Descartes' Physiological Method: Position, Principles, Examples *

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When Descartes wrote as a biologist—especially in his *Treatise of Man* (1632)[1] and his *Description of the Human Body* (circa 1648) †[2]—what questions was he trying to answer? How much—and what—did he accept as (a) *already factually established,* but (b) *still needing to be explained?* What axioms

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†Abbreviations used in the notes:

AT Charles Adam and Paul Tannery, *Oeuvres de Descartes* (Paris: Cerf, 1897–1910 [republ., 1956–7, and 1964–7]), cited by volume and page.

K C. G. Kühn, *Medicorum graecorum quae exstant* (Leipzig: Knobloch, 1821–1833), cited by volume and page.

1. Written in French in 1632. First published posthumously in a Latin transl. by F. Schuyl, *De Homine Figuris et Latinitate Donatus* (Leyden: apud P. Leffen & F. Moyardum, 1662). Original publ. later, *L'Homme de René Descartes* [*et un Traitté de la formation du foetus du mesme auteur,* see below, note 2] *avec les Remarques de Louys de la Forge, . . .* (Paris: Angot, 1664), AT 11:119–202.

Note on the terms *biology, biological, biologist.* Objections are sometimes raised to the anachronistic application of these terms to events or persons that antedated the introduction of the terms themselves. But this objection seems narrow. From Greek times, science has investigated the conditions and varied manifestations of life in general, and from this point of view it seems permissible to think of Aristotle—and Descartes—as biologists, and of their endeavors as biological.

2. "La Description du corps humain" (alternate title "De la formation du foetus"), first publ. jointly with "L'Homme de René Descartes" (see above, n. 1), AT 11:223–290.

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and assumptions chiefly governed his explanatory procedures? What were, in effect, his interpretive methods and goals?

It is not easy to find, in the secondary literature on Descartes, satisfactory answers to these questions. His biology has been on the whole rather sparingly studied by scholars. Sebba's bibliography (1964),[3] which covers the period 1800 to 1960, lists only a handful of titles on this subject. The two best of these deal critically, one of them—extremely well—with Descartes' physiological theories (Georges-Berthier, 1914, 1920-21) and the other—usefully but less well—with his biomedical ideas (Dreyfus-Le Foyer, 1937).[4] More recently, A. C. Crombie has analyzed the epistemological posture of Descartes as well as his contributions to physiological optics (for example, Descartes was the first to insist that the lens changes shape according to the distance of the object). Finally, L. Chauvois has monographed Cartesian physiology (mostly its weaknesses) as presented in the Fifth Part of the *Discourse on Method* and K. E. Rothschuh has provided important new insights on the historical setting and sources of *Man* and *Description of the Body* in his just published German translations of those works.[5] The present paper will differ from those mentioned in focusing sharply on *three physiological topics* selected to illustrate (a)

3. Gregor Sebba, *Bibliographia Cartesiana* (The Hague: Nijhoff, 1964).

4. A. Georges-Berthier, "Le Mécanisme Cartésien, et la physiologie au 17e siècle," *Isis* 2 (1914), 37–89; 3 (1920), 21–58. H. Dreyfus-Le Foyer, "Les conceptions médicales de Descartes," *Revue de métaphysique et de morale*, 44 (1937), 237–286. See also P. Mesnard, "L'Esprit de la physiologie cartésienne," *Archives de philosophie*, 13 (1937), 181–220. The longer monograph of B. de Saint-Germain, *Descartes considéré comme physiologiste et comme médecin* (Paris: Masson, 1869), is reportorial and not helpful from an interpretive point of view. There are useful materials on Descartes' biology in J. Roger, *Les Sciences de la vie dans la pensée française du XVIIIe siècle* (Paris: Colin, 1963). See also the commentaries on the "Fifth Part" of the *Discourse on Method* by E. Gilson, *R. D., Discours . . . texte et commentaire* (Paris, Librairie Philosophique, 1939), pp. 293–348, and K. E. Rothschuh on D.'s biological theories in his *Physiologie . . . vom 16. bis 19. Jahrhundert* (Freiburg: Albert, 1968), pp. 111–115.

5. A. C. Crombie, "Descartes," *Scientific American, 201* (1959), 160–173; also "Some aspects of D.'s attitude to hypothesis and experiment," *Collection des travaux de l'Académie d'Histoire des Sciences* (Florence: Bruschi, 1960), pp. 192–201; and "The mechanistic hypothesis and the scientific study of vision, etc." in S. Bradbury and G. L'E. Turner (eds.) *Historical Aspects of Microscopy* (Cambridge, Eng.: W. Heffer for the Royal Microscopical Society, 1967), esp. pp. 66–112. L. Chauvois, *D.: Sa méthode et ses erreurs en physiologie* (Paris: Éditions du Cèdre, 1966). K. E. Rothschuh, Über den Menschen . . . (Heidelberg: Lambert Schneider, 1969). See, also, Rothschuh's "R. D. und die Theorie der Lebenserscheinungen," *Sudhoff's Archiv* 50 (1966) 25–47.

the *kinds of sources* used by Descartes and (b) his *detailed explanatory method.* But, first, a suggestion concerning the position of Descartes in biomedical history.

Does the relative neglect of his biology imply a general disregard for its merits? Georges-Berthier has sampled three centuries of opinion on this subject and has found that estimates vary. One can read that as a biologist Descartes "blazed new trails on which, however, he then went astray" (La Mettrie, 1745).[6] And, in another century, that what he built was a "physiology of fancy, almost entirely imagined" (Bernard, 1872).[7] But one may also read that it was Descartes who "founded biology, by first explaining life in a scientific, naturalistic way" (Lemoine, 1862).[8] And that he "laid the foundations of modern physiology—just as he did of modern physics" (Fouillée, 1893).[9] A negative judgment, acceptable even though not wholly documented, is put forward by Dreyfus-Le Foyer—namely, that Descartes' biological essays are marked by "inadequate rigor in regard to verification, inordinate rigor in regard to explanation," and that *"C'est pour lui [Descartes], l'essentiel n'est pas de constater juste mais de 'rendre compte.'"* [10] Georges-Berthier concluded that the biological effort of Descartes was *scientifically unsuccessful* (its premises were not new, its conclusions not accepted) but *philosophically sound* (it sought a common method for science as a whole, biology included). Whatever position we adopt on these questions, it seems worthwhile, for three reasons, to examine Descartes' analytical method.

First, more consciously and clearly than any contemporary thinker, he articulated the crucial biological question of the day. The point at issue was *the nature of the latent cause, or causes, of the patent phenomena of life.* Were these causes essentially *psychic* (as almost all earlier biologists had believed) or, rather, *physical* (as Descartes quite strongly affirmed)? Some historical notes on this question are contained below, in section one.

Second, without succeeding admirably himself (because his

6. J. O. de LaMettrie, "Histoire naturelle de l'âme," first publ., The Hague, 1745, *Oeuvres philosophiques* (Amsterdam, 1753), 1, 24; see also the translation by C. G. Bussey et al., of extracts only, published with *Man a Machine . . .* (Chicago: Open Court, 1912), p. 158.

7. Claude Bernard, *Leçons de pathologie expérimentale . . .* (Paris: Baillière, 1872), p. 481.

8. [Jacques] Albert [Felix] Lemoine, *L'Ame et le corps: études de philosophie morale et naturelle* (Paris: Didier, 1862), p. 206.

9. A. J. E. Fouillée, *Descartes* (Paris: Hachette, 1893), p. 65.

10. Dreyfus-Le Foyer, n. 5 above, p. 261.

method was too deductive), Descartes clearly showed what the future goal of physiology must be, namely, the construction of conceptual micromodels to "explain" life as it presents itself to the senses. This form of reductive analysis was not new to biology, but it had scarcely been undertaken earlier on nonpsychistic assumptions (however, for certain exceptions to this statement, see below).[11]

Third, by limiting soul-functions to mind-functions, and by insisting rigorously on the distinction between mind (*res cogitans*) and body (*res extensa*),[12] Descartes gave a special cast to the mind-body problem and largely laid down the lines along which physiological psychology, and psychology in general, were thereafter developed and debated. This aspect of his influence will be treated in this paper only in that one of our three examples will be of a neurophysiological nature.

I. NONPSYCHISTIC BIOLOGY

Historians have often noted but not always sufficiently stressed one of the central facts of the conceptual revolution that overtook biology during the seventeenth century—namely, the effective (though by no means immediate or total) overthrow of putative *psychic* causes of *physiological* function. The most persistently influential Greek thinkers (Plato, Aristotle, Galen) had attributed *life-as-action* (usually *bios, zoe*) to a variously depicted causal *life-soul (psyche)*. This idea, transmitted to Western science by the Arabs, had been elaborated in the Schools and reaffirmed (and altered) by sixteenth-century

11. The most serious approach to a kind of nonpsychistic biology in earlier Western thought had been that of Epicurus, who considered all phenomena of life, including cognition, to result from the proper configuration of immanently inanimate atoms. Yet even Epicurus was an animist in that he supposed that four sorts of small rapidly moving atoms composed the soul, larger and slower atoms the body. However, Epicurus looked on the organism as a diphase system comprising two interlocking networks of atoms—one somatic and the other psychic—neither being able to function adequately in the absence of the other. Thus soul—materialized, to be sure—plays a crucial role in Epicurus's physiological scheme. See, e.g., Lucretius, *De natura rerum*, bk. 2, lines 944–961, and bk. 3, lines 548–557.

12. See esp. René Descartes, *Meditationes de prima philosophia . . .* (Paris: Soly, 1642), the *Third Meditation*. And his *Principia philosophiae*, first publ. in Latin (Amsterdam: Elzevir, 1644) and then in a translation by "un de ses Amis" (Picot), *Les Principes de la philosophie* (Paris: Le Gras, 1647), pt. 1, sects. 8, 53 (AT 8:7, 25 [and 9:28, 48]).

authors, including Fernel (1542, 1554–55),[13] Paré (1561),[14] and Piccolhomini (in a version adapted to church doctrine, 1586),[15] to mention but three.

We usually and rightly think of the mechanization of biology as an extension of the partly antecedent but still continuing "mechanization of the world picture"[16] in general. But it is important to keep before us what "mechanization" entailed. In *cosmology* it had involved, among other things, an incomplete and irregular, but generally progressive, substitution of *physical* for *psychic* (and often transcendental) causes of *celestial* motion. In *biology*—in the seventeenth century—a similar development began, namely, a substitution of physical for psychic (and often transcendental) causes of *vital* motion. Thus the biological revolution partly took the form of a cogent and ultimately decisive assault on the Greek (and Medieval and Renaissance) idea of a causal, physiological soul.

To whom should we chiefly attribute the soulless biology that now began—with many false starts and backslidings—to gather momentum? This question will be considered by the author in a separate paper, but, on partial evidence, a tentative judgment may be offered here.

It is reasonable to think not of one but of three arguments about the cause of vital functions as developing during the seventeenth and early eighteenth centuries. In one of these, with Descartes (from 1637) its principal but not only inceptor,[17] the very existence of the life-soul was questioned. In another, culminating with Stahl (from 1684),[18] the life-

13. Jean Fernel, *De naturali parte medicinae* (Paris: apud S. Colinaeum, 1542); rev. ed. in *Medicina* (Paris, 1554), trans. C. de Saint-Germain, *Les VII Livres de la Physiologie . . .* (Paris: J. Guignard, 1655), of which bk. 5 deals especially with the physiological soul and its several faculties.

14. See Ambroise Paré, *Anatomie universelle* (Paris: Le Royer, 1561), p. cxliv ff; also, "Livre de la generation de l'homme, recueilly des anciens et modernes," *Oeuvres* (Paris: Buon, 1575), pp. 802–850.

15. Archangelo Piccolhomini, *Anatomicae praelectiones* (Rome: Bonfadini, 1586), pp. 11–14.

16. The phrase is adopted from the title of Dijksterhuis' indispensable book on the subject (London: Oxford University Press, 1961, 1964).

17. The automatism question had occurred in various forms in Scholastic thought, and Gomez Pereira had suggested a mechanical conceptual model of man in his *Antoniana Margarita* (Medina del Campo: de Millis, 1554). See, on the unoriginality of Descartes' bioautomatism, Georges-Berthier, n. 4 above, 1914, pp. 80–85.

18. See, e.g., G. E. Stahl, "Medicinae dogmatico-systemicae partis theoreticae sectio I quam constituit physiologia," *Theoria medica vera* (Halle: Orphanotrophei, 1707, 1708), passim but esp. p. 260. For an earlier

soul was affirmed but its mode of intervention was argued. And in a third, the life-soul was acknowledged—but neglected: it was not denied but neither was it used in detailed explanation.

The first of these three debates—over what we may term philosophical mechanicism—did not always pay much attention to body-functions, and, when it did, derived its explanations of them from its answers to larger, axiomatic questions. *Is man, are animals, soulfull—or, are they soulless? If soulfull, how is soul allied to the body? Is its role both physiological and cognitive—or exclusively the latter?* These and related problems continued to be debated for more than a century by Descartes' defenders, developers, and detractors.[19, 20] They were to become central issues of the Enlightenment at least as far as psychology was its concern.

The second—explicitly psychistic—tradition, as embodied in Stahl, was partly a counter-reaction to the mid-seventeenth-century drift away from the life-soul idea. But Stahl's was not a reversion to the conventional (Galenic) idea of different soul-faculties for different physiological functions. He saw the soul as governing, rationally, every detailed operation of the body, and as doing this either consciously and deliberately (his term for this sort of soul function was *ratiocinatio*) or through unconscious but nevertheless rational intervention (*ratio*) at what we should think of as the molecular level.[21] Stahl was not the first to think animistically in other than strictly Greek terms. Something similar to his two-level interpretation of soul-function (*ratio* and *ratiocinatio*) had appeared slightly earlier, for example, in the *Tractatus de Homine* of Honoratus Faber (1677),[22] whose ideas, however, were otherwise still Galenic. Earlier still, there had been van Helmont (d. 1644) with his concept of *mind linked with soul,* both mind and soul holding sway in the pyloric end of the stomach —whence soul governs the body, according to van Helmont,

statement, "De sanguificatione in corpore semel formato," first publ. Jena, 1684, trans. T. Blondin, in *Oeuvres médico-philosophiques de G. E. Stahl* (Paris: Baillière, 1859), 6, 556–562.

19. On medical Cartesianism, see Georges-Berthier, n. 4 above, 1920, pp. 23, 29.

20. See, on the philosophic consequences of Cartesian physiology, A. Vartanian, *Diderot and Descartes* (Princeton, N.J.: Princeton University Press, 1953), esp. ch. 4; and L. C. Rosenfield, *From Beast-Machine to Man-Machine* (New York: Oxford University Press, 1940).

21. See esp. G. E. Stahl, *Propempticon inaugurale de differentia rationis et ratiocinationis* (Halle, 1701).

22. H. Faber, "de Homine," *Tractatus duo . . .* (Nuremberg: sumpt. Endteri, 1677).

through the intermediation of a hierarchy of directive "archei." [23]

The third argumentative tradition engaged many of the experimentally—and in some cases quantitatively—oriented biologists on whom we usually think of the real progress of physiology as depending. They occupied a variety of conceptual positions between the outright mechanicism of Descartes and the equally explicit animism of Stahl. Some—among them Gassendi (before 1655)[24] and Thomas Willis (1672)[25]—not only acknowledged but "materialized" the life-soul; they gave it a corpuscular constitution. Others were less definite; they admitted the life-soul's existence, but used it rarely in their explicative procedures; this was true, for example, of Harvey (1651),[26] Hooke (1665),[27] Mayow (1674),[28] and Borelli (be-

23. J. B. van Helmont, "Sedes animae," and "Jus duumviratus," short treatises first publ. posth. in *Ortus medicinae* (Amsterdam: Elzevir, 1848).

24. Gassendi's position was a blend of Epicurean, neo-Platonic, Aristotelian, and ecclesiastic elements, involving a corporeal, *mortal* (in these respects Epicurean) *nutrient-sentient* soul that animals share with men, and a separate incorporeal *rational soul* (a Platonic and, incidentally, Cartesian conception) which is *immortal* (as denied by Epicurus but demanded by ecclesiastic Aristotelianism). See P. Gassendi, 'Liber tertius: De anima,' "Physicae: sectio tertia," Syntagma Philosophicum, first publ. posth. in *Opera omnia* . . . (Leyden: Anisson & Devenet, 1658); republ. in facs. (Stuttgart-Bad Cannstart: Frommann, 1964), II, 250–259.

25. Willis adopted a five-element chemistry (spirit, sulphur, salt, water, earth) and saw the corporeal soul-particles as based on the first two of these elements. The soul has three parts, vital (equated with vital spirits), animal (equated with animal spirits), and genital (an abstract of the other two); see T. Willis, *De anima brutorum* . . . first publ. London, 1672, trans. S. Pordage, "Two Discourses Concerning the Soul of Brutes," (= Treatise XI in) *Dr. Willis' Practice of Physick* . . . (London: Bassett and Crooke, 1684), pp. 4, 6–7, 39.

26. Harvey makes blood "the generative part, the fountain of life, the first to live, the last to die, and the primary seat of the soul." See William Harvey, *Exercitationes de Generatione Animalium,* first publ. London, 1651, trans. R. Willis, *The Works of William Harvey, M.D.* (London: Sydenham Society, 1847), p. 377.

27. Hooke mentions (apparently only once) "an *anima* or *forma informans* that does contrive all the Structures and Mechanismes of the constituting body, to make them subservient to the great Work or Function they are to perform." *Micrographia* (London: Martyn & Allestry, 1665), p. 95.

28. Mayow disagreed with Willis who (see above, n. 25) "corpuscularized" the soul; Mayow saw the "nitroaerial" corpuscles as vehicles for an immaterial soul associated with the soul of the cosmos. See John Mayow, *Tractatus quinque medico-physici* . . . (Oxford: Sheldonian Theater, 1674); trans. A. C. Brown and L. Dobbin, *Medico-physical Works* . . . (Edinburgh: Alembic Club, 1907), p. 259. For the influence of Descartes on Mayow, see W. Böhm, "John Mayow und Descartes," *Sudhoffs Archiv für Geschichte der Medizin und der Naturwissenschaften,* 46 (1962), 45–68.

fore 1680).[29] Finally, many made no open issue of the life-soul problem, passing it over for the most part in silence; this group included Steno (1669),[30] Redi (1688),[31] Keill (1698),[32] and Baglivi (1700, 1703)[33] as well as later "iatromechanists" ranging in their methods from the highly speculative Boerhaave (1708)[34] to Stephen Hales, who was capable of cautious, quantitative experimentation (from 1727).

The story of the decline of *psychistic biology* must be sought in the evolution and mutual accommodation of the *two mechanistic biologies* just mentioned—one philosophical (which undermined the life-soul idea by open opposition), the other scientific (which undermined it by progressive inattention). The influence of Descartes on the former—the philosophical—tradition is apparent enough. His scientific influence is more difficult to assess.

29. According to Borelli, the soul "as principle and as efficient cause of animal movements" was that "through which the animate live (*animantia per animam vivant*)," but he rarely mentioned the soul in his explanations of function; see G. Borelli, *De Motu Animalium*, first publ. posth. Rome, 1680–81; 2nd ed. (Leyden: vander Aa, 1865), pt. 1, ch. 1, pp. 1–4.

30. Steno praises the endeavor of Descartes, but disagrees with his scientific results; see N. Steno, "Discours sur l'anatomie du cerveau," first publ. Paris: Ninville, 1669, *Opera Philosophica* (Copenhagen: Tryde for Carlsberg Foundation, 1910), 2, 7–12; in a rare allusion to the individual soul, he dismisses it from his interpretive scheme, "De solido intra solidum naturaliter contento," first publ. Florence, 1669, *Opera*, 2, 188–189.

31. See, e.g., F. Redi, "Esperienze intorno alla generazione degl'insetti," first publ. Florence, 1688, *Opere* (Milan: Soc. Tipogr. de' classici Italiana, 1809–11), 3, 13ff.

32. See J. Keill, *Anatomy of the Humane Body*, abridged, first publ. London, 1698; many subsequent editions.

33. Without singling out the physiological life-soul in particular, Baglivi attacks ancient assumptions and urges mechanistic and micromechanistic analytical procedures. He mentions favorably, but does not develop, Descartes' solutions of the mind-body problem. See the introductory chapters in G. Baglivi, *Specimen quatuor liborum de fibra motrice et morbosa* (London and Basel: Konig, 1703).

34. Georges-Berthier (above, n. 4) says Boerhaave got his physics from Newton rather than Descartes; and indeed Boerhaave was sometimes critical of Descartes (see J. Roger, n. 5 above, p. 150). But Boerhaave's *bio*physics was more Cartesian than Newtonian; like Descartes, he built—largely *deductively*, *nonexperimentally*, and *non-numerically*—an elaborate conceptual micromodel of the patent functions of the body. Boerhaave was Cartesian, likewise, in his view of man as comprising body plus mind. Boerhaave owed much, to be sure, to Baglivi and especially to Harvey (Boerhaave made the body an "hygraulic machine"). See H. Boerhaave, *Institutiones medicae . . .*, many editions from 1708; especially that of von Haller, *Praelectiones academicae . . .* (Amsterdam, 1739–42), trans. anon. Dr. Boerhaave's *Academical Lectures* (London: Innys, 1742–47), 1, 65. On Boerhaave's micromechanics, see T. S. Hall, *Ideas of Life and Matter* (Chicago, Ill.: University of Chicago Press, 1969), ch. 26.

The new physiology was to be—by contrast with the old—experimental, quantitative, reductive, and nonpsychistic. All of this, Descartes quite clearly proclaimed. But was the new physiology really new? What Descartes proclaimed was, to some extent, already in the air. For example, even Vesalius (1543) had adopted, on the life-soul as on so many subjects, an agnostic position. And some of the post-Vesalian anatomists, notably Columbus (1559) and du Laurens (1600), had made little use of soul as an explicative device. Again, Sanctorius' influential *Medicina Statica* (1614) had proceeded mathematically, experimentally, and nonpsychistically in a spirit more modern than anything Descartes himself was later to produce. Thus, Descartes was partly focusing and crystallizing a trend that was already present, if somewhat diffuse. Moreover, his own effort at crystallization, his proposal that the life-soul be given up entirely, was, as just seen, neither promptly nor universally adopted.

But the latter point is not entirely to Descartes' discredit. It may even suggest that he was ahead of his time. The fact is that gradually and unevenly—but irrevocably—the life-soul was destined to disappear (with unimportant exceptions) from the main line of physiological inquiry. Separately, the present author is making a detailed study of late seventeenth-century attitudes toward Descartes' physiological theories. Pending the outcome of that study, it may be suggested that his causal role in biomedical history was illuminative and accelerative rather than inceptive or decisive. He helped the new biology move forward by pinpointing the goals toward which it was already groping.

II. EXPLANATORY PRINCIPLES AND PROCEDURES

Certain broad features of Descartes' biology are familiar to readers of his *Discourse on Method* (1637),[35] which includes a partial paraphrase of the slightly earlier (but only posthumously published) *Treatise of Man*. In the *Discourse*, Descartes sharply separates *life* (which men and animals have in common) from *soul* (only present *sensu stricto* in man). Life is an ensemble of functions that have their kinetic origin in *heat*—specifically a certain "fire without light" that burns, in men and animals, in the heart.

35. *Discours de le methode pour bien conduire la raison, & chercher la verité dans les sciences*, first publ. anon. with *La Dioptrique, les meteores, et la geometrie* (Leyden: Maire, 1637), often republished and translated. AT 6:1–78.

The *feu-sans-lumière* of the heart resembles corpuscularly the sort of lightless fire—or heat—that occurs in various kinds of fermentation.[36] In Descartes' *Treatise of Light,* designed for simultaneous publication with the *Treatise of Man* (and, like it, suppressed), we hear that all invisible (as well as all visible) heat is reducible to the rapid movement of particles —though not indivisible (atomic) particles[37]—of a certain fiery matter that is the first of three elements acknowledged by Descartes.[38] The other two elements are: a second, airy substance (*matière de ciel*) whose particles are somewhat coarser; and a third, or earthy, element whose particles are coarser still. The matter of which the elements are composed is the same for all three, the differences residing in the shapes and sizes of the particles into which this matter is subdivided. The first element composes the sun and fixed stars; the second, the interstellar heavens; the third, the tangible contents of the earth, the planets, and the comets. In tangible bodies, including man's, the interstices between the earthy particles of the third element are occupied by airy particles of the second whose own interstices in turn are completely filled by the fiery particles of the first.[39]

Readers of the *Treatise of Man* and of the *Discourse* are especially made aware that the *soul*—given, by God, exclusively to man[40]—lacks the lower faculties (those permitting

36. AT 6:46. For Descartes on this, see also AT 1:521–534; 4:573; 8:256 (9:250–251); 11:23, 228, 333, 538, 599, 631–632.

37. Descartes placed no lower limit of divisibility on his constitutive corpuscles ("particules," "petites parties"). For references to his explicit objections to Democritean atomism, see E. Gilson, *Index Scolastico-Cartésien,* first publ. Paris, 1912 (New York: Franklin, 1913), p. 31.

38. Specifically, fire entails continuous direct agitation of third-element particles by first-element particles without intermediation of second-element ones. See also Descartes on the same subject in his *Principles,* n. 12 above, AT 8:218, 249–250 (and 9: 215–217).

39. AT 11:23–31. In the *Principles* (1644), Descartes no longer calls the second element airy, because familiar, atmospheric air comprises primarily, in his view, particles of the third or earthy element. Descartes presents his doctrine of matter commencing at pt. 3, sect. 46, AT 8:100 (and 9:124). The characterization of the atmosphere as composed of detached delicate, feather-like particles of the third element also appears in the *Principles,* AT 8:23 (and 9:225–226).

40. On the automatism (which meant above all, for Descartes, soullessness) of animals see esp. the *Discourse* (AT 6:57–60), and letters to Mersenne (AT 3:121), the Marquis de Newcastle (AT 4:573), and Henry More (AT 5:276–279). It is, however, not quite true that Descartes always eliminated the soul from animals. He sometimes acknowledged at least a material equivalent of soul—in one place (letter to Buitendijck, AT 4:64) equating it with blood whose subtlest part separates off in the brain as

generation, nutrition, and unconscious motion) with which the Greeks and many Medieval and early Renaissance thinkers had endowed it.[41] The soul is concerned, according to Descartes, with conscious perception, voluntary motion, and the intellective activities of memory, imagination, and reason.[42]

There is no need to elaborate these widely known aspects of Descartes' biological—and psychobiological—program. Our object, rather, will be: *to show how he used his nonpsychistic, triadic, particulist physics in a reductive explanation of familiar biological function.* For, such explanation was the central core of his entire physiological effort. That such was his goal becomes clear as soon as we read what he wrote (and we shall do this in a moment) about such cardinal physiological problems as (1) assimilation, (2) the initiation of embryonic differentiation, and (3) the receptor action of sensors.

If we pay close attention to Descartes, we find that he used a kind of *strategy of inquiry* which, far from being new with him, had been extensively developed in Greek biomedical science. This classic procedure (which began with the pre-Socratics and culminated, in antiquity, with Galen) proved fruitful—and flexible—enough to be used in all subsequent periods. (Indeed, from a certain point of view it is the strategy still followed by physiologists today). Its cardinal assumption is that the goal of physiological inquiry is to discover the *latent equivalents* of *patent biological function.* It is true of Descartes' pursuit of this goal—and this point is crucial—that neither the *patent phenomena* he interpreted nor the *latent equivalents* he posited were fully original with him; most of the explanations he offered were only partly his own. Indeed, the principal point we wish to make about Descartes' physiological method is that *the explanations he developed were corpuscularized, nonpsychistic versions of psychistic explanations put forth earlier by others* (namely, by the major Greek biological writers, by Scholastic authors whom Descartes is known to have studied,[43] and by a group of Renaissance

animal spirit, and elsewhere arguing that being corporeal, the dog's soul cannot be separated from the body and saved (Letter to Voetius, AT 8:167–168). Thus soul in animals is *res extensa* rather than, as in man, *res cogitans.*

41. AT 6:46, and esp. *Man,* AT 11:202, and *Description of the Body,* AT 11:224–225; see also Descartes to Plempius, AT 1:523, and to Regius, AT 3:369–370 and 371–375.

42. See, esp., Descartes *Passions of the Soul,* first publ. *Les Passions de l'ame* (Paris: Le Gras, 1649), pt. 1, arts. 17–20, AT 11:142–144.

43. Possible Medieval sources of Descartes' world-system are suggested by E. Gilson in his *Index,* n. 37 above.

anatomists whom he rarely mentions in his published works but with whose ideas he was clearly acquainted).[44]

Descartes created a problem for historians by generally omitting any reference to his sources. This omission was in line with his goal of building biology anew, by reasoning logically from certain axioms that seemed inescapably clear. He wished to extend to biology the logic that had served him so well in his mathematical investigations. But, despite this aim of disengagement, we sense, in the examples that follow (and in almost everything he wrote about biology), a thorough immersion in already existing ideas, ideas *within* the context of which, and *not outside* them, his own opinions were developed. We obtain, in consequence, a paradoxical impression: his explanations seem new on the one hand, yet strangely familiar on the other. The paradox is less surprising when we realize that what Descartes had to offer were not *explanations of fact.* They were *explanations, rather, of other peoples' explanations* (often dismembered and reassembled with various additions and deletions).

III. EXAMPLES

The present author will shortly publish English translations of the *Treatise of Man* and the *Description of the Body,* with suggestions concerning the origins of the ideas that Descartes borrowed and inserted into his own interpretive machinery. The following illustrations of his method could be multiplied many times by sampling the texts of the treatises more or less at random.

Example 1: Assimilation of nutriment to the body solids

Descartes' interpretation of assimilation is, in effect, a "cartesianized"—that is, corpuscular and antipsychistic—amalgamation of two already established interpretive traditions. The *first* of these was a classic concept concerning the *central nature of nutrition.* According to this idea, a prime distinction of living systems is their continuous and balanced involvement in material displacement and replacement. Elsewhere, we have considered this idea—of life as opposed transformation—as it appears in pre-Socratic and Hippocratic theories; in Plato, who speaks in the *Timaeus* of the body's emptying (*anachoresis*) and filling (*plerosis*); in Aristotle and Galen; in several Arab authors; in Arnald of Villanova, Paracelsus, and Francis Bacon

44. For biomedical sources of Descartes, see Georges-Berthier, n. 4 above, 1914, pp. 43–44.

(who speaks of "depradation" and "refection"); as well as in a sequence of post-Cartesian theorists up to, and into, the twentieth century. All of these thinkers endeavored to lay bare the *latent equivalents* of *patent intake and output.*[45]

The *second* tradition which Descartes incorporated in his scheme envisioned the body-solids as *composed of subvisible fibers.* Galen, in a reformulation of even earlier ideas about fibers, had given muscle a fibrous microstructure, supposing that within the muscle the terminal subdivisions of nerves combine with the terminal subdivisions of ligaments to form fibers that emerge from the farther end of the muscle as tendons.[46] With the reaffirmation of Galenic doctrine in Europe, variations on the fiber-theme were proposed by many theorists, including such immediately pre-Cartesian authors as Fernel (1542),[47] Vesalius (1543), Jacques Dubois,[48] and Jean Riolan (1610) who extended Fernel's ideas to make fibers the basis of the "whole architecture" of the body.[49]

With respect to assimilation, Descartes thus envisioned his task as one of describing, *in the language of his own corpuscular physics,* how the body's constitutive *fibers* are continuously *displaced and replaced.* He saw the fibers as being *constantly added to* by the arterioles (at the tips of which they arise), and *constantly eroded* (at their free outer ends by friction or evaporation). Descartes had developed his own re-explanation of Harvey's explanation of the circulation,[50] but the idea of a

45. Thomas S. Hall, "Life as Opposed Transformation," *J. Hist. Med. Allied Sci. 20* (1965), 262–275.

46. *De placitis Hippocratis et Platonis,* bk. 1, ch. 9, K 5:204. Galen gave certain viscera a triple muscle-coating of circumferential, longitudinal, and oblique fibers, to account for their various functional capacities.

47. J. Fernel, *Medicina,* see above, n. 13, bk. 7, ch. 10.

48. Jacobius Sylvius (Jacques Dubois), *Introduction sur l'anatomique partie de la phisiologie d'Hippocras & Galien,* trans. J. Guillemin (Paris: Hulpeau, 1555), pp. 43ff.

49. According to A. Berg, "Die Lehre von der Faser als Form- und Funktions-Element der Organismus," *Virchow's Archiv für pathologische Anatomie und Physiologie, 309* (1942), pp. 394ff. This paper details important aspects of the history of fiber-theory.

50. Blood is volatilized by the heat of the heart, and the resulting expansion induces diastole: *Man,* AT 11, from 123; *Description of the Body,* AT 11, from 228; *Discourse,* AT 6, 48–49; letters to Plempius, AT 1:521–534, and Beverwijck, AT 4:3–6. Harvey thought the innate heat of the blood caused it to swell in the auricles, causing them first to dilate and then contract in response, driving the blood into the ventricles where a similar cycle of dilation and contraction occurs. The swelling of the blood is reminiscent of, but is not in fact, fermentation, in Harvey's opinion. See W. Harvey, "A second disquisition to John Riolan . . . ," first publ. Cambridge, 1649, *Works,* n. 23 above, pp. 132, 140–141.

closed capillary connection between the arteries and veins had not been introduced at this time;[51] hence, there was nothing to prevent the tips of the arterioles from giving rise to fibers. Listen to Descartes himself on the subject:

> For, at the moment when the arteries are inflated [by the pulse],[52] the blood particles they contain will here and there strike the roots of certain fibers which—emanating from the ends of the branchlets of the arteries—compose the bones, flesh, membranes, nerves, and brain, and the rest of the solid parts according to the different ways in which they are joined or interlaced. They [the escaping particles] thus have force enough to push [the fibers] before them slightly, and so to replace them. Then, at the moment when the arteries are disinflated, each such particle stops where it is and is united, by that fact alone, to the particles [of the fiber] it touches, in accordance with what was said heretofore.
>
> Now if it is the body of a child that our machine represents, its matter will be so tender and its pores so easily stretched, that the part[icle]s of the blood which enter thus into the composition of its solid members will generally be a little coarser than those whose places they take, or it will even happen that two or three together will replace a single one, which will be the cause of its growth. However, the matter of its members will harden little by little so that after a few years its pores will no longer be able to stretch so much; and so, ceasing to grow, it will represent the body of an older man.[53]

In unpublished notes inspired by his own experience in the dissecting room, Descartes distinguished between appositive and immutative [intussusceptive] accretion (a dichotomy not original with him);[54] the picture just drawn is his own reduc-

51. Harvey thought that the blood percolated through pores or channels in the tissues; see esp. his *Exercitatio de motu cordis et sanguinis in animalibus* (Frankfurt: sumpt. Fitzeri, 1628), ch. 7.

52. Descartes did not have the idea of a pulse wave but of a simultaneous enlargement of all arteries synchronized with the forced diastole of the heart. AT 11:125.

53. *Man*, AT 11:126–127.

54. For Descartes on this, see *Anatomica quaedam ex M^to^ Cartesii* (a manuscript from the hand of Leibniz), first publ. in *Oeuvres inédites de Descartes* (Paris, 1859–60), AT 11:596–598. See also Galen, *De naturalibus facultatibus* K 2:82. Also, for a possible Scholastic source of Descartes on this concept, Gilson, *Index*, n. 37 above, art. 508, p. 333.

tive interpretation of immutation (as far as the body-solids are concerned). Incidentally, the idea of maturation, of aging, as a process of gradual hardening and drying was also pre-Cartesian. Aristotle had said that "the matter of which bodies are composed among the living consists of hot and cold, dry and moist. But as they grow old they must dry up."[55] Galen said that "that which all men commonly call old age is the dry and the cold constitution of the body."[56] During the early Renaissance, the idea was common that the body's innate or "radical humour," being—unlike the other parts—irreplaceable, gradually dries up. Thus Paré (1575): "Now in old age men are cold and dry . . . [because of] the consumption of the radical or substantific humour proceeding from the multitude of years."[57] For Fernel, a body engendered of blood and semen must begin by being hot and wet. Weighing whether maturation is primarily a cooling or a drying process, he decided that both are involved.[58]

In Descartes' later *Description of the Human Body* (written 1648), he altered his model of fiber formation somewhat and made the fibers emerge from pores along the arterial walls instead of at the tips. He specified how they are eroded at their free outer ends. He also, in the later treatise, stipulated that particles of the first and second elements flow alongside the fibers, encouraging the continual outward movement of each from its arterial base.[59] To sum up, what Descartes advances in connection with assimilation is an eclectic, reductive restatement of classical ideas, adapted to fit his own cosmological and physical doctrine.

Example 2: Initiation of differentiative development

We hear about generation, from Descartes, in some of his letters as well as in disconnected posthumous fragments and especially in the *Description of the Human Body*. Studies of generation had dealt, traditionally, with certain recurrent questions. What is the constitution of the seed-stuff, or germ? Where and how does it arise in the bodies of the parents? Do both father and mother contribute something to the offspring?

55. Aristotle, *De longitudine et brevitate vitae*, trans. W. S. Hett, *On Length and Shortness of Life* (Loeb Classical Library Series, Cambridge, Mass.: Harvard University Press, and London: Heinemann, 1935), 466a20ff.

56. Galen, *De sanitate tuenda*, trans. R. M. Green, *Galen's Hygiene* (Springfield, Ill.: Thomas, 1951), bk. 5, ch. 9.

57. A. Paré, *Oeuvres*, n. 14 above, bk. 1, ch. 9.

58. Jean Fernel, *Physiologie*, n. 13 above, bk. 3, ch. 10.

59. AT 11:245–250.

If so, is the contribution of both sexes the same? What triggers the beginning of development? Through what subsequent events and in what sort of sequence does the organism acquire and mature each organ? This way of resolving the general problem into subproblems had been charted by Greek biomedical theorists and variously elaborated in Medieval and early Renaissance science.

Descartes addressed himself to some—but only some—of the classic subproblems into which the general problem of generation had been resolved by earlier thinkers. Though influenced, here as elsewhere, by a mixture of past and prevailing ideas, he perhaps came nearer on this than on other biological subjects to a theory distinctly his own. Assume three elements, he argues, differing only in the shapes and sizes and motions of the particles they comprise. And assume these particles to be subject to orderly varieties of mechanical interaction. How account, on the basis of these assumptions, for the sequential appearance—commencing with an undifferentiated initiative substance—of: first, the future left ventricle of the heart; next, the future aorta with its primary branches the carotids and spermatics; then, related to the foregoing, the rudiments of the brain and genitalia; then, in relation to the brain, the sensory nerves and sense organs; also, at about the same time, certain major arteries (and their branches) and veins (and their branches); and, finally, the fibrous micro-units that constitute the solid organs? Note, in the following example, how Descartes sees the process as beginning and how he gives it a typically Cartesian, corpuscular interpretation.

> I assert nothing definite touching the shape and arrangement of the particles of the seed. Suffice it to say that the *seed of plants,* being solid and hard, may have its parts arranged and situated in a definite way which could not be altered without their being rendered ineffective. But it is not the same with the *seed of animals,* which, being very fluid and ordinarily produced by the coming together of the sexes, seems to be only a mixture compounded of two liquors which, serving each as a ferment to the other, are so heated that some of the particles, acquiring the same agitation that fire has, move apart and press against others, and by this means gradually arrange the latter in the way required to form the members [of the body].[60]

The foregoing introduction to the subject of generation is

60. AT 11:253.

partly an echo of pre-Cartesian opinion. The Greeks had transmitted three speculations, or streams of speculation, about the seminal substance. Either

(1) two similar—or equally important—seminal substances are involved, one supplied by each parent; or
(2) a single substance is needed, and this is supplied by the father; or
(3) two different substances are supplied: semen by the father and blood (or blood and female semen) by the mother.[61]

The *two-semina* theory appeared, pre-Platonically, in the writings of Democritus (probably)[62] and in the Hippocratic treatise *On Regimen.*[63] The idea of a *single-seed stuff* was taken over from Alcmaeon by Plato, whose "panspermia" (also "marrow," *myelos*) is depicted as descending from the brain, by way of the spinal canal, to the urethra for transfer to the "plowed soil" of the womb.[64] Plato gives this idea a rather cryptic formulation; it had a number of Medieval and Renaissance revivals.[65]

61. For a rather different classification of ancient ideas on the seed-stuff, see Erna Lesky, 'Der enkephalomyogene Samenlehre,' "Die Zeugungs-und Vererbungslehren der Antike und ihr Nachwirken," *Abhandlungen der geistes- und sozialwissenschaftlichen Klasse,* Akademie der Wissenschaften und der Literatur in Mainz (Wiesbaden, 1950), pp. 1233–1254.

62. As reported by Aristotle, *De generatione animalium,* 721b6–722a2; see also Hermann Diels, *Die Fragmente der Vorsokratiker, 7th ed.,* edited with additions by W. Kranz (= a photographic repr. of the 5th ed.), Berlin: Weidmann, 1954, 68 A 41 and B 32.

63. "On Regimen," *Hippocrates,* trans. W. H. S. Jones (Loeb Classical Library Series, Cambridge, Mass.: Harvard University Press, and London: Heinemann, 1931), vol. 4, bk. 1; the theory is contained, also, in the two treatises (which Littré combines into one) "On Generation" and "On the Nature of the Child," *Oeuvres complètes de Hippocrates,* ed. Littré (Paris: Baillière, 1851), 7, 470–543.

64. Plato, *Timaeus,* 90E – 91D. A similar idea appears in the Hippocratic treatise "On Generation," see above, n. 63, pp. 472–473, but, there, it is in both sexes that seminal substances descend from the head, via the spine, to the genitalia. The metaphor of the womb as a field was a commonplace thereafter until *ca.* 1700.

65. One of the famous coition-figures of Leonardo shows two channels in the penis, one connected with the spinal marrow, the other with the testes. For a rather late pre-Cartesian adaptation of this theory, see Jacobus Sylvius (Jacques Dubois), *Livre de la generation de l'homme recueilly des antiques & plusseurs autheurs de medecine & philosophie,* trans. G. Chrestian (Paris: Morel, 1559), p. 25 and esp. his "Livre de la nature et utilité des moys des femmes," bound with the foregoing, pp. 113–116. (Note: these two works combined were published earlier as *De mensibus mulierum et hominis generatione . . . Jacobi Sylvii . . . commentarius* (Paris, 1555; Basel, 1556.)

The third idea, of semen and blood, was elaborated by Aristotle, who linked generation with nutrition. Both parents' bodies, he said, "concoct" the nutriment they absorb in order to ready it for assimilation to the tissues, a process entailing the actualization of the food's unexpressed morphological potential. An unassimilated residue of concocted nutriment passes to the genitalia for further concoction into semen in the male and catamenial blood in the female. The latter is less highly elaborated—possessing only vegetative potentialities—than the former, which possesses sensitive potentialities as well. Semen acts on the catamenia, at coition, to commence an actualization of its morphogenetic potentialities by a kind of "setting" or curdling effect. The process is abetted by an indispensable but inadequately explicated *pneuma* brought in with the semen.[66]

Galen gives two principal, and a number of peripheral, accounts of the origin of the offspring. One of these is a Galenized adaptation of Aristotle's idea; it depicts the seminal *pneuma* as vehicle for an alterative faculty which changes the blend of elements in the catamenia so as to convert it into tissues.[67] The other account eliminates the catamenial blood as a seminal substance, substituting intravascular blood from the mother. The semen, with its *pneuma,* is coagulated by contact with the womb and forms a capsule. Vascular (not catamenial) blood of the mother, along with *pneuma* and heat, penetrates the capsular membrane in multiple streams, which come together inside to form the umbilical vein. Some (mostly fleshy) organs derive from the blood; other (mostly more solid and membranous) organs, from semen.[68]

The foregoing and other Greek ideas reappeared, variously modified and combined, in Medieval and Renaissance physiological theory. The two-semina scheme was variously adapted by Paracelsus,[69] Fernel (see below), Jacobus Sylvius (Jacques Dubois),[70] du Laurens,[71] Realdo Colombo,[72] Caspar Bartho-

66. *De partibus animalium,* 647b4–7, 650a4–15, 678a1–20; *De juventute,* 468a10, 469a27 to b20. *De generatione animalium,* 727b30, 729a22–b19, 732a10, 738b20ff.

67. Galen, *De naturalibus facultatibus,* n. 54 above, bk. 2, ch. 3.

68. Galen, *De semine,* bk. 1, chs. 9 and 10, K 4:545–552.

69. Paracelsus, "Das Buch von der Gebärung der empfindlichen Dinge in der Vernunft (Tractatus secundus)" *Paracelsus sämtliche Werke,* eds. K. Sudhoff and W. Matthiessen (Munich: Barth, and Munich and Berlin: Oldenbourg, 1922–33), 1, 257–265.

70. Sylvius' theory appears to be a synthesis of Galenic with Hippocratic beliefs, especially as the latter were developed in the two treatises

lin,[73] and many others. Note, for example, Fernel's adaptation which served with others as grist for the mill of Descartes: Fernel posited similar male and female seminal fluids, made of highly elaborated blood supplemented by three *pneumata* (vital, natural, and animal) plus a set of other *pneumata* that rush to join the seminal fluid at the moment of orgasm. These *pneumata* carry corresponding faculties of the soul. The activation of the seminal *mélange* is due to a power peculiar to the womb which creates a capsule that is relatively warm and subtle within, cold and earthy without. Within this capsule a special faculty arises to guide the steps of morphogenesis, commencing with bladders representing the future liver, and brain, and heart.[74] Fernel's theory is an amalgamation of Galenic facultative pneumatology with the pre-Platonic "similar *semina*" doctrine. Descartes retains the similar *semina* but substitutes micromechanisms for the faculties and *pneumata:*

> And for this [reciprocal fermentative activation] the two [male and female seminal] liquors need not be very different. For, as we see that old dough can make new dough rise, and that the foam that beer throws up suffices as a ferment for other beer, so it is easy to believe that the seminal liquids of the two sexes, being mingled, serve as ferments to each other.
>
> Now I believe that the first thing that happens in the mixture of seminal fluid, and that makes every drop of it stop resembling every other drop, is that heat is excited there which, acting as in effervescent new wines, or in hay when stored before dry, makes some of the particles gather near a particular part of the containing space; and these particles, expanding there, press against others that surround them; which starts to form the heart.[75]

mentioned in n. 65 above. Sylvius seems to envision (a) apparently *equivalent* male and female *semina* (Galen, too, acknowledged a female semen but assigned it an auxiliary rather than a participative role, *De semine,* K 4:536–538) and also (b) the *catamenia;* (a) and (b) give rise, as in Galen, to seminal and sanguinary tissues respectively, see above n. 68.

71. A. du Laurens, *Toutes les oeuvres de M^e A. du Laurens . . .* , trans. T. Gelée (Rouen: R. du Petit Val, 1621), pp. 240–242.

72. Realdo Colombo, *De re anatomica libri XV* (Venice: Bevilacqua, 1559), p. 246.

73. C. Bartholin, *Anatomicae institutiones* (Strassburg: Scher, 1626), pp. 125–126.

74. J. Fernel, *Physiologie,* n. 13 above, bk. 7.

75. AT 11:253–254. Descartes' point that the male and female *semina* need not be very different from each other harks back to an earlier idea he

Descartes follows, here, his usual procedure of recrystallizing mixed traditional ideas along the lines of Cartesian particle theory. There was nothing new in linking the act of conception to the manifestation of ebullient heat. The Hippocratic treatise "On the Nature of the Child" had argued that a heating of newly mixed male and female *semina* in the womb produces *pneuma* in a process comparable to burning green wood or foliage (a smudge).[76] Aristotle, discussing the fate of the *semen,* depicted it as dissipated through vaporization,[77] and Galen, writing critically, later asked whether Aristotle meant this process to resemble the effervescence of wines. Galen agreed with the idea of a vapor produced at about the time of conception but not with an Aristotelian anathymiasis of the *semen* as a whole; both the *pneuma* and the *semen* persist, Galen said, and are used in building the brain and other parts.[78]

Pre-Cartesian Renaissance theorists (*ca.* 1542–1632) had mostly attributed the initiative heat in the semen to the influence of its intra-uterine surroundings. The womb arouses the dormant developmental faculties of the semen, according to this view; and it also provides a milieu for "fomentation." Fernel, for example, compared the effect of the uterus on semen to that of the stomach on food.[79] Externally effected fomentation—rather than spontaneous fermentation—was acknowledged by du Laurens,[80] Bartholin,[81] Crooke,[82] and other pre-Cartesian authors. Descartes' view differed from theirs. It was in line with his physiological method to liken the heat of conception to a fermentation or leaven. Such heat-producing chemical actions—generating "fire-without-light"—were a subject

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had that the lungs and liver form first, and that spirits from the former and blood from the latter then meet in a heat-producing, combative interaction to form the heart. AT 11:508–511 and 599. He has changed his mind.

76. *Oeuvres de Hippocrates* (ed. Littré), n. 63 above, vol. 7, p. 487.

77. Aristotle, *De generatione animalium,* 737a10–15.

78. Galen, *De semine,* bk. 1, ch. 8, K 4:540.

79. J. Fernel, *Physiologie,* n. 13 above, p. 733.

80. A. Laurentius, *Toutes les oeuvres,* n. 71 above, p. 248.

81. C. Bartholin, *Anatomicae institutiones,* n. 73 above, pp. 125–126.

82. Thus: "The wombe rowzeth and raiseth upp the sleepy and lurking power of the seeds, and that which was before but potentiall, it bringeth into act . . . The generative faculty which before lay steeped, drowsie, and as it were intercepted in the seede, being now raised up by [the] heat and inbred propriety of the wombe breaketh out into acte, as raked Cinders into a luculent flame." He goes on to attribute to *pneuma* ("wherewith the frothy seed swelleth") the role of a builder or painter, acting in response to the soul (*Mikrokosmographia* . . . , 2nd ed. [London: Sparke, 1631], pp. 262–264).

he never wearied of discussing, usually in terms of his own corpuscular theory of matter.

An important chapter in the scientific system of Descartes is his handling of the physics of motion, that of individual particles as well as of aggregates thereof. All motion in his theory was, originally, God-given. And, though motion may be transferred from particle to particle or from aggregate to aggregate, the total amount of it in the universe as a whole, he said, never varies. A particle or aggregate, once moving, tends, unless resisted or deflected, to continue moving without any change of direction.[83] But, since the universe is a plenum, the movement of particles or aggregates to any locus entails a displacement of the particles or aggregates already there. A natural destination for those thus displaced is the former locus of those that displaced them. The resultant movement is circular in pattern, and the cosmos, as depicted by Descartes, contains many examples of cycles of displacement-and-replacement.[84] Note how Descartes utilizes his theory of motion in continuing his analysis of embryonic development.

> Next, since particles thus expanded [by fermentative heating in the heart-region] tend to continue to move in a straight line; and since the heart—beginning to take form—resists them, they move off a certain distance and make their way toward the place where the base of the brain will later be formed, and in so doing they displace certain other particles which circle back to replace them in the heart. There, after a brief period needed to bring them together, they expand and move out along the same path as the preceding [toward the future brain region]. And this causes some of those that went there before and which happen still to be there to come again to the heart—along with others that come in from other places to take the place of those that, all this while, have been leaving. And those [that thus arrive in the heart], being promptly expanded, leave in their turn. And it is this [heat-induced] expansion, occurring over and over, that constitutes the heartbeat, or pulse.

Outflow from the heart is thus circularly balanced by inflow so that arteries and veins are generally formed in pairs. Such

83. *Principles*, pt. 2, sects. 36–43 (AT 8:61–67 and [9:83–88]).

84. Such cycles had an antecedent in the biophysics of Plato who, in discussing respiration, said that exhaled fire and air particles displace environmental fire and air particles which, in his opinion, enter the surface-pores of the body to replace those being exhaled. The cycle then reverses itself, fire and air moving out through the pores and displacing ambient fire and air which make room by being inhaled (*Timaeus*, 79A–E).

flows are envisioned as liquid streams moving in a less liquid matrix (morphogenetic currents had been stipulated by Galen;[85] after a rather uneven career they were still being invoked in 1809 by Lamarck).[86] With considerable ingenuity, and fidelity to his physics, Descartes goes on to detail how, later, the currents become surrounded by membranes (blood-vessel walls). And how, in the case of arteries, the pulsing of the membranes permits the extrusion of particles—and the consequent formation of fibers that constitute the body-solids. Among such solids are the walls of the heart, whose derivation from particles extravasated by the coronary artery is fully detailed. Descartes continues to construct the body with a kind of gratuitous precision that is likely to repel the reader who forgets the author's intention. What he is building, so he assures us, is a hypothetical model—mostly a micromodel—not of man but of a mechanism that *simulates man.* To this model—a kind of conceptual robot—we shall return after listening briefly to Descartes on the subject of sensory reception.

Example 3: The sense of smell

In the microneuroanatomy of Descartes, the functional peripheral units are hollow nerve-tubules, each containing several longitudinal fibrils surrounded by animal spirits.[87] The fibrils, if peripherally disturbed, act (comparably to a bellpull)[88] to initiate, in the brain, a reflexive outflow of spirits. Flowing back through the same—or out through other—nerve-tubules, the spirits act, in a very special way, to trigger muscular contraction.[89] We shall not concern ourselves here with the role of the pineal gland, which Descartes notoriously saw as intermediating—in man

85. See above, n. 78.

86. J. B. Lamarck, *Philosophie zoologique . . .* , first publ. Paris, 1809, 2nd ed. (Paris: Baillière, 1830), 1, 409.

87. *Discourse* AT 6:54; *Corps humain* AT 11: from 129. Spirits were for Descartes just as inanimate and corpuscular as other things. They are "all bodies consisting of terrestrial particles that [a] are bathed in subtle matter and [b] are more agitated [by their direct contact with particles of the first element] than those of air but less so than those of flame" (Letter to Adolphus Vorstius, AT 3:687). For several score further references to animal spirits (psychic *pneuma*) in Descartes, see Gilson's *Index,* p. 99.

88. The arriving spirits do not pump up the muscle; they operate certain valves that regulate the flow of spirits, already present, from the flexor to the extensor or vice versa. See *Man,* AT 11:133–137 (here he discusses the reciprocal action of muscle antagonists on which see also AT 11:336) and 142 (here he uses the bell-pull analogy, on which see also AT 11:337).

89. Considerable detail on the micromechanism of reflexes is given at *Man,* AT 11: from 170, and at *Passions,* AT 11:338–342; also, letter to Mersenne, AT 3:123.

alone—between the intracerebral flow of spirits on the one hand and the activities of the consciously motive-and-perceptive soul.[90] What we wish rather to stress is *that whatever aspect of Descartes' neurobiology we examine (we have chosen olfaction for convenience), we find the same corpuscularizing analysis that we discovered in his treatment of assimilation and the initiation of development.* We find, too, that what he explained were not empirical data but earlier writers' opinions (disassembled and reassembled with additions and deletions). Thus, his theory of sensation in general was a reductively reinterpreted synthesis of already existing ideas—mostly sixteenth- and early seventeenth-century revisions of Platonic, Aristotelian, and Galenic theories of perception.

Galen had regarded the sensory nerves of the head as protrusions of the brain-substance, permitting an extension of the sensitive faculties of the soul to the organs of special sense. The nerves contain psychic *pneuma* which acts as a substrate for the faculty extended by the nerve. Galen had considered smell to be the only sense mediated *entirely inside the brain.* He reasoned that odoriferous matters pass first through holes in the ethmoid bone and then through the presumably permeable floor of the brain itself, within which the soul's olfactory faculty resides. The same apertures in bone and brain permit *an inflow of air* (for conversion to animal spirits) as well as an *outflow of excremental excesses* (if these are superabundant; otherwise, they drain postnasally via the palate).[91]

During the sixteenth century, the status of the *mamillary processes* (our olfactory tracts with terminal bulbs) was debated. Should they or should they not be thought of as nerves? Vesalius (1543) was noncommittal on this subject.[92] Realdo Colombo (1559) considered the terminal thickenings of the mamillary processes (our olfactory bulbs) to be the proper organs of smell.[93] Piccolhomini (1585) agreed, and to him this seemed to project smell to a locus *outside the brain* (though not outside the cranial cavity); he called the olfac-

90. For which see: *Man,* AT 11: from 175; *Passions,* AT 11:351–352; and two letters, D. to Meysonnier, AT 3:18–21 and especially D. to Mersenne, AT 3:262–265. Descartes' chief reason for choosing the pineal was that he wanted a single organ "inside" the brain ventricles where impressions from paired organs (eyes, ears) could form a single image; more generally the soul was, for him, unitary.

91. Galen, *De usu partium,* bk. 8, chs. 6, 7, K 3:647–656.

92. A Vesalius, *De humani corporis fabrica* (Basel: *ex off.* Oporini, 1543), pp. 322–323, 643.

93. R. Colombo, n. 72 above, pp. 193–194.

tory tracts *nervi odorati* because they seemed to connect the bulbs with the brain.[94] Caspar Bauhin (from 1597) took a similar position, pointing especially emphatically to the existence of olfactory nerves (where we see olfactory tracts).[95] In this sequence of ideas we witness a tendency to place the olfactory receptor farther and farther from the brain ventricle, where it had been located by Galen. Descartes carried the same tendency one step farther.

> The sense of smell, as well [he has just been speaking of taste], depends on several fibrils that extend from the base of the brain toward the nose beneath those two little hollowed-out parts that anatomists have likened to nipples [olfactory tracts, termed *processus mammilares* by Renaissance anatomists]. And these fibers are in no way different from nerves that serve for touch and for taste, except that [a] they do not extend outside the cavity of the head that contains the whole of the brain and [b] they can be moved by smaller earthy part[icle]s than can the nerves of the tongue both because they are slightly finer and because they are touched more directly by the objects that move them.
>
> For you should know that when this machine [this hypothetical mechanical analog of a real man] breathes, the subtlest air part[icle]s that enter it through its nose, passing through the pores of the bone denominated spongy [ethmoid] penetrate if not all the way into the brain cavity [as stipulated by Galen] at least as far as the space between the two membranes that envelop the brain [the subdural space]. From this space, particles may simultaneously *leave* through the palate [again, as stipulated by Galen]—just as, reciprocally, when air leaves the chest, its particles can *enter* this [subdural] space by way of the palate and *leave* by way of the nose.[96] [You should] also [know] that on entering this [subdural] space they encounter the ends of the [aforementioned] fibrils which are quite bare, or covered with so extremely delicate a membrane that little force is needed to move them.

The foregoing paragraphs well illustrate the paradoxical impression—of novelty combined with familiarity—created by

94. A. Piccolhomini, n. 15 above, p. 292.

95. See, e.g., C. Bauhin, *Theatrum anatomicum* (Frankfort: Becker, 1605), pp. 643–644.

96. For Descartes elsewhere on the respiratory current see his *Excerpta Anatomica*, n. 54 above, AT 11:599–600.

Descartes' explanatory method: the paradox stems, in this case, from his fusion of a rather new view of biodynamics (based on his own corpuscular physics) with ancient errors of Galen about the flow of matters into and out of the brain and skull. The correct idea that olfactory fibrils actually traverse the cribiform plate was put forward, with certain errors, by Conrad Schneider (1654) and Thomas Willis (1664).[97]

> You should also know that these pores [in the ethmoid bone] are so arranged, and so narrow, that they prevent access to these fibrils of particles coarser than those which, in speaking earlier on this subject, I designated *Odors*—except, perhaps, for certain ones that constitute *eaux de vie* because their shape renders them especially penetrant.
>
> Finally, you should know that among the extremely small earthy particles that are always found in greater abundance in air than in other composite bodies, only those which are [a] a little coarser or [b] a little finer than the others—or which because of their shape are more or less easily moved —will be able to occasion in the soul the different sensations of odors. Similarly, only those in which these excesses are very moderate and mutually tempered will cause agreeable sensations, for those which act only ordinarily will not be able to be sensed at all; and those that act with too much or too little force cannot but be unpleasant.[98]

CONCLUSION

The three cases just cited are merely examples of Descartes' analytical method, but they typify rather well his approach to physiology in general. Whatever the immediate *explanandum* —heart action, respiration, reciprocal innervation, muscular antagonism, secretion, digestion, absorption, blood-formation, nervous action, bio-optics, bio-acoustics—Descartes is discovered to follow a fairly predictable practice—namely, a reductive (corpuscular, nonpsychistic) interpretation partly of empirical fact but primarily of earlier Renaissance revisions of Greek physiological doctrine. His sources are often only semirecognizable because of the reconstruction to which he submits them in preparing them for "cartesianization." As for the physics to which he assimilates his biological data, that too

97. C. Schneider, *Liber de osse cribriforme* . . . (Wittenberg: Mevius & Schumacher, 1655), p. 169, and T. Willis, *Cerebri anatome*, first publ. London, 1644, trans. in S. Pordage, *Dr. Willis's Practice of Physick*, see n. 25 above, p. 112.

98. *Man*, AT 11:148–149.

is partly his own and partly an altered conceptualization of earlier elementary-particle theory.[99] To what extent is Descartes' procedure—that, namely, of re-explaining not empirical data so much as earlier explanations—the procedure of theory-builders in general? We leave this question for separate and more extended exploration.

From the point of view of scaling, it would be correct to think not of one but of three mechanical sciences as arising during the sixteenth and seventeenth centuries: a celestial or *megamechanics* treating such very large things as the earth and the heavenly bodies; an intermediate *mesomechanics* having to do with usable machinery, automata,[100] and so on, and with their biological analogs, namely, plants and animals and their visible parts; and finally a *micromechanics* concerned with subvisible things, ranging downward in size from those which would presently become visible through the microscope all the way to elementary particles.[101] Descartes reasoned as a mechanist on all of these levels. In his biology he drew a number of comparisons between the body-parts and various sorts of visible machinery, water-works, clocks, and the like. He made no sharp distinction between meso- and micromechanics, but if we take the lower limit of (unaided) visibility as the line of division, the mesomechanical allusions in his works are, though trenchant, relatively rare: his biology is mostly micro- rather than mesomechanical.

A question finally remains as to the epistemological status of the "Man" whom (or which) Descartes portrays. With what in mind does he picture not man himself—so he assures us—but, rather, a hypothetical analog of man? A clue is contained in the *Treatise of Light,* where we read that the "World" that Descartes would portray is not the one that actually exists. It is merely a possible world, one that God *could have created*

99. The Greek, Medieval, and Renaissance sources of Cartesian physics have been the subject of much historical study. See Marie Boas, "The Establishment of the Mechanical Philosophy," *Osiris, 10* (1952), 412–541; and J. R. Partington, "The Origin of the Atomic Theory," *Annals of Science,* 4 (1939), 245.

100. See, on automata and mechanicism, D. J. de S. Price, "Automata and the Origins of Mechanism and the Mechanistic Philosophy," *Technology and Culture,* 5 (1964), 9–42.

101. Thus, Robert Boyle in 1674: "the mechanical affections of matter are to be found and the laws of motion take place not only in great masses, and in middle sized lumps, but in the smallest fragments." See his "Of the Excellency and Grounds of the Mechanical Hypothesis," *The Works of the Honourable Robert Boyle in Six Volumes . . .* (London: J. & F. Rivington, 1772), 4:71.

had he wanted to construct a mechanical analog of the world he created in fact. Did this seemingly ambiguous presentation —of man and the world—stem from Descartes' willingness to guard himself, or his system, against ecclesiastical censure? Historians have supposed that it did; and we know that the example of Galileo partly caused Descartes to postpone publication of his own *Treatises of Light* and *of Man.* Another interpretation of Descartes' tentativeness has often been suggested: He was notoriously aware of the *limitations of sensation,* but he was also aware of the *limitations of reason.* He saw himself not as *stating the truth* but as *developing a model* —a metaphor—that somehow squared with truth on the one hand and with sensory experience on the other. In the *Principles,* he expresses the wish that "what I shall write be taken as only an hypothesis which may be very far from the truth"; and he continues that "even though it be such [only an hypothesis] I shall think I have done much if all the things which shall be deduced from it are entirely conformant to experience; because if that be the case, it will be no less useful to life than if it were true, because one will be able to use it just as well in arranging natural causes to produce desired effects." [102]

102. *Principles,* pt. 3, sect. 44 (AT 8:99 [and 9:123]).