts” and sharply contextualizing the notion of scientific knowledge
- 1963 ..... First electronic calculating device (the Sumlock)
- 1971 ..... First pocket electronic calculator
- 1973 ..... Internet conceived and designed
- 1974 ..... First PC kit: Altair
- 1977 ..... First working PCs: Apple II and Tandy
- 1983 ..... Internet rollout
- 1989 ..... The Web
- 1990 ..... First gene replacement therapy

## Glossary

**A Posteriori:** Known or knowable on the basis of experience of some sort.

**A Priori:** Known or knowable independent of experience of any sort.

**Analytic:** Traditionally, the character of a statement that can be shown to be true or false by logical analysis; logically necessary. See **Synthetic**.

**Analytic Falsehood:** Traditionally, a statement whose predicate denies what is contained in its subject; a self-contradiction or necessary falsehood.

**Analytic/Synthetic Distinction:** An alleged “dogma” of empiricism (see Biographical Note for **Quine, W. V. O.**) in terms of which statements can be neatly sorted into necessary and contingent categories.

**Analytic Truth:** Traditionally, a statement whose predicate is contained in its subject; a tautology or necessary truth. See **Tautology**.

**Argument:** An arrangement of statements in which one or more (premises or assumptions) are presented as evidence or support for the truth of another (the conclusion).

**Association:** A key classificatory operation of the mind, connecting words, ideas, or experiences based on similarity, proximity in time or place, habit, and so on. According to Hume, our idea of causation is rooted in our habitual association of contiguous events. According to Freud, our psyche is revealed in our patterns of word association.

**Behaviorism:** The theory that mental phenomena, states, and processes can be reduced to, or explained in terms of, observable behavior and/or dispositions to behave.

**Belief:** An experiential expectation, usually based on mental processing of experiences that have already occurred or are occurring.

**Bifurcate:** To radically divide, as Descartes divided mind and body, Plato divided ideas and appearances, and transcendentalists divide the divine and the mundane.

**Blick:** A distinctive way of taking things, a picture of, or perspective on reality. More basic (and less considered than a *weltanschauung*), a blick is rather like a paradigm.

**Boolean Algebra:** Two-valued logic where the operators are based on negation and the logical AND or the logical OR.

**Ceteris Paribus:** All things held equal.

**Circumstantial:** Accidental, contingent.

**Common Sense:** Whatever beliefs are held by consensus in a community but usually focused on beliefs that are directly supported by everyday experience.

**Complement:** Every set (or term naming a set) has its complement, which (unlike an opposite) is whatever is not included in the set itself. Thus, the sum of any set and its complement is *everything*.

**Connotation:** See **Sense**.

**Consensus:** Common agreement, considerably more than majority opinion but not necessarily unanimous.

**Contingent:** Circumstantial or accidental, depending on external factors.

**Covering Law:** A scientific (descriptive) law of very general scope and application and of great explanatory power, thought to be universally true. Covering laws may subsume many particular laws of narrower scope under their aegis, entailing this one or that one in various specific natural circumstances. Example: *Universal gravitation*. See **Hypothesis, Theory, and Law**.

**Cultural Relativism:** The view that value (moral cultural relativism) and/or truth (epistemic cultural relativism) are local to a culture, being produced by the culture itself rather than found in the external world.

**Deduction:** Argument (or reasoning) is called *deductive* when its grounds offer ironclad support for its conclusion; that is, if it is said to give “closure.” Traditionally, the paradigm for deduction was Euclidian proof, typified by inference from general truths to particular outcomes (cf. **Induction**).

**Definition:**

**Essential:** Defining a term or phrase in terms of the “essence” of its referents, that is, the universal necessary and sufficient conditions of its use.

**Family Resemblance:** Defining a term or phrase in terms of overlapping similarities that may be observed in its referents.

**Operational:** Defining an abstract term or phrase in terms of observable phenomena or operations; for example, defining *gravity* as the acceleration of objects toward one another.

**Ostensive:** Defining a term or phrase by pointing to its referent.

**Paradigm Case:** Defining a term or phrase by reference to a stipulated model.

**Denotation:** See **Reference**.

**Dialectic:** A process for discovering first principles through probing the presuppositions of common sense beliefs, usually carried out in a question-and-answer dialogue. *Socratic dialectic* aims at debunking false opinions. *Platonic dialectic* seeks underlying reality. *Hegelian dialectic* is the alleged historical process of mind through thesis and antithesis toward synthesis. *Marxian dialectic* sees this historical process as material and economic, not mental.

**Distribution:** To say that a proposition “distributes” its subject term is say that it makes a claim about each and every member of class named by that term. A term is “undistributed” in a proposition (or “fails to distribute”) when the proposition does not make so inclusive a claim. Thus, for example, the proposition “All Athenians are Greeks” distributes “Athenians” (that is, it says something about each and every Athenian) but does not distribute “Greeks” (that is, it does not say something about each and every Greek).

**Empiricism:** The view that experience (sometimes limited to sense experience) is the primary (or even the exclusive) source of human knowledge (cf. **Modern Rational Empiricism**).

**Enlightenment:** An age of humanism, naturalism (and some deism), broadly associated with the 18<sup>th</sup> century.

**Epistemic Relativism:** The view that the knowable and known vary independently of what is the case, as a function of one’s culture, paradigm, mind set, or circumstances; a variety of collective subjectivism.

**Epistemology:** Knowledge theory, one of the main traditional branches of philosophy.

**Evidence:** That which is offered as a basis for inferences. It may amount to observations, recollections, axioms of one sort or another, or even revelations. Some kinds evidence are much more reliable than others.

**Experience:** A covering term for the source of any external data for thought. Usually, sense experience (seeing, tasting, smelling, feeling, hearing), but other input can be included (encounters, visions, and the like). Experience can be objective or subjective, private or public, one-off or replicable.

**Experiments:** Organized work to test hypotheses, discover new facts, establish connections, and so on. Often done in a lab or in the field and, sometimes (as in the case of *thought experiments*), done in one’s head.

**Explanation:** The rendering intelligible of a state of affairs by carefully noting how it came about and how it relates to other states of affairs (causal), why or for what purpose it occurred (teleological), or the use that it serves (functional).

**Extension:** Contrasts with **Intension**. See **Reference** and **Sense**.

**Felicity Conditions:** The circumstances in which a locution is “happy,” (for example, a description is felicitous if it is true, a promise is felicitous if it is sincere, a joke is felicitous if it is funny).

**Foundationalism:** The view that only some states of affairs are directly known and that all other knowledge is derived from that foundation. Different schools of thought pick different foundations.

**Hypothesis:** A descriptive proposition, not known to be true, that is entertained provisionally in an attempt to explain observed phenomena. It may be narrow or broad in scope and, ideally, will be open to testing in terms of whether or not its various implications are confirmed experientially. Example: *That acquired characteristics can be passed on to one's offspring.* See **Theory, Law, and Covering Law.**

**Idealism:** The metaphysical view that there is a non-physical reality “behind” or “above” the apparent reality of everyday events.

**Imply, Entail:** To provide sufficient grounds for the truth of, as a premise implies a conclusion. If an implication is logically necessary, it is called an entailment.

**Incommensurable:** Of two or more statements, theories, or paradigms, not measurable or assessable on a common standard.

**Induction:** Argument (or reasoning) is called *inductive* when its grounds offer probable support for its conclusion but do not give “closure.” Traditionally, the paradigm for induction was generalization, typified by inference from particular truths to universal outcomes (cf. **Deduction**).

**Inference:** That process of thought by which we move from some grounds or evidence to a thought or opinion said to be based on it or to follow from it. People infer; statements imply. (See **Deduction** and **Induction**.)

**In principle:** By definition, not accidental.

**Intension:** See **Sense.**

**Intuition:** Direct (unmediated) understanding, knowledge, or insight; also unexplained understanding, knowledge, or insight. Often, to say something is intuited is only to say we don't know how we got it.

**Invention:** Creation. People invent devices, such as telescopes. They also invent ideas, such as the general theory of relativity. Sometimes, invention involves only the synthesis of preexisting bits. Occasionally, however, it involves a *de novo* “leap.”

**Knowledge:** Justified true belief, at least, but more than that according to skeptics who deny its occurrence.

**Law:** A law is either a prescriptive statement that is desired to be exceptionless (prescriptive law), or a descriptive statement that is thought to be exceptionless (descriptive law). Prescriptive laws (whether common laws or statute laws) are in the realm of social control and are aimed at influencing and directing things in one way or another. Descriptive laws are in the realm of explanation and are aimed at accurately capturing things the way they are. Prescriptive laws may be good or bad, and can be revised when the interests of the law maker change. Descriptive laws may be true or false, and are open to revision in the light of new data. Descriptive laws have *no* prescriptive force. In science, the term ‘law’ is descriptive and is commonly used as an honorific for a theory that has repeatedly passed rigorous tests across a range of applications. Example: *That for every action, there is an equal and opposite reaction.* See **Hypothesis, Theory, and Covering Law.**

**Logic:** A system of rules of inference to determine whether or not (and, if so, to what extent) the premises of an argument support its conclusion. A rational reconstruction of effective thinking. (See also **Modal, Predicate, and Sentential Logic**; also **Boolean Algebra**.)

**Logical Empiricism:** A philosophical position identified with the Vienna Circle that insisted that all cognitively meaningful language is, in principle, either empirically or formally verifiable; logical positivism.

**Logical Form:** The syntactical structure of an argument, such as *modus ponens* (that is, “If P, then Q; P, therefore Q”) and *modus tollens* (that is, “If P, then Q; Not-P, therefore Not-Q”).

**Logical Positivism:** See **Logical Empiricism.**

**Meaning:** The sense or the reference (or both) of a word, phrase, or other representation or the intention of one who uses such.

**Meaning, Theory of:** An account, such as the use theory or the naming theory, of how a word, phrase, or other representation conveys a sense and picks out a reference.

**Memory:** Recollection or recall or the mental faculty by means of which we recollect or recall. Accurate memory presupposes that what is remembered actually happened the way it is remembered to happen. Not all memory is accurate.

**Metaphysics:** In Aristotle's collected works, what comes after *Physics*. To logical positivists, nonsense. To the ambitious, speculative "theories of everything." More generally, abstract inquiry about "the furniture of the world." Ontology.

**Methexis:** Interaction or, in the case of Plato's Forms and the appearances, "participation." Usually occurs in the locution *methexis problem*, as in: "We have no idea how the Cartesian minds and bodies interact. His dualism causes a real *methexis problem*."

**Modal Logic:** Logic applied to the notions of possibility and necessity (in contrast to the ordinary logic of contingent statements).

**Modern Rational Empiricism:** The typical epistemological stance of Western science: reason and experience working together to discover, understand, and anticipate facts.

**Moral Relativism:** The view that what is good, moral, or right varies independently of what is factually the case, as a function of one's culture, paradigm, mind set, or circumstances; a variety of collective subjectivism.

**Naming Theory of Meaning:** A still common view that words and phrases mean by naming something. It encounters difficulty with such words as *nothing* and such phrases as *the present king of France* (which are meaningful but don't name anything),

**Natural Law:** "Natural law" may be used as a synonym for "scientific law," in which case the label denotes a strictly descriptive proposition. In many contexts, however, "natural law" is taken to denote one or another *prescriptive* principle of nature. In the latter sense, it has everything to do with religion and metaphysics and nothing to do with science. See **Law**.

**Nominalism and Realism:** Metaphysical positions on the status of abstract nouns. Realism insists that they name actual entities (such as the Good), while nominalism allows that they express only notions.

**Ockham's Razor:** The primary tool of theoretical economy; hypothesizing no more than is necessary to save the appearances.

**Operationalism:** Metaphysical position that abstract nouns must be given operational definitions (see **Definition**).

**Opposite:** see **Complement**.

**Paradigm:** Generally, a model, template, or pattern. In recent usage, the frame of reference or perspective in which one operates that determines how things appear and, hence, how one describes or explains them.

**Pattern Discernment:** Picking out (usually visually but other sense modes can be used) some similarity, structure, organization, or recurrence in occurring experiences; for example, noticing that most of the native residents of Spanish Wells have reddish hair.

**Pattern Recognition:** Connecting a discerned pattern to a remembered one.

**Positivism:** The philosophical position of Auguste Comte, typified by the rejection of myth, magic, and metaphysics and the affirmation of "positive science." A precursor of logical positivism.

**Post Hoc Ergo Propter Hoc:** "After, therefore because of"—a common fallacy.

**Postmodernism:** A point of view that rejects "modern" rationalism and empiricism, usually focused on Descartes. It is notably committed to both epistemic and normative cultural relativism, trades heavily on such notions as the "sociology of knowledge" and "paradigm shifts," and suggests that *everything* is a text open to interpretation.

**Predicate Logic:** Logic that involves the analysis of the internal structure of subject/predicate sentences (in contrast to sentential logic, which treats simple sentences as unanalyzed units). The logic of syllogisms and of set theory.

**Premise:** An assumption or starting point for argument; the basis from which an argument's conclusion is inferred.



**Rationalism:** The view that genuine knowledge (perhaps all of it) must be achieved through the exercise of the mind rather than through experience (cf. **Modern Rational Empiricism**).

**Realism:** See **Nominalism and Realism**.

**Reason:** (1) Cognitive processing, including deductive and inductive inference, classification, hypothesis construction, and the like. Not to be confused with affective processing (the emotions) or conative processing (the will). (2) The basis or grounds for a belief or act. (3) The goal of an act.

**Reductionism:** A philosophical enterprise that consists of translating accounts of one sort of phenomena into the vocabulary of an allegedly simpler and more inclusive sort of phenomena. Behaviorism, for example, is a reductionist theory of mind.

**Reference:** Denotation or extension; that which is referred to or picked out by the sense of a word or phrase.

**Scholasticism:** High medieval thought.

**Semantic:** Having to do with the sense and reference of language, as opposed to its internal structure or logic. See **Syntactic**.

**Sense:** The connotation or intension of a word or phrase; the set of characteristics or properties so invoked in terms of which one can pick out the reference.

**Sentence, Compound:** A sentence composed of two or more simple sentences, joined together (such as “It’s 5 o’clock, and I’m ready to quit for the day” and “If I quit now, then I will be home before sundown.”) Some compound sentences are truth functions of their components (such as the examples just given), but others are not (such as “John believes that Mary loves Bill”).

**Sentence, Simple:** A sentence no part of which is a sentence in its own right (such as “Today is Friday” and “Grass is green”). See **Sentence, Compound**.

**Sentence, Truth-Functional:** A compound sentence, the truth or falsity of which is a function of the truth or falsity of its component parts and the meaning of the connector with which those parts are joined. Simple sentences joined by verbal connectors, such as “and,” “or,” and “if...then,” produce truth-functional compound sentences.

**Sentential Logic:** Logic that examines the implications of simple and truth-functional compound sentences but does not involve the analysis of the internal structure of the simple sentences themselves (as is the case with **Predicate Logic**).

**Sociology of Knowledge:** The idea, sometimes associated with Karl Mannheim, that what is known is always a function of the culture in which one operates. *Epistemic cultural relativism* is the more common label now.

**Sound:** The quality of an argument that is valid and has true premises.

**State Description:** In Newtonian physics, the precise specification of the location and vector of all the bits in a closed physical system. A map of a reality slice.

**Syllogism:** An argument in predicate logic composed of two premises and a conclusion, each of which has exactly two terms (subject and predicate), each of which occurs twice (one in the first premise and the conclusion, one in both premises, and one in the second premise and the conclusion). See **Predicate Logic**.

**Syntactic:** Having to do with the internal structure or logic of language (as opposed to its meaning). See **Semantic**.

**Synthetic:** The character of a statement that cannot be shown to be true or false by logical analysis alone. See **Analytic**.

**Theory:** A hypothesis that has been well confirmed and, generally, is of sufficiently broad scope to have wide application and utility. Example: *That the physical characteristics of biological organisms are, for the most part, genetically determined*. See **Hypothesis, Law, and Covering Law**.

**Thinking:** The contemplation of an idea, the holding of a belief, or (most notably) using your mind to get from A to B.

**Tautology:** A statement that is necessarily true, true by virtue of its form, or analytically true (for example, “In base-10 arithmetic,  $2 + 2 = 4$ ,” and “If P, then if Q then P”).

**Truth Conditions:** Circumstances in which a statement will be true or false. These may be experiential or logical, at least.

**Truth Criteria (Tests):** Ideas about how we can ascertain whether a statement is true or not, such as *correspondence* (seeing if it “matches” the way things really are), *coherence* (seeing if it is consistent with other statements that are held to be true), and *pragmatic* (seeing if it works in use).

**Truth Theories:** Ideas about what makes a statement true, such as *correspondence* (actually matching the ways things are), *coherence* (meshing with other statements that are true themselves), and *pragmatic* (being reliable in use).

**Use Theory of Meaning:** The theory, associated with Wittgenstein, that the meaning of a statement amounts to nothing more than the uses to which the statement can be put.

**Valid:** The quality of an argument with a logical form such that the truth of its premises assures the truth of its conclusion.

**Venn Diagrams:** Graphics used to represent sets, set membership, and the relations between sets by means of overlapping circles, shading, and the placement of Xs. They are used to evaluate syllogisms.

**Verification:** Testing a statement for truth.

**Verificationism:** The notion, associated with logical empiricism, that a statement can be meaningful only if it is testable by either experience or logic.

## Biographical Notes

The information included here has been gathered from a variety of reference sources, both conventional and electronic. The purpose of these sketches is to identify some of the more influential philosophers and works referred to in the lectures, not to argue their merits. Further information can be found in: *The Directory of American Scholars* (U.S. and Canada), *The Dictionary of National Biography* (Britain), *The Encyclopedia of Philosophy*, and at Web sites such as:

<http://www.biography.com/> Biography.com  
<http://www.philosophypages.com/> Philosophy Pages from Garth Kemerling  
<http://www.newadvent.org/cathen/> The Catholic Encyclopedia  
<http://www.utm.edu/research/iep/> The Internet Encyclopedia of Philosophy  
<http://www-groups.dcs.st-and.ac.uk/~history/index.html>  
History of Math Archive  
[http://www.formalontology.it/history\\_of\\_logic.htm](http://www.formalontology.it/history_of_logic.htm)  
History of Logic Bibliography

**Aristotle (384–322 BCE).** Aristotle was a native of Stagirus in northern Greece. Son of a physician, it is likely that he received some training in that direction himself before his father's death. Later a student (and then a teacher) in Plato's Academy, and eventually founder of his own school (The Lyceum), Aristotle brought a keen interest in methodical observation to philosophy. He was also committed to the notion that all areas of knowledge, especially what we would call the theoretical sciences, can be axiomatised into deductive systems. He was not the first to suggest such a program, however. Indeed, Plato had suggested that there might be a single axiom system to embrace all knowledge; and, at a somewhat more concrete level, Euclid and his axiomatic geometry had come before him. In *Prior Analytics*, he proposed the now familiar syllogistic, a form of logic that, along with the rest of the Aristotelian corpus, became dominant in western thought until the end of the 17<sup>th</sup> century.

**Aquinas, St. Thomas (1225–1274).** An Italian Dominican Scholastic theologian, logician and philosopher, Aquinas was markedly Aristotelian in temperament and method. Something of a mystic, and concerned with witchcraft and alchemy, he is most noted by modern philosophers for his monumental works: *Summa Contra Gentiles* and *Summa Theologica*. The definitive voice of Roman Catholic theology and philosophy, Thomas is never an easy read but always a profitable one.

**Averroës (1126–1198).** Averroës was a notable Arabic philosopher and astronomer whose career came toward the end of the Moorish domination of Spain. He was a major contributor to the preservation of Aristotle's influence on Jewish, Muslim and Christian thought in the Middle Ages.

**Ayer, Sir Alfred Jules (1910–1989).** An English philosopher, Ayer studied at Oxford under Gilbert Ryle, and (after the war) taught there, at University College London, and again at Oxford as Wykeham Professor of Logic from 1959. His most influential book was *Language, Truth and Logic*, a forceful introduction of Logical Empiricism to the English-speaking world. Other works include *The Problem of Knowledge* and *The Central Questions of Philosophy*. Your lecturer was privileged to attend his lectures at Oxford in 1975, and found him as witty and astute at the lectern as he was at his writing desk.

**Bacon, Sir Francis (1561-1626).** The son of Nicolas Bacon, the Lord Keeper of the Seal of Elisabeth I, Francis Bacon entered Trinity College, Cambridge, at age 12. He turned to the law and at 23 he was in the House of Commons. He rose to become Lord Chancellor of England, and fell in the course of a struggle between King and Parliament. Rejecting Aristotelianism and Scholasticism, Bacon saw himself as the inventor of a new method, *Novum Organum* (1260), which would kindle a "a light that would eventually disclose and bring into sight all that is most hidden and secret in the universe." His method involved the collection of data, their judicious interpretation, the carrying out of experiments, thus to learn the secrets of nature by organized observation of its regularities. Bacon's proposals had a powerful influence on the development of science in seventeenth century Europe. Thomas Hobbes served as Bacon's last secretary.

**Boole, George (1815-1864).** Son of a shoemaker (with interests in scientific instruments that distracted him from his cobbling) and a lady's maid, Boole began his education at a tradesmen's school. With a passion for languages, he

became proficient in Latin, Greek, German and French without formal training. Boole began correspondence with De Morgan in 1842 and wrote a paper applying algebraic methods to differential equations that was published in 1844. In November 1849 Boole became the first Professor of Mathematics at Queen's College, Cork, where he taught the rest of his life. In 1854 he published *An investigation into the Laws of Thought, on Which are founded the Mathematical Theories of Logic and Probabilities*. This began the development of “Boolean algebra,” now an important component of the “languages” of computers and switching circuits.

**Comte, Auguste (1798–1857).** A French thinker, the inventor of sociology and the founder of classical positivism, Comte argued that science has emerged from theological and metaphysical stages into its modern “positive” (operational or experiential) posture, and that human reverence should be for humanity itself. His works include six volumes on *Positive Philosophy* and four on *Positive Polity*. He is said to have practiced what he called “mental hygiene” by avoiding reading the works of others.

**Copernicus, Nicholas (1473–1543).** The son of a Polish copper trader and educated at the University of Krakow, Copernicus studied Latin, mathematics, astronomy, geography and philosophy. Astronomy then consisted of mathematics courses which introduced Aristotle’s and Ptolemy’s view of the universe so that students could understand the calendar, calculate the dates of holy days, and navigate at sea. While a student, Copernicus also became familiar with Euclid’s *Elements*, the Alfonsine Tables (planetary theory and eclipses) and spherical astronomy. Notable as the author of what we now call the “Copernican Revolution,” he brought three tools of thinking to the table: painstaking observation, mathematical/logical skill and the creative capacity to reconceptualize what we observe under a new paradigm.

**DeMorgan, Augustus (1806–1871).** Born in India, DeMorgan was educated at Trinity College, Cambridge, where he matriculated at the age of 16 in 1823. He began the use of a slash to represent fractions, perfected the principle of Mathematical Induction (1838), and made many contributions to the development of symbolic logic, including “DeMorgan’s laws.” He held the chair in mathematics at University College, London, from which he resigned (twice) on issues of principle. Not a warm person, he is remembered for his devotion to abstract reasoning.

**Descartes, René (1596–1650).** A French rationalist philosopher and mathematician, Descartes was Jesuit trained and strictly Catholic, but no Scholastic. He was notable for his reconstruction of rational knowledge by way of systematic doubt. Apart from the “cogito” and everything built on it, he is also noted for the invention of analytic geometry. His notable works include *Discourse on Method* and *Meditations on First Philosophy*. The model Cartesian tool of thinking is precise deduction. The bases of that deduction are to be found in those indubitable truths that are available to us (such as, allegedly, the axioms of geometry). If such “necessary” truths are not available, of course, there will be issues about the output of our thinking, however fool-proof the tool we use to process our data.

**Einstein, Albert (1879–1955).** Born in Germany, Einstein had a lackluster record in his early schooling there. He continued his education at the Zurich Technical High School, and after becoming a Swiss citizen in 1901 found temporary employment as a secondary school mathematics and physics teacher in Winterthur. While employed at the Bern Patent Office (1902–1905), Einstein wrote numerous articles on topics in theoretical physics in his spare time and completed a Ph.D. at Zurich in 1905. In the years that followed, Einstein contributed to his own “Scientific Revolution” by way of his Special and General theories of relativity and his reconceptualization of space and time. He also contributed to the philosophical revolution from genetic to confirmational empiricism. Not only at the forefront of all things theoretical (though he did not share the general enthusiasm for Quantum Mechanics), he was also influential in international affairs. Eventually a citizen of both Switzerland and the United States, he was an unflinching advocate of world peace.

**Euclid of Alexandria (circa 325 BC–circa 265 BC).** Euclid is best known for his treatise *The Elements*. Little is known of his life except that he taught at Alexandria. There is even argument about whether he actually existed. Most likely, he was a student of Plato and lived during the reign of Ptolemy I. Whether the content of *The Elements* is wholly (or even in part) his own, that work set the pattern for “axiomatizing” bodies of knowledge. We are also in Euclid’s debt for the pattern of “*reductio ad absurdum*” proof (where we assume the falsehood of an hypothesis and, by showing that this leads to absurdity, infer that the hypothesis is true).

**Frege, Gottlob (1848–1925).** Son of a schoolmaster in Wismar, Frege entered the University of Jena shortly after the Seven Years’ War, and completed his doctorate at Göttingen in 1873. He returned permanently to Jena in 1874 where he taught all branches of math; but his works on the philosophy of logic, mathematics and language are key.

In 1879 his *Begriffsschrift*, a book on “conceptual notation,” laid out a logical system with negation, implication, universal quantification, and the essential idea of truth tables. His *Foundations of Arithmetic* (1884) attempted to axiomatize it, in keeping with his belief that it is reducible to logic. In 1902, Frege received a letter from Bertrand Russell pointing out a contradiction in his system of axioms. This generated lengthy correspondence and a revision to an axiom, but the system remained inconsistent.

**Galileo (1564–1642).** Born near Pisa, the son of a musician and teacher, Galileo seemed destined for a career in medicine but was seduced by mathematics. An early reader of Euclid and Archimedes, he abandoned his medical studies altogether by 1585. A student of the theory of motion, he worked out many important ideas (such as the parabolic path of a projectile), but they were not published until the 1630s. In 1609 he came into possession of a spyglass, took up lens making, made telescopes, and turn his gaze skyward. This serendipitous combination of intellect and artifact (creative thinking and a telescope) opened the door to a thorough reconceptualization of the universe and our place in it.

**Heisenberg, Werner (1901–1976).** Born in Würzburg, Germany and educated at the University of Munich, Heisenberg is remembered for his contributions to physics in the form of matrix mechanics, quantum mechanics, atomic structure and the indeterminacy principle. Calling Newtonian notions about causation and predictability in question, he contributed heavily to the twentieth century “revolution” in theoretical physics. While there may be no questions about accuracy of quantum mechanics, there are questions about its implications. Heisenberg’s own interpretations of them, in *Physics and Philosophy* (1962), are controversial.

**Hume, David (1711–1776).** A Scottish philosopher and historian, Hume studied at Edinburgh, but was denied professorships there and at Glasgow for religious reasons. His many important works include *An Inquiry Concerning Human Understanding*, *A Treatise of Human Nature*, and *Essays Moral and Political*. He was the definitive British Empiricist, noted for his views on causation, the association of ideas and the roots of induction in habit rather than in demonstrable truth. He is notably credited for awakening Kant from his “dogmatic slumbers” and for his aversion to “sophistry and illusion.” His long-term influence on British Analytic philosophy is unmistakable at every turn, but is especially evident in the works of Russell, Ryle, Wittgenstein, Austin and your present lecturer.

**Kant, Immanuel. (1724–1804).** A German philosopher, perhaps the first *professional* philosopher, Kant was a career academic. His three *Critiques* (of *Pure Reason*, *Practical Reason* and *Judgment*) are landmarks in modern philosophical history, responding to Hume’s empiricism and permanently marking out the limits of reason in such a way as to exclude any knowledge whatever of “things in themselves.” Most of the subsequent philosophical discussion of the analytic/synthetic distinction and of the impossibility of synthetic *a priori* knowledge has been influenced for good or ill by his notions of the “transcendental analytic.”

**Kepler, Johannes (1571–1630).** Son of a mercenary soldier who died in war, Kepler began life in Swabia and was raised by his mother in her father’s inn. After school and a regional seminary, he enrolled at the University of Tübingen. Now remembered for the laws of planetary motion named for him, he also worked with optics and made discoveries in solid geometry, demonstrated how logarithms work, and contributed to the eventual development of calculus. Not only a keen mathematician, he was also a painstaking observer. His remarkably precise astronomical tables also helped to establish the truth of heliocentric astronomy.

**Kuhn, Thomas (1922–1996).** An American philosopher and historian of science, Kuhn taught at Harvard, Berkeley, Princeton and MIT. His *The Structure of Scientific Revolution* was published at mid century as a volume in the *International Encyclopedia of Unified Science*—a surprisingly positivistic venue for a non-positivistic treatise. If Kuhn did not invent paradigms and paradigm shifts, he certainly put them on the map for the rest of us. On his view, there is no rational basis for choosing one paradigm over another. Other works include *The Essential Tension: Selected Studies in Scientific Tradition and Change* and *The Road Since Structure: Philosophical Essays, 1970–1993*.

**Mill, John Stuart (1806–1873).** Born in London, the son of the Scottish philosopher James Mill, and the product of an early excursion into home schooling, Mill took on Greek at the age of 3, Latin and arithmetic at 8 and logic at 12. With the security of a nominal career at the India Office, he devoted much time to the Utilitarian Society, the Westminster Review, and the London Debating Society. His first major work, *A System of Logic*, was published in 1843. Later important pieces include *Liberty* (1859), *Utilitarianism* (1863) and *Three Essays on Religion* (1874). His influence on Bertrand Russell and John Maynard Keynes was substantial. The reputation of Mill’s *Logic* was

largely due to his analysis of inductive proof. He sought to provide the empirical sciences with a set of formulas and criteria which might serve the same purpose for them that the formulas of the syllogism had served for classical deductions from general principles.

**Newton, Sir Isaac (1643–1727).** The most famous of English scientists, Newton entered Trinity, Cambridge, to prepare for law in 1661 (after a thoroughly spotty career in school). The slightly non-restrictive atmosphere there allowed him to read widely (including Aristotle, Descartes, Gassendi, Hobbes, Boyle, Galileo and Kepler). He started reading mathematics in 1663, by way of a book on Astrology, but soon progressed to Euclid and to the analytical geometry and algebra of Descartes and Viète. When the plague closed the University in the summer of 1665 Newton returned to Lincolnshire where, in two years time, he began revolutionary advances in optics, physics, and astronomy, and laid the foundations for differential and integral calculus, several years before its independent discovery by Leibniz. Best remembered for the laws of motion constituting “Newtonian Mechanics,” he laid out the basic dimensions of orthodox scientific thinking for the next two centuries, before turning his attentions away from science and mathematics for the last half of his life.

**Peano, Giuseppe (1858–1932).** Son of a farming family in the Piedmont, Peano began his education at a village school but completed it at the University of Turin. He went on to teach there in 1880. In 1887, he published a method for solving systems of linear differential equations, and in 1888, a geometrical calculus including a chapter on mathematical logic. In 1900 he presented at the International Congress of Philosophy in Paris. Of him, Bertrand Russell said, in his *Autobiography*, “this was the turning point of my intellectual life ... In discussions at the Congress I observed that [Peano] was always more precise than anyone else, and that he invariably got the better of any argument on which he embarked. ... I decided that this must be owing to his mathematical logic ... an instrument of logical analysis such as I had been seeking for years.”

**Peirce, Charles Saunders (1839–1914).** A man of notably erratic temperament and son of a Harvard astronomer/mathematician, Peirce was born in Cambridge and educated at Harvard himself. Early research with the U.S. Coastal Survey into geodesy and gravimetrics, and his work on Boolean logic, led to contact with such logicians as W. S. Jevons and Augustus De Morgan. Noted for his essays “The Fixation of Belief” and “How to Make our Ideas Clear,” Peirce was appointed to a position at Johns Hopkins in 1879 where he developed a theory of relatives and quantifiers independently of Frege’s work. His career was beset with difficulties in the wake of his indiscretions; but his influence (particularly by way of Pragmatism, of which he was a primary founder) was substantial in the long run.

**Plato (427–347 BCE).** Student of Socrates, founder of the Athenian Academy, and teacher of Aristotle, Plato exercised the dialectical method not only to discover error but also to lead the way to insight. While we may debate the accuracy of the details of his insights, the broad sweep of the Platonic message remains intriguing. Plato’s notions of the human mind, will and appetites, his fundamental models for social organization, and his basic dualism of appearance and reality, have all found their way (through Aristotle, Descartes and others) into the modern mind set. Of primary interest here is his notion that the mind (in pre-existent circumstances) once had immediate access to reality (the Forms), and that the process of thought that leads to present understanding is essentially one of elucidating (through dialectic) what the mind remembers of what it already knows.

**Popper, Karl (1902–1994).** A very influential Austrian philosopher of science and politics, Popper insisted in *The Logic of Scientific Discovery* (1935) that scientific knowledge never advances by proving the truth of a theory (since that is impossible), but only through the systematic experiential falsification of alternatives to one. His controversy with Wittgenstein is legendary. In the long run, his political philosophy (in *The Open Society and Its Enemies*), has had greater impact than his theory of falsification; but that theory certainly influenced the development of Logical Empiricism, being particularly prominent in A. J. Ayer’s accounts of that movement.

**Port Royal Logic (1662).** Port Royal was a Jansenist convent near Paris, noted by logicians for *The Port Royal Logic*, one of the most widely used philosophical works of the 17th century. This volume dealt with traditional logic with a strong Cartesian flavor, and was in the vernacular. Written by Antoine Arnauld (1612–1694), and Pierre Nicole (1623–1695), and first published anonymously, it was translated into many languages and was widely influential.

**Quine, W. V. O. (1908–2000).** Son of an engineer and a school teacher, Quine was educated at Oberlin and Harvard. Having read James’s *Pragmatism* in school, and Russell and Whitehead’s *Principia Mathematica* as an undergraduate (!), he turned to mathematics and philosophy of mathematics at Harvard where, after his PhD, he was

appointed Junior Fellow in 1933 and instructor in philosophy in 1936. The lines of influence between Quine, the Logical Positivists, Russell and Whitehead were many and mutual. A prolific writer, perhaps his most influential essay was “Two Dogmas of Empiricism” in which he called empirical orthodoxy into serious (pragmatic) question, arguing that “it is folly to seek a boundary between synthetic statements, which hold contingently on experience, and analytic statements, which hold come what may.” Your lecturer had the honor to meet him at Oxford in 1974, finding him terse and more than a little intimidating, but warmly interested in the work of a young philosopher from the provinces.

**Russell, Lord Bertrand (1872–1970).** An English philosopher, logician, mathematician, freethinker and essayist, Russell was a student, fellow and professor at Cambridge, where he influenced the shape of philosophy for generations (by way of “both” Wittgensteins as well as the Vienna Circle), and set the course of all subsequent philosophy of logic and mathematics. His early works included *Principles of Mathematics* and *Principia Mathematica*. Mid-career books included *An Enquiry into Meaning and Truth* and *Human Knowledge*, plus myriad essays and polemics on topics ranging from education and marriage to nuclear disarmament. Social and political issues were his primary focus after 1949.

**Socrates (470–399 BCE).** A legendary, not to say mythic, figure in Western intellectual history, Socrates is remembered as the teacher of Plato, the gadfly of Athens, an alleged corrupter of youth and worshipper of false gods, and the master of what has come to be called “Socratic dialectic.” Convinced that wisdom begins in the realization of ignorance, Socrates committed himself to convincing one and all—in maddening conversations—of just how ignorant we are. Since Socrates appears repeatedly as a major player in the Platonic dialogues, it is not at all easy to know where Socrates leaves off and Plato takes over. It is likely, however, that the dialectical method of inquiry itself is truly Socratic. The notion of dialectic has been corrupted historically in the metaphysical schemes of Hegel and Marx.

**Venn, John (1834–1923).** Grandson of the founder of the Clapham Sect (a socially progressive religious movement) and son of the Secretary of the evangelical Church Missionary Society for Africa and the East, Venn was educated at Gonville and Caius College, Cambridge. Ordained a priest himself, Venn eventually pursued an academic life, with strong interests in both literature and mathematics. He significantly extended Boole's mathematical logic and is remembered for his diagrammatic representations of sets and their relationships with three circle figures. The relationships of these circles nicely represent the structure of all 256 types of classical categorical syllogisms.

**William of Ockham ( c.1280–c.1349).** An English Scholastic, Franciscan and philosophical nominalist, Ockham studied theology at Oxford (perhaps under Duns Scotus) and Paris, where he taught. Charged with heresy, and subsequently a refugee in Bavaria, he denied papal authority over temporal matters. A dogged opponent of metaphysical *largess*, he is more remembered today for his “razor” than for any particular treatise.

**Wittgenstein, Ludwig (1889–1951).** A Viennese/English philosopher, inventor and sometime schoolteacher, Wittgenstein studied engineering at Berlin and Manchester and mathematical logic at Cambridge, where he taught (with lengthy interruptions) between 1929 and 1947. The most influential Western philosopher of the 20th century, Wittgenstein's two major works, *Tractatus Logico-Philosophicus* and *Philosophical Investigations*, laid the foundations for Logical Atomism and Logical Positivism, on the one hand and for “ordinary language analysis” on the other. Neither an easy person nor an easy philosopher, this brilliant and quirky thinker stirs interest even among non philosophers, as evidenced by the reception of David Edmonds' and John Eidinow's *Wittgenstein's Poker*.

## Bibliography

### Essential Reading:

Asimov, Isaac. *Asimov's Chronology of Science and Discovery*. New York: Harper Resource, 1991, ISBN 0062700367. Asimov's work is notable for its combination of scientific accuracy and accessibility to the general reader. This particular book will give you a good overview of the sweep of scientific progress and, more important, an insight into the methodology by which that progress was won.

Copi, Irving. *Introduction to Logic*. 11<sup>th</sup> ed. Upper Saddle River, NJ: Prentice-Hall, 2002, ISBN 0130337358. This book is clear and meticulous and covers all the bases, from informal logic (critical thinking), through classical and modern treatments of the syllogism and the basics of symbolic deductive logic, to inductive reasoning and probability. It has many useful exercises and has gone through many editions. The 11<sup>th</sup>, cited here, is not the latest, but it is readily (and cheaply) available on the used-book market.

Hempel, Carl. *Philosophy of Science*. Upper Saddle River, NJ: Prentice Hall, 1966, ISBN 0136638236. Not the newest but one of the best presentations of "mainstream" 20<sup>th</sup>-century philosophy of science. The book is short, clear, thorough, and uncompromising. Hempel's posture is empirical, as far as evidence is concerned, but his empiricism is nuanced in terms of the issues laid out in the next citation. Most important for present purposes, Hempel lays out a clear analysis of how hypotheses work in scientific explanations and of how they are formulated and supported.

Kuhn, Thomas S. *The Structure of Scientific Revolutions*. 3<sup>rd</sup> ed. Chicago: University of Chicago Press, 1996, ISBN 0226458083. This is where all the talk of "paradigms" and "paradigm shifts" comes from. As usual, you should have a look at the source of these notions before you make up your mind about the popularizers use (and misuse) of them. Kuhn is trying to show that science is not inevitably progressive and that its movement over time is not linear. Another important idea that crops up here is that scientific claims are "theory laden" and, hence, *not* "value-free." If so, then the tools that scientists use in their thinking are influenced by the immediate scientific milieu and by the larger culture in essentially political ways. This book channels Wittgenstein into postmodernism. It is not easy going.

### Recommended Reading:

Aristotle. *Prior Analytics*. Robin Smith, ed. Indianapolis: Hackett Publishing, 1989, ISBN 0872200647. Here, as with other volumes mentioned below, we are indebted to Hackett for a high-quality edition of a classical text at an affordable price. This part of Aristotle's legacy is devoted to basic logic. It is the wellspring of the enterprise in the west.

Ayer, A. J. *Language, Truth and Logic*. New York: Dover Publications, 1952, ISBN 0486200108. This is the classic manifesto of logical positivism in English. Ayer's skeptical rejection of everything "metaphysical" fairly bristles. It is not for the fainthearted. Even though this sort of aggressive empirical reductionism was reined in by Wittgenstein's move to "ordinary language," this is still a good account of the knowledge/evidence connection.

Beck, Lewis White. "Constructions and Inferred Entities." *Philosophy of Science*, XVII, 1950. Reprinted in *Readings in Philosophy of Science*, Herbert Feigl and May Brodbeck, eds. New York: Appleton-Century-Crofts, 1953. This essay explores the status of the unobservable "bits" that modern science has so much to say about, showing how scientific theory is empirical even though it is not directly about what we see, taste, smell, feel, and hear. It is a classic presentation of the essential role of responsible hypothesis construction in science.

Berlinski, David. *Newton's Gift: How Sir Isaac Newton Unlocked the System of the World*. New York: Free Press, ISBN 0743217764. This work captures the scope and impact of Newton's "revolution" with just enough attention to the technical side to make it useful for non-scientists in getting a handle on the history of science. It also provides useful insights into Newton himself and his era. The style is a little arch but not unbearably so.

Best, Joel. *Damned Lies and Statistics*. Berkeley: University of California Press, 2001, ISBN 0520219783. Evidence is important, but some evidence is much more important than the rest. Written strictly for the popular market, this book is about the difference. It will either teach you how to mislead others with statistics or how to avoid letting them mislead you. It is transparent, important, and funny and should be universally required reading.

Butler, Christopher. *Postmodernism—A Very Short Introduction*. Oxford: Oxford University Press, 2002, ISBN 0192802399. Part of an excellent new series, this (very) little book will help the reader figure out what is going on



when people start talking about *deconstruction* and other things “postmodern.” Much has been said in recent years to suggest that modern philosophy and modern science are hopelessly flawed and that all “knowledge” is local, relative, and agenda- and culture-driven. A few hours with this book will help the reader see the grounds and implications of those allegations and make a judgment about their merit.

De Kruif, Paul. *Microbe Hunters*. New York: Harvest Books (Harcourt), 2002, ISBN 0156027771. This is the original “gee-whiz” book about the heroes of modern medical discovery. Every boy and girl should read it for inspiration. Every adult should read it for increased understanding and appreciation of how hands-on experimental inquiry is done. Medical and scientific progress is not easy or cheap.

Descartes, René. *Meditations*. Indianapolis: Hackett Publishing, 1999, ISBN 0872204200. Rationalism embodied. It has been said that all of modern philosophy amounts to either the embellishment or the repudiation of Descartes. This little book is the nub of the matter. Here, “systematic doubt” allegedly leads to the deductive reconstruction of all knowledge from one necessary truth (*cogito ergo sum*). Empiricists disagree.

Dewey, John. *The Quest for Certainty*. Carbondale, IL: Southern Illinois University Press, 1988, ISBN 0809314932. Too often overlooked (perhaps because of its turgid style), this is a very important presentation of why epistemologies such as Descartes’ rationalism are doomed by their improper inclusion of “certainty” as one of the necessary conditions of knowledge. Dewey’s own pragmatic reconstruction of knowledge makes it provisional, dynamic, and possible (in contrast to Descartes’, which leaves it absolute, static, and unobtainable).

Fearnside, W. Ward. *Fallacy: The Counterfeit of Argument*. Upper Saddle River, NJ: Prentice-Hall, 1959, ISBN 0133017702. Not new, but worth scouting out on the Web for a used copy, this book catalogs (and gives examples of) just about every informal fallacy there is. Somebody needs to do a 21<sup>st</sup>-century update with current examples from the media, but the fallacies themselves haven’t changed, and this is a handy place to learn what they look like.

Hall, James. *Practically Profound*. Lanham, MD: Rowman & Littlefield, 2005, ISBN 0742543277. Modesty prevents me from assessing the quality of this and the next item. Suffice it to say here that most introductions to philosophy don’t take the time to tackle the question of what makes various beliefs and opinions good, bad, or indifferent. This one does.

———. *Logic Problems for Drill and Review*. Washington, DC: University Press of America, 1991, ISBN 0819183792. This little book contains the skeleton of symbolic deductive logic, plus several hundred problems (with solutions). If you want to learn logic from scratch, I recommend Copi. But if you want a quick profile (or a review), this will be useful.

Hawking, Stephen W. *The Illustrated Theory of Everything: The Origin and Fate of the Universe*. Los Angeles: New Millennium Press, 2003, ISBN 1932407073. This book is not cited because it is *true* or even because your lecturer *thinks* that it is true. It is cited because it dramatically illustrates the sweep of mature modern rational empiricism. No one should either dismiss science (whether on postmodern, religious, or other grounds) or pay homage to it without reading this book (alongside Asimov’s *Chronology*, cited above).

Hempel, Carl. “Problems and Changes in the Empiricist Criterion of Meaning.” *Revue Internationale de Philosophie*, Vol. 1, No. 11, 1950. Reprinted in *Classics in Analytic Philosophy*, Robert R. Ammerman, ed. Indianapolis: Hackett Publishing, 1990, ISBN 0872201015. This is the classic account of the core of logical positivism’s “verificationism.” It shows the pitfalls in this brand of rational empiricism and sketches out possible ways to work around them. The book in which this is reprinted is a gem of a collection. Kudos to Hackett for getting it back in print and keeping it there. When you have read Hempel’s essay, read the others.

Huff, Darrell. *How to Lie with Statistics*. New York: W. W. Norton & Co., 1993, ISBN 0393310728. This book is a cousin of Joel Best’s little volume, cited above. It is less a handbook for deceiving others than a manual for avoiding statistical landmines yourself. This is an enjoyable (even amusing) read, but more important, it is a crucial guide to how mathematics can be used and misused in “proofs,” scientific or otherwise.

Hume, David. *An Enquiry Concerning Human Understanding*. Eric Steinberg, ed. Indianapolis: Hackett Publishing, 1993, ISBN 0872202291. Empiricism embodied. This book does for empiricism what Descartes’ *Meditations* did for rationalism (but with greater success). Hume, too, dances with skepticism. As a result, he arrives at a rather startlingly confined profile of what we know. The treatment of induction and causation, the analysis of beliefs in terms of habits of mind, and the dismissal of “sophistry and illusion” are legendary. No serious thinker can ignore this work.

Jones, W. T. *A History of Western Philosophy*, Volume I, “The Classical Mind.” Belmont: Wadsworth Publishing, 1969, ISBN 0155383124. The five-volume series is old, but the presentation is balanced and the commentary is

illuminating. The advantage and the disadvantage of Jones's approach both lie in his reliance on lengthy quotations from the primary sources. This may tempt the reader to avoid tackling the primary sources head on, but it also helps the reader see whether or not Jones's own analysis is responsible to the texts.

Mill, John Stuart. *A System of Logic: Ratiocinative and Inductive*. New York: Harper and Brothers, 1891. Available as a reprint from University Press of the Pacific, ISBN 1410202526. Far too expensive for a casual purchase, this work can be found in any nearby college library. It is the source of "Mill's method," the backbone of inductive reasoning as it is presented in standard logic texts, such as Copi's (cited above).

Okasha, Samir. *Philosophy of Science—A Very Short Introduction*. Oxford: Oxford University Press, 2002, ISBN 0192802836. Short, excellent, and current, if not as systematic and meticulous as Hempel's treatment (cited above). This book will give the reader an idea of what the current issues are among those who try to map and explain what scientists are up to.

Pinker, Steven. *How the Mind Works*. New York: W.W. Norton and Company, 1997, ISBN 0393318486. If there are any tools of thinking, surely the mind is one of them. But the mind has been the subject of more heat than light in philosophical discussions over the last 2,000 years. Pinker brings neuroscience and other modern tools to the analysis of how this tool operates. This is an exciting read and is totally accessible to the layman.

Plato. *Meno*. G. M. A. Grube, trans. Indianapolis: Hackett Publishing, 1980, ISBN 0915144247. Plato's ideas about how the mind works are not like Pinker's. This little dialogue lays out his basic notion that "recollection" is the key to learning, thinking, and understanding. But that presupposes the preexistence of the "soul" and the objective reality of the "Forms." This is the taproot of traditional rationalism and mind/body dualism.

———. *Republic*. G. M. A. Grube, trans. Indianapolis: Hackett Publishing, 1974, ISBN 0915144094. This is Plato's gem. Everyone should read it for its political, social, and moral implications (some of which are chilling, as noted by Karl Popper in his masterpiece, *The Open Society and its Enemies*—a book worth chasing down). What is of interest here, however, is Plato's conceptions of appearance and reality, the mind (cognitive soul), and knowledge. In the Myth of the Cave, Plato lays all that out metaphorically. The point is the same as in the *Meno*, and if the metaphor is supposed to describe reality, then the metaphysical price tags (and their Cartesian legacy) are even more obvious.

Popper, Karl. *The Logic of Scientific Discovery*. New ed. New York: Routledge, 2002, ISBN 0415278449. In this work, Popper disputed one of the initial tenets of logical positivism, viz. that all meaningful propositions are verifiable in principle. Because that would rule out universal claims, however, Popper suggests that all meaningful propositions are falsifiable in principle. This is all explained nicely in Hempel's essay, cited above. The value of this book is not to be found in the details of the arguments over verification and falsification, however. Its value resides in the notion that scientific discovery is hypothesis driven. This, too, is explained well in the Hempel essay, as he discusses scientific *method*.

Quine, W. V. O. "Two Dogmas of Empiricism." In *From a Logical Point of View*. Cambridge: Harvard University Press, 1980, ISBN 0674323513. Reprinted in *Classics in Analytic Philosophy*. Robert R. Ammerman, ed. Indianapolis: Hackett Publishing, 1990, ISBN 0872201015. This essay calls into question the notion that there is a bright-line distinction between analytic and synthetic statements (and, derivatively, between *a priori* and *a posteriori* knowledge). If there is no such bright-line distinction, then the traditional distinctions between deductive and inductive reasoning need to be rethought. This article contributed in a major way to the postmodern relativizing and pragmatizing of secure inference.

Rosenberg, Jay F. *The Practice of Philosophy: Handbook for Beginners*. 3<sup>rd</sup> ed. Upper Saddle River, NJ: Prentice Hall, 1995, ISBN 0132308487. This simple book lays out basic philosophical methods in very attractive and intelligible form. Reading it will help you understand what is going on in the philosophical essays and books that you read.

Schilpp, P. A. *Albert Einstein: Philosopher-Scientist*. Chicago: Open Court Publishing, 1988, ISBN 0875482864. We are indebted to Professor Schilpp for a large set of volumes about 20<sup>th</sup>-century philosophers, of which this is one. Here you will find Einstein's statement of his own philosophical/scientific outlook, numerous essays by his contemporary critics, and his reply to them. It is not a scientifically technical collection. It is about the broad sweep of Einstein's thought.

Turing, A. M. "Computing Machinery and Intelligence." *Mind*, Vol. LIX, No. 236 (1950). Reprinted in *Minds and Machines*. Allen Ross Anderson, ed. Upper Saddle River, NJ: Prentice Hall, 1964. This really is a classic. The point

of bringing it up is that it was one of the first persuasive essays written that suggested the *possibility* of artificial intelligence. This has become very important as the computer has become more and more central as a thinking tool.

Unger, Peter. *Ignorance, A Case for Skepticism*. Oxford: Oxford University Press, 2002, ISBN 0198244177. This is a definitive presentation of modern radical skepticism. You don't have to agree with Unger to see the power of his arguments to the effect that no one ever knows anything. Of course, if he is correct, then it doesn't matter whether you agree with him or not. Your lecturer does not agree with Unger, and I have tried to refute the line of argument he takes in my *Practically Profound*. I bring him up here simply because everything we have explored about *how* we know presupposes the possibility of knowing something—a presumption that we cannot ignore.

White, Jamie. *Crimes Against Logic*. New York: McGraw-Hill, 2004, ISBN 0071446435. This is another treatment of fallacious reasoning. It is less systematic but far more amusing, than Fearnside's work, cited above.

### **Internet Resources**

#### **Critical thinking:**

<http://www.austhink.org/critical/>

<http://www.criticalthinking.org/>

#### **History of logic:**

[http://www.formalontology.it/history\\_of\\_logic.htm](http://www.formalontology.it/history_of_logic.htm)

#### **History of mathematics:**

<http://www.maths.tcd.ie/pub/HistMath/>

#### **History of science:**

<http://www.fordham.edu/halsall/science/sciencesbook.html>

#### **History of science emphasizing chemistry (Chemsoc timeline):**

<http://www.chemsoc.org/timeline/index.html>

#### **History of ideas and inventions:**

<http://www.ideafinder.com/history/index.html>

<http://inventors.about.com/>

#### **History of calculators and computers:**

<http://www.xnumber.com/xnumber/> (click on "vintage calculators")

<http://www.hitmill.com/computers/computerhx1.html>