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# Contents

## Essays & Lectures



## Poem

# The Dispassionate Study of the Passions

Eva Brann

Plato's dialogue *Gorgias* ends with a long speech culminating in a rousing cry by an aroused Socrates. He is speaking to Gorgias's student Callicles about his swaggering opinionatedness and their common uneducatedness. The words he uses are *neanieusthai,* "to act like a youth," to behave like a kid, and *apaideusia,* "lack of teaching," ignorance. And then he concludes with a condemnation of Callicles's whole "way of life"—*tropos tou biou*—"to which you summon me, believing in it"—*hōi su pisteuōn eme parakaleis. esti gar oudenos axios, ō Kallikleis*—"For it is worth nothing, Callicles!" My fine 1922 edition of the *Gorgias* by the classicist Otto Apelt rightly translates the address *O Kallikleis,* jingling in the Gorgian manner with *parakaleis,* as "My Callicles," for there is a curious, straining intimacy in Socrates's peroration.[1] The rest is silence. It is a favorite question of mine to ask our freshmen at St. John's College, who all read this dialogue, what happened that night at home, when Callicles was, perhaps, by himself.

Now some of you may have heard of the late Seth Bemardete, a student of Leo Strauss and a brilliant classicist at New York University. In our youth we traveled together, and Seth once imparted to me the following wild conjecture. "Plato," it was said, was a nickname given to him because of his broad shoulders.[2] His real name was Aristocles: Callicles, Aristocles—he of noble fame, he of good fame; *kalos*

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*k'agathos* was the Greek way of denominating what Chaucer calls "a verray parfit gentil knicht," a good and noble knight, a perfect gentleman.[3] So Plato represents himself in this dialogue as a noble yet rudely unregenerate youth in his moment before conversion, a conversion accomplished by a usually imperturbable Socrates impassioned to speak, for once, extendedly and hotly.

Do I believe this clever combination of clues? Not really. Plato was, after all, of good family and a writer of tragedies before Socrates captivated him, and the swaggering surly youth Callicles has little of the high-bred, suave poet about him, a poet who was, moreover, probably already philosophically involved when he met Socrates.[4]

Nonetheless, this anecdote about a conjecture seems to me thought-provoking. Here, for once, Plato permits us to see the spectacle of rational Socrates in a passion, un-ironic, touched to the quick—surely this is not a mere mean anger at being dissed by a Gorgiastic know-it-all.

Many of you are already teachers, though perhaps young in comparison to Plato (b. 427 B.C.E.) when he wrote the Gorgias (c. 387 B.C.E.). He was probably forty, and his Socrates (b. 470) was probably about the same age at the dramatic date of this dialogue (shortly after 429, the year of Pericles's death, which is mentioned as a recent event in 503c). You will have experienced the unbalancing sense that the stakes are high and souls are to be pierced and that passion, or an exhibition of it, is in order. It is, to be sure, a wonderful question about the nature of passion whether deliberate demonstrativeness or disciplined reticence, either in the speaker or the listener, does more to nourish it or to dampen it, and how spontaneity and artfulness play into the effect. But we do know that Aristotle believed Socrates's display in the *Gorgias* was effective. He tells of a Corinthian farmer who was inspired by his reading of the dialogue to leave his vineyard to its own devices, to join the Platonic circle, and henceforth to make his soul the "seedbed," that is, the seminar, of Plato's philosophy.[5]

The *Gorgias* is, therefore, a good reference for beginning to talk about the affects as an object of study. Not merely because it documents, so to speak, that people concerned with the soul have in fact plenty of temperament—be it sober Socrates or meek Jesus (e.g., Matt. 21:12, Jesus wreaking havoc in the temple)—and that they don't leave their affect at the entrance to their inquiries or preachings. I don't, of course, mean the little negative furies that Socrates calls "eristic," the eruptions of the contentious desire to win arguments, but I'm thinking of a large positive passion.

So this is where I zero in on my particular problem for this talk. I have read my way through a tiny fraction of the huge mass of contemporary writing on the emotions. I've come away with the cumulative—documentable—impression that there is a thoroughgoing misapprehension about a putative pagan rationalism and a supposed Western tradition for which it is held responsible and which breaks out with insidious virulence in the Enlightenment. This view owes something, I suppose, to Nietzsche's brilliantly skewed portrait of the "despotic logician," Socrates, the monster with the "one, great Cyclopean eye," in whom "the lovely madness of artistic enthusiasm never glowed."[6] The attribution of monocular Cyclopeanism—i.e., vision without depth, carrying with it the charge of despotic sobriety—implies thought unravished by beauty. All this imputed to a man who thought that our soul contained a world that we could recover by going within,[7] and believed that true poetry requires a Dionysiac frenzy inspired by the Muses, one cognate in kind to the philosophical longing for beauty![8] All this ascribed to a man who, attending a drinking party, bathed for once and wearing shoes, slyly paints a verbal picture of Eros that is in fact a self-portrait—Socrates looking at himself from a distance and recognizing the unwashed and unshod god![9]

So much for the picture of Socrates the rationalist. And something similar holds for Aristotle the intellectualist. His great work, the founding book of institutionalizable philosophy (since it pre-sets the problems to be solved in *Meta-*

*physics* III), begins with an appetite, a root passion, which, in the form of the desire to know, is humanly universal and culminates in a passionate portrait of the ultimate object of appetition. This ultimate object is a divinity that attracts, without returning, love—an object that satisfies, that fulfills, by its mere actuality, by its unadulterated *energeia* (*Metaphysics* II; XII.7), as in Shakespeare's Sonnet 94:

> Who, moving others, are themselves as stone,
> unmoved . . .

except that the pure *energeia* of the divinity is the very opposite of the practically complete inertia of those unaffectable human objects of attraction, these beautiful but hyletic lumps of mere resistance that the speaker of the poem is excoriating.

Would it be too much to claim that this is *the* difference between the philosophical Greeks and the God-regarding Hebrews, more significant than Homer's anthropomorphic polytheism, which is in any case more characteristic of the poets and the people than of the philosophers? I mean the lack of reciprocity between adoring human and worshipped divinity: The Socratic forms are great powers (*Sophist* 247e), but even when they come on the comic stage in visible shape—which they do in Aristophanes's *Clouds* where they appear as wordily nebulous beings, as shaped mists—they don't do a thing for their summoning worshipper, Socrates. In fact they abandon him to possible suffocation in his thinkaterion—the play leaves this uncomic outcome open—and exit satisfied with their "temperate" performance (*Clouds* 269, 1509). The Aristotelian divinity, *Nous,* is similarly unresponsive, an object of uninvolved attraction. The God of the Jews, on the other hand, is beneficently or banefully involved with his people, and when a certain Jewish sect grows into a great religion, He becomes caring outreach itself, namely, Love (e.g., Exodus 20:1-6, I John 4:8, 16).

Why am I dwelling first on the pagans and on the Christians in talking to you about the study of the passions, when the contemporary writers on the emotions simply drown out these earlier voices by their volume? It's not that I have much faith in the explanatory power of chronology or in those longitudinal studies by which a genetic history is attributed to ideas, and which tend to develop more arcane information than illuminating depth. I can think of a half-dozen reasons for my distrust, which there is no time to set out at the podium, though we might talk about the implied historicism of such studies in the next few days. Moreover, it is probably less necessary at a Catholic university than at any other to try to induce respect for the tradition. There is, however, a particular way in which I think that emotion studies should begin with, or pick up at some point, the great ancient and medieval works—of the latter, above all, Thomas's "Treatise on the Passions," which he placed in the very center of the *Summa Theologiae,* for this monk knew—God knows how—everything about human passion.

I think these pre-modern works should be studied for their *shock value,* for the *news* they contain for us. Such a reading, a reading that places them not in the bygone superseded past but in a recalcitrantly unfashionable present, requires a difficult and never quite achievable art, one that graduate students should certainly be eager to acquire: first, the art of summing up, with some credibility, what a philosopher is really and at bottom about (I don't mean "all about," a hand-waving locution, but the compact gist of his intention); and second, the art of discerning how the particular part on which you mean to focus is, or fails to be, properly derivative from that central intention. Then, opposing gist to gist and consequence to consequence, there will emerge a coherent and discussable schema both of the general notions that preoccupy the denizens of modernity willy-nilly and of the sophisticated twists that studious scholars and trendy intellectual elites have given them. Approached in this way, emotion studies seem to me as necessary to our self-understanding as any subject can be—necessary to us as human beings with a contemporary affectivity.

So now let me give you some, perhaps vulnerably sweeping, observations about more recent emotional studies, particularly in English-speaking lands. The groundbreaking works for us were English; I will name Errol Bedford (1956)[10] and Anthony Kenny (1963).[11] But the American father of this field is Robert Solomon with his book *The Passions* (1976).[12]

The Solomonic beginning and its consequences are full of oddities. (I am avoiding the harsher term "self-contradictions.") The thesis of the book is "to return the passions to the central and defining role," snatched from them by Socrates, and "to limit the pretensions of 'objectivity' and self-demeaning reason that have exclusively ruled Western philosophy, religion, and science" since his days.[13]

Well, I guess we've read different works of Western philosophy. But now comes a surprise. How will this salvation from two and a half millennia of despotic rationalism be achieved? We must recognize that "an emotion is a *judgment.*"[14] Of course, this dictum runs into difficulties concerning the meaning of non-rational judgments. Indeed, Solomon eventually accepted that his claim is actually a cognitive theory. As such, he says rightly, it has "become the touch-stone of all philosophical theorizing about emotions." He could, in any case, hardly escape this cognitivist denomination, since it turns out that we become responsible for our emotions by adopting this very theory of cognitive emotion. For as the theory works its way into our unconscious volitions, it will become true, and our emotions will indeed be as much in our control as our judgments;[15] so control is what it's—after all—about.

The Stoics are the moderns among the ancients. Their cognitive theories, the first truly representational theories, are more future-fraught than any others in antiquity that I know of; they dominate modernity until Heidegger's *Being and Time.* The Stoics are hard to study, because the deepest of them, belonging to the so-called Early Stoa, exist only in fragments. But we have an extended text on Stoic passion theory, the third and fourth books Cicero's *Tusculan Disputations.* Some of you, who have read the work, will recognize that the modern dictum "an emotion is a judgment" is pure Neostoicism. Neostoicism has, in fact, dominated modern emotion studies. One major work in this vein is Martha Nussbaum's *Upheavals of Thought: The Intelligence of Emotions* (2001).[16]

But how strange! The Stoics meant to reduce emotions to *mistakes,* to diseases, to pathologies, of judgment. An emotion is a false appraisal, a perturbed opinion about what matters: an "upheaval of thought." It is a deep and complex theory underwritten by the Stoics' fearless physicalism, their notion of a material substratum, the *pneuma,* on whose ground the psychic capacities can morph into one another. But there is no question that, taken summarily, rationality trumps affect. How odd, then, that modem theories so largely save the emotions from rationalism by rationalizing them. And I'll list associated oddities.

First is the pervasive fear *for* the emotions, the sense that we moderns have suppressed and demeaned them, that they *need* saving. What teacher of the young (as scholars by and large are) or observers of the world (as some of them may be) could possibly think that *that* was what was troubling the nations, cities, neighborhoods!

Second is a curtailed sense of thought in the West. I think I've given some prime examples of the interpenetration of thought and affect, even of the primacy of appetition in the human soul in antiquity. When the ancients fight the passions it is because they are so alive, experientially alive, to the meaning of the word *pathos,* "suffering," and the effect of its licensed reign, its invited tyranny. It is really, I think, a modern idea of emotion that is at work here, among our contemporaries, one which pits its softness against hard reason.

Inherited Enlightenment terminology indeed conveys this sense that our passions are attenuated, all but quelled by reason. The pivotal figure here is Hume. In his *Treatise of Human Nature,* the term "passion" begins to be displaced by "emotion." He uses both, mostly interchangeably. But emotion is the word of the future. Solomon's book is entitled *The Passions,* but the key word inside is "emotions." Your own conference called for papers on "Emotion."

"Emotion" derives from *e-movere,* Latin for "to move out." The significance of this substitution of emotion for passion is powerful. Ancient *pathos,* passion, was an affect emanating from an object; the object elicited the responsive affect, from the *outside in.* Modern emotion comes from *inside out;* it emphasizes expression; subject prevails over object. It is the Romantic worm eating its way out of the Enlightened apple.

At the same time, the non-affective, the rational part of the subject becomes mere reason. Hume, famously, says: "Reason is, and *ought* only to be the slave of passions, and can never pretend to any other office than to serve and obey them."[17] He can say that because Humean and enlightened reason is not deeply affective, not driven by love, and so its relation to emotion may indeed be one of subservience, standoff, or finally, enmity. I need hardly add that with this transformation of the appetitive, longing, loving, intellect into manipulative, instrumental, willful rationality, philosophy loses its proper meaning and becomes a profession. My brush here is broad, but, I think, it has some good overlap with the case. So my second oddity is the severely foreshortened view of the capabilities of passionate thought.

Now a third curious notion, the oddest one of all: the unreflective launching of an enterprise which is, on the face of it, like embarking on a destroyer with the idea of going swimming. The vessel of war displaces, cleaves, churns up the element, but, absent a shipwreck, the sailor stays dry. So the student of emotion banishes perturbations, analyzes wholes, whips up terminology, and, unless melancholy seizes him, sails high and dry over the billowing depths of feeling, with much solid bulkhead keeping him from immersion in the element to be apprehended. This not very elegant simile is just a way of expressing my surprise at the fact that emotion studies tend to precipitate themselves into a dispassionate subject without much thought about how such a subject can come to be—about how emotion *can* be subjected to thought without being denatured in the process.

Here, incidentally, lies, it seems to me, the best reason why cognitive scientists, and those philosophers who like to be on solid ground, are by and large physicalists and might well regard the Stoics as their avatars.[18] What matter-and-its-motions has in its favor in emotion studies is that in this spatial form the different motions of the mind appear not to occlude each other; spatio-temporal events, laid our in extension and sequence, have patency. However, since cognitive brain studies, including the emotion research, depend on prior conceptualization and introspective protocols, it is hard to think of them as independent of a philosophical phenomenology.

Therefore, in the unavoidable preparatory philosophical exploration, the perplexity of thinking about feeling remains a vexing one, the more so since it appears to me to be a variant of the greatest quandary, now and always: How is thinking about any form of our consciousness even conceivable? How is it—or is it, indeed—that thought about awareness does not collapse into a union, as does "thinking of thinking," the *noēsis noēseōs* of the *Nous*?[19] How can we know that thought about itself or its fellow internalities does not transform its object out of its true being?

Just this latter eventuality makes emotion studies problematic. Study does have its own affect, one of the most interesting in the list of feelings, namely, *interest* itself. The word—from *interesse,* "to be in the midst of"—signifies what student parlance calls "being into it."[20]

To study is to bring to bear received learning and native analytic and combinatory capacities on a determinate object. If study is of a high quality, it is preceded and accompanied by its opposite, leisure—free time for meditating or musing, during which original questions rise up and take shape. But the business itself focuses on problems such as Aristotle first set for himself and left for his successors. Nowadays it's the dissertation advisor's job. Now all the questions become formulated as demands for reasoning, and under reasoning all things turn to reason—as under studious production all thinking turns to footnoted paper-writing.

It is indeed curious that this fact is not more of a perplexity to students of the emotions. Yet on second thought, it is perhaps not so surprising that emotion studies seem so desiccated—perhaps they are not really more so than serious scholarship ever must be. Robert Browning has his lovingly respectful students sing at the "Grammarian's Funeral":

> Learned we found him.
> Yea, but we found him bald, too, eyes like lead,
> Accents uncertain:
> "Time to taste life," another would have said,
> "Up with the curtain!"
> This man said rather, "Actual life comes next?
> Patience a moment!
> Grant I have mastered learning's crabbed text,
> Still there's the comment."

Here is the picture of interest raised to the pitch of passion. There is a sort of pure, dry, professional love (Browning's grammarian's passion was for Greek syntax, the particles in particular) that can capture the loving admiration of students. I know this from my own student days. But I doubt that it suits philosophy, and, in particular, philosophizing about the emotions. Here another poem expresses our condition more aptly: Wordsworth's "The Tables Turned." It begins:

> Up! up! my Friend and quit your books;

and this is its seventh verse:

> Sweet is the lore which Nature brings;
> Our meddling intellect

> Mis-shapes the beauteous forms of things:—
> We murder to dissect.

To be sure, there are now less intrusive ways of getting inside Nature. Yet the conceptualizing of feeling will ever and always be an abstraction in the basic sense—a removal, a drawing away, from life. And in respect to the affects, this sort of abstraction is doubly dubious. For in ordinary abstraction, the concept incarnate in concrete things is, by a specifically human cognitive operation, separated off from them. But it is simply a premature, a prejudicial notion that the affects "stand under" (to use Kantian diction) abstractable concepts in the same way as do things.

It might follow that to view as problematic the dispassionate, studious study of the affects—be they impositions from without or stirrings from within—is a *sine qua non* for beginning rightly. I think it *does* follow.

There are early bonuses. I'll give you in turn a suspicion, a conjecture, and a figure. The *suspicion* is that we really are partite beings, so that our affective and our thinking capacities are terminally distinct, structurally and dynamically heterogeneous. The *conjecture* is that it is this very *dis*junction in their being which makes possible their conjunction in thought and action, their effective complementarity. Here I've written a sentence that I don't even quite understand as I'm reading it to you, and yet I have some faith in it. Finally, my *figure* is that our affective capacities lie deeper in our nature than our reflective powers.

To be sure, neuroscientists also say that certain brain structures expressly subserving the emotions are located deeper within the brain and appeared early in evolutionary history, but that is not dispositive: What is biologically primitive might, after all, *not* be humanly primary. What I mean, rather, is that affectivity has a certain abysmal, incomprehensible character that makes it feel—I don't know how else to put it—submersed; affects touch us ("to feel" is related to the Latin *palpare,* to pat) in intimate, that is, "innermost" regions, while articulable thought-activity intends, "stretches toward," emerges, towards comprehension of objects. We might be constitutionally bipolar, extended between emotional depth and thoughtful height. Perhaps an original question might be formulated from this figure. It is something we could discuss later, if you like.

Wordsworth's lines imply that the murderous dissection is performed on a lovely, living object. I must tell you that emotion studies sometimes—too often—read as if they were carried out on a latex-injected corpse that suffers every cut with supine springiness. This is, as I've tried to show, a partly inevitable result of making affectivity a "subject," a thing lying still under thought, literally "thrown under" its wheels.

Nonetheless, I feel tempted, by way of an ending, to say how I think we can mitigate the dilemma, for if we can't think about our feelings, we'll come apart. I'll try to be practical.

First, then, you can't study emotions at even the kindliest advisor's prompting. They are a subject that requires experiential urgency, some pressure for the relief of confusion. In brief, you not only have to be a feeling being—as are we all—but also a being enticingly oppressed by the enigma of emotionality, the arcanum of affectivity. Some topics are well approached in the brisk spirit of pleasurable problem-solving. Not this one, I think.

Second, listen to what Socrates says in the *Apology.* He does not say, as is often reported, that "the unexamined life is not worth living." What he really says is, I think, something stronger: that such a life is "not livable for a human being," *ou biōtos anthrōpōi* (38a), is not a possible life, not a lived life. That is what the *-tos* ending of *biōtos* signifies: "livable or lived." He means, I think, that experiences, passions among them, that are not internally re-viewed, introspectively re-lived, are in effect *un*lived—an unexamined experience is not *yours.* A nice corroborating illustration comes in Thomas Mann's *Magic Mountain,* whose hero—meant to be a paradigm of simple humanity—engages in an introspective discipline he calls *regieren,* "ruling, regulating,"—in short, digesting, appropriating his affects and images.[21] For as experimental emotion research requires protocols drawn from inner experience, so conceptual emotion studies cannot do without introspection. And unlike egocentric self-analysis, which is a spontaneous sport, disciplined self-inspection is an art learned by practice. So now I seem to have contravened everything I've just said, which was that feeling is choked by thinking.

Here, then, is my last attempt at being practical about our problem as students: how to keep feeling before ourselves while bringing thought to bear on it. Or, more learnedly put: how to turn what is, regarded in itself, the most subjective element of our being, perhaps our very subjectivity itself, into an object. (I will get myself into a word muddle here, unless I remind you that before the eighteenth century "subject" meant just what we now call "object"—for example, the being that arouses passion, and we still use it in this way, as in "the subject to be studied." But by means of an inversion that is only partial, "subject" is now used for the host of the emotion rather than for its object, and "subjective" signifies a feature of emotional affect.)

Deliverance from the quandary of objectifying the essentially subjective seems to me to come from our great representational faculty, *the imagination*. Mental images are summoned by feeling, arouse feeling and are, famously, affect-fraught, feeling-laden. There are those who deny that we have analogue images before an inner eye, but they are in retreat. The cognitive scientist Stephen Kosslyn (the prime defender of mental analogue images),[22] lay persons in general, and most students of the imagination are convinced by their own inner experience of imaginative vision and its affectivity—and what claim could possibly override such personal, one might say, eye-witness knowledge? (I might add here that the very latest neuroscience seems, though incidentally, to clinch the argument for mental visuality; mental images are directly machine-retrievable.[23])

These affect-laden sights can indeed be held in mind, and thinking can turn to them, play over them, study them. So, it seems to me, emotion studies require an imaginative life. Here is a practical consequence: Your profession requires you to read scholarly articles, but your mission needs you to read works of fiction, particularly novels. For these not only stock your minds with visualizable scenes of passion on which to dwell while you think, they also school you in the adequately expressive diction with which to articulate what you discovered. For, my fellow students, if you speak of feeling either in flabbily pretentious or technically formalizing diction, your papers will be worth—well, next to nothing.

## NOTES

1. *Platons Dialog Gorgias,* ed. Otto Apelt (Leipzig: F. Meiner, 1922), 166. This is the very end of the dialogue, at 527e.

2. Debra Nails, *The People of Plato* (Indianapolis: Hackett, 2002), 243.

3. Geoffrey Chaucer, *Canterbury Tales,* Middle-English edition, Prologue, l. 72 (New York: Penguin Classics, 2005), 5.

4. Diogenes Laertius, *Lives of the Eminent Philosophers*, Book III, Chapter 5, "Plato," trans. R. D. Hicks, Loeb Classical Library 184 (Cambridge, Mass.: Harvard University Press, 1925).

5. This anecdote is found in a fragment from Themistius in the so-called *Akademie-Ausgabe* of Aristotle's works edited for the Prussian Academy of Sciences by Immanuel Bekker (Berlin: G. Reimer, 1870), 1484b. The fragment is translated in *The Works of Aristotle,* ed. W. D. Ross, Vol. 12 (Oxford: Clarendon Press, 1952), 24. The story is translated in its original context in Robert J. Penella, *The Private Orations of Themistius* (Berkeley: University of California Press, 2000), 122.

6. Friedrich Nietzsche, *The Birth of Tragedy,* section 14: "das eine große Zyklopenauge des Sokrates . . . in dem nie der holde Wahnsinn künstlerischer Begeisterung geglüht hat."

7. Plato, *Meno,* 81c.

8. Plato, *Phaedrus,* 245a, 249d.

9. Plato, *Symposium* 203d.

10. Errol Bedford, "Emotions," *Proceedings of the Aristotelian Society,* LVII (1956-57), 281-304.

11. Anthony Kenny, *Action, Emotion, and Will* (London: Routledge & Kegan Paul, 1963).

12. Robert Solomon, *The Passions: Emotions and the Meaning of Life* (New York: Doubleday, 1976).

13. Solomon, *The Passions,* xiv.

14. Ibid., 185.

15. Ibid., 188ff.

16. Martha Nussbaum, *Upheavals of Thought: The Intelligence of Emotions* (Cambridge: Cambridge University Press, 2001).

17. David Hume, *A Treatise of Human Nature* (1739), 2.3.3. Emphasis added.

18. See, for example, Antonio Damasio, *Looking for Spinoza: Joy, Sorrow, and the Feeling Brain* (New York: Harcourt, 2003), 275.

19. Aristotle, *Metaphysics,* Book XII, Chapter 9.

20. See Silvan Tomkins, *Affect, Imagery, Consciousness,* 4 vols. (New York: Springer, 2008), Volume I, Chapter 10, "Interest–Excitement," 185-202.

21. In Thomas Mann, *The Magic Mountain,* Chapter 6, "Of the City of God and of Evil Deliverance."

22. See, for example, Stephen Kosslyn, *Image and Brain: The Resolution of the Imagery Debate* (Boston: MIT Press, 1996).

23. Francisco Pereira et al., "Generating text from functional brain images," *Frontiers in Human Neuroscience* 5 (August, 2011): Article 72.

# On Biblical Style

Tod Linafelt

The western tradition has not focused much attention on the literary style of the Bible. Although it is true that the classical literary critic Longinus (or "Pseudo-Longinus"), writing in the first century C.E., makes a brief but famous reference to the opening lines of Genesis in his treatise *On the Sublime*,[1] the context for the reference is his treatment of "greatness of thought" rather than any strictly literary qualities. More typical of pre-modern literary attitudes toward the Bible is Augustine's judgment that biblical literature exhibits "the lowest of linguistic style" (*humillimum genus loquendi*), and had seemed to him, before his conversion, "unworthy of comparison with the majesty of Cicero."[2] Of course, readers have not traditionally gone to the Bible in search of literary artfulness but rather for its religious value—that is, primarily as a source for theology or for ethics. For Augustine, as for so many religious readers after him, the Bible's theological truths and ethical teachings won out over its literary art or lack thereof.[3] But the fact is that the Bible—and my concern here is more particularly with the Hebrew Bible or Christian Old Testament—presents to the reader distinctly literary narrative and poetic works that both demand and reward expressly literary attention. Not only can we speak about the literary style of the Bible, then, but we can and ought to speak more precisely about its *narrative* style or *poetic* style, since biblical narrative and biblical poetry each work with a very different set of conventions and techniques—with different

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literary toolkits, we might say. Reading the Bible "as literature," then, means more than just close reading, as it is often understood. It also means becoming familiar with and attending to the distinctive and specific workings of narrative texts and poetic texts. It seems clear that the ancient authors were very much aware of the differing conventions and possibilities associated with narrative and with poetry, respectively, and that their audiences would have responded differently to these two primary literary forms. The better we understand these forms, the better readers we will be.

### I. Ancient Hebrew Narrative

One must admit that Augustine was not entirely wrong. It is hard to deny that from a certain angle the Bible is among the most "unliterary" works of literature that we have. Working as it does with a very limited vocabulary and often repeating a word several times rather than resorting to synonyms, biblical Hebrew narrative exhibits a style that can seem simple, even primitive, in comparison with the classics of world literature. (Things are very different with biblical poetry, as we will see below.) Its syntax too seems rudimentary to modern ears, linking clause after clause with a simple "and" (what the linguists call *parataxis*) that reveals little about their syntactical relation, instead of using complex sentences with subordinate clauses *(hypotaxis)*. Notice, for example, the dogged repetition of "face" and the run-on syntax in the following very literal translation of Genesis 32:21 (where Jacob is sending ahead of him a very large gift to his estranged brother Esau, in hopes that Esau will be placated over Jacob's earlier stealing of his blessing): "For he said, 'Let me cover his face with the gift that goes before my face and after I look upon his face perhaps he will lift up my face.'" Although modern translations tend to obscure these features, even in translation one is bound to notice the paucity of metaphorical description, the brevity of dialogue, the lack of reference to the interior lives of characters, the limited use of figural perspective, and not least the jarring concreteness with which God is sometimes imagined to be involved in human history.

Many of these features are elements of biblical literature's *economy of style*, or essential terseness. We may compare, for example, Homer's use of sometimes startling metaphors in describing a scene with the practice of biblical authors (all of whom are essentially anonymous), who by and large avoid such elaborate figurative language. Contrast this description in the *Iliad* (16.480-85, Fagles' translation) of the death of a single, obscure Trojan charioteer:

> Patroclus rising beside him stabbed his right jawbone,
> ramming the spearhead square between his teeth so hard
> he hooked him by that spearhead over the chariot-rail,
> hoisted, dragged the Trojan out as an angler perched
> on a jutting rock ledge drags some fish from the sea,
> some noble catch, with line and glittering bronze hook[4]

with the blunt recounting in Genesis 34 of the massacre of an entire city by two of Jacob's sons: "Simeon and Levi, Dinah's brothers, took their swords and came against the city unawares, and killed all the males. They killed Hamor and his son Shechem with the sword" (Gen 34:25-6). This brief passage is typical of the tendency in biblical narrative to avoid description of any sort, metaphorical or otherwise. The principle applies, with some exceptions of course, not only to *physical* description—so that we are rarely told what either objects or people look like—but also, and more importantly, to the *inner* lives, thoughts, and motivations of characters in the narratives. It would be a mistake, however, to take this economy of style as an indicator of the Bible's essential simplicity or primitiveness as a work of literature. In fact, it is primarily this terseness that lends biblical narrative its distinctive complexity as literature.

In beginning to think about the workings of biblical narrative one could do no better than to read Erich Auerbach's "Odysseus' Scar," the opening chapter of his book *Mimesis*, in which he compares biblical narrative style with Homeric epic style.[5] Auerbach offers the first and best modern articulation of how the austere terseness of biblical narrative is not just the absence of style but is in fact a distinctive and profound literary mode in its own right. Auerbach describes Homeric style as being "of the foreground," whereas biblical narratives are by contrast "fraught with background." In other words, in the *Iliad* and the *Odyssey* both objects and persons tend to be fully described and illuminated, with essential attributes and aspects—from physical descriptions to the thoughts and motivations of characters—there in the foreground for the reader to apprehend. But with biblical narrative such details are, for the most part, kept in the background and are not directly available to the reader. So, as noted above, we are very rarely given physical descriptions of either objects or people in the biblical narrative.[6] What do Adam and Eve look like? We do not know. Abraham? Sarah? Moses? We do not know. As Auerbach puts it in his comments on Genesis 22, where God commands Abraham to sacrifice his son Isaac, it is unthinkable that the servants, the landscape, the implements of sacrifice should be described or praised, as one might expect in Homer: "they are serving-men, ass, wood, and knife, and nothing else, without an epithet."[7] Occasionally a certain quality is ascribed to some person or object: we are told that Eve perceives that the tree of knowledge is "a delight to the eyes" (Gen. 3:6), and likewise we are told that Joseph is "handsome and good-looking"

(Gen. 39:6). But as a rule such minimal notations are given only when necessary to introduce some element that is important to the development of the plot. In the present cases the attractiveness of the tree of knowledge leads, of course, to the eating of its fruit (But what kind of fruit? We are not told, the long tradition of the apple notwithstanding), and Joseph's attractiveness leads, in the next verse, to the sexual aggression of Potiphar's wife, and thus indirectly to Joseph's imprisonment. And even here one notices that we are not told what it is that makes the fruit lovely to look at or what exactly makes Joseph so beautiful.

Beyond a lack of physical description in the biblical stories, descriptions of personal qualities are also largely absent. That is, characterization is rarely explicit, but rather must be teased out of the narrative based on what characters *do* and *say* (on action and dialogue, in other words, rather than on direct evaluation by the narrator). The presentation of Esau and Jacob in Genesis 25 illustrates this nicely. We are told that Esau is "a man skilled in hunting, a man of the field" (v. 27), but the essential characterization of Esau as impulsive and unreflective, indeed almost animal-like, is conveyed by action and dialogue. Thus, coming in from the field to discover that his brother Jacob has prepared a stew, Esau inarticulately blurts out, "Let me eat some of that red, red stuff, for I am famished" (v. 30). Robert Alter notes that Esau "cannot even come up with the ordinary Hebrew word for stew (*nazid*) and instead points to the bubbling pot impatiently as (literally) 'this red red.'"[8] And then, after agreeing to trade his birthright to Jacob in exchange for some of the stew, Esau's impetuous, action-oriented character is suggested by the "rapid-fire chain of verbs": "and he ate and he drank and he rose and he went off."[9] The character of Esau is starkly contrasted in the story with the character of Jacob. If Esau is all instinct and action, Jacob is all calculation and deliberateness. The stew is prepared and waiting for the return of Esau from the field, and one cannot fail to notice the businesslike manner in which Jacob first suggests, and then demands formal confirmation of, the trading of the birthright: "And Jacob said, 'Sell now your birthright to me.' And Esau said, 'Look, I am at the point of death, so why do I need a birthright?' And Jacob said, 'Swear to me now'" (vv. 31-33). These initial thumbnail characterizations of Esau and Jacob will be fleshed-out further two chapters later, in Genesis 27, where the blind Isaac is deceived into bestowing his blessing on Jacob rather than the intended son Esau. The elaborate ruse carried out by Jacob with the invaluable help of his mother Rebekah, in which he impersonates Esau, confirms his calculating ambition even as it adds outright deceit to his resume of character traits. Jacob will become a consummate trickster as the story proceeds—though he will also, as an elderly man, be tricked by his own sons (ch. 37)—but he is never actually *described* by the narrator as tricky or deceptive, in the way that Odysseus is described repeatedly in terms of his resourcefulness or Achilles in terms of his rage, for example, but instead has his character revealed by what he says and what he does. Esau, for his part, will play a lesser role in the narrative that follows, although his reappearance in Chapter 33 is striking and in some ways unexpected, but both his inarticulateness and his utter lack of calculation are revealed by his response upon hearing that Jacob has stolen his blessing: "he cried out with an exceedingly great and bitter cry and he said to his father, 'Bless me, me also, Father'" (v. 34); and again, a few verses later, "'Do you have but one blessing my father? Bless me, me also, Father.' And Esau lifted up his voice and wept" (v. 38). By not directly revealing the qualities of character of the actors in the narrative, the narrator puts the onus of interpretation on the readers, who must work out on their own—albeit with hints given—what they think of these characters. To repeat, this is not the *absence* of characterization, but is a *certain mode* of characterization, and in fact a fairly complex mode at that.

We may best see the complexity of this mode of characterization, and indeed of the Bible's economy of style more generally, when it comes to the inner lives of the characters. Readers are often used to having access in one form or another to the thoughts, feeling, and motivations of the characters about whom they read. Again, Auerbach on Homer: "With the utmost fullness, with an orderliness which even passion does not disturb, Homer's personages vent their inmost hearts in speech; what they do not say to others, they speak in their own minds, so that the reader is informed of it. Much that is terrible takes place in the Homeric poems, but it seldom takes place wordlessly."[10] And so, for instance, the tragic death of Hector at the hands of Achilles near the end of the *Iliad* (in book 22) has devoted to it, in the Greek, fourteen lines of lament by Hector's father, seven lines by his mother, and fully forty lines by his wife Andromache. We may compare this with the brief notations of grief in biblical narrative. On the death of Sarah: "And Sarah died at Kiriath-Arba (that is, Hebron) in the land of Canaan, and Abraham went in to mourn for Sarah and to weep for her" (Gen. 23:2). On the death of Moses: "And the Israelites wept for Moses in the plains of Moab thirty days; then the period of mourning for Moses was ended" (Deut. 34:8). One might object that since both Sarah and Moses had lived long and fruitful lives their deaths lack the tragedy of noble Hector being cut down in his prime over the affairs of his less-than-noble brother Paris, so that their deaths inspire less intense expressions of mourning. But even with more obviously tragic deaths we see in biblical narrative the restraint of the narrator, who acknowledges the grief of the survivors but refrains from allowing them full expression of it. We noted above, for example, Jacob's response to what he takes to be evidence of the death of his young, beloved son Joseph: "A vicious beast has devoured him, Joseph torn to shreds!" (Gen. 37:33). In a scene that seems intended to characterize Jacob as an extravagant mourner, the narrator goes on to describe Jacob as rending his clothes and donning sackcloth and refusing to be comforted by his other children: "'No, I shall go down to Sheol to my son, mourning.' Thus his father bewailed him" (37:35). Yet even here the few scant lines in Hebrew do not come close to matching the sixty lines of direct lament over the death of Hector, not to mention the extended scene in Book 24 of the *Iliad* where Hector's father Priam goes to the tent of Achilles to beg for the return of his son's much-abused corpse.

Consider also the notoriously ambiguous story in Leviticus 10 of the burning Nadab and Abihu, the sons of Aaron. The reader is told that the two young priests brought "strange fire" or "alien fire" (*'esh zara*) before the Lord, "and fire came out from before the Lord and consumed them, and they died before the Lord" (10:2). Moses very quickly offers a sort of cryptic theodicy, cast in verse form, in the face of the shocking event: "This is what the Lord spoke, saying, 'Through those near me I will show myself holy / and before all the people I will be glorified'" (10:3). No more laconic response could be imagined, both to the death of the young men and to Moses' extemporaneous theologizing, than that attributed to Aaron: "And Aaron was silent." Surely we are to imagine Aaron's grief as real and deep—indeed, a few verses later Moses forbids Aaron and his other sons to go through the public rituals of mourning while they are consecrated for service in the temple (10:6-7)—and yet all we are given is his silence. Unless one imagines this silence to indicate a complacent assent to what has just been witnessed, the narrator gives us, to borrow from Auerbach again, "a glimpse of unplumbed depths." It is, in short, a silence that is "fraught with background," a silence that demands interpretation on the part of the reader. Is Aaron feeling pure shock? Overwhelming sadness? Anger at God? Confusion or despair? Is his silence a rejection of Moses' statement of God's intent? And if so, on what basis? The fact is that we are given no access whatsoever into the inner life of Aaron, and because we do not know what he is thinking we also do not know what motivates his silence.

It is with regard to this latter issue, the question of character motivation, that we may see the importance of recognizing the distinctively terse mode of biblical narration. As I noted above in considering the story of Jacob and Esau, the narrator reveals very little about the inner lives of characters, instead reporting mainly action and dialogue, what the characters *do* and what they *say*. If we are given little or no access to the thoughts and feelings of the characters about whom we read, then it follows that the motivation behind what they do and say is also largely obscure. The importance of this obscurity of motivation can scarcely be overstated for any literary reading biblical narrative, since it more than anything else is what gives the literature its profound complexity as it forces the reader to negotiate the many possible ways of imagining the characters' inner lives. Let me try to justify this claim with reference to the literature itself.

A classic example of the ambiguity of character motivation in the Bible may be seen in Genesis 22. In a story that has never failed to engage the imagination of interpreters ancient and modern, God commands Abraham to take his son

Isaac and sacrifice him as a burnt offering. Although a few chapters earlier we have seen Abraham challenge the justness of God's decision to destroy Sodom and Gomorrah, here Abraham says nothing in response. Instead, there is the narrator's terse report: "So Abraham rose early in the morning, saddled his donkey, and took two of his young men with him, and his son Isaac; he cut the wood for the burnt offering, and set out and went to the place in the distance that God had shown him" (vv. 3-4). Abraham's silent obedience here is often taken to be motivated by an untroubled and unquestioning faith in God, which, depending on one's perspective, may be seen positively as an expression of ultimate piety, or negatively as an expression of unfeeling religious fanaticism. But both interpretations fail to recognize the fundamental literary convention of the refusal of access to the inner lives of characters. The fact that we are not told of Abraham's inner, emotional response to the demand that he slaughter his son does not mean that he has no inner, emotional response. Surely we are to imagine that he does, but rather than describing it for us or allowing Abraham to give voice to it the narrator leaves us guessing as to what that response might be and thus also as to his motivation for his actions. Now, it is possible to fill that gap left by the narrator with an inner calm that reflects absolute faith, but it is equally possible to imagine that Abraham is feeling anger, disbelief, and even disgust. (With God for demanding the slaughter? With himself for not protesting?) And however one fills the gap of Abraham's inner life initially, surely it is complicated by Isaac's calling out to him in v. 7, "Father!" and by the plaintive question that follows, "The fire and the wood are here, but where is the lamb for a burnt offering?" It is precisely because we do not know what Abraham is thinking or feeling that his brief response to Isaac's question ("God will see to the lamb for the offering my son," v. 8) takes on a deeply ironic double meaning. On the one hand, it may be read as a ruse, if not an outright lie, to deflect any suspicions that may be dawning on the son; on the other hand, it may be read as a straightforward statement of faith that a sheep will indeed be provided. It may even be the case here that the author makes use of the ambiguities of Hebrew's seemingly rudimentary syntax in order to signal the potential irony to the attentive reader. For there is no punctuation in the Hebrew text and one may also construe the syntax to mean: "God will see to the lamb for the offering: *namely*, my son."

To go back to Abraham's initial response to Isaac, we may see how what at first instance looks like wooden repetition may in fact be a subtly modulated use of a key word or theme. When God first calls out to Abraham to begin the episode, Abraham's response is "Here I am"; when Isaac calls in the middle of the episode, on the way to the place of sacrifice, Abraham's response is, once again, "Here I am, my son"; and when, at the climactic moment when the knife is raised over the boy, the angel of Lord calls out "Abraham, Abraham!" (22:11) his response is again "Here I am." In each case the single Hebrew word *hinneni*, "here I am" or "behold me," is repeated by Abraham. To substitute a synonym for the sake of variety, as for example the JPS Tanakh does in translating the second occurrence as "Yes, my son," is to lose a concrete expression of what is certainly a central theme for the story, namely the anguished tension between the demands of God and the ethical demands of another human being (Abraham's own child no less!). Surely every ethical impulse demands that Abraham not kill his son, and yet precisely this is what God demands that he do. He responds "Here I am" to both God and Isaac, and yet he cannot be fully "there," fully present, to both equally. It is only with the third, very late, repetition of "Here I am" that the tension is resolved and Abraham is no longer caught between these opposing demands on his loyalty. One might say that Abraham's threefold response provides the underlying armature for the story, marking in a classically Aristotelian way the beginning, the middle, and the end. Although the single word *hinneni* is literally repeated each time, it acquires a new depth of meaning—and certainly a new tone—with each repetition. And to the end of the story it remains the case that we are never quite sure what Abraham is thinking as he first travels in silence, then responds to his son, then binds and raises the knife, and finally sacrifices the ram instead.

If we do not know what motivates Abraham in Genesis 22, it is also the case that we do not know what motivates Isaac to make his enquiry as to the whereabouts of the sheep or what he is thinking as his father binds him and lays him on the makeshift altar. But by this point we are not surprised by this fact, since we have begun to see that the biblical authors make use of this convention in order to allow for depth of character and depth of meaning. It is perhaps somewhat more surprising to note that this convention applies to God too, who is, after all, a character in these narratives as well, and so the *literary* art of biblical narrative has distinct *theological* implications. What motivates God to demand the sacrifice of Isaac? The narrator refuses to tell us, though for any reader, religious or not, this must certainly be a compelling question. We are told that "God tested Abraham" (22:1); but this does not give us an answer to our question. The sense of the word "test" (Hebrew *nissah*) is something like "trial" or "ordeal," and so God decides to put Abraham through an ordeal, presumably to test his mettle. (A comparison with the opening chapters of Job is apt.) But why, and to what end? Is it to find out how strong Abraham is under pressure? To see whether he values his son more than he values God? Does God genuinely learn something new about Abraham, about humanity, or about God's self through this test? ("*Now I know* that you fear God, because you have not withheld from me your son, your only son" [22:12].) Without knowing what motivates God or what God is thinking as the knife is raised, we cannot finally even know whether Abraham has passed or failed the test. Most readers assume that he has passed, but a few have dared to suggest that God wanted not blind obedience from Abraham but bold resistance—after all, such resistance was honored when Abraham argued on behalf of Sodom and Gomorrah—and that in failing to argue with God, Abraham failed to show the strength of character that God hoped to see.[11] This reading may seem to go against the grain of the narrative, especially in light of 22:16-17: "By myself have I sworn, said the LORD, for because you have done this thing, and have not withheld your son, your only son: That in blessing I will bless you, and in multiplying I will multiply your seed as the stars of the heaven, and as the sand which is on the sea shore." But the fact that such a reading is nonetheless possible—if only just—witnesses to the profound but productive ambiguity of Hebrew literary style, which exploits to great effect its distinctive economy of style.

There is very much more that could be said about the literary art of Hebrew narrative, especially about the patterns or structures that authors and editors have used to construct both individual stories and larger blocks of material, but before moving to consider poetry, I want to point out one final way in which the literary and the theological are bound together. I mentioned at the beginning of this essay the jarring concreteness with which God is sometimes imagined in the Bible as active in the world: God walks in the garden of Eden and enjoys the evening breeze; God shows up at the tent of

Sarah and Abraham to promise them offspring; God destroys Pharaoh's army at the Red Sea; God inscribes with God's own hand the tablets of the covenant at Sinai; and in the final, poignant scene of the Torah at the end of Deuteronomy, God buries Moses after allowing him a vision of the promised land that he is not finally to enter. But if the Hebrew literary imagination is relentlessly concrete in its workings, including its imaginings of God, it does not follow that it is without craft or nuance. In fact, divine agency and human agency are almost always imagined in these narratives as being inextricably but ambiguously bound together in such a way that neither agency is autonomous or effective in and of itself.[12] And so, God announces to Rebekah in Genesis 25 that the elder of her twins (Esau) will serve the younger (Jacob); but two chapters later, when the time has come to deliver the blessing to the proper son, God has apparently left the matter to Rebekah to work out, which she does with great effectiveness (see ch. 27). In Genesis 50, Joseph may declare to his brothers, who had sold him into slavery thirteen chapters and many years earlier, that "Even though you intended to do harm to me, God intended it for good"; but the story also suggests that it is largely his own wits and talent, rather than any supernatural intervention, that allows him to survive and prosper in Egypt.

Even in the Exodus story, where God's salvific power seems more tangible than anywhere in the Bible, the divine plan requires human agents for implementation. And so, after a flurry of first-person active verbs by which the Lord resolves to liberate Israel from slavery ("I have seen . . . , I have heard . . . , I have come down to rescue . . . , I will bring them up [3:7-8]), God shifts unexpectedly to the second person, saying to Moses, "And now, go and I will send you to Pharaoh, and you will bring my people the Israelites out of

Egypt" (3:10). Moses quite naturally responds, "Who am *I,* that *I* should go to Pharaoh and that *I* should bring out the Israelites from Egypt?" God's answer is telling with regard to the interdependence of divine and human agency: "I will be with you" (v. 12). Who is it that liberates Israel—God or Moses? It is both. But even that answer is too simple, since the liberation of Israel requires not only the cooperation of God and Moses but of *Israel* as well. Thus, Moses dutifully announces to the enslaved Israelites God's plan to liberate them, which is again stated in a surge of first-person verbs: "I will take you out . . . , I will rescue you from bondage . . . , I will take you . . . , I will be your God . . . , I will bring you to the land I promised" (Ex. 6:6-8). The response? "They did not heed Moses because their spirits had been crushed by cruel slavery." The point would seem to be a sociological one: that the people cannot be liberated before they are ready, and after generations of bondage and hard labor it will take more than promises to get them ready. Only after seeing the very real power of Pharaoh broken by repeated plagues are the Israelites able to summon the energy to come out of Egypt.

Pharoah himself is also a locus for this fundamental tension—in this case it is paradoxical—between divine sovereignty and human agency. On the one hand, *God* claims responsibility for "hardening" Pharaoh's heart so that he refuses to allow Israel to leave (Ex. 7:3; 14:4); but on the other hand, Pharaoh is said by the narrator to have hardened *his own* heart (8:11, 28). At other times a passive voice is used, so that Pharaoh's heart "was hardened" or "became hard" (7:14; 8:15; 9:4)—thereby leaving the agency behind the hardening unclear. This shifting of agency allows the narrative to retain a sense of God's sovereign activity in history, while at the same time affirming the moral culpability of Pharaoh, whose repeated failure to fulfill his promise of freeing the Israelites represents rather realistically the psychology of a tyrant. Logically, we readers may want to know, Which was it? Did God harden Pharaoh's heart, or did Pharaoh harden his own heart? But the story refuses to settle the question, giving us a "both/and" that reflects a pronounced trend in biblical narrative to render not only the inner lives of both humans and God, but also creation and history itself, as unfathomably complex and finally unresolvable mysteries.

## II. Ancient Hebrew Poetry

"If I feel physically as if the top of my head were taken off," Emily Dickinson once wrote, "I know *that* is poetry."[13] Dickinson was, of course, somewhat more than averagely tuned in to the effects of poetry. In truth, poetry—even great poetry—often fails to take the top of one's head off, and even sometimes goes unrecognized *as* poetry. There is no more striking example of this than the Bible, which contains a distinctive body of poetry that has been, for two thousand years, only rarely and inconsistently represented on the page in the form of verse rather than prose. Though some passages are lined out in the ancient and medieval manuscript traditions, these include not only ones that we would now recognize as poetry but also lists of names that are clearly not poetry (in the same way that the phonebook is not poetry just because it is lined out). And printed Bibles from Guttenberg on, until the twentieth century, represent most of the poetic sections of the Bible as blocks of text indistinguishable from prose.

The question of whether biblical poetry even exists has been around since ancient times, and it has been exacerbated by the fact that our primary models for what counts as poetry are drawn from the highly metrical verse found in classical literature. Already in the first century C.E., Jewish intellectuals like Philo and Josephus, feeling the need to defend their cultural heritage in terms of Greek and Roman ideals, went looking for iambs and hexameters in the Torah. And they were followed in this task by later Christian writers such as Origen (in the early third century) and Jerome (in the fourth and fifth centuries), who also assumed that if poetry existed in the Bible then it must exist in metrical form. The search for meter in biblical literature has been revived on occasion in the modern period as well, but it has never amounted to much, for the simple fact that ancient Hebrew verse is not metrical. This lack of conformity to classical standards—as well as to virtually all poetry in the West until the nineteenth century—has no doubt been a major factor in the tradition's lack of appreciation for biblical poetry, but so has the Bible's status as religious literature. Attention to literary *form* has been a low priority for interpreters of the Bible, eager as they have been to move to the *content* or the *meaning* of any given passage. There has been very little allowance in biblical interpretation for the possibility that, as Wallace Stevens puts it, "poetry is the subject of the poem."[14]

A major breakthrough in understanding biblical poetry came with Robert Lowth's *Lectures on the Sacred Poetry of the Hebrews*, first delivered in association with Lowth's chair in poetry at Oxford and then published in 1753. Lowth's most lasting contribution, for good and ill, was his identification of *parallelismus membrorum*, or parallelism of lines, as the primary structuring principle of ancient Hebrew verse. "Things for the most part shall answer to things, and words to words," Lowth writes, "as if fitted to each other by a kind of rule or measure."[15] From Psalm 114, for example:

> The mountains skipped like rams,
> the hills like lambs.

Or from the Song of Songs:

> Love is strong as death,
> jealousy harsh as the grave.

Notice how "mountains" matches "hills," and how "rams" matches "lambs." And notice the strict parallelism of "love//jealousy," "strong//harsh," and "death//grave." Lowth admitted that many lines of biblical poetry did not display the same equivalence of terms that we see here, but nonetheless the recognition that lineation was based on the matching of two or three short lines in a couplet or triplet form, which did not depend on meter, opened the way for more sustained attention to such poetry *as poetry*, rather than just repetitious-sounding prose.

For 200 years after Lowth nearly all attention to biblical verse was on this phenomenon of parallelism, and most especially semantic parallelism (or parallelism of meaning), which too often was reduced to the idea that the second or third line in a couplet or a triplet simply restates the basic idea from the first line. But recent scholarship has shown that the relationship between lines is more intricate and more interesting than this. Adele Berlin, Michael O'Connor, F. W. Dobbs-Allsopp and others have shown that that parallelism involves not only semantic features but also grammatical, syntactical, and phonological patterns (generally not apparent in translation), and that there are complex syntactical constraints that underlie the ancient Hebrew poetic line, which are not in the end reducible to "parallelism."[16] Moreover, Robert Alter and James Kugel have shown that even when the relationship between lines looks to be semantically parallel at first glance, there is often a subtle dynamism in which the second line moves beyond the language or imagery in the first by making it more concrete, more specific, more intense, or more emotionally heightened.[17] Thus, in the matched lines quoted above from the Song of Songs: *jealousy* is a more specific emotion associated with *love*; *harsh* heightens and intensifies the connotation of *strong*; and *the grave* serves as a concrete symbol of *death*.

Beyond the question of line structure, however, the cluster of other features that typify biblical verse has mostly been overlooked by scholarship of recent decades. But one can get a much richer sense of the distinctive workings of biblical poetic style by recognizing these features—features that can be seen more clearly when compared with the workings of biblical prose narrative. As we saw above, ancient Hebrew authors developed a prose style that was especially suited for narrative (or storytelling) and that prefigured in important respects the style and techniques of both modern novelistic fiction and history-writing. Virtually all other long narratives in the ancient world—from the Epic of Gilgamesh to the Babylonian Enuma Elish to the Canaanite epics to the *Iliad* and the *Odyssey*—take the form of verse, reflecting the oral origins of the epic genre. By casting their stories in the form of prose, biblical authors pioneered a "writerly" form of narrative that did not depend on the rhythms of oral poetry and that allowed for the development of a genuine third-person narrator, whose voice could be distinguished from the direct discourse attributed to characters within the narrative. It also allowed for a depth-of-consciousness and an opaqueness in its literary characters, so that, as we saw above, readers are seldom told what characters are thinking or feeling at any given moment, even though it is often vitally important to characterization and to plot development.

Stylistically, however, biblical poetry works very differently. There are in the first place the formal differences that mark the poetry as verse (instead of prose): not only lineation, but also a compressed syntax that tends to drop particles and pronouns in order to achieve the conciseness of the poetic line. (Unfortunately, such syntactical structures are mostly invisible in translation.) And biblical poetry is, to borrow

Terry Eagleton's vague but appropriate characterization of poetry in general, much more "verbally inventive" than biblical prose narrative.[18] The terse, straightforward style of biblical narrative means that it tends to avoid elevated diction or figurative language. But the poetry is filled with figurative language, from the mostly conventional imagery found in the psalms, for example, to the more inventive imagination of the book of Job, to the double entendres of the Song of Songs. Thus, the troubled fate of the psalmist is, often as not, imagined in terms of "the pit" that threatens to swallow or "the flood" that threatens to overwhelm; and God is imagined as a "rock," a "fortress," or a "shield." As the suffering Job imagines blotting out the day of his birth, he both personifies and eroticizes it, imagining night longing for day which, in his counterfactual curse, never arrives:

> Let the stars of its dawn be dark;
> let it long for light in vain,
> and never behold the eyelids of morning. (Job 3:9)

Later, Job imagines God's enmity toward him in terms of the ancient grudge between God-as-creator and the chaotic force of the personified Sea:

> Am I the Sea, or the Dragon,
> that you set a guard over me? (7:12)

Answering Job, thirty chapters later, God returns to this image, but redefines and re-personifies the chaotic Sea not as an enemy combatant but as an infant to be nurtured:

> Who is it that contained the Sea
> as it emerged bursting from the womb?—
> when I clothed it in clouds,
> and swaddled it with darkness. (38:8-9)

The Song of Songs, erotic poetry set in the alternating voices of two young lovers, prefers a lush, bodily-based array of metaphors. For example, the male voice proclaims:

> Your breasts are like two fawns,
> twins of a gazelle,
> that feed among the lilies. (4:5)

Or this, from the female voice:

> Like an apple tree found in the forest
> is my beloved among the youths;
> I delight to sit in his shade,
> and his fruit is sweet to my taste. (2:3)

If line structure and other formal markers are enough to establish the presence of verse in the Bible, they still do not tell us much about its use or function. Again, a comparison with biblical prose is instructive, since one of the most striking features of biblical poetry is that it is relentlessly non-narrative. Once ancient Hebrew culture had developed the flexible prose form that gets used for recounting stories, both long (e.g., Genesis, 1 and 2 Samuel) and short (e.g., the books of Ruth and Esther), it seems that verse was reserved for more specialized, highly rhetorical uses. For example, the prophets are most often represented as casting their messages in poetic form. Note the parallelism and figurative language in, for example, Amos' well-known *cri de coeur*,

> Let justice roll down like the waters,
> and righteousness like a mighty stream. (5:24)

This familiar parallel structure is combined with hyperbole and a striking visual imagination (both very much lacking in biblical narrative, though common in the ancient epic tradition)[19] in the prophet Isaiah's utopian vision of the future:

> The wolf shall live with the lamb,
> and the leopard shall lie down with the kid. (11:6)

Verse also seems to have been the preferred form in ancient Hebrew, as in so many languages, for the aphorism—the pithy and often didactic observation on the nature of the world—which, like poetry more generally, aims for a maximum of meaning in a minimum of words. The book of Proverbs is filled with such aphorisms in verse form, such as,

> A soft answer turns away wrath;
> a harsh word increases anger. (15:1)

For more skeptical versions of such aphorisms, one can turn to the book of Ecclesiastes, as in

> All streams run to the sea,
> but the sea is never filled . . .
> The eye is not satisfied with seeing,
> nor the ear filled with hearing. (1:7)

or

> With much wisdom comes much grief;
> to increase knowledge is to increase sorrow. (1:18)

But one of the most interesting uses of biblical verse is as an early form of what will later go by the name of "lyric poetry," that intensely subjective, non-narrative and non-dramatic form that has dominated modern poetry at least since Wordsworth. This early form of lyric foregrounds two final characteristics of biblical poetry, both of which further distinguish it from biblical prose narrative. First, biblical poetry is invariably presented as direct discourse, the first-person voice of a speaking subject (a precursor of the modern "lyric I"). Again, ancient Hebrew narrative separates the third-person *narrator* from the dialogue spoken by *characters*, which is grammatically marked (by expressive forms and deictics, to use the technical terms) as direct discourse, whereas the narrator's voice is not.[20] Biblical poetry is also marked in this way; it is, in other words, always presented as if it were dialogue. So, for example, the biblical narrator will never be represented as speaking in poetry, but characters can be, as in the deathbed blessing of Jacob near the end of the book of Genesis or the Song of Deborah in the book of Judges.

The second way that biblical lyric poetry distinguishes itself from narrative is in its willingness to give access to the inner lives of its speakers. If biblical narrative trades in opaqueness of characterization, biblical poetry fairly revels in the exposure of subjectivity. When biblical authors wanted to convey feeling or thought, they resorted to verse form. Obvious examples of this formal preference include poetic books like the Psalms and the Song of Songs, where the expression of passion, whether despairing or joyful, is common. We find also in narrative contexts briefer poetic insets that serve to express or intensify emotion. Take, for example, Jacob's reaction to the bloodied robe of Joseph, which as Alter has pointed out is rendered as a perfect couplet of Hebrew poetry: *hayya ra'ah 'akhalathu / tarof toraf yosef* ("A vicious beast has devoured him, / torn, torn is Joseph!").[21] The book of Job serves as an example on a much larger scale. It begins in the narrative mode and gives precious little insight into Job's thoughts or feelings. But when the story moves to Job's anguished death wish ("Blot out the day of my birth, / and the night that announced, 'A man-child is conceived'"), narrative gives way to the passionate but finely modulated poetic form of chapter 3, followed by many chapters in verse containing Job's impassioned defense of his integrity.[22]

T. S. Eliot's pronouncement that "when we are considering poetry we must consider it primarily as poetry and not another thing" might seem like a truism, but it's a sentiment that sometimes needs repeating.[23] This is especially true when it comes to considering the poetry of the Bible, which has so often been treated precisely as "another thing"—traditionally as theology or as ethics, but more recently, under the guise of literary criticism, as narrative. By the latter, I mean that even in recent "literary approaches" to the Bible, critics often look for things like plot or characterization in biblical poetry, categories more appropriate to narrative texts. But biblical poetry is, in both the simplest and the most complicated ways, *poetry*. To consider a biblical poem as poetry is to pay attention to its line structure, to its status as direct discourse, to the sort of speaking voice it presents, to its diction and imagery, and to its willingness to express inner thought and emotion as biblical narrative rarely does. It is, in other words, to attend not only to *what* the poem means but also to *how* it means.

## NOTES

1. Longinus, *On Sublimity*, trans. D. A. Russell, in *Ancient Literary Criticism: The Principal Texts in New Translations*, ed. D. A. Russell and M. Winterbottom (Oxford: Oxford University Press, 1972), 470: "Similarly, the lawgiver of the Jews, no ordinary man—for he understood and expressed God's power in accordance with its worth—writes at the beginning of his *Laws*: 'God said'—now what?—'Let there be light,' and there was light; 'Let there be earth,' and there was earth."

2. *Confessions*, VI.v and III.v, respectively.

3. So for example, C. S. Lewis, *The Literary Impact of the Authorized Version* (London: The Athlone Press, 1950), 4: "There is a certain sense in which 'the Bible as literature' does not exist. It is a collection of books so widely different in period, kind, language, and aesthetic value, that no common criticism can be passed on them. In uniting these heterogeneous texts the Church was not guided by literary principles, and the literary critic might regard their inclusion between the same boards as a theological and historical accident irrelevant to his own branch of study." It is not as clear as Lewis suggests that literary principles played no role in the formation of the biblical canon; but even if one conceded the point that does not mean that literary qualities are absent from the Bible, as this essay endeavors to show.

4. Homer, *Iliad,* trans. Robert Fagles (New York: Penguin, 1991), 426.

5. Erich Auerbach, *Mimesis: The Representation of Reality in Western Literature* (trans. Willard R. Trask; Princeton: Princeton University Press, 1953), 3-23.

6. This contrasts with non-narrative cultic or liturgical prose texts where, for example, we are given quite detailed descriptions of the tabernacle and its furnishings; see, e.g., Exodus 25-27.

7. Ibid., 9.

8. Robert Alter, *Genesis: Translation and Commentary* (New York: W. W. Norton, 1996), 129.

9. Ibid., 131-32.

10. Auerbach, *Mimesis*, 6.

11. Elie Wiesel, *Messengers of God: Biblical Portraits and Legends* (New York: Summit, 1976), 93-94; Danna Fewell and David Gunn, *Gender, Power, and Promise: The Subject of the Bible's First Story* (Nashville: Abingdon Press, 1993), 52-54.

12. In a related vein, see Robert Alter, *The Art of Biblical Narrative* (New York: Basic, 1981), 33-34, who writes of the dialectic between "God's will" and "human freedom." For Alter, the "refractory nature" of human freedom is imagined primarily as working against God's will, whereas to my mind that is not always the case.

13. Emily Dickinson, Letter 342a (to Thomas Wentworth Higginson), in *Selected Letters* (ed. Thomas H. Johnson; Cambridge: Harvard University Press, 1985), 208.

14. Wallace Stevens, *The Man with the Blue Guitar and Other Poems* (New York: Knopf, 1937), 22.

15. Robert Lowth, *Lectures on the Sacred Poetry of the Hebrews*, translated from the Latin by G. Gregory (London: Thomas Tegg, 1839), 205.

16. M. O'Connor, *Hebrew Verse Structure* (Winona Lake, IN: Eisenbrauns, 1980); Adele Berlin, *The Dynamics of Biblical Parallelism* (Bloomington: Indiana University Press, 1985); F. W. Dobbs-Allsopp, "Poetry, Hebrew," *New Interpreters Dictionary of the Bible*, vol. 4 (Nashville: Abingdon Press, 2006).

17. James Kugel, *The Idea of Biblical Poetry: Parallelism and its History* (Baltimore: Johns Hopkins University Press, 1981); Robert Alter, *The Art of Biblical Poetry* (New York: Basic, 1985).

18. Terry Eagleton, *How to Read a Poem* (Oxford: Blackwell, 2007), 25.

19. This visual quality is what Aristotle might refer to as *enargeia* (*Poetics* 1455a; *Rhetoric* 1410b) or "vividness." So also Demetrius, *On Style,* 209-220. On *enargeia* in classical poetry, see Egbert J. Bakker, "Mimesis as Performance: Rereading Auerbach's First Chapter," *Poetics Today* 20:1 (1993), 11-26, who ties it to the nature of orally performed epic; also Andrew Ford, *Homer: The Poetry of the Past* (Ithaca: Cornell University Press, 1993). On vividness in epic poetry more generally, see Suzanne Fleischman, *Tense and Narrativity: From Medieval Performance to Modern Fiction* (Austin: University of Texas Press, 1990); and in classical history writing Andrew D. Walker, "*Enargeia* and the Spectator in Greek Historiography," *Transactions of the American Philological Associaton* 123 (1993): 353-377. This quality of vividness, present also in biblical Hebrew poetry, is largely absent in biblical Hebrew narrative.

20. On this phenomenon, see Robert Kawashima, *Biblical Narrative and the Death of the Rhapsode* (Bloomington: Indiana University Press, 2004), ch. 3.

21. Alter, *Genesis*, 215.

22. Chapters 1 and 2 and then 42:7-17 of the book of Job take the form of prose narrative, but the long central section of the book in 3:1-42:6 is in verse form. Modern scholarship has mostly taken this as an indication of different authors (though recent years have seen a rethinking of this), without recognizing that the shift in literary form can be understood as motivated by the differing literary resources offered by Hebrew prose and Hebrew poetry. By convention, verse form allows the necessary access to Job's inner life in a way that prose does not, and it also allows for the sometimes extravagant figurative language that we find in the poetic section of the book.

23. T. S. Eliot, Preface to the second edition of *The Sacred Wood: Essays on Poetry and Criticism* (London: Methuen, 1928), viii.

# What is the Surface Area of a Hedgehog?

Barry Mazur

Well, I don't know the answer to the question of the title and no hedgehog will be harmed, or even mentioned again, until the very end of my lecture.

Eva Brann suggested tonight's lecture might address the question, *What is area?* I'm delighted to do this, and I'm delighted to be here, and to be among people—you, the St. John's community—with whom it will be such a pleasure to contemplate this question.

In this lecture I'll discuss the concepts of

- *area*—how it is familiar to us, and how when we push it to the limit we get some surprises;
- *length*—since, at least at first impression it is a more primitive "prior" concept— seemingly simpler than area;
- *proportion*—crucial to the understanding of both length and area;
- *invariance*—as a way of characterizing length and area;
- *quadrature*—as a crucial "format" for expressing profound area relationships in geometry.

And I'll conclude by alluding to Archimedes' wonderful "mechanical method" in which he transmutes the problem of computing area into the problem of computing something akin to weight[1] and thereby achieves the quadrature of the

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parabola. This offers us a glimpse of the power of analogy, and the use of the thought-experiment as already practiced in ancient mathematics.[2] It also gives us the opportunity to touch in passing on broader issues in mathematical thought such as analogy, heuristic, paradox, invariance, and something I'll call characterization (a version of axiomatization).

### 1. Area as familiar

We all know what the word *area* signifies. It often refers to a territorial cordon, as in *restricted area* or *hard-hat area* or even *area studies*. It sometimes comes as a *number,* but always with a unit attached, such as square miles, square feet, square inches, acres, or if it's a bed area you're interested in, you can ask for it to be King-size or Queen-size, or a size of lesser nobility.

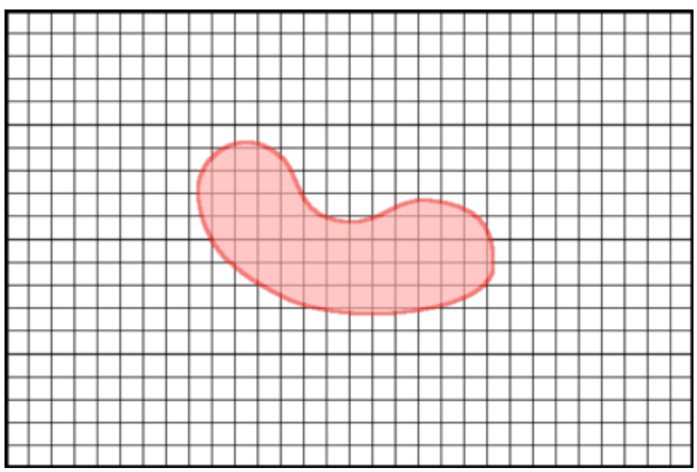


Fig. 1

If you want to approximate the area of the enclosed shape in Fig. 1 on a grid with a mesh of one-foot by one-foot squares, you might count the number of one-square-foot patches that comprise a union of squares that completely cover the figure (in the above case it is 81) and count the number of one-square-foot patches that the figure covers completely (in the above case it is 39). Then you know that the area of the figure in units of square feet is squeezed between these two numbers; that is, the area is smaller than the first number (or equal to it), and bigger than the second. In the above case, we would have

$$81 \text{ square feet} \geq \text{area of figure} \geq 39 \text{ square feet}.$$

If you want a better estimate, do the same thing with one-inch by one-inch squares.

If any of us were asked to calculate the square-footage of this auditorium we'd come up with some figure or other, confident that we could refine it to any degree accuracy required. And you may be painfully aware of the area of your dorm room. So, what else is there to say?

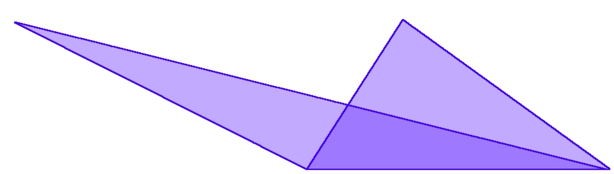


Fig. 2

## 2. How good are you at comparing areas?

I'm not very good. Here's an example. The area of the two shaded triangles in Fig. 2 are equal.

I know this thanks to Proposition 37 of Book I of Euclid's *Elements*. All of you either know that proposition now, or will after your freshman year. This is the proposition that says that triangles with the same base and height have the same area. Proposition 37 of Book I will be a recurring theme in my lecture; it is a marvelous piece of mathematics that demonstrates many things, including the maxim that to be profound and to be elementary are not mutually exclusive virtues.

But if I simply compared those figures visually—without either explicitly remembering or somehow "internalizing" Euclid's proposition—I would probably grossly underestimate (if that's a possible phrase) the area of the spiky triangle in comparison with the seemingly fat one. In a sense, then, Euclid's proposition–embedded in my central nervous system as it is—has improved (a tiny bit, not much) my ability to make off-the-cuff judgments and rough comparisons. Our native intuition, combined with a data bank of geometric experiences, determines our effectiveness in making judgments about all sorts of attributes belonging to objects that we see. I'm guessing that our eyeball comparisons are more reliable in relation to straight-line lengths than in relation to curved lengths,[3] and much more reliable than our ability to estimate area and volume, given the variety of possible configurations. In teaching Euclid's *Elements,* one often emphasizes "logical thinking" as the great benefit that students take away from learning geometry. But I also see a type of pre-logical—if I can call it that—or intuition-enriching benefit as well. This is hard to pinpoint, but it comes out as a general sharpening of faculties in regard to thinking about, guessing about, negotiating, comparing, and relating geometric objects.

Such a benefit is very different from the other valuable reward just mentioned—that is, being able to actually argue the proof of Proposition 37 of Book I by making the elegant construction shown in Fig. 3.

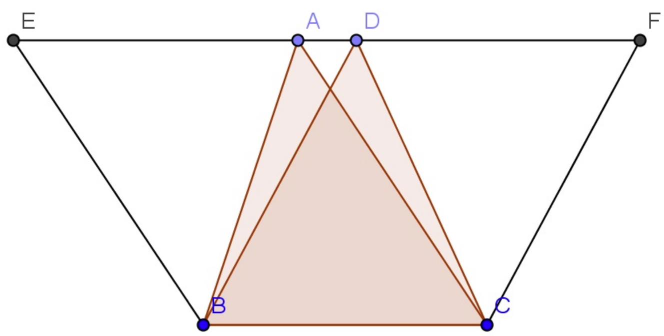



Fig. 3

To continue our review of how good our intuitions are, let's pass to a slightly deeper basic geometric comparison authored by Archimedes that astonishes me now just as it must have astonished Archimedes' contemporaries. We will get into this in more depth later on,[4] but consider the following striking way of *recreating* the area of any circle: the area of any circle is *equal* to the area of a right-angle triangle defined by the property that the two of its sides making the right angle have lengths equal to the radius of the circle, and to the length of the circumference of the circle, respectively. (Fig. 4)

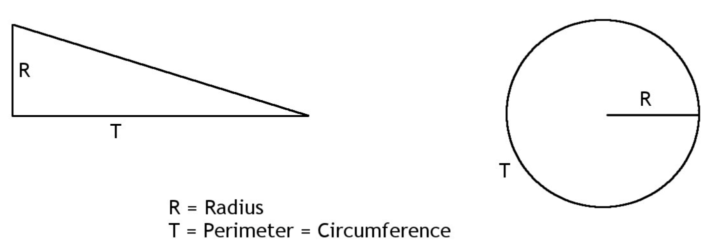



Fig. 4

Here, as in the previous example, I "see" it not visually (if this can be said), but only with the help of my memory of its proof. (I will say more about this below).

Let us push a bit further. The two examples we've just reviewed are examples of nicely enclosed, finite figures. We are even poorer in intuition when faced with planar figures (no matter how smooth and simple their boundaries seem to be) that "asymptote" off to infinity. It may be quite difficult, even if given long chunks of such a shape, to extrapolate and guess by eyeball alone whether it extends out to a figure with infinite area or finite area.

For example, consider Fig. 5, which was drawn as accurately as possible. I wonder whether you can guess if the area bounded by the blue curve or the pink curve has finite area. My point is that there's no reason why you should be able to do it no matter what talents of visual acuity you may possess.

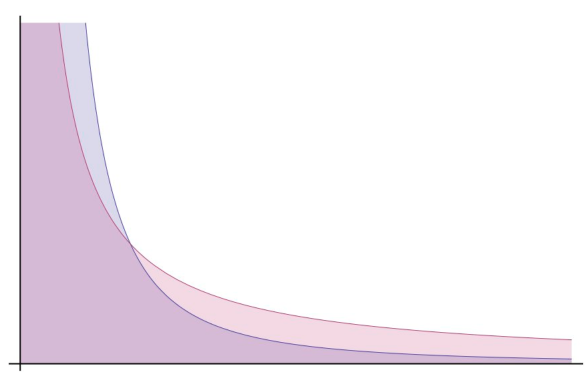


Fig. 5

But, just in case you are wondering, if you continued tracing the curved regions ad infinitum in the manner smoothly begun by the sketch—meaning that the pink curve is the graph of the function $y = 1/x$ and the blue curve is the graph of the function $y = 1/x^2$—then the (infinite) red-bounded region happens to have infinite area while the (infinite) blue-bounded region has finite area. As a side issue, many calculus students are amazed to find that if you "construct" an infinite "trumpet" by rotating the red curve of the above figure around the $x$-axis, then its surface area is infinite, even though the volume it subsumes is finite. To put it in colloquial, but misleading, terms: you can fill this trumpet with a finite amount of paint, but you need an infinite amount of paint to paint it.

This phenomenon illuminates much, especially for people who know calculus, and could be the subject of a question following the lecture. But I won't dwell on this; I mention it as a hint that there are things to dwell on here.

### 3. Pushing to the limit

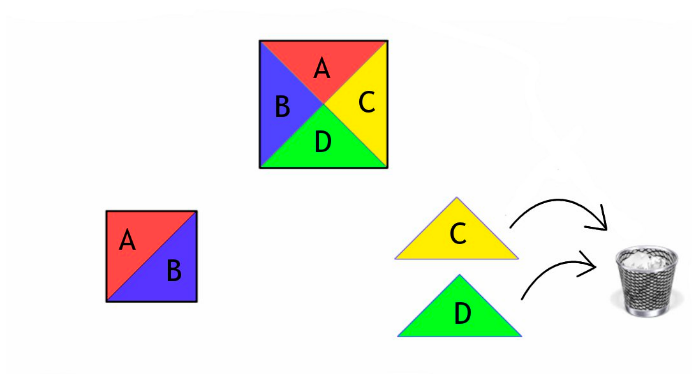
You might wonder what is to be gained by asking questions about infinite area versus finite area, or by considering the concept of *area* in various extreme contexts. Mathematics often does that sort of thing: it is a useful strategy to examine a concept when it is brought to its limit, in the hope that the strains inflicted on the concept will reveal important facets of it that would be hidden in less stressful situations. If you push a concept to its extreme border, you may see things that would otherwise be overlooked if you remain in the comfortable zones. For example, you can learn what its precise borders are. Some of the most beautiful mathematics—and the deepest—has emerged by seeking the extremes.

The issue we have just addressed, areas of infinitely extended regions, can be broadened, for it raises the question: exactly how many subsets of the plane *deserve* to have a well-defined area? Do *all* subsets have a reasonable notion of area?

### 4. Area as paradoxical

To get the blood circulating, let's contemplate something that is evidently impossible: Can you

**(1)** take a square $S$ in the Euclidean plane, cut it (say, with a scissors) into four pieces $A, B, C, D$ of equal area—so no two of these pieces overlap, and the four of them cover the square?




In standard notation:[5]

$$S = A \cup B \cup C \cup D;$$

**(2)** and now can you throw away two of the pieces (say $C$ and $D$) and move the other two ($A$ and $B$) around by Euclidean motions to get congruent shapes $A', B'$ in the plane so that these two pieces cover the exact same square again, i.e.,

$$S = A' \cup B' ?$$

The answer, of course, is No, you can't do this. Certainly not if the concept of area has the properties that we expect to have. By "properties" I'm referring to these two self-evident axioms:

**(1)** the area of a union of non-overlapping figures is the sum of the areas of each of the figures; and
**(2)** the area of a figure is preserved under Euclidean motion.

For if you could do this, then our two formulas for $S$ displayed above will give contradictory answers to the question, *What is the area of S?*

With this in mind, consider the following strange fact about *spherical* rather than *Euclidean* geometry. Let $S$ be the surface of a ball (that is, what mathematicians call the two-dimensional sphere). There is a way of separating $S$ into four sets $\mathcal{A}$, $\mathcal{B}$, $\mathcal{C}$, $\mathcal{D}$, no two of which overlap, such that each of these sets are—in an evident sense—congruent to any of the others. (This means that, for example, there is a way of rotating the sphere that brings $\mathcal{A}$ precisely to the position that $\mathcal{B}$ occupied (before that rotation)—and similarly, there are ways of rotating the sphere to bring $\mathcal{A}$ to $\mathcal{B}$ and to $\mathcal{C}$ and to $\mathcal{D}$. *Nevertheless,* you can throw two of them away (say, $\mathcal{C}$ and $\mathcal{D}$) and find a way of rotating the sphere so that $\mathcal{A}$ is brought to a set $\mathcal{A}'$ and a (different) way of rotating the sphere so that $\mathcal{B}$ is sent to a set $\mathcal{B}'$ *and* these maneuvers have the strange property that $\mathcal{A}'$ and $\mathcal{B}'$ together cover the sphere; i.e.,

$$S = \mathcal{A}' \cup \mathcal{B}'.$$

This is called the *Banach-Tarski Paradox.* Despite first appearances this is not actually a paradox although there is indeed a subtlety lurking in the way in which I worded things.[6] It is merely a *para-dox,* that is: *something contrary to expected opinion.*

I brought this apparent paradox up not to confuse you but rather to point out, at the very outset, that

- even though area is a concept we tend to feel perfectly at home with, to get closer to its essence is to appreciate more keenly its complexity, and so
- in our discussion about area we had better start from the very beginning, by noting that
- despite its reputation for having what are called "proper foundations," mathematics doesn't seem to have a "beginning."

## 5. Length in everyday life

Nevertheless, let's begin with something seemingly a bit simpler than area: plain old lengths of straight line-segments. I say "seemingly" because as often happens in mathematics, the simpler-seeming concept (in this case, length) contains, in a more visible form, lots of the essential aspects of its complicated companions (e.g., area and volume).

We all know what is meant when someone says "a ten foot pole." This is a relative statement, comparing the pole to some foot-long ruler, and claiming that we can lay ten copies of our measuring device onto the pole, covering it completely with no overspill or overlap. Usually, of course, the speaker of this phrase has something on his mind other than this length-measuring thought-experiment.

In slight contrast, when we are told that the circumference of this cup is eight inches long and we want to verify this directly, we must set aside our rigid, calibrated, ruler and use something like a tape-measure, wrapping it around the rim of the cup.[7] Of course, there is also a well-known indirect way of verifying this measurement which starts by using our rigid ruler to calculate the diameter of the cup—but this indirection already involves a certain amount of mathematical experience with π.

In even greater contrast, when we are told that the star cluster NGC 1929 within the Large Magellanic Cloud (a satellite galaxy of our own Milky Way shown in Fig. 6[8]) is 179, 000 light-years away from us, other measuring devices are required, and—given relativistic issues—what *distance* means is already a subtle business.

Fig. 6

### 6. Equality [of length] in Euclid

The concept *length* occurs—in a somewhat cryptic form—early in the *Elements*. It appears as *mēkos* in the definition of *line* (Def. 2):

*A line is breadthless length.*

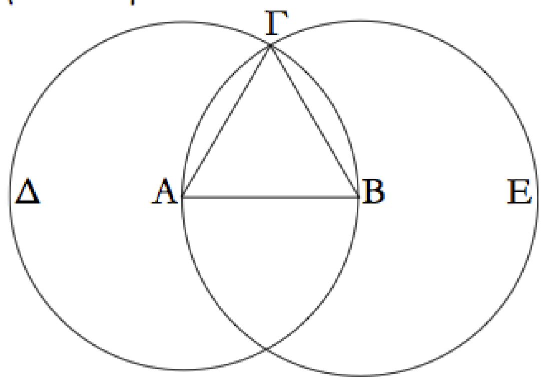
The concept reappears as *diastēma* (translated often as *distance* but meaning, more specifically, *interval* or *gap*) as something of a surprise. Euclid slips it into the discussion in Book I in the definition of *circle* (Def. 15), which is described as—and I'll put it in modern vocabulary—a figure bounded by a curve the points of which are equidistant from a given point.

Thanks to this definition and the ability we have—given to us by Postulate 3—of *drawing a circle with any center and any radius,* we can begin to construct many line segments that, in Euclid's terms, are "equal" (meaning, *are of equal length*). Even better, we are supplied with tools for establishing equality. Euclid wastes no time making use of these tools: the very first proposition (Proposition 1 of Book I, see Fig. 7[9]) goes straight to the task of constructing, on any line segment, an equilateral triangle, that is, a triangle in which all three sides are "equal." And we're off and running, at least as far as understanding *equality* of length goes.

On the facing page you see it in its full glory, ending with a triumphant *hoper edei poiēsai*—i.e., "as was to be constructed."

When later mathematics takes on the issue of length, things proceed quite differently from the way Euclid proceeded. Modern mathematics throws a spotlight on *transformations* in a way that ancient mathematics did not. Nowadays, as we introduce a new concept or new type of structure, often—at the same time—we make explicit the types of transformations or mappings between exemplars of this structure that we are willing to consider (or rather, that we are willing to *allow*). These *allowed transformations* are the ones that respect the inner coherence of the structure we are studying. In Euclidean geometry, the *allowed transformations* are the mappings of the Euclidean plane onto itself that preserve the notion of congruence. They consist of rotations about points in the plane, translations, and also those α΄.

Ἐπὶ τῆς δοθείσης εὐθείας πεπερασμένης τρίγωνον ἰσόπλευρον συστήσασθαι.




Ἔστω ἡ δοθεῖσα εὐθεῖα πεπερασμένη ἡ ΑΒ.

Δεῖ δὴ ἐπὶ τῆς ΑΒ εὐθείας τρίγωνον ἰσόπλευρον συστήσασθαι.

Κέντρῳ μὲν τῷ Α διαστήματι δὲ τῷ ΑΒ κύκλος γεγράφθω ὁ ΒΓΔ, καὶ πάλιν κέντρῳ μὲν τῷ Β διαστήματι δὲ τῷ ΒΑ κύκλος γεγράφθω ὁ ΑΓΕ, καὶ ἀπὸ τοῦ Γ σημείου, καθ' ὃ τέμνουσιν ἀλλήλους οἱ κύκλοι, ἐπί τὰ Α, Β σημεῖα ἐπεζεύχθωσαν εὐθεῖαι αἱ ΓΑ, ΓΒ.

Καὶ ἐπεὶ τὸ Α σημεῖον κέντρον ἐστὶ τοῦ ΓΔΒ κύκλου, ἴση ἐστὶν ἡ ΑΓ τῇ ΑΒ· πάλιν, ἐπεὶ τὸ Β σημεῖον κέντρον ἐστὶ τοῦ ΓΑΕ κύκλου, ἴση ἐστὶν ἡ ΒΓ τῇ ΒΑ. ἐδείχθη δὲ καὶ ἡ ΓΑ τῇ ΑΒ ἴση· ἑκατέρα ἄρα τῶν ΓΑ, ΓΒ τῇ ΑΒ ἐστιν ἴση. τὰ δὲ τῷ αὐτῷ ἴσα καὶ ἀλλήλοις ἐστὶν ἴσα· καὶ ἡ ΓΑ ἄρα τῇ ΓΒ ἐστιν ἴση· αἱ τρεῖς ἄρα αἱ ΓΑ, ΑΒ, ΒΓ ἴσαι ἀλλήλαις εἰσίν.

Ἰσόπλευρον ἄρα ἐστὶ τὸ ΑΒΓ τρίγωνον. καὶ συνέσταται ἐπὶ τῆς δοθείσης εὐθείας πεπερασμένης τῆς ΑΒ. ὅπερ ἔδει ποιῆσαι.

transformations that can be viewed as the composition of a "flip," (that is, a symmetry about some straight line) with a translation or rotation. In one of the modern formats, the concept of Euclidean *length* and the collection of the *allowed transformations* of Euclidean geometry are yoked concepts, working in tandem:

- The allowed transformations are precisely those transformations that preserve length of all line-segments,

while

- two line-segments have equal length if and only if there are allowed transformations bringing any one of them onto the other.

In effect, these notions—"length between points in Euclidean geometry" and "the transformations that preserve Euclidean geometry"—are yoked, chicken-and-egg style, in that each can be used to begin the discussion and *characterize* (that is, explicitly determine) the other. Think of it this way: We could invoke each of these concepts to provide the vocabulary for a system of axioms in a geometry, and the other concept would then be one of the many features of that geometry. You can have length as your basic concept and stipulate the transformations that preserve your geometry to be those that preserve length, or you may start with the stipulation of transformations of your geometry and derive length as one of its invariants—in effect, deriving the entire geometry from its group of symmetries. (The second viewpoint represents a celebrated shift of emphasis, known as the *Erlangen Program.*) But there is also an important difference of mood between "axiomatization," which sets up a theory starting from one direction or the other, and presenting things in a balanced way, where each concept "characterizes" the other.

## 7. Proportions

Length is, at bottom, a *relative* concept: that is to say, “length compared to what?” is a bona fide question. What are the units? Inches? Feet? Miles?[10] That is, when we deal with length, we are dealing—unavoidably—with a proportion.[11] This puts us in the mood of Euclid’s Book V, a work that deals exclusively with proportions among magnitudes.

Say we are interested in the length of our ten-foot pole *P*. We compare it to our one-foot ruler *F*, we might emphasize the proportional aspect of length by recording the answer symbolically this way:

$$(*)\ P : F \text{ “=” } 10 : 1$$

I’ve put quotation-marks around the equality sign to emphasize that it is indeed a serious abbreviation of thought, turning what began as an analogy ($P$ is to $F$ *as* 10 is to 1) into an equality (the relationship that $P$ has to $F$ *is* the relationship that 10 has to 1)—turning an *as* into a straight *is*. This is a curious transition. The older notation for equality sign in quotation marks is a double-colon,

$$(**)\ P : F :: 10 : 1,$$

capturing equally well, I believe, the *“as”* aspect of the relationship. That a proportion of lengths *is interpretable as* a proportion of numbers may well be self-evident, but that it is an *interpretation* is worth bearing in mind.

The legacy of the Pythagoreans offers us yet another interpretation for the versatile notion of a proportion of lengths:

> *As the length is to the length,*
> *So the heard tone is to the heard tone.*

After this discussion it is safe to remove the quotation marks in formula (*) displayed above, and write

$$P/F = 10/1.$$

We thereby see arithmetic in geometry (that is, by going from left to right in the above equation). In other words, we have an "arithmetic" (of proportions of straight line segments) that mirrors "ordinary" arithmetic (of ratios of numbers). For example, you can add proportions of lengths of line segments:

*A*· – – – – – – – ·*B*· – – – – – – – – – – – – – – – ·*C*

*D*· – – – – – – – ·*E*

$$AB/DE + BC/DE = AC/DE$$

and multiply proportions of lengths of line segments:

*A*· – – – – – – – ·*B*

*C*· – – – – – – – – – – – – – – – – ·*D*

E· – – – – – – – – – – – – – – – – – – – – – – ·F

$$AB/CD \times CD/EF = AB/EF$$

and we have a natural interpretation of *inequalities* between these proportions. These behave formally "just like fractions," as the notation indicates, and we have a veritable algebra of geometrical proportions.

### 8. Common Measures, and uncommon measures

All this makes perfect, and natural, sense and conforms to the most elementary basic ideas we have about arithmetic as long as we treat proportions of lengths that "admit a common measure."

That is, imagine that you are given two intervals,

*A*· – – – – – – – ·*B*

*C*· – – – – – – – – – – – – – – ·*D*

and you know that there is a certain unit measure, say given by another interval EF,

$$E\cdot - - \cdot F$$

such that *AB* and *CD* are measured by (whole) number multiples of *EF*. For example, say *AB* is seventeen *EF*s long and *CD* is four hundred ninety one *EF*s long; so we may write:

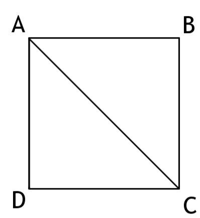
$$AB/EF = 17/1 \text{ and } CD/EF = 491/1.$$

We then say that *EF* is a common measure for the line segments *AB* and *CD*. And, in this particular case, we then comfortably write

$$AB/CD = 17/491.$$

But the fun, as I think you all know, is already there at the very outset of geometry for one of the most fundamental of geometric proportions—that between the *diagonal* and the *side* of a square

the diagonal *AC* / the side *AB*




—was shown to have *no common measure,*[12] and nevertheless the proportion *AC/AB* (alias $\sqrt{2}/1$) was still regarded as a genuine object of study, with the consequence that it forced us—by the analogy between proportions of lengths and proportions of numbers—to extend our very idea of what it means to be a number. It is worth thinking about what it means for *geometry* to guide us in our evolving concept of *number*.

For all this is a beginning of one of the great analogies,

**arithmetic ↔ geometry,**

in which each profoundly influences the other. This type of thinking goes against a view held by Aristotle (a view often referred to as *purity*), namely:

> We cannot, in demonstrating, pass from one genus to another. We cannot, for instance, prove geometrical truths by arithmetic.[13]

### 9. The ubiquity of "analogy" in mathematical thought

In the previous section we have been working through the idea that straight line segments stand in relation to each other "just as" numerical quantities stand in relation to each other; that is, we are now faced with—as we've mentioned—one of the primordial analogies between geometry and arithmetic.

That this "just as" relation is an analogy and not a direct equality takes some convincing. A curious phenomenon occurs with many mathematical analogies once they get embedded in our thought. If *A* is seen to be analogous to something else, *B,* there is the impetus to think of *A* and *B* as, somehow, special cases of, or aspects of, a single more encompassing *C;* and somehow to rethink the analogy as *equality.* This switch is a form, but not the only form, of *abstraction* that is indigenous to mathematical sensibility. Versatile switching of viewpoints is one of the reasons for the power of a mathematical frame of thought. This replacement of a pair of analogous contexts for a single encompassing context occurs so often that people with experience in mathematics have this type of thought engrained in them as second nature.[14]

As I mentioned, replacing the two parts of an analogy by a common generalized concept is powerful and occurs often in mathematics, but in other contexts of thought it might seem a strange thing to do. One rarely does this kind of generalizing with analogies and metaphors that occur in literature: when thinking about the metaphorical comparison in

*Shall I compare thee to a summer's day?*

do we conceive of a more general entity that encompasses "thee" and "summer's day" as instances?

### 10. Length and straight line segments

You may have noticed that, although I've gone on at some length, I never defined *straight line segment.* Now, you can postpone talking about straight line segments if you phrase things in terms of *distance.* That is, for any two points $P$ and $Q$ on the Euclidean plane, if you have a notion of *the distance between $P$ and $Q$*—denote it by $\mathrm{dist}(P, Q)$—you can pick out the points on the straight line segment between $P$ and $Q$ as precisely those points $X$ such that

$$\mathrm{dist}(P, Q) = \mathrm{dist}(P, X) + \mathrm{dist}(X, Q).$$

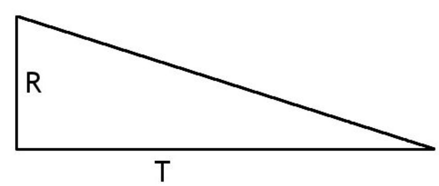
But the ancients seem not to have defined straight line segment this way. Euclid's definition (Def. 4 of Book I) is elegantly enigmatic:

*A straight line is a line which lies evenly with the points on itself.*

This is reminiscent of Plato's definition of a straight line segment as "whatever has its middle in front of its end" (*Parmenides* 137e). Here, Plato seems to be taking his straight line segment up to his eye to view it as you would look through a telescope, noting that the only thing he sees is its endpoint. In effect, a straight line is a *line of sight.*[15] A much later take on the matter defines a straight line segment with endpoints $P$ and $Q$ as the unique curve joining $P$ and $Q$ such that among all curves joining $P$ and $Q$ it is the one having the shortest length.[16] But to make sense of this you must know, at the very least, what it means for a curve to have a length. Hence . . .

### 11. Lengths of smooth curves

Nowhere in Euclid's *Elements* is the length of a curve that is *not* a straight line, or polygonal, segment discussed. The first nonpolygonal curve whose length was considered (in the texts that I know) is the circumference (called the *perimeter*) of a circle, as studied in Archimedes's *The measurement of the circle*.[17] And there the length of the circumference of a circle enters the mathematical discussion in the context of the elegant statement about area[18] that we have already briefly discussed in Section 2.




R = Radius
T = Perimeter = Circumference

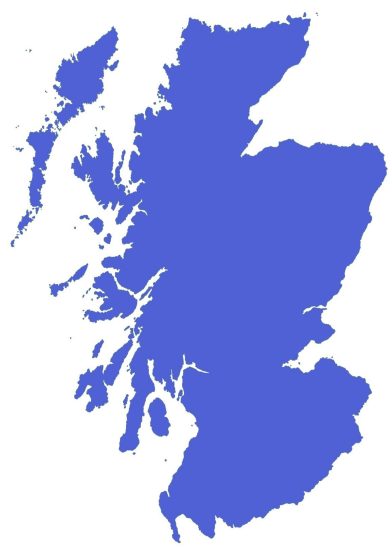
Here it is as Proposition 1 of Archimedes text:

> **Proposition 1:** Every circle is equal to a right-angled triangle, whose radius [*R*] is equal to one of the [sides] around the right angle while the perimeter [i.e., circumference *T* of the circle] is equal to the base [of the triangle].

This is proved by approximating the circle by a regular polygon with a large number of sides, and arguing appropriately.

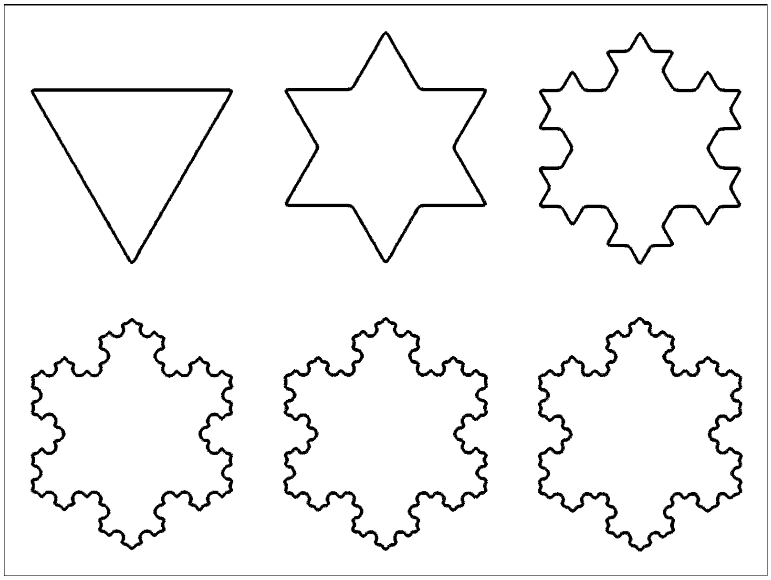
This is an *amazing* theorem, of course, but the more specific reason I'm mentioning it is that it exemplifies the general rule that the computation of the length of any curvy curve depends—perhaps very indirectly—on relating it to the length of approximating polygons. This is (quite directly) Archimedes's method here. He makes use of a result about polygons analogous to Proposition 1, where the polygons in question will be made to approximate the circle. For a slightly more extensive sketch of Archimedes's argument, see the Appendix, Section 20 below.

## 12. Lengths of crinkly curves



It has been said that there is no way to measure the length of the coastline of Scotland.

It is just too crinkly, and the length you find yourself computing depends on how fine a grid of measurements you make—the result getting longer and longer as the measurements grow finer. Mathematicians can easily model such an effect, the most famous construction being something called the Koch snowflake. This is a closed curve obtained by taking the limit of an infinite sequence of crinkle-operations. Start with an equilateral triangle and on an interval one-third the size of each side construct a small equilateral triangle. Here are the first few stages:

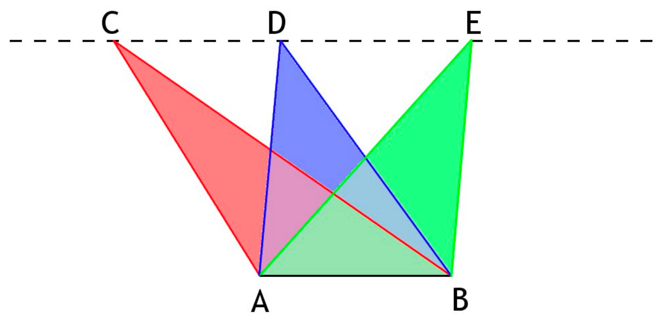


At each stage you are faced with a longer curve, and in the limit, you have seemingly contained a curve within a finite region that is so crinkly so as to have—in effect—infinite length.

### 13. What is area?

We'll be interested primarily in the areas of figures in the Euclidean plane. Given our discussion of *length* it won't be a surprise to learn that we will be dealing, again, with proportions; in this case, the proportion of (the area of) one figure to (the area of) another. Nor will it be much of a surprise to find that just as *straight line segments* played a fundamental role in all discussions of length, so too *polygonal figures* will play such a role in our treatment of area.

Euclid is again very helpful here. The first time he discusses area, it is—in his vocabulary— *parallelogramatic area:* Proposition 34 of Book I tells us that the diagonal of a parallelogram bisects the (area of) the parallelogram. He follows this up with the propositions (including the beautiful Proposition 37 I've alluded to already) stating that two triangles with the same base and height have the same area, as do two parallelograms with the same base and height.




And once we have these tools, we are in good shape to deal with areas of polygonal figures. We can even go further, as we saw in Section 11 above with Archimedes's proof that transforms the area of a circle into the area of a triangle by means of polygonal figures. (As I've said, we will discuss more in the Appendix, Section 20 below.)

### 14. Area as an "invariant"

Here is an exercise: make a (short) list of "axioms" that (you guess) characterizes the concept of ratios of areas for a large class of (plane) figures. You'll surely include a number of basic properties of the intuitive concept of *area* as hinted at in section 4 above. But let me start the game by insisting that one of your axioms be this:

**Axiom of Invariance under Euclidean motions:**

If $A$, $B$ are a pair of plane figures for which you have defined the ratio

area of $A$ / area of $B$

(or, for short, *A/B*) and if *A′* is the image of the figure *A* under a Euclidean transformation, then we have the equality:

area of *A* / area of *B* = *area of A′* / area of *B*

This is worth thinking about, but this is just a start, and note that in your personal "theory of area," part of the chore is to make precise exactly what class of figures you are going to be assigning a well-defined area. This might be a bit of fodder for discussion following the lecture. This exercise was solved elegantly and in somewhat astounding generality before World War II by the Hungarian mathematician Alfréd Haar.

### 15. Shears and Similarities

Given a well-working "theory of area," certain properties will follow as consequences. For example, here are two basic features—two further *invariance properties* for the concept of area.

**(1) Shears**

By a **horizontal shear transformation** let's mean a transformation of the Euclidean plane to itself that keeps every horizontal line in place, but moves it by a translation that is dependent on the "height" of that line above the $x$-axis. That is, for any point $(x, y)$ in the plane it keeps the $y$-coordinate fixed but allows the $x$ coordinate to change by a rule:

$$x \mapsto x + F(y)$$

where $F(y)$ is some civilized (e.g., continuous) function of $y$. This type of motion of the plane keeps all lines parallel to the $x$-axis intact, but translates them by different amounts depending on their height. By a **general shear transformation** let's mean an analogous transformation, but with respect to lines parallel to any fixed line: the line needn't be the $x$-axis.

*The area of figures is preserved by shears!*

Now we've actually seen examples of this in our previous discussion: think of Proposition 37 of Book I of Euclid's *Elements.* One way of revisiting the content of Proposition 37 is to note that any two triangles with the same base and same height can be brought one to another by a *shear.*

The three-dimensional version of this (where the question is about *volume* rather than *area*) is sometimes referred to as **Cavalieri's Principle**, and is illustrated, for example, by the following picture, where Cavalieri's Principle would state that the two stacks of coins on the next page occupy the same volume.

**(2) The behavior of area under similarity transformations.**

If

- $A$ and $A'$ are in the class of figures for which you have defined the ratio

$$\text{area of } A \,/\, \text{area of } A'$$

and if

- $P, Q$ are points in the figure $A$ with $P', Q'$ the corresponding points in the similar figure $A'$,

then the *square* of the ratio

$$\text{length of } PQ \,/\, \text{length of } P'Q'$$

is equal to the ratio

$$\text{area of } A \,/\, \text{area of } A'$$

This *square relation* tells us that we are dealing with a two-dimensional concept.[19]

*Dimensionality* as a concept opens up a host of marvelous questions to explore, not the least of which is the grand idea, initially due to Hausdorff, that the full range of possible geometric figures admits a continuous gamut of dimensions—not just dimensions 0, 1, 2, 3, . . .

That such strange figures possessing non-whole-number dimensions may have some bearing on questions in the natural sciences, economics, and finance—let alone pure mathematics—is the energy behind Benoît Mandelbrot's well-known fractals.[20]

### 16. Invariance as feature; Invariance as characterization

I have been alluding to the invariance properties of *length* and of *area*. Here is a summary and comparison.

**Euclidean Length and the collection of Euclidean motions suit each other's needs perfectly:**

- The (Euclidean) concept of *length* is invariant under the *Euclidean motions* (i.e., translation, rotations, symmetries about straight lines, and compositions of these). That is, these transformations *preserve* Euclidean distance.
- *Any* distance relation between points that satisfies certain natural axioms and that is invariant under any Euclidean motion *is* (after appropriate rescaling of its values) equal to the (Euclidean) concept of *length*.
- Moreover, any transformation that preserves length between any two points in the plane *is* a Euclidean motion.

**In contrast to *length,* the invariance properties of (Euclidean) concept of *area* is stranger:**

- The (Euclidean) concept of *area* is invariant under Euclidean motions, of course— but it is also invariant under a much greater collection of transformations. For example, any of the shear transformations we have discussed in the previous section (Section 15) preserves area.
- But as for characterizing this concept by invariance properties, things go the other way: *area* is characterized (up to a mere change of scale) by its invariance under translations alone—that's all the invariance you need invoke to pinpoint this concept!

It is quite fitting, then, that Euclid inserts his Proposition 37 in Book I, very early in his discussion of area: the proposition is, of course, a critical tool in establishing the simplest arguments regarding area—but from a modern perspective, it also points to one of the deep properties of the concept vis-à-vis invariance: there is a huge collection of transformations—far more of them than just Euclidean motions—that preserve area.

### 17. Classical Quadrature Problems

The phrase *quadrature of* . . . loosely refers to the problem of *finding the area of* . . . , which usually means expressing—as some simple numerical ratio—the proportion of the area of one figure to another figure.[21] First, here is a simple example related to Euclid's Proposition 37 in Book I of the Elements that we discussed earlier, and whose proof can be found by putting together propositions in Book I of Euclid's *Elements*:[22]

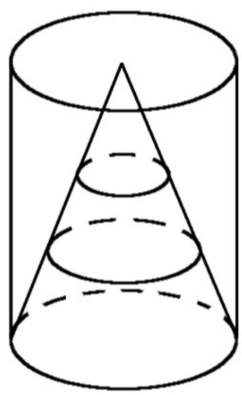
**Proposition:** Let $P$ be a parallelogram and $T$ a triangle, such that $P$ and $T$ have the same *base* and the same *height.* Then

$$P : T = 2 : 1.$$

This proposition follows the format of what I'll call a "Classical Quadrature Problem," which I want to mean to be a statement that *the proportion of areas (or lengths, or volumes) of two geometric figures, all described entirely in clear general geometric terms,*[23] *is equal to a specific numerical ratio.*

There are quite a number of classical problems that fit this mold, that is, problems expressing the proportion of the areas of two figures, or volumes of two solids (described in general terms) in terms of specific rational numbers. For example, Proposition 10 of Book XII of Euclid's *Elements* tell us that

> *the ratio of the volume of a cone to a cylinder that have the same base and the same height is 1 : 3.*



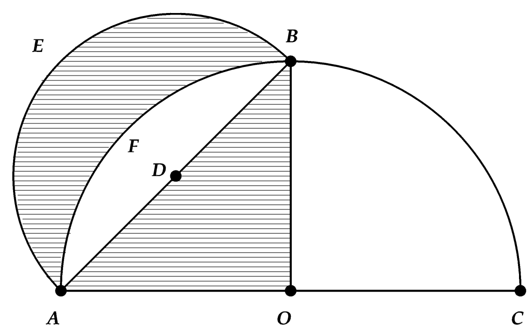
This "1 : 3" reoccurs as the ratio of the volume of a conical solid built on any base to the cylindrical solid built on the same base, and of the same height. The earliest text I know that "explains" the "1 : 3" in this more general context is *Arithmetica Infinitorum* by John Wallis, who did his work before the full-fledged invention of Calculus; for the people who know Calculus, this is an exercise.[24]

As with much of Archimedes's work there are stories that surround it. In one of his treatises,[25] Archimedes showed that

> *the ratio of the volume of a sphere to that of the cylinder that circumscribes it is 2 : 3.*

and according to legend, this being his favorite result, he had it engraved as a sculpture for his tomb.

The most intriguing, and thorny, of the ratios of elementary areas or volumes are the proportion relating the area of a circle to that of the square that circumscribes it, and the proportion relating the volume of a sphere to that of the volume of the *cube* that circumscribes it. The story of the many attempts to understand these ratios leads us in interesting directions. For example, Hippocrates of Chios in his attempt to *square the circle* studied classical quadrature problems relating the areas of *lunes* (which are figures consisting of the outer portion of a small circle when superimposed on a larger one, as in the figure below[26])



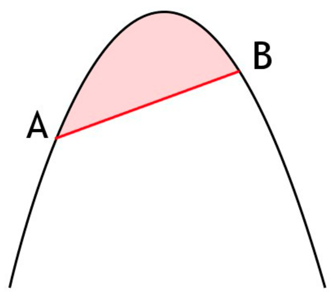

to areas of triangles constructed in relation to those lunes. He proves, for example, that the area of the lune (defined as the region between *E* and *F* in the figure above) is equal to the area of the triangle *ABO*. His results, however, go significantly beyond this.[27]

### 18. Weighing area

A famous example of a classical quadrature problem is Archimedes's "Quadrature of the parabola" and this is dealt with in not one, but two of his treatises in quite different ways:

- Propositions 14-16 of *The quadrature of the parabola,* and
- Proposition 1 of *The Method.*

The aim is to "find" the area of a segment of a parabola bounded by a chord.

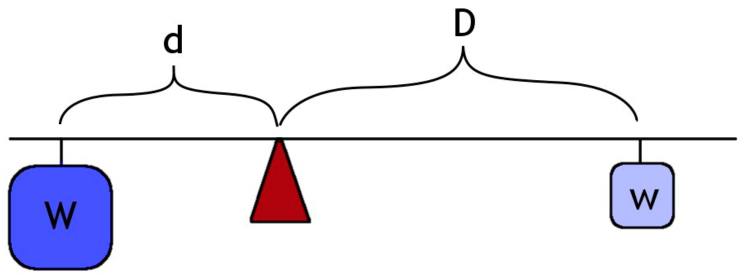



We know, of course, that this means finding a proportion between the red area of the above kind of figure and the area of some other figure.

This problem is especially illuminating in that Archimedes offers two approaches to it. The method in *The quadrature of the parabola* is via exhaustion, i.e., approximation by polygons—which is a method similar to the one we have already seen in the *Measurement of the circle.* This actually does prove what he wants. But the more curious method is the one that he himself refers to as a *mechanical method*—a mode of reasoning to which he does not give the full authority of proof: it's an example of a *heuristic*[28]—perhaps the first example of such a not-quite-a-proof of which we have any record.

A major tool Archimedes uses in this heuristic is his famous "law of the lever,"[29] which proclaims that if weights $W$ and $w$ are placed on the plank that is the lever, at opposite sides of the fulcrum but at distances $D$ and $d$ from the fulcrum respectively, then the lever will balance if and only if

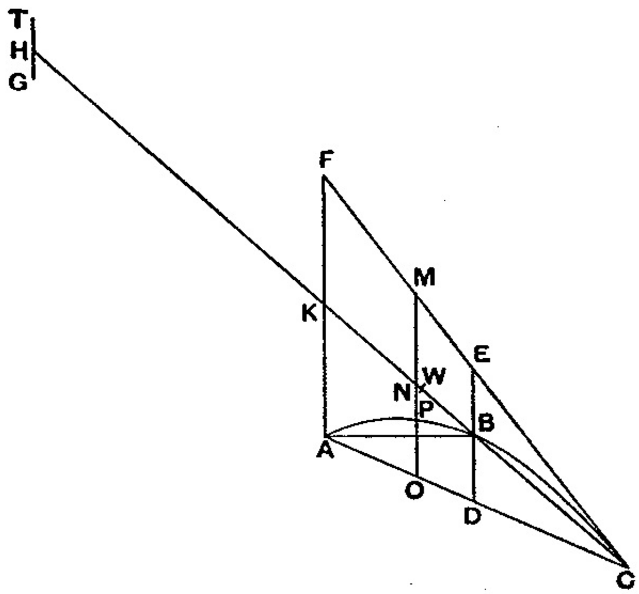
$$D \cdot w = d \cdot W$$




"Now what in the world does this have to do with *area*?" you might ask. The answer is that Archimedes is engaged here in an ingenious thought-experiment, where the rules of the game are dictated by some basic physical truths, and the link to *area* (he will also treat *volume* problems this way as well) is by a profound analogy. In the figure below, imagine the point *K* as the fulcrum of a lever. The plank of the lever is the line segment *HK*. Archimedes will construct a triangle *FAC* deployed onto the plank as shown, and will be weighing (yes, *weighing*) the parabolic segment $\mathcal{P}$ by weighing in a laminar manner each line in the parabolic segment parallel to the diameter of the parabola against corresponding lines in the triangle *FAC* placed at an appropriate distance (at *H*) on the other side of the fulcrum. Archimedes is thinking that you can view the parabolic segment and triangle as swept through by a continuum of line segments, and the area of these figures is somehow distributed as slivers dependent on the varying lengths of these line segments. So he uses his "law of the lever" to find the balance, thereby concluding his heuristic argument.

We can discuss this at greater length after the lecture if you like, but here—a bit more slowly—is a recap of what I've just said, broken up into the steps that Archimedes uses.

In the figure below, which is taken from one of the diagrams for Proposition 1 in the traditional text for *The Method,*




the chord is *AC* and the parabolic arc we are to study is the curve bounded by *A* and *C.* We are interested in the area of the parabolic segment—let us call it $\mathcal{P}$. Specifically, $\mathcal{P}$ is that region bounded by that chord *AC* and the parabolic segment that joins with it. For this task, the figure will give us all the constructions necessary.

**(1) The lever and fulcrum:** We are going to weigh things and balance thing so we need some apparatus. Don't mind that it is on a slant; but the straight line through *C* and *K* is going to be our *lever,* and *K* will be our *fulcrum.*

**(2) The tangent line:** We draw the line *CF* through *C* tangent to our parabolic arc at *C* (I'll say what *F* is in a moment).

**(3)** Let *D* be the bisector of *AC* and construct a straight line through *D parallel to the diameter of the parabola.* (Parabolas *do* have well defined "diameters." In simple English, if we draw the full parabola, rather than the piece of it as occurs in the above figure, the diameter is that straight line piercing the parabola around which the parabola is symmetric: in other words, flipping about the diameter preserves the parabola.) This straight line will intersect *CF* at a point that we'll call *E,* and the parabolic arc at a point *B.* So we can call the line *ED.*

**(4) The basic triangle:** Draw the lines *AB* and *BC* to form the basic triangle *ABC* (which I'll also call $\mathcal{T}$).

**(5)** Note that $\mathcal{T}$ sits neatly in the parabolic segment $\mathcal{P}$. Clearly the area of $\mathcal{P}$ is bigger than that of $\mathcal{T}$, but how much bigger? The upshot of this proposition, after Archimedes finishes proving it, is that we get an exact relationship, namely, $\mathcal{P} : \mathcal{T} :: 4 : 3$.

**(6) Laminating by lines parallel to the diameter:** The line *ED* is parallel to the diameter. In the figure above, you find a couple of other labeled lines parallel to the diameter: *MO,* and *FA*. What Archimedes wants to do is to think of the family of all lines that are parallel to the diameter and how they slice the figure as they sweep across it. (Think of them as forming a moving family). We will refer to any member of that family (and there are finitely many of them!) as a *laminar slice.* In a moment we will be slicing two figures by the lines of this family.

**(7) The big triangle:** This is *FAC,* built with edges the line *FA* parallel to the diameter and the chord *AC.* Simple geometry shows that $FAC : \mathcal{T} = 4$. So, thinking of the formula above, we want to prove that $\mathcal{P} : FAC = 1 : 3$.

**(8) Weighing slices on the balance beam:** Archimedes hangs the big triangle *FAC* from its center of gravity, *W,* on the balance bar *HK*, as indicated in the figure. He then considers laminar slices of it, comparing them to laminar slices (by the same line parallel to the diameter) of the parabolic segment *ABC.* He proves that to put each laminar slice of the big triangle *FAC* in equilibrium with the corresponding slice of the parabolic segment *ABC* you have to "hang" the laminar slice of the parabolic segment *ABC* at the point *H* on the other side of the fulcrum. This uses, of course, his law of the lever.

**(9) Weighing the figures themselves:** He then says that he has hung the parabolic segment at point *H* and the big triangle at point *W* and, again, the law of the lever gives the proportions of their areas.

There is a great amount of geometry that one can learn by considering this result. First, note that we do indeed have here an example of what I described as a "classical quadrature problem" in that (a) we specified each of our figures merely by generic prescriptions (take *any* parabolic, and cut it with *any* chord, etc.), and (b) we asserted that the proportions of these figures are given by a fixed rational ratio (4:3). That alone deserves thought.

You might wonder: how many other interesting generic geometric proportions can one come up with that have a fixed *rational* ratio? Or, perhaps, a fixed ratio involving, say, surds?[30]

What is gripping here is how we, using Calculus, could immediately convert into a genuine theorem what Archimedes does with his "method," and how a dyed-in-the-wool Euclidean could also come to terms with this by offering an appropriate menu of axioms and common notions. Each of these revisions of Archimedes's work—via Calculus, or via appropriate axioms—would have the effect of reframing Archimedes's mechanical analogy by encompassing it with something non-analogical that has, perhaps, the authority to explain more. And yet for me, the lesson offered by *The Method* lies—to return to the issue of purity I mentioned previously in Section 7 above—in the unconstrained impurity of the ideas behind it. *The Method* works on the strength of a correctly guiding, but nevertheless difficult to justify, analogy combining previously disparate intuitions that had originated in somewhat different domains—the *experience* one has with a certain weighing apparatus and the *intuition* one has via Euclidean geometry.

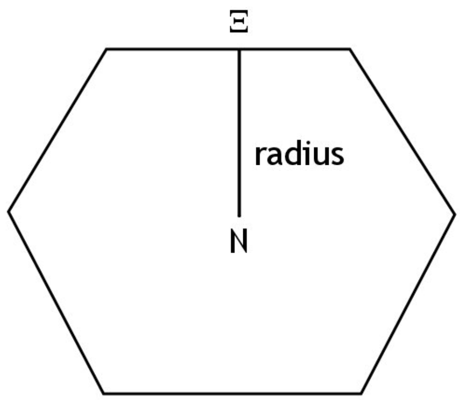
This type of thinking (working with profound analogies and relating them to, or turning them into, equalities) is today, as it was in Archimedes's time, the source of much of the most powerful mathematics.

### 19. Hedgehogs again

We have largely talked about areas of figures in the plane, except for our excursion in the spherical geometry with the Banach-Tarsky Paradox. This deserves more discussion, which I hope will happen in the upcoming conversation period.

### 20. Appendix: Sketch of a proof of Archimedes' Measurement of the Circle.

To describe Archimedes's argument succinctly, we need some vocabulary. Define the *radius* of a regular polygon to be the length of a line interval that is obtained by dropping a perpendicular to any side of the polygon from the center $N$ of the regular polygon. Define the *perimeter* (or *circumference*) of a polygon to be the length of its perimeter, i.e., the sum of the lengths of the sides of the polygon. If the polygon is a regular $M$-gon, then the circumference is $M$ times the length of any side.




Here is "my" version of Proposition 1 for regular polygons,[31] which is analogous to Archimedes's Proposition 1 for circles:

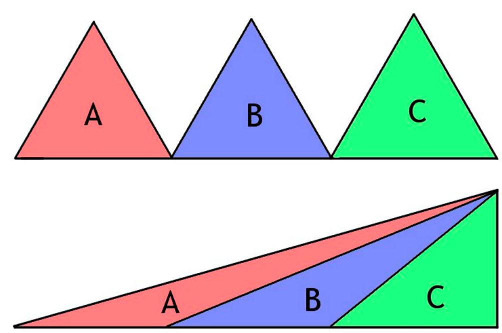
> **Archimedes's Proposition 1 adapted to regular polygons:** The area subsumed by a regular polygon is equal to the area subsumed by a right-angled triangle for which the two right-angle sides are of lengths equal to the *radius* and the *circumference* (respectively) of the polygon.

In contrast to the actual Proposition 1 of the *Measurement of the Circle,* this "polygon-version" of Archimedes's Proposition 1 is now nicely within the scope of Euclidean vocabulary; its proof is within the scope of Euclid as well.

**Some comments:**

**(1)** Both this "polygon-version" and Archimedes's Proposition 1 deal with a *right-angled* triangle whose base is the *circumference* and whose height is the *radius* of the figure to which this triangle is being compared. One could rephrase these propositions by omitting the requirement that the triangle be right-angled.

**(2)** A visual proof of this polygonal proposition can be effected simply by cutting and "straightening out to a line" the perimeter of the polygon, and then arguing that this paper-doll figure has the same area as the triangle displayed below.[32] (In the figure below we illustrate this with a 3-gon, otherwise known as a triangle, which produces, when cut-and straightened-out, the three triangles in a line labeled *A,B,C.* Each of these triangles have the same area as the three triangles that make up the large triangle in the lower figure, which has as base the *perimeter* and as height the *radius*.) This relies only the fact that the area of a triangle depends *only* on its base and height.




## NOTES

1. Since you read Archimedes's *On the equilibrium of planes* in Freshman Laboratory, this may not come as a complete surprise.

2. I am grateful to Paul Van Koughnett who drew most of the figures, and to Paul Dry for helpful and incisive comments about early drafts of these notes.

3. Straight-limbed geometry;
   In her arts' ingeny
   Our wits were sharp and keen.

From "Mark Antony," a poem by John Cleveland (1613-1658). See *The Best Poems of the English language: From Chaucer through Robert Frost,* ed. Harold Bloom (New York: HarperCollins, 2004), 154-55.

4. A sketch of its proof is in the Appendix, Section 20 below.

5. The $\cup$ ("cup") notation means "union." That is, if $X$ and $Y$ are sets, then $X \cup Y$ is the set whose members are either members of $X$ or members of $Y$ or members of both $X$ and $Y$.

6. For people who are familiar with group theory, a fairly complete description of what is going can be found here:
http://en.wikipedia.org/wiki/Banach–Tarski_paradox.

7. A delightful book that discusses calculations of this sort, and of more theoretical sorts, is John Bryant and Chris Sangwin, *How Round is Your Circle? Where Engineering and Mathematics Meet,* (Princeton: Princeton University Press, 2011.)

8. The composite image in Fig. 6 was created by the Chandra X-ray Observatory. The X-ray component was produced by NASA/CXC/U.Mich./S.Oey; the Infrared component by NASA/JPL, and the optical component by ESO/WFI/2.2-m.

9. Fig. 7 is drawn from *Euclid's Element of Geometry,* an edition of the Greek text with new English translation by Richard Fitzpatrick (Austin: Richard Fitzpatrick, 2007), 8.

10. Two cowboys:
    **A:** "My ranch is so big I can ride Old Paint from morning to night and still not cover it."
    **B:** "I know exactly how you feel. My horse is like that too!"

11. This issue is taken up by Kant from a slant perspective. (That's typical for Kant.) In Book I, Sections 25 and 26 of *The Critique of Judgment,* in discussing what he calls the *mathematical sublime*, he points out that in comprehending in our imagination a specific magnitude (say, this pole is ten feet long) one is engaging in two acts, of different natures: there is the mathematical one of counting a number of feet (and comprehending that act of counting) and then there is the essentially aesthetic one of comprehending—or internalizing in some way or other—what a *foot* is. From Kant's perspective, then, considering a proportion, per se, is an act that extracts the purely mathematical aspect of "comprehension of a magni-

tude" from the underlying, and otherwise unavoidable, aesthetic aspect: comprehending the unit. Of course, it is the latter that interests him.

12. At least if we insist that both intervals be measured by a whole number of multiples of the chosen "common measure."

13. Aristotle, *Posterior Analytics* 75a29-75b12.

14. Here is an important example of this that originated over a century ago, and is everywhere to be seen in modern mathematics: *numbers* are analogous to *functions.* There are whole branches of mathematics where these concepts are treated as not merely analogous, but as particular exemplars of a larger encompassing concept.

15. See, for example, the marvelous essay on this subject in *Euclid: The Thirteen Books of the Elements,* ed. Thomas Heath, 3 vols. (Mineola, New York: Dover Publications, 1956), 165-69.

16. This property distinguishes straight line segments as *geodesics* in modern terminology.

17. For source material, various translations, commentary, and more related texts, please go to:
http://isites.harvard.edu/icb/icb.do?keyword=k53966
(which is on the "Teaching" page of my web site).

18. That the ratio of the area of a circle to the length of its circumference is a simple expression in terms of its radius is what is behind the beauty of Proposition 1. This is a phenomenon that proliferates in higher dimensions; e.g., the ratio of the volume of a sphere to its surface area is, similarly, a simple expression in terms of its radius. This is worth pondering.

19. But neither of the above "invariance properties" need be, nor should be, included as axioms, for they will follow from your list of axioms (if you've formulated them correctly).

20. See Benoît Mandelbrot, *The Fractal Geometry of Nature* (San Francisco: W. H. Freeman, 1982).

21. Quadrature is the basic topic in the oldest existent Greek text, that of Hippocrates of Chios.

22. Or better, by doing it yourself.

23. This is admittedly a bit vague, but I hope the examples convey the kind of problem I'm referring to.

24. Hint: $\int x^2\, dx = \frac{1}{3} x^3$ when evaluated over the interval 0 to $x$.

25. *On the Sphere and Cylinder I.*

26. This figure can be found online at:
http://upload.wikimedia.org/wikipedia/commons/e/e0/Lune.svg

27. I think that there are truly interesting (entirely mathematical, not historical) issues that lurk in this, and it is one of my plans to understand it in depth.

28. This is especially fitting since it comes from the pen of the celebrated shouter of "Eureka," which derives from the same root.

29. There is an extensive earlier tradition of discussion about equilibrium and disequilibrium on a balance, and on the action of levers of all sorts. For example, this observation from Part Seven of Aristotle's *On the motion of animals:* "A small change occurring at the center makes great and numerous changes at the circumference, just as by shifting the rudder a hair's breadth you get a wide deviation at the prow." I want to thank Jean de Groot for conversations about this; I look forward to her forthcoming commentary on Aristotle's *Mechanics.*

There is also, to be sure, an extensive later tradition on this topic—notably, Ernst Mach's marvelous critique of the "law" itself, in the Introduction and first few chapters of his wonderful book *The Science of Mechanics* (Chicago and London: Open Court, 1919.)

30. That is, square roots. This is not an idle question.

31. I say "my" version because, even though it is—in my opinion—implicitly invoked in Archimedes's text, it isn't dwelt on.

32. I'm thankful to Jim Carlson for this suggestion.

# Some Reflections on Darwin and C.S. Peirce

**Curtis Wilson and Chaninah Maschler**

## Introduction

On a Saturday morning in the mid-1950s, I attended a St. John's faculty seminar on a selected reading from Darwin's *Origin of Species*. What chiefly remains in memory is an overall impression: the discussion was halting and desultory, failing to get airborne. In those days the available edition of the *Origin* was the sixth and last (1872); compared with the first edition of 1859, it suffers from excessive backing and filling, Darwin's attempts to answer his critics. Yet, even had our text been from the sprightlier first edition, I doubt our discussion would have got off the ground. After one spell of silence a senior tutor spoke up to ask: Isn't it [Darwin's theory] just a hypothesis? The implication, I thought, was: Can't we just ignore the whole idea?

The short answer to that second question is: we can't, because Darwin's theory is the grand working hypothesis (yes, it's a hypothesis!) of biologists everywhere, and as aspirant generalists at St. John's, we need to seek out its meaning. The search can be exhilarating *as well as* disquieting.

Major features of Darwin's theory are contained in his phrase "descent with modification through natural selection." The descent of present-day organisms from organisms of pre-

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ceding generations is obvious; Darwin requires us to keep this fact in focus. The offspring inherit traits from their parents, but some variation occurs. Since far more offspring are produced than can survive and reproduce, the variants best suited to surviving and reproducing are the ones that win out. Relative to a given environment, the surviving form will be better adapted than the forms that failed. Darwin saw this process as leading to diversification of kinds, or *speciation,* as indicated by the title of his book, *On the Origin of Species*.[1]

Darwin opened his first notebook on "Transmutation of Species" in July, 1837. In a sustained effort of thought from 1837 to 1844, he constructed the theory. The empirical evidence consisted chiefly of the biological specimens that he had observed and collected during his tour as naturalist aboard H.M.S. Beagle, from Dec. 27, 1831 to Oct. 2, 1836. (This voyage was sent out to chart the coasts of South America and determine longitudes round the globe; taking along a naturalist was an after-thought of the captain's.)

At the beginning of the Beagle voyage, Darwin was a few weeks short of his twenty-third birthday. So far in his life he had had no clear goal. Enrolled in medical school at age sixteen in Edinburgh, he dropped out, unable to endure seeing patients in pain. His father (a physician, skeptical in religion) then sent him to Cambridge with the idea that he might fit himself out to become a country parson, but young Darwin found the course of study uninteresting. He completed the A.B. degree, but later acknowledged that his time at Cambridge was mostly wasted. A chance by-product of it was a friendship with John S. Henslow, the professor of botany. Henslow it was who arranged Darwin's being offered the post of naturalist on the Beagle. Darwin's father flatly rejected the idea at first, but Josiah Wedgewood, young Darwin's maternal uncle, persuaded him to change his mind.

In hindsight, we can say that young Darwin was admirably suited to his new post. From boyhood he had been a persistent collector of a variety of objects, from stamps to beetles. As a naturalist he would prove to have an unstoppable drive toward theoretical understanding, seeking to connect the dots between his numerous observations. The voyage of the Beagle, proceeding first to the coasts of South America and the nearby islands, could not have been more aptly planned to yield observations supporting the theory that he would develop. The observations were chiefly of three types.[2] Fossils from South America were found to be closely related to living fauna of that continent, rather than to contemporaneous fossils from elsewhere. Animals of the different climatic zones of South America were related to each other rather than to animals of the same climatic zones on other continents. Faunas of nearby islands (Falkland, Galapagos) were closely related to those of the nearest mainland; and on different islands of the same island group were closely related. These observations could be accounted for on Darwin's theory; on the opposing theory of fixed species they remained unintelligible.

But why the uproar over Darwin's *Origin*, and why does it still today produce uneasiness? It is not merely that it appears contrary to the creation story in Genesis. As John Dewey put it in 1910:[3]

> That the publication of the *Origin of Species* marked an epoch in the development of the natural sciences is well known to the layman. That the combination of the very words origin and species embodied an intellectual revolt and introduced a new intellectual temper is easily overlooked by the expert. The conceptions that had reigned in the philosophy of nature and knowledge for two thousand years, the conceptions that had become the familiar furniture of the mind, rested on the assumption of the superiority of the fixed and final; they rested upon treating change and origin as signs of defect and unreality. In laying hands upon the sacred ark of absolute permanency, in treating the

> forms that had been regarded as types of fixity and perfection as originating and passing away, the *Origin of Species* introduced a mode of thinking that in the end was bound to transform the logic of knowledge, and hence the treatment of morals, politics, and religion.

More recently Ernst Mayr has characterized Darwin's new way of thinking as "population thinking," and the mode of thinking prevalent earlier as "typological thinking":

> Typological thinking, no doubt, had its roots in the earliest efforts of primitive man to classify the bewildering diversity of nature into categories. The *eidos* of Plato is the formal philosophical codification of this form of thinking. According to it, there are a limited number of fixed, unchangeable "ideas" underlying the observed variability, with the *eidos* (idea) being the only thing that is fixed and real, while the observed variability has no more reality than the shadows of an object on a cave wall. . . .
>
> The assumptions of population thinking are diametrically opposed to those of the typologist. The populationist stresses the uniqueness of everything in the organic world. What is true for the human species—that no two individuals are alike—is equally true for all other species of animals and plants. . . . All organisms and organic phenomena are composed of unique features and can be described collectively only in statistical terms. Individuals, or any kind of organic entities, form populations, of which we can determine the arithmetic mean and the statistics of variation. Averages are merely statistical abstractions, only the individuals of which the populations are composed have reality. The ultimate conclusions of the population thinker and of the typologist are precisely the opposite. For the typologist, the type (*eidos*) is real and the variation an illusion, while for the populationist, the type (average) is an abstraction and only the variation is real. No two ways of looking at nature could be more different.[4]

Mayr's abruptly nominalist "take" on the nature of species is not required by Darwin's theory, nor do all biologists espouse it.[5] One thing the theory does require is a new attention to individual differences. Species may result from processes that are fundamentally statistical, and yet be real. For young Darwin, gentleman naturalist, noting individual differences came naturally. His curiosity about connections may also have been natural to him, but he developed it into a powerful drive toward unifying theory.

Before coming to St. John's in 1948, I had taken undergraduate courses in zoology and embryology in which Darwin's theory was referred to; I accepted the theory as established. An occasion for reading Darwin's *Origin* had not arisen. On becoming a St. John's tutor, I immersed myself chiefly in problems of the laboratory on the side of physical science, to which my interests inclined me and for which my more recent graduate studies in the history of science to some degree prepared me.

In multiple ways, during my early years at St. John's, I took my cue from Jacob Klein. My admiration for him was unbounded. I respected him for his scholarly knowledge, shrewdness, and sharp discernment. It was he who drew the College community out of its 1948-49 leadership crisis and communal slough of despond in the wake of Barr's and Buchanan's departure, and he did so single-handedly and spiritedly. During his deanship (1949-1958), he gave the College a new lease on life, a new stability, and an incentive to move forward: testing, selecting, and improving the Program. Our debt to him is incalculable.

As dean, Mr. Klein in the opening lecture each year undertook to address the question of what we were doing here, what liberal education *was*. It was with trepidation, he told us, that he addressed this question. Typically, his lecture took a Platonic turn, as when he described the *metastrophē,* or turning round, of the prisoner in the cave of Plato's *Republic.* The former prisoner had to be brought to recognize that the shadows he had previously taken for truth were in fact only images of conventional images. Getting at the truth was a matter of penetrating beyond that scrim of images.

During the academic year 1954-55 I was co-leader with Mr. Klein ("Jasha" as we tutors called him) of a senior seminar. On one evening the assignment was from Darwin's *Origin*—this was perhaps the only place in the program where Darwin's theory was addressed in those days. I recall nothing of the discussion, but at its end Jasha asked the students: Did they consider Darwin's book important to their lives? One after another they replied with a decisive "No!"—a flood of denial.

Though failing to lodge a protest, I thought the indifference to Darwin a mistake, and I was disappointed by Jasha's standoffishness with respect to it. My opinion was reinforced in conversations I had at the time with Allen Clark, a Ford Foundation intern at the College in the years 1954-56.[6] Clark had done graduate studies at Harvard on American pragmatism, reading widely in the writings of C.S. Peirce, William James, Oliver Wendell Holmes, Jr., and the Harvard-educated Spanish émigré George Santayana. He was especially attracted to the writings of Peirce, who had been both a working scientist and a close student of philosophy, and had set himself to making philosophical sense of natural science. Peirce had embraced Darwin's theory and interpreted it.

Attempting to catch up with Clark in philosophy, I began reading such writings of Peirce as were readily available. These were two collections of essays, the earliest assembled by Morris R. Cohen under the title *Chance, Love, and Logic,* and a later one due to Justus Buchler, *The Philosophy of Peirce.* There were also the six volumes of *The Collected Papers of Charles Sanders Peirce,* published by Harvard University Press in 1931-35 under the editorship of Hartshorne and Weiss, but these were formidable, leaving the inquirer puzzled as to where to get a leg up or a handhold.

My enthusiasm for Peirce was challenged one summer evening in the later 1950s. During an informal discussion of a Peirce essay at Jasha's home, Jasha took exception to Peirce's "Monism," the doctrine that the world is made of a single stuff. Jasha saw this doctrine as contradicted by the *intentionality* of human thought. What was that?

The doctrine had been put forward by the Austrian philosopher Franz Brentano in 1874.[7] According to Brentano, to think is to think *of* or *about* something. Analogously, to fear or hope entails that there are objects (Jasha sometimes called them "targets") of these modes of consciousness. Their objects need not be existents in the empirical world. I can think of a unicorn, or imagine riding like Harry Potter on a broom stick, or fear an imagined bogeyman in a closet. Brentano therefore spoke of "intentional inexistence," meaning that such an object is somehow contained in the thought (*cogitatio* à la Descartes!) of which it is the object. Brentano sought to make Intentionality definitive of the mental. He concluded that mind, because of its intentionality, is irreducible to the physical.

Edmund Husserl, one of Jasha's teachers, had been a student of Brentano. For Husserl, Brentano's idea of intentionality became the basis of a new science which he called Phenomenology. Husserl followed Brentano in treating intentionality as coextensive with the mental, and in asserting the impossibility of a naturalistic explanation of intentional acts. Jasha's rejection of Peirce's Monism, I am guessing, stemmed from his acceptance, at least in part, of Husserlian philosophy.[8]

Jasha may have been unaware that what he regarded as

Peirce's Ontological Monism was an application of the maxim *Do not block the road of inquiry.* Dualism, as Peirce saw it, drew a line in the sand; naturalistic explanations were guaranteed to be impossible beyond this line. The line in the sand inevitably becomes a dare.

But I was still far in those days from understanding how the various parts of Peirce's thinking held together—or failed to. A major difficulty with the Cohen and Buchler collections and with *The Collected Papers* was that they did not present Peirce's papers in their order of composition. The editors did not sufficiently appreciate that Peirce's ideas developed over time. Throughout his life, Peirce's thought (like science as he understood it) was a work in progress.[9] When he died in 1914 he had not completed any single major work. During his last active decade, however, he succeeded in resolving certain major difficulties in his earlier philosophizing. A chronological edition of his work—published papers, lectures, and unpublished notes and correspondence—has now been undertaken by Indiana University Press. Of these post-1950 developments I was made aware only recently. And their full import did not dawn on me until encountering a book by the Chairman of the Board of Advisers to the Peirce Edition Project, Thomas Short. It is *Peirce's Theory of Signs.*[10]

Parts 1 and 2 of our essay provide an account of Peirce's pragmatism and of his progress from Kantian idealism to scientific realism. In Parts 3 and 4, with the help of Short's analysis, we shall indicate how Peirce accounts naturalistically for the emergence of intentionality and conscious purposefulness in the course of evolution.

## Part 1. Peirce and Pragmatism

Peirce is the man through whom the word "pragmatism" enters upon the world scene as a philosophic term. According to his own recollection,[11] confirmed by the report of his friend William James,[12] this happened in the early 1870s, in Cambridge, Massachusetts, amongst a group of young Harvard men, who used to meet for philosophical discussion. Later in the 1870s the opinions Peirce had defended viva voce were issued in print in two articles, "The Fixation of Belief" (1877) and "How to Make our Ideas Clear" (1878).[13] The first of these two essays prefigured what Peirce would in the course of a life-time come to say about science as an enterprise of ongoing inquiry rather than a collection of upshots of investigation.[14] The second was sent into the world, as the title indicates, as advice on how to go about gaining greater intellectual control over one's ideas than is furnished by the ability correctly to apply, or even verbally to define them. The advice runs as follows: "Consider what effects, which might conceivably have practical bearings, we conceive the object of our conceptions to have. Then our conception of these effects is the whole of our conception of the object." Note that the first person plural is out front. Also, that conceiving remains irreducible!

Peirce never became a full-time professor. Not even at Johns Hopkins, where John Dewey was briefly a student in his logic class. But just about every major American author in professional philosophy—William James, Josiah Royce, John Dewey, George Herbert Mead, C.I. Lewis, Wilfrid Sellars—acknowledges being profoundly indebted to Peirce's teachings, pragmatism being one of these.

> Pragmatism is, in itself, no doctrine of metaphysics, no attempt to determine any truth of things. It is merely a method of ascertaining the meanings of hard words and of abstract concepts. All pragmatists of whatsoever stripe will cordially assent to that statement. *As to the ulterior and indirect effects of practicing the pragmatistic method, that is quite another affair.*[15]

Some of the Cambridge friends whom Peirce initially persuaded to try bringing a laboratory scientist's "let's try it and see" approach to bear on the study of "hard words," particularly those used in metaphysics, suggested that he call what he was offering "practicism" or "practicalism." No, Peirce responded, he had learned philosophy from Kant, and in Kant the terms *praktisch* and *pragmatisch* were "as far apart as the poles."[16] *Praktisch* belongs to the region of thought where no mind of the experimentalist type can make sure of solid ground under his feet. *Pragmatisch* expresses a relation to some definite human purpose. "Now quite the most striking feature of the new theory [is] its recognition of an inseparable connection between rational cognition and human purpose."[17]

Here are two more statements of what pragmatism amounts to:

> I understand pragmatism to be a method of ascertaining the meanings, not of all ideas, but only of what I call "intellectual concepts," that is to say, of those upon the structure of which arguments concerning objective fact may hinge. Had the light which, as things are, excites in us the sensation of blue, always excited the sense of red, and vice versa, however great a difference that might have made in our feelings, it could have made none in the force of any argument. In this respect, the qualities of hard and soft strikingly contrast with those of red and blue. . . . My pragmatism, having nothing to do with qualities of feeling, permits me to hold that the predication of such a quality is just what it seems, and has nothing to do with anything else. . . . Intellectual concepts, however, the only sign-burdens that are properly denominated "concepts"—essentially carry some implication concerning the general behavior either of some conscious being or of some inanimate object, and so convey more, not merely than any feeling, but more too than any existential fact, namely, the "*would-acts*" of habitual behavior; and no agglomeration of actual happenings can ever completely fill up the meaning of a "would be."[18]

Again,

> Pragmaticism[19] consists in holding that the purport of any concept is its conceived bearing upon our conduct. How, then, does the Past bear upon conduct? The answer is self-evident: whenever we set out to do anything, we "go upon," we base our conduct on facts already known, and for these we can only draw upon our memory. It is true that we may institute a new investigation for the purpose; but its discoveries will only become applicable to conduct after they have been made and reduced to a memorial maxim. In short, the Past is the sole storehouse of all our knowledge. When we say that we know that some state of things exists, we mean that it used to exist, whether just long enough for the news to reach the brain and be retransmitted to tongue or pen or longer ago. . . . How does the Future bear upon conduct? The answer is that future facts are the only facts that we can, in a measure, control. . . . What is the bearing of the Present instant upon conduct? . . . There is no time in the Present for any inference at all, least of all for inference concerning that very instant. Consequently the present object must be an external object, if there be any objective reference in it. The attitude of the present is either conative or perceptive.[20]

## Part 2. Peirce's Transition from an Initial Idealism to Scientific Realism

As Peirce has told us, he learned philosophy from Kant. Yet from the start there was one Kantian doctrine he could not stomach: the doctrine of "things-in-themselves" (*Dinge an sich*) somehow standing behind the objects we meet with in experience—inaccessible beings of which, Kant says, we must always remain ignorant. In papers of the late 1860s, Peirce insisted that all of our cognitions are signs, and that each sign refers to a previous sign:

> At any moment we are in possession of certain information, that is, of cognitions which have been logically de-

> rived by induction and hypothesis from previous cognitions which are less general, less distinct, and of which we have a less lively consciousness. These in their turn have been derived from others still less general, less distinct, and less vivid; and so on back to the ideal first, which is quite singular and quite out of consciousness. The ideal first is the particular thing-in-itself. It does not exist *as such*.[21]

According to Peirce at this stage, all thoughts are of one or another degree of generality, each referring to an earlier thought, and none immediately to its object. Only if a cognition were immediately of its object, could it be *certain,* hence an *intuition.* Our lack of intuition, as thus argued by Peirce, was his initial ground for rejecting Descartes' *Cogito, ergo sum*. The *real*, as Peirce conceived it at this time, was an ideal limit to a series of thoughts, a limit to be reached in the future:

> The real . . . is that which, sooner or later, information and reasoning would finally result in, and which is therefore independent of the vagaries of me and you. Thus, the very origin of the conception of reality shows that this conception essentially involves the notion of a COMMUNITY, without definite limits.[22]

Peirce here conceived all conceiving as in an infinite sequence of thoughts, stretching backward toward the non-existent thing-in-itself (an external limit) and forward toward the real, to be achieved at some future time (a limit located *within* the thought sequence). A consequence was that any individual, considered as an "it" other than the universals true of it, is unreal.

With this consequence of his late-1860s theory of knowledge, Peirce was uncomfortable. If the aim is to get outside one's head and find a purchase on reality, it is indeed disastrous.[23]

Peirce at last found a way out in his "The Fixation of Belief" of 1877:

> To satisfy our doubts . . . it is necessary that a method should be found by which our beliefs may be caused by nothing human, but by some external permanency—by something on which our thinking has no effect. Such is the method of science. Its fundamental hypothesis . . . is this: There are real things, whose characters are entirely independent of our opinions about them; those realities affect our senses according to regular law. . . .[24]

In "How to Make Our Ideas Clear" (1878), Peirce combined the hypothesis of real things on which our thinking has no effect with his earlier notion of indefinite progress toward human knowledge of the real:

> Different minds may set out with the most antagonistic views, but the progress of investigation carries them by a force outside of themselves to one and the same conclusion. . . . The opinion which is fated to be ultimately agreed to by all who investigate, is what we mean by the truth, and the object represented in this opinion is the real.[25]

In the years 1879-1884, Peirce was a part-time lecturer in logic at the Johns Hopkins University, and he and his students O.H. Mitchell and Christine Ladd-Franklin (independently of Frege in Germany) introduced quantifiers into predicate logic and the logic of relations. Thus the familiar universal and particular propositions of Aristotelian logic, "All S is P," "Some S is P," come to be replaced by

$(x)(\mathrm{S}x \supset \mathrm{P}x)$ [read: For all *x,* if *x* is S, then *x* is P], and
$(\exists x)$ $(\mathrm{S}x \cdot \mathrm{P}x)$ [read: There is an *x* such that *x* is S and *x* is P],

where we have used a notation now standard. Note that the "*x*" denotes an individual in whatever universe of discourse, fictional or real, we have entered upon, without any presumption that the essence of this individual is known to us. In relational logic, which is needed for mathematics, indices are crucial for representing dyadic, triadic, *n*-adic relations, e.g., R*xy* (read: *x* bears the relation R to *y*). All our thinking, according to Peirce in the 1880s and later, is laced with indexical elements, tying discourse to the world we're in. The index asserts nothing; it only says "There!" Like such words as "here," "now," "this," it directs the mind to the object denoted.

The discovery of the nature and indispensability of indices led to a vast extension of Peirce's understanding of signs and significance (the science of semeiotic he was seeking to build). An index is anything that compels or channels attention in a particular direction. The act of attention responding to an index does not have to be a component of a thought. For instance a driver, on seeing a stoplight go red, may brake automatically without thinking; he thus interprets the red light as a command. Therefore the effect of a sign, in triggering an interpretation, need not be a thought; it can be an action or a feeling. The extension of semeiotic to nonhuman interpreters is now in the offing, as will become apparent in Part 4 below.

At the same time, Peirce has burst out of the closed-in idealism of his earlier theory of knowledge. The result is what we may call Scientific Realism.

## Part 3. Anisotropic Processes

Just twelve years after the first copies of *Origin of Species* landed in the U.S.A., Peirce wrote:

> Mr. Darwin proposed to apply the statistical method to biology. The same thing had been done in a widely different branch of science, the theory of gases. Though unable to say what the movements of any particular molecule of a gas would be on a certain hypothesis regarding the constitution of this class of bodies, Clausius and Maxwell [had been able, eight years before the publication of Darwin's immortal work], by the application of the doctrine of prob-

> abilities, to predict that in the long run such and such a proportion of the molecules would, under the given circumstances, acquire such and such velocities; that there would take place, every second, such and such a number of collisions, etc.; and from these propositions [they] were able to deduce certain properties of gases, especially in regard to their heat relations. In like manner, Darwin, while unable to say what the operation of variation and natural selection in any individual case will be, demonstrates that in the long run they will adapt animals to their circumstances.[26]

Thus Peirce took explanation in both statistical mechanics and Darwinian natural selection to be statistical. He meant, Short argues, *irreducibly* statistical, and *not* mechanistic.[27] Analyzed logically, a mechanistic explanation starts from a *particular* disposition of certain bodies at some time, and by applying general laws of mechanics, gravitation, chemistry, electromagnetism, or other general theory, derives the *particular* disposition of these bodies at a later time. "Particular" here is opposed to "general." The explanations of Celestial Mechanics are of this kind. The celestial mechanician, starting from the positions and velocities of the bodies in the solar system at one instant, and assuming gravitational theory, computes the positions and velocities of these bodies at a later instant. If we should propose to ourselves a similar calculation for molecules of a gas confined in a container, we would find it impracticable. The number of molecules is too large (in a cubic centimeter of gas at one atmosphere of pressure and 0°C. that number is about $2.7 \times 10^{19}$, or 27 quintillion). Ascertaining the positions and velocities of all these molecules at a specified "initial" instant is humanly impossible. Moreover, the motions are not governed by a single law like gravitation, but involve collisions of the molecules with each other and the walls of the container; these introduce discontinuities that are difficult to take into account.

But the crucial conclusion is this: even if such a computation were possible, it would not yield the conclusion for which statistical mechanics argues. Statistical mechanics seeks to establish that notably non-uniform distributions of molecules in the gas will in time be replaced by a more uniform distribution, with reduction in the spread of velocities amongst the molecules. The statistical argument invokes probability.

How to understand probability in this context is by no means settled, and we shall give only a rough indication of the type of solution that is believed necessary.[28] Consider a system of $n$ molecules of gas contained in a volume $V$. Let $V$ be divided into a large number $m$ of equal cells, $m$ being less than $n$ (if $n$ is in quintillions, $m$ could be in the millions or billions). If the molecules were distributed with perfect uniformity throughout $V$, then each cell would contain $n/m$ molecules. This distribution is a particular microstate—an extremely special one, hence unlikely. We would expect that, in most imaginable distributions, the numbers of molecules in different cells would be different. To take this likelihood into account, consider microstates in which the number of molecules in all cells falls within the range $n/m \pm e$, where $e$ is much less than $n/m$. Let the class of all microstates thus characterized be called $C$, and let the complementary class, or class of all microstates in which the number of molecules in some cells falls outside the range $n/m \pm e$, be called $C'$.

In the work of the earlier theorists, distinguishable microstates compatible with the overall energy of the gas were assigned equal probabilities, since no reason presented itself for assigning different probabilities to different microstates. Later theorists sought grounds other than "equal ignorance" for assigning probabilities to microstates. Whatever the mode of assigning probabilities, the outcome must show the gas progressing from less uniform to more uniform distributions, both spatially and with respect to the spread of velocities. For that is the empirical result: a quantity of gas under high pressure, when let into an evacuated chamber, spreads out through the chamber and is soon more homogeneously distributed, with a uniform temperature and pressure lower than the original temperature and pressure.

The Second Law of Thermodynamics extends this kind of reasoning to all natural systems. It says that *in any closed system* the processes have a direction: they progress toward greater homogeneity and reduced capacity to do mechanical work.[29] For processes that are directional in time, Short uses the term *anisotropic* (*a*-privative + *iso,* "equal" + *tropos,* "direction"). Anisotropic processes are defined by the *type* toward which they progress. We shall see that there are anisotropic processes other than those that instantiate the Second Law of Thermodynamics. All such processes, however, differ from mechanical processes, which proceed from a particular configuration to a particular configuration.

Whether the universe is a closed system we do not know, but everywhere in the observable world we see the effects of the Second Law, the "degradation of energy." Nevertheless, we also see that new forms of order, though improbable, sometimes emerge. They are produced in open systems that absorb energy from, and discard unused matter and energy to, the environment. Ilya Prigogine has described such forms of order, calling them "dissipative systems."[30] Locally, in the newly created form, the second law appears to be violated, but if account is taken of the exhausted fuel and other waste materials ejected to the environment, the second law is found to hold. Higher forms of order come to be at the expense of a decrease in order elsewhere, an increase in homogeneity and a lessened capacity to produce novelty.

The first coming-to-be of living forms in the universe presumably occurred in the manner of Prigogine's "dissipative systems." Such is the hypothesis generally accepted by scientists today. Living systems differ from the cases studied by Prigogine in their greater complexity and in having the capacity to self-replicate. In 1953 the graduate student S.L. Miller under the guidance of H.C. Urey circulated a mixture of methane, ammonia, water vapor, and hydrogen through a liquid water solution, and elsewhere in the apparatus continuously passed an electrical discharge through the vaporous mixture. After several days the water solution changed color, and was found to contain a mixture of amino acids, the essential constituents of proteins. Since then, most if not all of the essential building-blocks of proteins, carbohydrates, and nucleic acids have been produced under conditions similar to those obtaining when the Earth was young (the atmosphere needs to be free of oxidizing agents such as oxygen). The sequences of conditions and chemical pathways by which these building-blocks may have been assembled into a living cell remain matters of speculation.

Darwin's evolutionary theory, taking the existence of living things as given, goes on to show how, chiefly but not solely by means of natural selection,[31] biological evolution can occur. Our little word "can" here goes to signal what Nicholas Maistrellis calls "the highly theoretical, and even speculative character" of *Origin* chapter 4, dedicated to expounding that and how Natural Selection "works."

> We should not expect a series of examples of natural selection designed to win us over to his theory on purely empirical grounds. Even if Darwin had wanted to proceed in that way, he could not have done so, for such examples do not exist—or at least were not known to Darwin. . . . Notice that all the examples of natural selection in this chapter are, as Darwin repeatedly acknowledges, *imaginary* ones.[32]

Contemporary readers of Darwin have sometimes become so blasé about the shocking idea that order may emerge out of disorder that they don't notice how subtle, complex, and distributed the over-all argument of *Origin* is. We have found C. Kenneth Waters' "The arguments in the Origin of Species," along with the other essays included in Part 1: *Darwin's Theorizing* of *The Cambridge Companion to Darwin,* particularly conducive to waking us up.

Peirce wrote, in *A Guess at the Riddle* (1887):

> Whether the part played by natural selection and the survival of the fittest in the production of species be large or small, there remains little doubt that the Darwinian theory indicates a real cause, which tends to adapt animal and vegetable forms to their environment. A remarkable feature of it is that it shows how merely fortuitous variations of individuals together with merely fortuitous mishaps to them would, under the action of heredity, result, not in mere irregularity, nor even in statistical constancy, but in indefinite progress toward a better adaptation of means to ends.[33]

A little later in this same manuscript Peirce sums up the basic idea of Darwinian selection as follows:

> There are just three factors in the process of natural selection; to wit: 1st, the principle of individual variation or sporting; 2nd, the principle of hereditary transmission . . . ; and 3rd, the principle of elimination of unfavorable characters.[34]

Darwin and Peirce lacked the benefit of a workable theory of inheritance. Nothing like our genetics was available to them. We today single out genetic make-up as the causally significant locale of "sporting," And Peirce's phrase, "elimination of unfavorable characters," is replaced in more recent neo-Darwinian formulations by the phrase "relative reproductive success," meaning, the having of more numerous offspring. The process is statistical: If one variant of a species has more numerous offspring than do others, and if in addition these offspring survive to reproduce, the original variant, possessed of one or more genetic alleles (alternative forms of a gene), is more successful in propagating its genome to later generations.

The hypothesis of Natural Selection confers little in the way of predictive power. Its chief value is to provide a post-hoc explanation of what has occurred. For example, visual acuity is crucial to the survival of both predators and prey. Evidently predators are better off with eyes in the front of their heads as they pursue prey, and potential prey are better off with eyes on the sides of their heads to detect predators coming from any quarter. Another example: Flowers evolved as a device by which plants induce animals to transport their pollen (hence sperm) to the egg cells. The evolutionarily older plants had been pollinated by the wind. The more attractive the plants were to an insect, the more frequently they would be visited and the more seeds they would produce. Any chance variation that made the visits more frequent or made pollination more efficient offered immediate advantages.[35]

We can only guess at the detailed processes by which such adaptations have been brought about. What Darwin gives us is a heuristic for research, not a set of biological laws.[36] Partly on this account, because Darwinian explanation does not fit the model of explanation in mechanics, it has taken a long time before philosophers of science became willing to award a comparable degree of intellectual dignity to Darwinian as to Galilean and Newtonian science. The books listed in the Bibliography appended to Maistrellis's *Selections* help overcome the physics envy that stands in the way of appreciating Darwin. Particularly helpful have been Sober's persevering efforts to clarify and show the interconnections amongst the fundamental concepts of Fitness, Function, Adaptation, and Selection, while steadily reminding us of the ineliminably probabilistic character of most of the theorizing of modern evolutionary biology.

One of Sober's helps into the saddle is his distinction between *selection for* and *selection of:*

> Selection-for is a causal concept. To say that there is selection for trait T in a population means that having T causes organisms to survive and reproduce better (so having the alternative(s) to T that are present in the population causes organisms to survive and reproduce worse). In contrast, to say that there is selection of trait T just means that individuals with T have a higher average fitness than do individuals who lack T.[37]

Here is an illustration of the contrasting terms being put to use:

> Worms improve the soil, but that does not mean that their digestive systems are adaptations for soil improvement; rather, the worm gut evolved to help individual worms survive and reproduce. The benefit that the ecosystem receives is a fortuitous benefit—a useful side-effect unrelated to what caused the trait to evolve. The gut's ability to extract nutrition for individual worms is what the gut is an adaptation *for.*[38]

To balance our earlier quotation from Maistrellis stressing the not strictly empirically encountered character of Darwin's examples in his chapter about natural selection-at-work, notice that Sober feels quite comfortable about urging against the philosopher Jerry Fodor, a critic of Darwinism, that "biologists often think they have excellent evidence for saying that agricultural pests experienced selection for DDT resistance, [or] that there has been selection for dark coloration in moths."[39]

Short adopts Sober's *selection of/selection for* contrast and, integrating it with Peircian ideas of explanation by final causes, adapts it to new uses. The context is as follows. He asks us to distinguish four kinds of physical process:

> Mechanical processes that proceed from one particular configuration to another and are reversible.
>
> The processes described by statistical dynamics, which are anisotropic and result in an increase in entropy and disorder.
>
> The non-equilibrium processes studied by Prigogine, which are also anisotropic, but produce open systems that have increased order and diminished entropy. The dissipative structures can sustain themselves in the given environment for a time. Living things, we assume, are of this kind—complex open systems that metabolize and have an apparatus for replicating themselves.
>
> With living things, a third sort of anisotropic process comes into play: Natural Selection, the selection of characteristics for types of effect that conduce to reproductive success.[40]

Given living things and their struggle for existence, given heritable variability, given phenotypic features that in a given state-of-its-world enhance a creature's relative chance of producing fertile offspring, a new kind of *directional* process comes into being, natural selection. And with it, the possibility of purpose comes on the scene.

> Not that anything is a purpose or has a purpose in biological evolution before the actual occurrence of a mutation that happens to be selectively retained because of some advantage that it confers. Only at that time, that is, when a feature is selected for its effect, does the effect, say visual acuity, become a purpose. There was no purpose "visual acuity" or "adaptedness" or "survival" hanging around waiting for an opportunity. But once eyes with adjustable lenses become a feature of mammals, *then* it would only be mechanicalist prejudice that could keep us from saying that eyes exist for the purpose of seeing.[41]

Sober's polar terms *selection of/selection for* are perhaps worked harder and a little differently than they were previously:

> It is *because* lenses and focusing increase visual acuity that genetic mutations resulting in lenses and focusing were retained in subsequent generations; in fact, that happened in independent lines of animal evolution. The selection in those cases was *for* the visual acuity and *of* concrete structures (or the genes that determine them) that improved visual acuity in specific ways. . . . The of/for distinction is relative to the level of analysis, but the object of 'for' is always an abstract type and the object of 'of ' is always something genetic or genetically determined, hence concrete. . . . As the type selected-for is essential to explanation by natural selection, such explanation is like anisotropic explanation in statistical mechanics [in that] both explain *actual* phenomena by the *types* they exemplify. Hence it is not mechanistic. . . . It is qua adaptation—hence in that aspect—that [an adaptive feature, say S] is explained by natural selection. S could also be explained, had we knowledge enough, as a product of a complicated series of mechanical events. But, then, S's enhancing reproductive success would seem a surprising coincidence, a bit of biological luck. *S's being an adaptation would not be explained.*[42]

The "aptness" of organisms is one of the facts of life that the Darwinian program of explanation seeks to account for. Having had some success in this explanatory endeavor, we easily forget that there is no guarantee that evolution will bring about an increase in complexity or intelligence or other quality that we admire. Overstatement here, Short warns us, is common, and disastrous.[43] Notice too that natural selection was not itself selected, and therefore does not have a purpose. It just occurs.

## Part 4. The Emergence of Intentionality and Conscious Purposes

Cleverly joining Peircean reasoning to the more recent formulations of neo-Darwinian theory, Short's *Theory* sketches a narrative that strives to make intelligible the eventual emergence of the possibility of deliberately produced tools and self-controlled action out of advantageous anatomy and biologically useful animal behavior. *Here one must go slow and notice that it is as the world comes to hold new kinds of entity that new kinds of explanation become applicable.*[44] Short is not reducing biological explanation to chemical explanation. Nor will he assimilate human discourse to animal signaling.[45] The last three chapters of his book are given over to exploring the implications of applying Peirce's ideas of sign-action (= semeiosis) to distinctively human language, thought, and life. But unless we work from the bottom up, there is no explaining of emergents.

"Working from the bottom up" means for Short that he must develop so general an account of Peirce's semiotic triad Sign-Object-Interpretant that it will be applicable both to infra-human sign-interpretation—end-directed animal responses to stimuli—and, duly amplified, to distinctively human life and thought. For Short, this behaviorist interlude is in the service of Peirce's Synechism:[46] If successful in his defense of Peirce's ways, he will have warded off both Cartesian dualism and Reductionism.[47]

Among social animals, group behavior is determined by mechanisms that cause one individual to respond to another. A forager bee, for instance, having located nectar, returns to the hive and there exhibits what look like dances. The bees in the hive react to these dances as signaling the direction and distance in which the nectar will be found. Ethologists have instructed us that there is an immense variety of animal behaviors that operate as though they were intended as communicative signs. By what criteria one determines the *intendedness* of a bird- or monkey-cry the emission of which *tends to result* in fellow-birds or fellow-monkeys reacting with behavior that *makes sense* for the creatures in question (e.g., escaping in an appropriate way from a certain kind of predator, or overcoming reluctance to approach more closely) has been a topic for ethological investigation. But every parent is familiar with the fact that infant wailing and screaming is not, in the earlier phases of its life, an expression of the infant's intention to rouse its protectors. Yet when the infant is a little older its jealous brother may justly complain: "She is not crying for a reason. She's crying for a purpose!"

We have deliberately introduced the word "intend" in its ordinary sense before returning to the topic of intentionality in Brentano's scholastic and technical sense. (Unhappiness about the lack of a non-dualist treatment of Intentionality was what initially motivated our exploration of Short's book on Peirce's semeiotics.) Unlike many semioticians, Short follows in Peirce's footsteps by *beginning* with *interpretive behavior,* not with the *sending* of signs.[48] This permits him to take off from *responses.* For instance:

> The deer does not flee the sudden noise that startled it, but a predator; for it is to evade a predator that the deer flees. The instinct to flee is based on an experienced correlation of sudden noises to predators; the correlation is weak, but, unless the deer is near starvation, it is better for it to risk losing a meal than to risk being one. If no predator is there, the deer's flight is a mistake, albeit justified. Mistaken or not, the flight interprets the noise as a sign of a predator.

A *response* is not merely an *effect* if it can be *mistaken*. It ranks as an *interpretation*.

In what manner and measure this idea of mistake is available to infra-human animals is a hard question. When the dog that was, in some human observer's estimation, "barking up the wrong tree," corrects itself and, redirecting its bark to the neighboring tree, glimpses the spot where the cat in fact now is, does the dog think to itself, "Now I've got it right"? Consider two other examples of interpretive responses, both reported by the ethologist Niko Tinbergen: male sticklebacks, during the breeding season, tend to adopt a "threat posture" toward potential rivals.

> When the opponent does not flee . . . the owner of the territory . . . points its head down and, standing vertically in the water, makes some jerky movements as if it were going to bore its snout into the sand. Often it erects one or both ventral fins.[49]

Tinbergen's Plate I is a photo of a Stickleback exhibiting this posture to its own reflection in a mirror! *We* know this fish is making a mistake. Does he?

> Lorenz reports . . . an incident which demonstrates the power of [some varieties of Cichlid] to distinguish between food and their young. Many Cichlids carry the young back, at dusk, to a kind of bedroom, a pit they have dug in the bottom. Once Lorenz, together with some of his students, watched a male collecting its young for this purpose. When it had just snapped up a young one, it eyed a particularly tempting little worm. It stopped, looked at the worm for several seconds, and seemed to hesitate. Then, after these seconds of "hard thinking," it spat out the young, took up the worm and swallowed it, and then picked up its young one again and carried it home. The observers could not help applauding.[50]

The antelope that fled from a lion that wasn't there, the stickleback that threatened a rival that wasn't there, did they interpret something heard, something seen, as to-be-run-from, to-be-ousted? Their behaviors, while in error in the particular cases, were appropriate. And this holds true whether or not these individual animals "knew what they were doing."

Something like this is, we take it, what Short meant when he wrote: [51]

> The purposefulness of interpretation accounts for the significance of that which is interpretable. In particular, as that which has a purpose may fail of its purpose, the purposefulness of interpretations accounts for the possibility that what is signified *is not.* Because what is signified might not be, significance exemplifies Brentano's idea of intentionality, which he defined as having an "inexistent object," i.e., an object that *is* an object independently of its existing. Brentano asserted that intentionality is unique to human mentality, but the argument of [Short's] book is that sign-interpretation occurs independently of conscious thought and, hence, that Peirce's semeiotic applies to phenomena well beyond human mentality. Thus it provides for a naturalistic explanation of the mind. But that is possible only if purposefulness can occur without consciousness. Peirce's doctrine of final causation c. 1902 provides a defense of that assumption. For it identifies causation with selection for types of possible outcome, regardless of whether that selection is conscious. And it does so consistently with modern physics and biology.[52]

But the question that arose when we considered the dog that eventually managed to bark *at the cat* is still with us: The dog, in our judgment and in fact, "corrected itself." And we know that learning, in the sense of an individual's behavior being shaped "for the better" by its experience, is a constituent of the lives of very many (all?) animals. But did the dog *know* that it corrected itself? Consider Lorenz's much applauded Cichlid father, which had its worm and its baby too. Mustn't it have had some sort of "inner representation" of the alternative courses of conduct between which it chose?

We seem at last to have reached the question of when and how conscious purpose, planning, and self-control emerge. Short's entire book, not just the chapter bearing the name "Semeiosis and the Mental," is in pursuit of it. Given that

Peirce regarded thought to be internalized discourse, and that an individual's power of discourse is a skill that could not have been acquired had that individual's "instinct to acquire the art" (as Darwin put it) not been activated in the course of apprenticeship to speakers, Short and Peirce are clearly right that "the capacity to think for oneself and to act in despite of society is . . . social in origin." He adds: "Individual autonomy and varied personality are further examples of the irreducibility of new realities to their preconditions."[53] Among such "new realities" are not only new means to accomplish existing purposes but also new purposes.

Because Short, under Peirce's tutelage, is wholehearted about accepting the Reality of purpose and purposiveness and is unembarrassed about following Darwin in naturalizing man, his investigation of how purpose can and has become "emancipated" from biology has real content.[54]

## Conclusion

We have seen that, according to Peirce, both statistical mechanics and Darwinian natural selection entail anisotropic processes, defined by the *type* of result they lead to. The "population thinking" that Darwin and later biologists introduced into biology was aimed at accounting for the emergence of biological types or species. The new thinking differed from the typological thinking of pre-Darwinian times in that the types or species arose in time.

Among the virtues of Short's presentation of Peirce is that he gives a sufficiently detailed description of Peirce's Categories (in Ch.3) for readers to be supplied with opportunity to become persuaded that Peirce's trinitarian categorial scheme accommodates Individuals and Kinds as mutually irreducible. Here is, however, not the place to exhibit or argue the point.

Why was the reception of Darwin at St. John's so lukewarm in earlier days? The theoretical physicist's impatience with fussy descriptive details such as are dwelt on in *Origin* (and *must* be by natural historians) was probably a contributing factor; and one that would have been exacerbated if the assigned selection from *Origin* was pedagogically haphazard. But vague apprehensions about the moral and philosophical import of Darwin's theory may have contributed more heavily to avoiding serious intellectual engagement with it.

Darwin himself anticipated this reaction. He explains (in the Introduction to *Descent of Man*) that it was in order not to stand in the way of the reading public's making fair trial of his general views that he allowed himself just one tiny paragraph, on the final pages of *Origin,* that makes direct mention of man:

> In the distant future . . . psychology will be based on a new foundation, that of the necessary acquirement of each mental power and capacity by gradation. Light will be thrown on the origin of man and his history.

Twelve years later, in *Descent of Man,* the scope of Darwin's intellectual ambition is made manifest. In Ch.3 he takes on Kant:

> "Duty . . . whence thy original?" . . . As far as I know, no one has approached [this great question] exclusively from the side of natural history.

So "approaching it," Darwin writes:

> The following proposition seems to me in a high degree probable—namely, that any animal whatever, endowed with well-marked social instincts, would inevitably acquire a moral sense or conscience, as soon as its intellectual powers had become as well developed, or nearly as well developed, as in man.[55]

His plan is to show how, granted the rest of our mental attributes and the world's make-up, the human species does better *with* than it would *without* morality. Otherwise morality (sense of duty, conscience) and the instruments for its acquisition and maintenance could not have become "selected."

But isn't there something topsy-turvy about an explanation that subordinates, as means, something better, namely a creature competent to have a sense of duty, to an end less good, namely, mere comparative fitness for producing fertile offspring? The complaint, we urge, limps, because it fails to register that when something is fruitful and multiplies or fails to, it is *as a creature possessed of certain attributes that it does so.* Darwin freely ascribes sociability, intelligence, and emotions (sympathy, jealousy, ennui, curiosity, courage, maternal affection, and so forth) to, for instance, domestic animals.[56] Nevertheless, he reserves morality for human beings:

> As we cannot distinguish between motives, we rank all actions of a certain class as moral, when they are performed by a moral being. A moral being is one who is capable of comparing his past or future actions or motives, and of approving or disapproving of them. We have no reason to suppose that any of the lower animals have this capacity; therefore when a monkey faces danger to rescue its comrade, or takes charge of an orphan monkey, we do not call its conduct moral. . . . It cannot be maintained that the social instincts are ordinarily stronger in man than, . . . for instance, the instinct of self-preservation, hunger, lust. . . . Why, then, does man regret . . . and why does he further feel he ought to regret his conduct? . . . Man, from the activity of his mental faculties, cannot avoid reflection. . . . Whilst the mother bird is feeding or brooding over her nestlings, the maternal instinct is probably stronger than the migratory; but . . . at last, at a moment when her young ones are not in sight, she takes flight and deserts them. When arrived at the end of her long journey, and the migratory instinct ceases to act, what an agony of remorse each bird would feel if, being endowed with great mental activity, she could not prevent the image continually passing before her

> mind of her young ones perishing in the bleak north from cold and hunger. At the moment of action, man will no doubt be apt to follow the stronger impulse. . . . But after their gratification, when past and weaker impressions are contrasted with the ever enduring social instincts, retribution will surely come. Man will then feel dissatisfied with himself, and will resolve with more or less force to act differently for the future. This is conscience; for conscience looks backwards and judges past actions, inducing that kind of dissatisfaction which, if weak, we call regret, and if severe remorse.[57]

Darwin seems to have come upon Aristotle late in life and recognized a soul-mate in him. He would, we believe, have been in delighted agreement upon reading Aristotle's observation in *History of Animals,* Book 1, 488b24, that we are the only creatures capable of deliberating *(bouleutikon):*

> Many animals have the power of memory, and can be trained, but the only one that *can recall past events at will (dunatai anamimnēskesthai)* is man.

Where are we then? Conscience, says Darwin in the opening sentence of *Descent of Man*, Ch.3, is the chief mark of distinction of the human race. Conscience cannot come into existence or operate without the power of recollection. The power of recollection (though no texts come to mind where anyone of our three authors says this expressly) depends upon the power to learn and employ not just a communicative medium but an articulate language.[58] Beings of this sort, Peirce the logician will come to argue ever more strenuously as he ages, are capable of acting not just in a motivated way, but in accordance with an ideal:

> Every action has a motive; but an ideal only belongs to a line of conduct which is deliberate. To say that conduct is deliberate implies that each action, or each important action, is reviewed by the actor and that his judgment is passed upon it, as to whether he wishes his future conduct

> to be like that or not. His ideal is the kind of conduct which attracts him upon review. His self-criticism followed by a more or less conscious resolution that in its turn excites a determination of his habit, will, with the aid of sequelae, *modify* a future action; but it will not generally be a moving cause to action.[59]

Permit us to conclude with an anecdote. A recent movie presented a small group of adults with the situation of a male high-school teacher accepting seduction by one of his beautiful girl-students. Ever intent on discussing *la difference,* one of the men in the group of movie watchers asked "Do you blame the teacher?" "Yes," was the answer, "because although it may indeed be true that it is harder for young men than for young women to resist sexual arousal, the teacher knowingly entered upon a profession that he could foresee would present him with such situations as he was now in. He should, taking advantage of the human power of imagination, have *rehearsed inwardly* how he *would* act *if* the world presented him with an opportunity that he should turn down."[60]

With Peirce's help, and instructed by Short, we hope to have shown in this essay that nothing in Darwin interferes with acknowledging the emergence of organisms competent to entertain and criticize ideals. This is the kind of organism we human beings are.

## NOTES

1. According to Ernst Mayr in his *One Long Argument: Charles Darwin and the Genesis of Modern Evolutionary Thought* (Cambridge, Mass.: Harvard University Press, 1991), what later authors think and speak of as "Darwin's Theory" is a combination of four or five strands—evolution as such, common descent, multiplication of species, gradualism, and natural selection.

2. See Ernst Mayr's Introduction to Charles Darwin, *On the Origin of Species: A Facsimile of the First Edition* (Cambridge, Mass.: Harvard University Press, 1972), xii.

3. John Dewey, *The Influence of Darwin on Philosophy* (New York: Henry Holt, 1910).

4. Ernst Mayr in *Evolution and Anthropology* (Washington: Anthropological Society of Washington, 1959), 2; also given in Mayr's Introduction to Darwin's *On the Origin of Species: A Facsimile,* xix-xx.

5. See Elliott Sober, "Evolution, population thinking, and essentialism," *Conceptual Issues in Evolutionary Biology*, ed. Elliott Sober, (Boston: MIT Press, 2001).

6. In the seminar described at the beginning of this essay, Clark was the sole participant to speak up in defense of Darwin's theory.

7. In his book *Psychologie vom empirischen Standpunkt* (Leipzig: Duncker und Humblot, 1874).

8. Jasha spoke with admiration of Husserl's repeated efforts to start all over again from the beginning, in formulating the *archai* of philosophy. Husserl's notion of sedimentation in the sciences—our tendency to take earlier achievements for granted—was a theme that Jasha took up in his studies of the origins of algebra and of the work of Galileo. Seeking to understand Jasha's Husserlian antecedents, I read a good deal of Husserl during the years I was reading Peirce. A lecture I gave in September, 1959, was based on Husserl's *Erfahrung und Urteil.*

9. The importance of this fact was first established by Murray Murphey, in *The Development of Peirce's Philosophy,* (Cambridge, Mass.: Harvard University Press, 1961.)

10. Thomas L. Short, *Peirce's Theory of Signs* (Cambridge: Cambridge Universty Press, 2007). I was introduced to this book by Chaninah Maschler.

11. *The Essential Peirce,* edited by the Peirce Edition Project, 2 Vols. (Bloomingdale, Indiana: Indiana University Press, 1998), Vol. 2, 400. In further references to this publication will be abbreviated to *EP.*

12. Ibid., 516.

13. These articles are reprinted in *EP,* Vol. 1, 109-123, 124-141.

14. Thomas L. Short, in a forthcoming second book about Peirce, gives a detailed defense of this Peircean understanding of the sciences.

15. *EP,* Vol. 2, 400. Italics added.

16. See Immanuel Kant, *Critique of Pure Reason,* "Of the Canon of Pure

Reason," A800 = B828 ff. Kant there explains, "By the practical I mean everything that is possible through freedom."

17. *EP,* Vol. 2, 333.

18. Ibid., 401.

19. Peirce eventually (as here) made the name of the -ism ugly, "to keep it safe from being kidnapped." Consider what Peirce writes about how his thinking does or doesn't differ from that of William James, *EP,* Vol. 2, 421.

20. *EP,* Vol. 2, 358f. For a lucid brief description of Peirce's later "subjunctive" version of pragmatism, one which acknowledges that "modern science . . . is practice engaged in for the sake of theory," see Short, *Peirce's Theory of Signs,* 173, second paragraph.

21. *EP,* Vol. 1, 52.

22. Ibid.

23. For other difficulties with his theory in the 1860s, see Short, *Peirce's Theory of Signs,* ch. 2.

24. *EP,* Vol. 1, 120.

25. *EP,* Vol. 1, 138-139.

26. *EP,* Vol. 1, "The Fixation of Belief," 111; for the square bracketed emendations, see ibid., 377.

27. Cf. *EP,* Vol. 1, 289f.

28. See Paul Ehrenfest and Tatyana Ehrenfest, *The Conceptual Foundations of the Statistical Approach in Mechanics* (New York: Dover, 1958.)

29. Cf. *EP,* Vol. 1, 221.

30. Ilya Prigogine, *From Being to Becoming* (San Francisco: W.H. Freeman, 1980). See also *Stuart A. Kauffman,* "Antichaos and Adaptation," in *Scientific American,* August 1991, 78-84.

31. See the concluding sentence of the potent last paragraph of Darwin's Introduction to *On the Origin of Species.* Gould and Lewontin, in their famous protest against unrestrained Adaptationism ("The Spandrels of San Marco and the Panglossian Paradigm: A Critique of the Adaptionist Programme," in *Conceptual Issues in Evolutionary Biology,* ed. Elliott Sober, [Boston: MIT Press, 2001]), cite this sentence and add an approving reference to George. J. Romanes's essay "The Darwinism of Darwin, and of the Post-Darwinian Schools" (in *The Monist* 6:1 [1895], 1-27). Romanes would join Gould and Lewontin when they write: "We should cherish [Darwin's] consistent attitude of pluralism in attempting to ex-

plain Nature's complexity" (82).

32. *Selections from Darwin's* The Origin of Species: *The Shape of the Argument,* ed., Nicholas Maistrellis (Santa Fe: Green Lion Press, 2009), 43.

33. *EP,* Vol 1, 200. For a correction of this overly cheerful scenario of inevitable progress see, e.g., Elliott Sober, "Selection-for: What Fodor and Piattelli-Palmarini Got Wrong," 11. This essay is available on the internet at the following URL:
http://philosophy.wisc.edu/sober/Fodor%20and%20Piatelli-Palermini%20april%209%202010.pdf

34. *EP,* Vol. 1, 272. Cf. Darwin, *On the Origin of Species: A Facsimile,* 127.

35. Helena Curtis, *Biology* (New York: Worth, 1979).

36. Equally important, perhaps, is the inspiration of Darwin's intellectual attitude—omni-observant, persevering, sober—to which Maistrellis calls attention.

37. Elliott Sober, *The Nature of Selection: Evolutionary Theory in Philosophical Focus* (Cambridge, Mass.: MIT Press, 1984).

38. The example stems from Williams via Elliott Sober and David Sloan Wilson, "Adaptation and Natural Selection Revisited," in the *Journal of Evolutionary Biology* 24 (February 2011), 462-8. In this article, the authors are "revisiting" George C. Williams's book on adaptation in order to make sure the world knows that the book was a landmark in the development of evolutionary theory.

39. Elliott Sober, "Fodor's *Bubbe Meise* Against Darwinism," in *Mind and Language* 23 (February 2008), 43. (*Bubbe meise* is Yiddish for "old wives' tale.") This article is also available on the internet at the following URL:
http://philosophy.wisc.edu/sober/fodor's%20bubbe%20meise%20published.pdf

40. When Herbert Spencer attempted to explain evolution on mechanical principles, Peirce countered that the endeavor was illogical. See *EP,* Vol. 1, 289. Among Peirce's arguments was this: the law of conservation of energy implies that all operations governed by mechanical laws are reversible. Whence follows the corollary that growth *is not explicable by those laws, even though they are not violated in the process of growth.*

41. Private communication from Thomas Short, March 19, 2012.

42. Short, *Peirce's Theory of Signs,* 130. Italics in last sentence added.

43. Ibid., 145

44. Ibid., 144-145.

45. As Allen Clark wrote in a manuscript never published ("The Contributions of Charles S. Peirce to Value Theory," 4), "No philosopher . . . would be less inclined than Peirce to minimize the tremendous importance of the transformation that occurs when inquiry [or any other adaptive behavior] rises from the unconscious to the conscious level. For it is at this second stage that man transcends the animal faculty of merely responding to naturally given signs, those perceptual clues furnished by nature; he begins to *make* signs, and to respond to signs of his own making, and thus learns to provoke his own responses."

46. "Synechism is Peirce's doctrine that human mentality is continuous with the rest of nature," writes Thomas Short in his exchange with the critics of his book, "Response," in *Transactions of the Charles S. Peirce Society* 43 (Fall 2007), 666.

47. Ibid. Dewey's essay of 1896, "The Reflex Arc Concept in Psychology" (*Psychological Review* 3 [July, 1896], 357-370) is offered in the same, perhaps Hegel-inspired, spirit of synechism. (This article is available on the internet at the following URL:
http://psychclassics.yorku.ca/Dewey/reflex.htm.) But a more instructive comparison would be between Thomas Short's account of Peirce and the life-long work of James J. Gibson, for instance, *The Senses Considered as Perceptual Systems* (Boston: Houghton Miffin, 1966) and *The Ecological Approach to Visual Perception* (Boston: Houghton-Mifflin, 1979.).

48. See Short, *Peirce's Theory of Signs,* 156f.

49. Niko Tinbergen, *Social Behavior of Animals,* Methuen's Monographs on Biological Subjects, Vol. 1 (New York: Taylor and Francis, 1953), 9.

50. Ibid., 45. The following anecdote of Darwin's in his chapter comparing the mental powers of lower animals with human mental powers seems to be to the same effect: "Mr. Colquhoun winged two wild ducks, which fell on the opposite sides of a stream; his retriever tried to bring over both at once, but could not succeed; she then, though never before known to ruffle a feather, deliberately killed one, brought over the other, and returned for the dead bird." Charles Darwin, *Descent of Man* (Princeton: Princeton University Press, 1981), 48.

51. Further clarifying remarks on Intentionality are given by Short in *Peirce's Theory of Signs*, 174-177.

52. Elliott Sober, "Fodor's *Bubbe Meise* Against Darwinism," 669.

53. Short, *Peirce's Theory of Signs,* 147.

54. Ibid., 148.

55. Darwin, *Descent of Man,* 71.

56. See Charles Darwin's 1872 book *Expression of the Emotions in Man and Animals*, ed. Paul Ekman (Oxford: Oxford University Press, 2009).

57. Darwin, *Descent of Man,* Ch.3, 88-91.

58. Ibid., Ch.2, 54.

59. *EP,* Vol. 2, 377. Survey the Index to *EP,* Vol. 2 under "self-control."

60. The answer is inspired by Peirce's report of his childhood memory of his younger brother's having prepped himself in imagination for preventing the spread of a small fire. See *EP,* Vol. 2, 413.

# The Laws of Physics

Marlene Benjamin

*In Memoriam*

People say that the Laws of Physics
Are immutable,
Beyond the reach of hopes and dreams,
Immune to wishes,
And entirely indifferent to desire.

They say that the Laws of Physics
Are as solid in their abstractness as the materials
Whose movements they describe,
Whose broad encompassing axioms
Place with near precision all heavenly bodies,
All rocks and debris,
All breathing creatures—even us,
With all our singularity—
Within the vastness of this complicated
And wholly relational world,
Measuring all places with a confidence
In basic principles (as if some genius had bestowed upon
them personality)
The rest of us admire but so rarely can attain.

There is beauty in the Laws of Physics,
The beauty and elegance of those simple Euclidean equations
I struggled over long ago,
The amazing loveliness of a singularly striking accomplishment.

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And yet this question haunts us:
Why should we *not* believe as Greeks believed?
Why should we *not* believe
That what we now call myths are really legends,
Embellished, we agree, yet legends nonetheless . . .

Why should we not have the confidence with which the
Greeks were blessed,
And take some tales of ordinary people, whose lives were touched
By strange and unexpected happenings, as legends of our own,
So that the Laws of Physics or Biology
Or of all the Natural Philosophies
Were not, as we believe, constraining,
But rather showed us ourselves as god-like,
Whose dreams inscribe upon the world what pleases us,
Able, like Athena, come full blown out of Zeus's head
To enact the Laws of Physics to suit ourselves?

Then would you come walking back
To family and friends,
But especially, most especially, to wife and daughter;
All your molecules and atoms shaped perfectly again
Into your singularly recognizable form,
Striding purposefully and with that grin of yours
And, as on any ordinary day,
There would you be,
Arriving home,
Whole and un-bloodied,
Back into the life you should be living still.