The eye was a worry to Charles Darwin, giving rise to certain uneasy passages in his writings that are now favorites among proponents of the “Intelligent Design” and “Creation Science” movement. One such passage is in *On the Origin of Species* (1859):

To suppose that the eye with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by natural selection, seems, I freely confess, absurd in the highest degree.

In the continuation of the passage, Darwin explains how “a perfect and complex eye could be formed by natural selection.”¹ Still, the eye continued to trouble him. He confessed to a friend, the Harvard botanist Asa Gray, in 1860: “The eye to this day gives me a cold shudder.”² Perfection was the heart of the problem: Could so complexly perfect a device truly be the result of natural selection alone? Or mustn’t it require a divine Designer?

The exceptional qualms that Darwin felt when contemplating the eye must have gained force from the currency of the argument from design, with its chief exemplar, the complex and perfect eye. These were comparatively recent notions that were rapidly gathering steam. To be sure, philosophers and physiologists from Aristotle and Galen onward had considered the eye, along with all the other bodily organs and natural systems, to represent divine craftsmanship. And there was also an empirical tradition of proofs of God’s existence from the appearance of order and purpose in nature, the tradition of Aquinas.³ But empirical proofs of God’s existence by the purely mechanical workings of a purely material contraption required the particular

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² C. R. Darwin to Asa Gray, February 8–9, 1860, Darwin Correspondence Project [hereafter DCP], http://www.darwinproject.ac.uk/, Letter 2701. See also Darwin to Asa Gray, April 3, 1860, ibid., Letter 2743: “I remember well the time when the thought of the eye made me cold all over, but I have got over this stage of the complaint, and now small trifling particulars of structure often make me feel uncomfortable. The sight of a feather in a peacock’s tail, whenever I gaze at it, makes me sick!”

mode of mechanist empiricism (or empiricist mechanism) that emerged in the seventeenth century and was codified by people such as Robert Boyle. This kind of argument from design was, accordingly, a new entity, an innovation of the mid-seventeenth century, which gained force over the course of the eighteenth, and received its most powerful, definitive statement in 1802 by the philosopher and Christian apologist William Paley. His *Natural Theology; or, Evidences of the Existence and Attributes of the Deity, Collected from the Appearances of Nature* had gone through twenty editions by 1820 and exerted an important influence upon Darwin’s own early thinking. 

the eye. “Were there no example in the world, of contrivance, except that of the eye,” Paley wrote,

it would be alone sufficient to support the conclusion which we draw from it, as to the necessity of an intelligent Creator. It could never be got rid of; because it could not be accounted for by any other supposition . . . . [It is] an apparatus, a system of parts, a preparation of means, so manifest in their design, so exquisite in their contrivance, so successful in their issue, so precious, and so infinitely beneficial in their use, as, in my opinion, to bear down all doubt that can be raised upon the subject.5

The physiology of the eye and the argument from design developed in tandem during the latter seventeenth and the eighteenth centuries. A striking feature of this tradition in physiology and theology is that these writers on the eye excluded virtually any consideration of visual perception.

Focusing sharply on the eye while leaving deliberately blurry its association with vision, the protagonists of this story are interestingly irrelevant to recent historiography on the “history of vision.” This is a phrase that has lately commanded much attention among historians, anthropologists, and cultural critics. But it has tended to denote something quite distinct from the developments examined here: it has mostly meant the experience of seeing and the significance of the visual sense in modern culture, the cultural primacy of vision and its origins and consequences.6 Meanwhile, scholarly conversation about the history of the physiology of vision has turned upon theories of optics and dissections of eyeballs, while evincing little interest in the subjective or cultural experience of seeing.7 Our protagonists here represent an origin of this curious situation, the segregation of conversations about the eye from conversations about seeing.8

Scrupulously treating the eye as a device, these physiologists, philosophers, and natural theologians pored over the orb’s minutest parts and their slightest movements, while carefully leaving aside the experience of vision with which these moving parts were mysteriously associated. Any consideration of vision would, after all, undermine their organizing image: the analogy between an eye and a lens instrument. An eye resembles a telescope much more closely if one discounts the fact that an eye can see.

The conjoined development of ocular physiology and natural theology thus rep-

7 See, for example, David C. Lindberg, Theories of Vision from Al-Kindi to Kepler (Chicago, 1996); and Nicholas J. Wade, A Natural History of Vision (Cambridge, Mass., 1998).
8 This is not to say that the two conversations never come together: the field of visual psychophysics is devoted to that purpose. But this very circumstance reflects the existence of two clearly distinct conversations to be bridged. The duality is explicit in Gustav Theodor Fechner’s founding manifesto, Elemente der Psychophysik (Leipzig, 1860).
FIGURE 2: Frontispiece to Christoph Scheiner, *Oculus hoc est: Fundamentum opticum* (Innsbruck, 1619).
resents an instance of a more general phenomenon: the critical role of theological principles and purposes in shaping the most reductively device-like models of living structures.9 Machine-like-models of living creatures relied upon theological principles not just before the Scientific Revolution of the sixteenth and seventeenth centuries, but into and through it as well.

The Cambridge Platonist Henry More was among the first to call the eye to its new mission. In An Antidote against Atheism (1655), More invoked the eye as the first of his “Unavoidable Arguments for divine Providence.” The “number, the situation, the fabric” of the eyes was such, More argued, “that we can excogitate nothing to be added thereto.” Leaving the eye’s beauty to “Poets and amorous persons,” More dwelt instead, in minute detail, on its anatomy and physiology: the eyelids, “fortifi’d with little stiff bristles as with Palisades, against the assault of Flyes and Gnats, and such like bold Animalcula”; the transparency of the “Humours and Tunicles,” which meant that light and colors could enter “unfoul’d and unsophisticated by any inward tincture”; the convexity of the crystalline lens, serving to focus incoming light rays; the inner surface of the iris, “black’d like the walls of a Tennis court” so that the light would be absorbed there rather than being reflected back into the retina; the suspension of the lens, such that the ciliary muscle could thrust it forward or draw it back; the whiteness of the retinal membrane, suited like a piece of white paper to the reception of images; and the six ocular muscles that moved the eye in all directions.10

Overall, the body was so artfully formed, More reasoned, that if only we had had the same matter to work with, we would surely have built ourselves exactly as God built us: “If the wit of Man had been to contrive this Organ [the eye] for himself, what could he have possibly excogitated more accurate?”11 More’s collegial adversary in other matters, Robert Boyle, who called animals “Living Engines” and “Automata,” agreed with More in choosing the eye as the leading evidence for a divine Engineer.12 And next, cribbing extensively from More and Boyle, came the English naturalist and theologian John Ray, who propelled the argument from optical design in his much-translated and reprinted The Wisdom of God Manifested in the Works of

9 I use “device-like” here rather than the more euphonious “mechanist” because the latter term has such tangled implications. Some participants in the seventeenth-century argument-from-design tradition that originated with mechanists such as Robert Boyle saw themselves as at odds, in certain respects, with the form of mechanism that shaped the argument’s earliest formulations. John Ray, in particular, advanced the view that God must act in nature by means of an active, spiritual power. See Richard Olson, “On the Nature of God’s Existence, Wisdom and Power: The Interplay between Organic and Mechanistic Imagery in Anglican Natural Theology—1640–1740,” in Frederick Burwick, ed., Approaches to Organic: Permutations in Science and Culture (Dordrecht, 1987), 1–48. For my purposes here, the relevant consideration is that Ray remained very close to Boyle in his account of living structures, retaining the view of these as artifactual devices on the model of human-made instruments.

10 Henry More, An Antidote against Atheism; or, An Appeal to the Natural Faculties of the Mind of Man, Whether There Be Not a God, 2nd ed. (London, 1655), book II, chap. XII, 142–146. Humours were the fluids of the eye, and tunicles the membranes.

11 Ibid., 145.


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"the Creation (1692) by dwelling extensively on “the Eye, a Part so artificially composed, and commodiously situate.” Ray added his own refinements to More’s and Boyle’s lists: the biconvexity of the crystalline lens; the retinal cavity, a convenient “Room” in which to “collect the rays received by the pupil”; and the situation of the cornea, which “riseth up, as it were a Hillock” above the white of the eye, a good thing, since otherwise “the Eye could not have admitted a whole Hemisphere at one View.”

Natural theologians lingered especially and increasingly over the eye’s properties of accommodation: the pupil’s dilations and contractions in response to light and the several ways in which the eye varies its refracting power to see objects at different distances. The Jesuit astronomer Christoph Scheiner had described some aspects of ocular accommodation in his 1619 treatise *Oculus*. Ray described a simple experiment to demonstrate these phenomena, requiring only a candle, a bead, and a ready child:

> take a Child, and setting a Candle before him, bid him look upon it, and [you] . . . shall observe his Pupil contract itself very much, to exclude the Light, with the Brightness whereof it would otherwise be dazzled and offended.

Next, withdraw the candle and watch the child’s pupil re-expand. The same contraction will take place when the child looks at a bead held close to his eye, and the same expansion when he looks at the bead from a distance. The pupil that performed these feats, Paley wrote, was a structure extremely artificial. Let an artist only try to execute the same; he will find that his threads and strings must be disposed with great consideration and contrivance, to make a circle, which shall continually change its diameter, yet preserve its form. This is done in the eye by an application of fibres, i.e. of strings, similar, in their position and action, to what an artist would and must employ, if he had the same piece of workmanship to perform.

Paley also devoted several pages to distance accommodation, which he reckoned gave the eye indisputable superiority over the telescope. In a telescope, after all, the operator, rather than the instrument itself, performed the accommodations by switching lenses or even instruments. In the eye, in contrast, whenever it was directed at a nearby object,

three changes are produced in it at the same time, all severally contributing to the adjustment required. The cornea, or outermost coat of the eye, is rendered more round and prominent;

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13 John Ray, *The Wisdom of God Manifested in the Works of the Creation*, 7th ed. (London, 1717), 248–262. Ray lifted some passages from More virtually verbatim, for example, describing the eyelashes as “stiff Bristles, as it were Pallisadoes, against the Incursions of importunate Animals,” and the inner surface of the iris as “blacken’d like the Walls of a Tennis-Court, that the Rays may be there suffocated and suppressed, and not reflected backwards to confound the Sight.” Ray also mentioned the ligaments (zonule fibers) by which the lens is suspended, which contract and relax with the actions of the ciliary muscle to change the shape of the lens; and the eye’s six muscles “to move it upward, downward, to the Right and Left, obliquely and round about.”

14 Ibid., 258.

15 Christoph Scheiner, *Oculus hoc est: Fundamentum opticum* (Innsbruck, 1619). See also F. Roman, “The Discovery of Accommodation,” *British Journal of Ophthalmology* 79, no. 4 (1995): 375. It was Helmholtz who demonstrated that accommodation to distance takes place through changes in the shape of the lens.

16 Ray, *The Wisdom of God*, 252. More had also listed the ability of the pupil to dilate and contract among the eye’s perfections; *An Antidote against Atheism*, 144–145.
the crystalline lens underneath is pushed forward; and the axis of vision, as the depth of the eye is called, is elongated . . . Can anything be more decisive of contrivance than this is? The most secret laws of optics must have been known to the author of a structure endowed with such a capacity of change.

Now, you might think the fact that an eye can adjust itself, whereas a telescope cannot, might destroy the analogy. But Paley found another device to use here. In its capacity for self-regulation, the eye reminded him of John Harrison’s self-regulating marine chronometer, the clock that had won the Longitude Prize in 1773.17

Between Ray and Paley, a tradition of arguments from design resting heavily on the physiology of vision stretched through the eighteenth century, including the Scottish physician George Cheyne’s Philosophical Principles of Natural Religion (1705) and the English clergyman William Derham’s Physico-Theology (1713).18 But the essentials of the argument were in place by the end of the seventeenth century; subsequent texts included much that was paraphrased or unceremoniously lifted from the earlier ones.

Why the eye? The explicit answer, from Boyle to Paley, was the obvious analogy between the eye and lens instruments. Boyle wrote, “there is no more Rashness to say, that an Eye, than that a Telescope, was made for an Instrument to See with.”19 It was commonplace to describe the eye also as a camera obscura of unparalleled refinement. Paley wrote:

we can never reflect without wonder upon the smallness, yet correctness, of the picture, the subtlety of the touch, the fineness of the lines. A landscape of five or six square leagues is brought into a space of half an inch diameter; . . . The prospect from Hampstead-hill is compressed into the compass of a six-pence . . . A stage-coach, traveling at an ordinary speed for half an hour, passes, in the eye, only over one-twelfth of an inch, yet is this change of place in the image distinctly perceived throughout its whole progress.20

Even where the makers of optical instruments had deliberately imitated the mechanism of the eye, Paley derived proof of a divine Designer from the coincidence of the two structures. He pointed, for example, to the problem of chromatic aberration, caused by the differential refraction of different colors of light: “in the eye,” Paley wrote, “the evil was cured by combining lenses composed of different substances, i. e. of different refracting powers,” and opticians had developed telescopes using combinations of lenses in imitation of this.21 (In fact, “cured” was an overstatement: throughout the seventeenth and eighteenth centuries, people including especially Christiaan Huygens and Isaac Newton had worked to treat the problem of chromatic

17 Paley, Natural Theology, 440–441.
18 George Cheyne, Philosophical Principles of Natural Religion: Containing the Elements of Natural Philosophy, and the Proofs for Natural Religion, Arising from Them (London, 1705); William Derham, Physico-Theology; or, A Demonstration of the Being and Attributes of God from His Works of Creation (London, 1713). See Davidson, “ ‘Identities Ascertained.’ ”
19 Boyle, A Disquisition about the Final Causes of Natural Things, 148.
20 Paley, Natural Theology, 439. Paley also wrote: “I know no better method of introducing so large a subject, than that of comparing a single thing with a single thing; an eye, for example, with a telescope” (ibid.) and “We have made choice of the eye as an instance upon which to rest the argument of this chapter. Some single example was to be proposed: and the eye offered itself under the advantage of admitting of a strict comparison with optical instruments” (444). For a comparison of the eye to a camera obscura, see also 442.
21 Ibid., 440.
aberration. The trouble is that correcting it introduces other kinds of aberrations; the current field of aberration theory is devoted to studying this problem. There is of course no perfect optical instrument, the eye included, a point about which more to come.)\textsuperscript{22}

Apart from the analogy between the eye and the telescope, however, another factor was at work in placing the eye at the center of the natural theological tradition. More than any other part of the body, and because of the intimate connection that philosophers and physiologists identified between vision and consciousness itself, the eye was where the drama of the mind-body split most forcefully took place. The authors of optical arguments from design chose the bodily function closest to the very soul itself, and then they conspicuously restricted their discussion to the body. Even when they mentioned perception, as they rarely did, they treated it in purely mechanical terms. Cheyne, for example, marveled,

What can be more amazing, than that the Particles of Matter shou’d be so fram’d, as by their means to shew us the Shapes, Positions, Distances, Motions, yea and Colours of remote Bodies? . . . These things are not only contriv’d and fram’d with so great Wisdom and Skill, as not to admit of a better; but to any one who attentively considers them, they seem of such a Nature as scarcely to allow any other Method, for it seems impossible that Light shou’d represent Objects to us, at so vast a distance, but by the transmission of some fine Fluid, from the Object upon the Eye. And it seems impossible that any other Composition of the Eye, shou’d be equally fitted for that end.

As an example of this absolute fitness, Cheyne judged that the retina was shaped and positioned just right: with a different curvature, or at a different distance from the crystalline lens, he reckoned, objects would appear distorted, magnified, or minia-
turized.\textsuperscript{23}

The fact that people perceive objects right-side-up despite the inversion of images on the retina, which Scheiner had demonstrated in 1625, does not seem to have troubled Cheyne in his assumption that perception was identical to projection. Ray did take up the inversion of the retinal image, but explained its lack of effect on perception by reference to a material cause: the nerves’ ability to convey the situation and position of the objects that pressed upon them. Ray proved this ability by in-voking a common tactile illusion. Cross your first two fingers and press them against a round object. From the sensation in your fingers, you will have the impression that you are touching two separate objects.

The Reason is, because in that Posture of the Fingers the Body touches the Outsides of them, which in their natural Sight are distant one from another, and their Nerves made to signifie to the Soul Bodies separate and distant in like manner, two Fingers lying between them. And tho’ our Reason, by the Help of our Sight, corrects this Error, yet cannot we but fancy it to be so.\textsuperscript{24}


\textsuperscript{23} Cheyne, \textit{Philosophical Principles of Natural Religion}, par. XLV.

\textsuperscript{24} Ray, \textit{The Wisdom of God}, 255–256.
Here, as elsewhere, Ray took perception to be the literal impact of nervous fluids on the seat of common sense in the brain.\textsuperscript{25}

A deliberate disregard for the non-mechanical aspects of perception, or at least for those aspects that seemed to elude mechanical explanations, was built into the tradition of arguments from design from the outset. After all, an eye is nothing like a telescope if one takes into account that a telescope (as far as we know) does not see. Even if Boyle was right that the eye is made for vision as surely as the telescope is made for assisting it, one might well think that there is a world of difference between the two. But the authors of arguments from design carefully avoided finding evidence for the existence of God in the intractably mysterious fact that living creatures see. They had no truck with intractable mysteries. It was fully intelligible, solid, material proofs they were after. They cited the physical complexity of nature, the articulation of parts. Surely, More argued, such arrangements of matter could not have happened by accident, “For is it not a wonder that even all our flesh, should be so handsomely contriv’d into distinct pieces,” able to move independently of one another?\textsuperscript{26}

The exclusive insistence upon mechanism reached its pinnacle, like other aspects of the argument from design, in Paley’s rendition. Unlike previous writers, Paley acknowledged the potential objection that the eye, unlike the telescope, could see. But he declared this difference to be irrelevant:

To some it may appear a difference sufficient to destroy all similitude between the eye and the telescope, that the one is a perceiving organ, the other an unperceiving instrument. The fact is, that they are both instruments. And, as to the mechanism, . . . this circumstance varies not the analogy at all. For, observe what the constitution of the eye is. It is necessary, in order to produce distinct vision, that an image or picture of the object be formed at the bottom of the eye. Whence this necessity arises, or how the picture is connected with the sensation, or contributes to it, it may be difficult, nay, we will confess, if you please, impossible for us to search out. But the present question is not concerned in the inquiry. It may be true, that, in this, and in other instances, we trace mechanical contrivance a certain way; and that then we come to something which is not mechanical, or which is inscrutable. But this affects not the certainty of our investigation, as far as we have gone . . . In the example before us, it is a matter of certainty, because it is a matter which experience and observation demonstrate, that the formation of an image at the bottom of the eye is necessary to perfect vision . . . [T]he apparatus by which it is formed is constructed and put together . . . upon the self-same principles of art, as in the telescope or the camera obscura. The perception arising from the image may be laid out of the question; for the production of the image, these are instruments of the same kind.\textsuperscript{27}

The choice of the eye, of all body parts, as the leading example upon which to rest their arguments, together with the ostentatious restriction of these arguments to its physical mechanism, epitomized the natural theologians’ project to endow the deity with an unprecedented and absolute accessibility, his power made utterly comprehensible, his presence and his nature directly measurable.\textsuperscript{28} Here was philosoph-

\textsuperscript{25} Ibid., 260.
\textsuperscript{26} More, \textit{An Antidote against Atheism}, 146.
\textsuperscript{27} Paley, \textit{Natural Theology}, 439–440.
ical mechanism working at the heart of a theological program and, reciprocally, a theological program shaping the development of philosophical mechanism, propelling it to its most reductive and eliminative extreme.

Theological mechanism, let us then call it, led the authors of arguments from design to an important intellectual outcome, namely the concept of physiological adaptation or fitness: that one must understand the structures and functions of living creatures in terms of their suitability to particular tasks and environments. This idea, or methodological principle, developed—not exclusively, but importantly—within the argument-from-design tradition of natural theology. In its simplest form, fitness as the suiting of means to ends, structures to functions, it followed simply from casting God as an engineer. Thus the eye, Boyle wrote,

(to single out again that Part for an Instance) is so little fitted for almost any other Use in the Body, and is so exquisitely adapted for the Use of Seeing, and That Use is so necessary for the welfare of the Animal, that it may well be doubted, whether any Considering Man can really think, that It was not destinated to that Use.

And Ray concurred: “to this Use and Purpose of informing us what is Abroad round about us in this spectable World, we shall find this Structure and Mechanism of the Eye, and every Part thereof, so well fitted and adapted, as not the least Curiosity can be added.”

Boyle generalized the argument by taking it beyond human structures, and he added a new dimension to the notion of fitness: suitability to a particular environment. He sought examples of fitness and adaptation to various circumstances in the structures of the different animals occupying them. Frogs, for example, need a nic-


30 Boyle, A Disquisition about the Final Causes of Natural Things, 146–147.

31 Ray, The Wisdom of God, 249; emphasis added.
titating membrane to protect their eyes from sedges and other plants as they move through the water, and birds to shield their eyes from twigs and leaves. Flies, unable to move their eyes, are compensated by “a multitude of little protuberant parts, finely ranged upon the convex of their large and protuberant Eyes,” allowing them to see in many directions at once. Grazing animals have a seventh ocular muscle, beyond the six they share with humans, which enables them to look downward for long periods without weariness. These animals also have a horizontal pupil, affording them a wide view of the ground from which they gather their food. In contrast, the vertical pupil in cats gives them a tall view of the world to help them glimpse their climbing prey. Moles have tiny eyes because, living underground, they do not need to see much. Chameleons can move their eyes independently of one another, the better to catch flies approaching from different directions. The crystalline lens in fishes has a greater curvature to accommodate the different refraction of light in water.32

Paley extended the list, which can go on indefinitely: Eels have a “transparent, horny, convex case” over their eyes to protect them from sand and gravel. Different species exhibit different degrees of ocular accommodation, corresponding to the range over which they need to see things. For example, fish eyes in their relaxed state are accommodated to near objects but have muscles that can flatten them to view objects that are farther away. Birds need to see things from the tips of their beaks to a distance of miles; accordingly their eyes have a bony rim, which, confining the action of the muscles to that part, increases their lateral pressure upon the orb, for the purpose of looking at very near objects . . . [and] an additional muscle, called the marsupium, to draw . . . the crystalline lens back, and to fit the same eye for the viewing of very distant objects.

“Thus,” Paley concluded (and one can hear in this passage how Darwin would echo the meter and phrasing as well as the content of Paley’s writing), “in comparing the eyes of different animals, we see in their resemblances and distinctions, one general plan laid down, and that plan varied with the varying exigencies to which it is to be applied.”33

So physiological fitness seemed the appropriate measure of perfection for an Engineer deity. And yet there were difficulties inherent in the project of demonstrating, from the physical mechanisms of the material world, the existence of a single omnipotent and perfect God.

The first difficulty was that these mechanisms are many and varied. Yet early modern natural theologians assumed that human bodies were the most perfect.34

32 Boyle, A Disquisition about the Final Causes of Natural Things, 52–55 (see also 193), 59–64 (see also 201–202). Ray repeated the argument about the nictitating membrane; The Wisdom of God, 262. Cheyne repeated all of the arguments mentioned here; see Philosophical Principles of Natural Religion, par. XLV. And for Paley’s version of the same arguments, see Natural Theology, “Application of the Argument,” 17–49. (The nictitating membrane, for example, is discussed on p. 443.)


34 Natural theologians who promulgated arguments from design often rejected the doctrine of original sin and the concomitant notion that humans were fundamentally frail and flawed. But the attribution of perfection to human structures such as the eye could also be rendered compatible with the doctrine of original sin in various ways. For one thing, Scholastic tradition had long held that man had retained his intellectual and physical gifts through the Fall. Then, although sixteenth- and seventeenth-century
Why, then, would the all-powerful Author of nature ever diverge from this plan? According to this logic, Boyle pointed out, “we may think he must make no Animals but Men.” Boyle’s answer added another new level of complexity to the notion of fitness. Since an animal structure needed to adapt the animal to its particular surroundings, Boyle argued that one could not determine perfection or imperfection, where fitness was concerned, in the abstract: “the eye is not to be consider’d abstractedly as an Instrument of Vision, but as an Instrument belonging to an Animal of this or that kind; and who is ordinarily to make use of it in such and such Circumstances.” Moreover, not only did environments vary, but any given structure had many aspects. So fitness must be measured not only in context but along several axes at once. Boyle observed, “Divers Things may be Useful in an Organical Part”; for example, the eyelids have no role in vision, but they protect the eye. In keeping with this principle, Boyle enumerated four separate sorts of utility to be found in the human body: anatomical, chemical, mechanical, and, in the eyes, optical. Perfection in engineering, even divine perfection, in other words, was a multifarious and deeply contextual quality.

There was a further problem, which may well by now have occurred to the reader, which is that eyes not only are various, but they are also decidedly imperfect. Apart from the inversion of images on the retina, which natural theologians seem not to have treated as an imperfection, there was the even more troubling matter of the retinal blind spot.

Edme Mariotte, a Dijon prior, natural philosopher, and early member of the Académie des sciences, identified the retinal blind spot in 1660. He was investigating a curious anatomical fact, namely that the optic nerve did not join the retina at its center, but rather “somewhat higher, and on the side towards the Nose.” Testing the consequences of this ugly, asymmetrical arrangement, Mariotte fixed two circles of paper to the wall two feet apart. Standing in front of the leftmost piece of paper with his left eye shut and his right eye fixed upon it, he backed away from the wall. At a distance of ten feet, he made a remarkable discovery: “the second paper totally disappear’d.” He could still see objects beyond it to the right, ruling out the possibility that the angle was too oblique; moreover, he could make the paper reappear by shifting the position of his eye ever so slightly. Having repeated the experiment with his left eye, and using different arrangements of pieces of paper, Mariotte drew a momentous conclusion: at the point where the optic nerve joined the retina, the eye was blind.

No matter: natural theologians inverted the retinal blind spot as neatly as the

Protestants returned to a more severe, Augustinian view of the consequences of original sin, everything still depended upon where one located these consequences. Empiricists such as Francis Bacon located them in the human intellect, and treated the senses as the means of redemption and restoration to a prelapsarian state of knowledge and power. See Peter Harrison, “Original Sin and the Problem of Knowledge in Early Modern Europe,” Journal of the History of Ideas 63, no. 2 (April 2002): 239–259.  

Boyle, A Disquisition about the Final Causes of Natural Things, 66; see also 218.  

Edme Mariotte, Nouvelle découverte touchant la veuë (Paris, 1668); published in English translation as “A New Discovery Touching Vision,” Philosophical Transactions of the Royal Society 3, no. 35 (1668): 668–671, cited passages from 668–669. The anatomist Jean Pecquet, to whom Mariotte reported his discovery, responded: “Every one wonders, that no person before you hath been aware of this Privation of Sight, which every one now finds, after you have given notice of it.” On Mariotte, see Michael S.
sensing soul does the retinal image. Two imperfections, they discovered, constituted a perfection. The blind spot provided a reason for the apparently arbitrary lack of symmetry in the eye’s structure, that displeasing arrangement of an off-center junction between optic nerve and retina, which Mariotte had been investigating when he discovered the blind spot. That the optic nerve was “not situate directly behind the Eye, but on one side,” Ray observed, turned out to be a very good thing, because otherwise the blind spot would be in the middle of our visual field. Cheyne added that the off-center placement of the optic nerve meant that what was invisible to one eye was visible to the other. By the time Paley repeated these arguments, they had the feel of truisms, and he passed over them with little interest. The eye’s perfection was by this time so well established that Darwin, as we have seen, felt unshakably daunted by it.

But Darwin must have felt daunted for another reason, too: not only because the eye’s perfection was so well established, but also because it was so deeply ingrained—through the concept of physiological fitness—in his own theory. Darwin was deeply marked by Paley’s work, which he had studied as a student at Cambridge. “In order to pass the B.A. examination,” he recalled in his autobiography, it was . . . necessary to get up Paley’s Evidences of Christianity, and his Moral Philosophy. This was done in a thorough manner, and I am convinced I could have written out the whole of the Evidences with perfect correctness, but not of course in the clear language of Paley. The logic of this book and as I may add of his Natural Theology gave me as much delight as did Euclid.

Perhaps it is no surprise that the concept of physiological fitness, having undergone an important part of its development within and through the argument-from-design tradition of natural theology, retained the ghostly aura of the divine Optician. Evacuating God from his machinery, mechanists and authors of arguments from design had left behind a device-world, an artifact-world, a world, in other words, that depended utterly upon an external source of meaning and purpose.

Symmetrically, the failure of the argument from design, which Darwin said he had delivered with the law of natural selection, seemed to have been well prepared by the natural theologians themselves. Georges Buffon put the point compellingly:


39 Cheyne, Philosophical Principles of Natural Religion, par. XLV.

40 Paley, Natural Theology, 442. Paley also, however, argued that perfection was not essential to the case. “It is not necessary that a machine be perfect, in order to show with what design it was made: still less necessary, where the only question is, whether it were made with any design at all” (436). See also 447: “When we are inquiring simply after the existence of an intelligent Creator, imperfection, inaccuracy, liability to disorder, occasional irregularities, may subsist in a considerable degree, without inducing any doubt into the question: just as a watch may frequently go wrong, seldom perhaps exactly right . . . Irregularities and imperfections are of little or no weight in the consideration, when that consideration relates simply to the existence of a Creator. When the argument respects his attributes, they are of weight; but are then to be taken in conjunction (the attention is not to rest upon them, but they are to be taken in conjunction) with the unexceptionable evidences which we possess, of skill, power, and benevolence, displayed in other instances,” so that we must imagine apparent imperfections are actually perfections.


42 Ibid., 87.

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Who in fact has the greater idea of the Supreme Being, he who sees him create the Universe, order all that exists, found Nature on invariable and perpetual laws, or he who seeks and finds him attentively conducting a republic of flies, and greatly occupied with how a beetle’s wing should fold?43

As David Hume also explained, the argument from design ought to have been its own undoing, and the questions about blind spots and other imperfections were a bit of a red herring, too. The trouble was not imperfections of contrivance, but contrivance itself as an argument for an omnipotent being. Any contrivance, after all, is a particular and limited affair.44 It might be a good thing, as Boyle pointed out, that flies, not being able to move their eyes, have compound eyes to compensate for it. But why make them unable to move their eyes? He left the question between parentheses, where Paley picked it up in its more general form.45

One question may possibly have dwelt in the reader’s mind during the perusal of these observations, namely, Why should not the Deity have given to the animal the faculty of vision at once? Why this circuitous perception, the ministry of so many means; an element provided for the purpose, reflected from opaque substances, refracted through transparent ones; and both according to precise laws, to produce an image upon a membrane communicating with the brain? Wherefore all this? Why make the difficulty in order to surmount it? . . . [C]ould not a simple volition of the Creator have communicated the capacity? Why resort to contrivance, where power is omnipotent? Contrivance, by its very definition and nature, is the refuge of imperfection. To have recourse to expedients, implies difficulty, impediment, restraint, or defect of power.46

Why, indeed, resort to contrivance where power is omnipotent? Paley’s best answer to this difficulty was to suggest that only by means of contrivances could the Deity make known to his rational creatures his existence, agency, and wisdom. Thus, although “Whatever is done, God could have done without intervention of instruments or means,” nevertheless he

has been pleased to prescribe limits to his own power, and to work his ends within those limits . . . [I]t is as though one Being should have fixed certain rules; and if we may so speak, provided certain materials; and, afterwards, have committed to another Being, out of these materials,

44 For Hume’s case against the argument from design, see David Hume, An Enquiry Concerning Human Understanding (London, 1748), sec. XI; Hume, Dialogues Concerning Natural Religion (London, 1779); and J. C. A. Gaskin, “Hume on Religion,” in David Fate Norton, ed., The Cambridge Companion to Hume (Cambridge, 1993), 313–344. Despite the current consensus among philosophers that Hume’s argument was devastating, it was not received as such at the time; witness the success of Paley’s book a generation later. On the fortunes of Hume’s argument against the argument from design, see Andrew Pyle, Hume’s Dialogues Concerning Natural Religion: A Reader’s Guide (London, 2006), 136: “The lack of impact of Hume’s Dialogues in early nineteenth-century Britain is very clear from the immense popularity of Paley’s Natural Theology (1802).” See also J. C. A. Gaskin, “Introduction,” in Hume, Principal Writings on Religion: Including “Dialogues Concerning Natural Religion” and “The Natural History of Religion” (Oxford, 1993), ix–x: “William Paley’s Evidences of Christianity (1794) and Natural Theology (1802) had in effect been refuted by Hume in the Dialogues (1779) and elsewhere before they were even written; but Paley, not Hume, was the standard reading on religion for students throughout the nineteenth century and into the twentieth. Even when the balance changed in Hume’s favour, under the influence of Logical Positivism in the 1930’s and philosophical analysis in the post-war decades, the fashion was still to discuss a single argument or section of Hume’s work in isolation from the rest.”
45 Boyle, A Disquisition about the Final Causes of Natural Things, 55.
46 Paley, Natural Theology, 443.
and in subordination to these rules, the task of drawing forth a creation: a supposition which evidently leaves room, and induces indeed a necessity for contrivance. Nay, there may be many such agents, and many ranks of these.47

Just look where we have suddenly arrived, and how we got here! It was the logic not of natural selection but of the argument from design that led to this startling turn of events, in which the single, omnipotent Engineer whose existence has been being irrefutably demonstrated abruptly gives way to legions of anonymous and limited agents.

Meanwhile, Darwin, who famously renounced the idea of a good and all-powerful God, conjured, in his very rejection of the argument from design, a Creator infinitely more awesome than Paley's Optician.48 “It is scarcely possible to avoid comparing the eye to a telescope,” Darwin confessed.

We know that this instrument has been perfected by the long-continued efforts of the highest human intellects; and we naturally infer that the eye has been formed by a somewhat analogous process. But may not this inference be presumptuous? Have we any right to assume that the Creator works by intellectual powers like those of man? If we must compare the eye to an optical instrument, we ought in imagination to take a thick layer of transparent tissue, with a nerve sensitive to light beneath, and then suppose every part of this layer to be continually changing slowly in density, so as to separate into layers of different densities and thicknesses, placed at different distances from each other, and with the surfaces of each layer slowly changing in form. Further we must suppose that there is a power always intently watching each slight accidental alteration in the transparent layers; and carefully selecting each alteration which, under varied circumstances, may in any way, or in any degree, tend to produce a distincter image. We must suppose each new state of the instrument to be multiplied by the million, and each to be preserved till a better be produced, and then the old ones to be destroyed . . . Let this process go on for millions on millions of years; and during each year on millions of individuals of many kinds; and may we not believe that a living optical instrument might thus be formed as superior to one of glass, as the works of the Creator are to those of man?49

Consider the contrast between Paley's utterly accessible, knowable Engineer and the inscrutable, boundless, eternal power that Darwin describes in this passage.

The eye, however, still retained its transcendent superiority. It was not Darwin but Hermann von Helmholtz who gave the eye its decisive demotion. In his monumental study of the physiology of vision the Handbuch der Physiologischen Optik (1867), and in his philosophical and popular writing, Helmholtz insisted that the eye was anything but superior. It was, in fact, quite a lousy instrument, riddled with aberrations and blind spots.

To begin with, our vision is accurate over only a very small part of the visual field, corresponding to the fovea or pit of the retina, where the cones are packed most tightly, “so that the image we receive by the eye is like a picture, minutely and elaborately finished in the centre, but only roughly sketched in at the borders.” Moreover,

47 Ibid.
48 “I cannot persuade myself that a beneficent and omnipotent God would have designedly created the Ichneumonidae with the express intention of their feeding within the living bodies of caterpillars, or that a cat should play with mice.” C. R. Darwin to Asa Gray, May 22, 1860, DCP, Letter 2814.
the point of clearest vision is less sensitive to weak light than the other parts, a fact with which astronomers were familiar, having found that they could perceive faint stars better in their peripheral vision (where, of course, they could see them least distinctly). Next, look at a street lamp through a violet glass, Helmholtz advised, and you will see a red flame surrounded by a bluish halo, the “dispersive image of the flame thrown by its blue and violet light.” Such halos constitute “simple and complete proof of the fact of chromatic aberration in the eye.”

The cornea is not a perfectly symmetrical curve, which leads to astigmatisms of varying degrees. Stars look star-shaped because the fibers of the crystalline lens are arranged around six diverging axes, “so that the rays we see around stars and other distant lights are images of the radiated structure of our lens.” Dark objects are hard to see next to bright ones because the cornea and crystalline lens are not clear but rather a dingy whitish color, endowing bright objects with a halo that obscures darker ones nearby. The lens is also full of “entoptic objects”—fibers and spots—which you can see when you look at a bright surface. There are also fibers, corpuscles, and folds of membrane that move about with the motions of the eye and become visible when they come close over the retina. In addition to the retinal blind spot, there are plenty of other, smaller gaps in the visual field caused by the blood vessels of the retina. These are small, to be sure, but still big enough for an astronomer to lose a fixed star in one. In short, the eye “has every possible defect that can be found in an optical instrument, and even some which are peculiar to itself.” Helmholtz concluded cheerfully, “Now, it is not too much to say that if an optician wanted to sell me an instrument which had all these defects, I should think myself quite justified in blaming his carelessness in the strongest terms, and giving him back his instrument.”

The marvel, Helmholtz argued, is that creatures are able to see smoothly despite such a faulty apparatus. In this fact—that the eye is as good as it needs to be and no better—Helmholtz found support for Darwin. He also found that one needed to bring perception back into the conversation. Vision transcends the limits of the eye, Helmholtz argued, not thanks to any divine artificer, but because of the mental processes that accompany and crucially help to constitute vision: the very processes of perception that natural theologians had ruled out of bounds, having fully outsourced all that was not mechanical in nature and physiology. The “extraordinary value [of the eye] depends upon the way in which we use it: its perfection is practical, not absolute.” Directing our attention here and there, we overcome every impediment—an inverted retinal image, aberrations, blind spots, entoptic objects, poor peripheral vision—to form a smooth picture of the world. And we do this, Helmholtz argued, by a continual, unconscious process of inductive inference. In short, we see by thinking.

51 Ibid., 140–143, 147.
52 Ibid., 141.
But that is a story for another day. To end where we began, the eye troubled Darwin when he regarded it purely as a mechanism. Viewed in strictly mechanical terms, it seemed irresistibly to imply a Maker. But when he restored to the picture that crucial part of the rudimentary, nascent eye that already differentiated it from any telescope, the “nerve sensitive to light” waiting beneath the thick layer of transparent tissue, he was back on firm ground, able to explain the eye as a product of natural selection. In this apparent contradiction lies a lesson regarding the earlier development of machine-like models of life during the seventeenth and eighteenth centuries, and also regarding Darwin’s relation to these models. The most insistently reductive, device-like models of living creatures—models that left their unmistakable mark on Darwinism—relied upon a theology, a supernatural power to provide meaning and purpose.

Thus there was a central irony in the development of mechanist theories of life and the artifactual models of living beings to which they gave rise. The authors of these models, including natural theologians of Paley’s tradition, proponents of arguments from design, insisted upon the distinction between God and his handiwork. They saw this insistence as important on both sides of the matter: crucial to the autonomy of the New Science as well as the source of a new, powerful kind of argument for God’s existence. But precisely by removing God so starkly from his creation, as G. W. Leibniz warned with increasing vehemence, such new philosophers permeated their ostensibly autonomous science with a pervasive appeal to a supernatural power.

Meanwhile, the first evolutionary images of life came at the hands of people such as Leibniz, Julien Offray de La Mettrie, Denis Diderot, David Hume, and Jean-Baptiste Lamarck, all of whom rejected the idea of nature as passive mechanism and the accompanying argument from design. In the next generation, those seeking a

54 See, for example, G. W. Leibniz, “Postscript of a Letter to Basnage de Beauval” (1696), in Roger Ariew and Daniel Garber, eds., Leibniz: Philosophical Essays (Indianapolis, 1989), 147–149, 147; Leibniz, “From the Letters to Clarke” (1715–1716), ibid., 320–346, 344; and Leibniz, Against Barbaric Physics: Toward a Philosophy of What There Actually Is and Against the Revival of the Qualities of the Scholastics and Chimerical Intelligences (1710–1716?), ibid., 312–320, 318–319.

55 For Leibniz’s descriptions of living nature as in a perpetual state of flux, of waxing and waning, development and growth, envelopment and diminution, see G. W. Leibniz, Principes de la philosophie [Monadologie] (1714), in Leibniz, Principes de la nature et de la grâce: Monadologie et autres textes, 1703–1716, ed. Christiane Frémont (Paris, 1996), esp. pars. 71, 73, 76, 82. La Mettrie described an essentially active sort of living mechanism in L’homme-machine (1747). Here and in Système d’Épicure (1750), he surmised that animals transformed gradually over indefinitely many generations through a process of trial and error. For Diderot’s Starkly non-progressive and contingent picture of species change over time, see Denis Diderot, Le rêve de d’Alembert (1769), in Diderot, Mémoires, correspondance et ouvrages inédits de Diderot, 4 vols. (Paris, 1830), 4: 160–239. Hume wrote: “The world plainly resembles an animal or a vegetable, more than it does a watch or a knitting loom. Its cause, therefore, is more probable, resembles the cause of the former. The cause of the former is generation or vegetation. The cause, therefore, of the world, we may infer to be something similar or analogous to generation or vegetation.” Hume, Dialogues Concerning Natural Religion, 131. In Lamarck’s view, God was only indirectly the creator of the observable world, acting through the intermediary force of nature itself. And nature, Lamarck judged, was “certainly not a reasonable being,” but rather a “blind power, everywhere limited and constrained.” To attribute “an intention, a goal, a determination in its acts” to such a power was utterly mistaken. See Jean-Baptiste Lamarck, Système analytique des connaissances positives de l’homme: Réseintes à celles qui proviennent directement ou indirectement de l’observation (Paris, 1830), 9–10, 12, 33. On the opposition between Lamarckism and the natural theology of Paley’s tradition, see Ernst Mayr, “Lamarck Revisited,” in Mayr, Evolution and the Diversity of Life: Selected Essays (Cambridge, 1997), 222–250; Ludmilla Jordanova, “Nature’s Powers: A Reading of Lamarck’s Distinction between Creation
newly secular mode of understanding, notably Darwin and Helmholtz, worked to naturalize agency and order rather than outsourcing these to an extra-natural Engineer. Accordingly, even as they adopted the notions of design and adaptation, they also turned away from the strictly device-like approach of the design-school natural theologians—the word “machine” appears not once in the first edition of *On the Origin of Species*—and so away from timeless perfection. Helmholtz did away with the perfect eye, but he restored, in an important sense, the (human) miracle of perception. Ironically, in other words, those who most reductively rendered creatures as machines were the ones who believed in a divine Mechanic, while the secularizers invited something else, some extra-mechanical element, back in.

And yet Paley’s artisan deity, as we well know, did not quite disappear. Instead, the divine Optician assumed a liminal position in the age of evolutionism: too connected with particular contrivances to be the full-fledged God of old, yet too ingrained in the development of the machine-like physiological model from which Darwinism departed to be well and truly gone.

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56 I am grateful to Robert Richards for pointing this out to me. The word “machinery” does appear once, and relevantly, this appearance occurs in a passage in which Darwin attributes agency to “Nature”: “She can act on every internal organ, on every shade of constitutional difference, on the whole machinery of life.” Darwin, *On the Origin of Species*, 82. Machinery implies a mechanic. Such passages are in tension with others, for example on 102, where Darwin characterizes natural selection as “unconscious.”