

DESCARTES AND MEDICINE



THE AGE OF DESCARTES
DESCARTES ET SON TEMPS

VOLUME 9

*Centro Dipartimentale di Studi su Descartes
e il Seicento 'Ettore Lojacono' Università del Salento*

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Descartes and Medicine

Problems, Responses and Survival of a Cartesian Discipline

edited by

FABRIZIO BALDASSARRI



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CENTRE FOR THE STUDY OF
MEDICINE AND THE BODY
IN THE RENAISSANCE

V I V A M E N T E
The Garden of Ideas



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Acknowledgments

This volume is the result of several meetings and seminars in Padua, Venice, Lecce, Utrecht, Leiden, Bologna, Bloomington, and a conference, organized online on November 18, 19 and 20, 2020, with the technical support of CSMBR and Vivamente, and sponsored by the Institutio Santoriana, University of Exeter, UEFISCDI, Università degli Studi di Padova, and Studio Firmano. I must thank the president, vice-president, director, and vice-directors of the CSMBR, namely, Vivian Nutton, Jonathan Barry, Fabrizio Bigotti, Fabio Zampieri and Fabiola Zurlini, for their help at different stages, as well as Tomaso Maria Pedrotti dell'Acqua and Mark Ferretti for their technical help. On all these very well-attended seminars, the rich presentations and productive discussions led all of us to the belief that Descartes's study of medicine, and its reception, would be a major feature of his natural philosophy, although not an easy one to deal with in its entirety. Obscurities appear now and then in Descartes's medical enterprise, although this latter represents a prominent discipline of his entire philosophical project. During the pandemic nothing has been easy: neither the organization of online events, nor the planning of a volume. When I developed the aim to collect a re-elaboration of a few papers discussed in seminars and meetings, I also asked a few colleagues to add their own contribution to enlarge the picture of Cartesian medicine. As a result, I hope that the reader may appreciate the importance of (and the problems and difficulties related to) medicine in the age (and the philosophy) of Descartes, and the strives for survival that Cartesian medicine deployed throughout the seventeenth century. This is the main topic of the present volume, now published in Giulia Belgioioso's series with Brepols. And I hope that further investigations may develop on this topic to enrich the studies in early modern philosophy, sciences, and medicine.

I thank Giulia Belgioioso and Igor Agostini for having guided me through the difficulties of editing the volume, and Theo Verbeek, who has been a safe haven for the study of Descartes and Cartesianism throughout the years. I also thank Marco Sgarbi and Domenico Bertoloni Meli, who have supported me through the Marie Skłodowska-Curie fellowship scheme.



Bloomington (IN), September 2022

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List of contributors

Laurynas ADOMAITIS has defended his doctoral thesis cum laude at the Scuola Normale Superiore and carried out research visits at the École Normale Supérieure in Paris, the University of Münster and at the University of Montreal, studying Leibniz and early modern science. He is currently a researcher at the Atomic Energy Commission (CEA) in Paris. His main areas of research are data ethics, AI ethics, and the ethical issues of extended reality.

Fabrizio BALDASSARRI is a Marie Skłodowska-Curie postdoc at Ca' Foscari University of Venice and Indiana University Bloomington, with a project on plants in early modern philosophy. He co-edited several special issues and volumes such as *Vegetative Powers* (2021), and has widely published on Descartes's naturalistic studies and philosophy in journals such as the *BJHS*, *ESM*, *Physis*, *Historia philosophica* and the *Rivista di storia della filosofia*. In 2021, he has published a monograph entitled, *Il metodo al tavolo anatomico. Descartes e la medicina* (Rome, 2021).

Tawrin BAKER is currently Visiting Assistant Professor in the History and Philosophy of Science at the University of Notre Dame. In 2014 he received his PhD in the History and Philosophy of Science and Medicine from Indiana University, Bloomington. He was a 2016-2017 Dibner Research Fellow in the History of Science at the Huntington Library in San Marino, California, and has also been a Mellon Postdoctoral Fellow in the History and Philosophy of Science at the University of Pittsburgh and a Visual Studies Postdoctoral Fellow at the University of Pennsylvania. He works on the intersection of anatomy and medicine, natural philosophy, and mathematics in the early modern period, focusing especially on vision and physical color theory, and more recently on images, diagrams, and visual cultures of science and medicine, in the sixteenth and early seventeenth centuries.

Annie BITBOL-HESPÉRIÈS published *Le principe de vie chez Descartes* in 1990 (Paris, Vrin) and edited René Descartes' *Le Monde, L'Homme* in 1996 (Paris, Le Seuil). She has worked on *Monsters from the Renaissance to the Age of Reason* for a virtual exhibition on the website of the main medical library in France : Bibliothèque interuniversitaire de santé (BIUS, Médecine, 2004). She is presently editing Descartes' medical texts to be published in René Descartes, *Œuvres complètes* edited by the late Jean-Marie Beyssade and Denis Kambouchner (Paris, Gallimard-Tel, vol. II). Her critical edition of Descartes' biography by Adrien Baillet (*La vie de Monsieur Descartes*, 2 vols, Paris, 1691) will be published by Encre marine (Les Belles Lettres).

Erik-Jan BOS (Erasmus University Rotterdam) is a specialist of the life and works of René Descartes and also interested in the history of Dutch Cartesianism. He is one of the editors-in-chief of the new critical edition of Descartes' correspondence with complete English translation (Oxford University Press).

Maria CONFORTI is professor at La Sapienza University of Rome, where she teaches History of medicine and directs the museum of medical history. She has widely published on the history of medicine in the early modern period, especially focusing on the Italian context, but also on the communication of medicine from the seventeenth to the twentieth century. She has edited several volumes and special issues; in 2014, she co-edited with Marco Beretta a volume entitled *Fakes!? Hoaxes, Counterfeits and Deception in Early Modern Science*, just to name one. She has been editor in chief of *Nuncius: Journal of the Material and Visual History of Science* between 2017 and 2020, and is a member of the editorial board of several journals and institutions of history of medicine and history of science.

Mihnea DOBRE teaches and does research at the University of Bucharest. He has a PhD in philosophy (Radboud University Nijmegen and University of Bucharest), and his research focus is in the history of philosophy and science; in particular on the relations between philosophy, science, and religion in the early modern period. He is also interested in new scholarly approaches (Digital Humanities) and different ways of communication and dissemination of research results (Open Science). He has published two monographs, *Cosmologia carteziană* [*Cartesian Cosmology*; in Romanian, 2021] and *Descartes and Early French Cartesianism: between metaphysics and physics* (Zeta Books, 2017), and co-edited the volume on *Cartesian Empiricisms* (Springer, 2013).

Jan FORSMAN is a recent PhD in Philosophy from Tampere University, Finland. His doctoral thesis concentrated on Descartes's skepticism in the *Meditations*. He is currently working on postdoc research at the University of Iowa on the skeptical influence of early modern women philosophers. In his spare time, he enjoys writing, playing basketball and taking care of animals.

Lynda GAUDEMARD is lecturer at the Department of philosophy of the University of Aix-Marseille, where she received her Ph.D in 2012. In addition to her research, she works for the French Ministry of Justice. She held several positions at the University of Geneva and the University of Lausanne. She published extensively on Descartes's philosophy of mind, metaphysics and embryology, as well as on bioethics, children's rights and legal epistemology. Her publications include the monograph *Rethinking Descartes's Substance Dualism* (Springer, 2021). Recently, she was also invited by the *Annals of the University of Bucharest* to be a guest editor of a special issue dedicated to emotions and cognition in early modern philosophy. In 2021, she received a Harvard certificate in child protection. She is currently working on ethics of children's rights.

Benjamin GOLDBERG is a historian and philosopher of science at the University of South Florida. His work concentrates on the intersection between medicine and philosophy in the early modern Europe, as well on larger philosophical issues concerning the nature of experience and evidence, underdetermination, and the philosophy of experiment. He is currently working on the pedagogical aspects of William Harvey's lecture notes for the Lumleian Lectures. You can find him at <http://metabenny.com>.

Stefano GULIZIA is an intellectual historian specializing in the early modern period, with a focus on scholarly networks, print culture, and other themes. Trained as a classicist and philologist, he taught extensively in the U.S. (after his PhD from Indiana University) and held fellowships in California, Oxford, Chicago, Montreal, Berlin, Wolfenbüttel, Bucharest and Warsaw. He has joined the University of Milan as a member of TACITROOTS, and he is the editor-in-chief of the *Scientiae Studies* series at Amsterdam UP.

Simone GUIDI is a Researcher in the Institute for the European Intellectual Lexicon and History of Ideas (CNR-ILIESI) at the National Research Council of Italy. He teaches at the Roma Tre University in Italy. His work focuses on the history of early modern philosophy, with particular attention to Descartes and early modern Scholasticism. He authored and edited several monographs, articles, book chapters, and collective volumes, among which are *L'angelo e la macchina. Sulla genesi della res cogitans cartesiana* (2018), *Francisco Suárez. Metaphysics, Politics and Ethics* (2020, with Mário Santiago de Carvalho and Manuel Lazáro Pulido), and *Pedro da Fonseca. Humanism and Metaphysics* (2022, with Mário Santiago de Carvalho). He is the scientific coordinator of the Conimbricenses.org project (directed by Mário Santiago de Carvalho).

Nabeel HAMID is Assistant Professor of Philosophy at Concordia University (Montreal). He works on the history of German philosophy, in particular on early modern German scholasticism and the reception of Cartesianism in German universities. He has published articles in venues such as *Oxford Studies in Early Modern Philosophy*, *Journal of Modern Philosophy*, *History of Universities*, and *British Journal for the History of Philosophy*.

Gideon MANNING is Associate Professor of History of Medicine and Humanities at the Cedars-Sinai Medical Center in Los Angeles, California, where he directs the Program in the History of Medicine. He is also Research Associate Professor at Claremont Graduate University. The author of numerous articles and book chapters, as well as the editor or co-editor of four books, his most recent publications include "Women, Medicine, and the Life Sciences," "Circulation and the New Physiology" and, with Anna Marie Roos, the edited volume *Collected Wisdom of the Early Modern Scholar*. He continues his research on René Descartes and his long reception, but is also trying to productively bring together the history of medicine, science and philosophy to address questions about illustrations and visualization in science, the early modern fate of Galenism, the history of surgery, philosophies of the good death, and translational science and evidence-based medicine.

Franco A. MESCHINI is an Associate Professor at the University of Salento, Lecce (Department of Humanities). He has been scholar of Tullio Gregory (Roma, La Sapienza). His interests focus on the philosophical and scientific thought of seventeenth century scholars, especially dealing with the medical writings of René Descartes. On Descartes, he has published: *Neurofisiologia cartesiana* (1998); *Materiali per una storia della medicina cartesiana* (2013); *La dottrina della digestione secondo Descartes* (2015), of which he is now retracing and defining the concept of disease, *Descartes su vita, morte e malattia. In margine alla questione del rapporto di anima e corpo* (2019).

Jil MULLER, after a PhD thesis on Montaigne, Descartes and the original sin, has turned her research focus on French Women Philosophers and Scientists in the early modern period, such as Marie de Gournay, Sophie Germain and Emilie du Châtelet. She has mainly focused on their moral theories and their understanding of man in society, as well as with the status or role of man in the creation of God. Recently, she published a book by Classiques Garnier: *Soigner l'humain — Péchés et remèdes chez Montaigne et Descartes*, in May 2022.

Elena RAPETTI is Assistant Professor at the Catholic University of Milan, where she teaches History of Philosophy. Her research is carried out in two main directions: the philosophical, scientific, and theological debates of post-Cartesian philosophy and the reception of Origen's thought in the seventeenth century. She has published on the reception of Descartes and Spinoza, mostly focusing on the figure of the anti-Cartesian thinker Pierre-Daniel Huet and his milieu.

Clément RAYMOND is a former student of the Ecole Normale Supérieure d'Ulm, holder of the agrégation in philosophy. He is currently a PhD student in philosophy at the Université Jean Moulin Lyon 3 and member of the "Institut d'Histoire des Représentations et des Idées dans les Modernités" (IHRIM). His research interests include Descartes, Cartesianism(s) and the women's quarrel.

Daniel SAMUEL is a PhD candidate at the Warburg Institute, University of London. His thesis examines how developments in natural philosophy and medicine influenced the formation of new theories of emotion in seventeenth-century England. He studied medicine at the University of Cambridge and Imperial College London and worked as medical doctor before commencing his doctoral studies.

Carmen SCHMECHEL is a historian of science and medicine. She currently holds a German Research Foundation-sponsored postdoctoral fellowship at the Institute for Philosophy of the Freie Universität Berlin, exploring theories about ferments and fermentation in premodern European medicine and chemistry. Her broader interests extend to other theories of transformation of matter, such as distillation, sublimation, or metabolism, including the metaphorical usages of these terms and their *longue-durée* philosophical backgrounds. Most recently she has authored "Descartes on Fermentation in Digestion: Iatromechanism, Analogy and Teleology," in *The British Journal for the History of Science*, 2022, 101-116.

Aaron SPINK is currently a lecturer in philosophy at Dartmouth College. He works primarily on methodological issues related to the early adoption of Cartesian philosophy in the seventeenth century. He is also co-editor and translator for an upcoming collection of selected philosophical works from Blaise, Jacqueline, and Gilberte Pascal.

Andrea STRAZZONI, Ph.D. (Erasmus University Rotterdam, 2015), is Marie-Curie fellow at the Ca' Foscari University of Venice. He has published monographs and articles on the history of early modern philosophy and science, and editions of primary sources.



Descartes's Abbreviations

Alquié	François Alquié, <i>Œuvres philosophiques de René Descartes</i> , 3 vols, Paris, Garnier, 1963-1973.
AT	<i>René Descartes. Œuvres</i> , édités par Charles Adam et Paul Tannery, 13 vols, Paris, Léopold Cerf, 1897-1913. Nouvelle présentation par J. Beaudé, P. Constable, A. Gabbey et B. Rochot, 11 vols. Paris, Vrin, 1964-1974.
Aucante	René Descartes, <i>Écrits physiologiques et médicaux</i> , présentation, textes, traduction, notes et annexes de Vincent Aucante, Paris, PUF, 2000.
BL	Giulia Belgioioso (a cura di), <i>René Descartes. Tutte le lettere 1619-1650</i> , con la collaborazione d'I. Agostini, F. Marrone, F. A. Meschini, M. Savini, e J.-R. Armogathe, Milano, Bompiani 2009 [2005].
BO	Giulia Belgioioso (a cura di), <i>René Descartes. Opere 1637-1649</i> , con la collaborazione d'I. Agostini, F. Marrone e M. Savini, Milano, Bompiani, 2009.
BOp	Giulia Belgioioso (ed.), <i>René Descartes. Opere postume 1650-2009</i> , con la collaborazione d'I. Agostini, F. Marrone, e M. Savini, Milano, Bompiani, 2009.
BOS	Erik-Jan Bos, <i>The Correspondence between Descartes and Henricus Regius</i> , Ph.D. dissertation, Utrecht, Zeno, 2002.
Clerselier I-II-III	Claude Clerselier, <i>Lettres de Mr Descartes</i> , 3 vols, Paris, Charles Angot, 1657, 1659, 1667. [Reprint ed. by J.-R. Armogathe, G. Belgioioso, Lecce, Conte, 2005; and now also in www.cartesius.net].
CSM I-II	<i>The Philosophical Writings of Descartes</i> , 2 vols, edited and translated by John Cottingham, Robert Stoothoff, and Dugald Murdoch, Cambridge-New York-Port Chester-Melbourne-Sydney, Cambridge University Press, 1984.
CSMK	<i>The Philosophical Writings of Descartes</i> , vol. III <i>The Correspondence</i> , edited and translated by John Cottingham, Robert Stoothoff, Dugald Murdoch, and Anthony Kenny, Cambridge-New York-Port Chester-Melbourne-Sydney, Cambridge University Press, 1991.
G	René Descartes, <i>The World and Other Writings</i> , ed. and transl. by Stephen Gaukroger, Cambridge, Cambridge University Press, 1998.
Shapiro	<i>The Correspondence between Princess Elisabeth of Bohemia and René Descartes</i> , edited and translated by Lisa Shapiro, Chicago, The University of Chicago Press, 2006.
Verbeek	Theo Verbeek, Erik-Jan Bos, and Jeroen van de Ven, <i>The Correspondence of René Descartes 1643</i> , with contributions of H. Bos, C. R. Palmerino, C. Vermeulen, Utrecht, Zeno, 2003.

Other Abbreviations

- Acad. Cicero, *Academica* (Eng. translation by Rackham, H.; original Latin text included) in *De Natura Deorum*; *Academica*, Cambridge (Ma.), Harvard University Press, 1972.
- C. Acad. St Augustine, *Answer to Skeptics* (*Contra Academicos*, transl. by D. J. Kavanagh) in L. Schopp, ed., *The Fathers of the Church: A New Translation*, vol. 5, New York, Cima Publishing Co., 1984.
- CM *Correspondance du P. Marin Mersenne religieux minime*, commencée par Mme Paul Tannery, publiée et annotée par Cornelis de Waard et Armand Beaulieu, 17 vols, Paris, Editions du CNRS, 1945-1988.
- De Mem. Aristotle, *On Memory and Recollection* (*Περὶ μνήμης καὶ ἀναμνήσεως*, translation by Hett, W. S.; original Greek text included) in *On the Soul*; *Parva Naturalia*; *On Breath*, Cambridge, Harvard University Press, 1975.
- De Ins. Aristotle, *On Dreams* (*Περὶ ἐνυπνίων*, translation by Hett, W. S.; original Greek text included) in *On the Soul*; *Parva Naturalia*; *On Breath*, Cambridge, Harvard University Press, 1975.
- M Sextus Empiricus, *Against the Mathematicians I-VI, VII-VIII, & XI* (*Πρὸς μαθηματικούς*, translation by Bury, R.G; original Greek text included) in *Against the Logicians, Against the Physicists, Against the Ethicists, and Against the Professors*, Cambridge, Harvard University Press, 2000.
- Meth. Aristotle, *Metaphysics* (*Τὰ μετὰ τὰ φυσικά*, translation by Kirwan Christopher), Oxford, Clarendon Press, 1971 [1993].
- QM John Buridan, *Quaestiones in Aristotelis Metaphysicam* (Eng. translation by Guyla Klima) in Gyula Klima, Fritz Allhoff and Anand Jayprakash Vaidya (eds.), *Medieval Philosophy: Essential Readings with Commentary*, Oxford, Blackwell Publishing, 2007
- PH Sextus Empiricus, *Outlines of Scepticism* (*Πυρρώνειοι ὑποτυπώσεις*, translation by Annas, Julia & Barnes, Jonathan), Cambridge, Cambridge University Press, 2002.
- SQO Henry of Ghent, *Summa Quaestionum Ordinariam*, in *The Cambridge Translations of Medieval Philosophical Texts*, vol. 3, ed. by R. Pasnau, Cambridge, Cambridge University Press, 2002.
- ST Aquinas, *Summa Theologiae*, vols II, V, IX, XI & XII (Eng. translation by McDermott, Timothy; Gilby, Thomas; Foster, Kenelm; Suttor, Timothy and Durbin, Paul T.; original Latin included), London-New York, Blackfriars, in conjunction with Eyre & Spottiswoode, & McGraw-Hill Book Company, 1964-1968.
- Tht Plato, *Theaetetus* [*Θεαίτητος*], in *The Theaetetus of Plato*, ed. by Miles Burnyeat, Indianapolis, Hackett Publishing Company, 1990.
- Trin. St Augustine, *On the Trinity* (*De Trinitate*, translation by McKenna, Stephen) in *On the Trinity*, Books 8-15 (ed. Matthews, Gareth B.), Cambridge, Cambridge University Press, 2002.

Fermentation as 'Heat-Rarefaction' and Animal Spirits in Descartes' Medical Philosophy

▼ **ABSTRACT** Crucial to Descartes' physiology in general, fermentation is also at the root of muscular movement and embryo formation. I argue that in contrast to theories of fermentation popular with chymists, Descartes' own version of how fermentation happens is best described as a 'heat-rarefaction' model, whose essential components are the presence of heat and its rarefying effect on matter, resulting in an expansion in volume. This is an eminently mechanist model, which resonates most closely with certain corpuscularist medieval reworkings of ancient Aristotelian and Galenic ideas. Descartes' use of fermentation is traced across writings such as *Treatise on Man*, *Description of the Human Body*, *Passions of the Soul*, *Primae Cogitationes*, *Excerpta anatomica*, and Descartes' correspondence including some sections of the 1638 Plempius letters omitted in previous translations. By explaining the misunderstanding arising out of different ways of conceptualizing fermentation, this hypothesis sheds new light on the tensions between Descartes and some of his contemporaries, especially Plempius. It also shows how 'fermentation' is negotiated between chymists and mechanists around the middle of the seventeenth century. While both schools of thought see fermentation as a model for processes happening in the natural world, each ascribes fermentation a different manner of action in matter.

▼ **KEYWORDS** Fermentation, Descartes, Heat-rarefaction, Scientific Model, Animal Spirits, Muscle Movement, Generation, Innate Heat, Physiology, Aristotle



Carmen Schmechel • Institute for Philosophy, Freie Universität Berlin, Germany.
Contact: <carmen.schmechel@gmail.com>

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1. Introduction: The Importance of Fermentation in Cartesian Physiology

It is known that Descartes holds fermentation to be central for most physiological processes,¹ starting with digestion, the circulation and the formation of the blood, the formation of the embryo and the growth of the foetus, and even the movement of the muscles. Fermentation fuels the “fire without light” that is at the basis of life, making all physiological functions — and hence organic life² — possible.³

The importance and significance of fermentation is also a result of what it replaces, in its explanatory function. It is known that Descartes aimed to eliminate the traditional Aristotelian and Galenic⁴ notions of nutritive and vegetative ‘souls’ in order to establish what Dennis Des Chene calls a “restrictive mechanistic ontology”⁵ in biology — a framework in which living bodies were understood as moving by mechanical forces only.⁶ Hence it was decisive what properties could or could not be assigned to the new element replacing the ‘souls’. As the ‘fire without light’ of fermentation now takes over the task of making life possible (as well as sustaining it through the intertwined processes of the beating of the heart and of various physiological transformations), its nature and properties come under close scrutiny. What exactly does Descartes mean by fermentation, and how does the employment of this concept play out within a mechanistic biology?

2. Descartes’ Fermentational Analogies: An Update of Ancient Ideas

Descartes supposes that God placed in the human body, more precisely in the heart,⁷ a fermentational fire which works in the manner of fermenting wine or damp hay: a

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- 1 See VINCENT AUCANTE, *L’horizon métaphysique de la médecine de Descartes*, Ph.D diss., Université de Paris-Sorbonne, Paris IV, 1997, esp. ch. IV, “Les fermentations”; also VINCENT AUCANTE, *La philosophie médicale de Descartes*, Paris, PUF, 2006; ANNIE BITBOL- HESPÉRIÈS, *Le principe de vie chez Descartes*, Paris, Vrin, 1990.
 - 2 On the other hand, fermentation as a criterium for life is problematic. Karen Detlefsen thinks that because fermentations and their heat also happen in the natural world, the innate heat cannot be a viable criterion of demarcating living beings from non-living forms of being: “we must dismiss the ‘heat without light’ candidate as a viable one for Descartes’ theory of life.” KAREN DETLEFSEN, “Descartes on the Theory of Life and Methodology in the Life Sciences,” in *Early Modern Medicine and Natural Philosophy*, ed. by P. Distelzweig, B. Goldberg and E. J. Ragland, Dordrecht, Springer, 2016, p. 141-173, esp. p. 147.
 - 3 See *L’Homme*, AT XI 202; G 169.
 - 4 On the role of the ‘vegetative soul’ in the physiology of Galen, see JACQUES ROGER, *The Life Sciences in Eighteenth-Century French Thought*, ed. by K. R. Benson and transl. by R. Ellrich, Stanford, Stanford University Press, 1997, p. 57-58.
 - 5 DENNIS DES CHENE, “Mechanisms of Life in the Seventeenth Century: Borelli, Perrault, Régis,” *Studies in History and Philosophy of Science Part C*, 36 (2005), p. 245-260, p. 246.
 - 6 This refers to immediate, efficient causes. Descartes does reserve the ultimate agency for the rational soul, in humans only. This issue is, however, beyond the scope of the present paper.
 - 7 This was an ancient location and understanding. Aristotle, too, likens the heart to a hearth (*De partibus animalium*, 170a23).

fire “without light,” of the same nature as “the one which heats the hay when it has been enclosed before it turned dry, or the one which makes new wines seethe when one leaves them to mature on the lees.”⁸

Thus commonly known fermentations in the natural world⁹ serve as analogies¹⁰ for how human physiology works. As Descartes will hold up until at least 1645, the fermentational fire is the “sole cause of cardiac activity”¹¹ and the source of all innate heat:

Il me semble que toute la chaleur des animaux consiste en ce qu'ils ont dans le coeur une espece de feu, qui est sans lumiere, semblable à celui qui s'excite dans l'eau forte, lors qu'on met dedans assez grande quantité de poudre d'acier, & à celui de toutes les fermentations.¹²

This alleged similarity goes beyond a convenient analogy. Firstly, I argue that Descartes systematically employs fermentation (or more precisely, what he understands by it) as a descriptive model¹³ for physiological processes at the micro-level of particles. Fermentation thus performs an explanatory function, in the sense of generating hypotheses about how bodily processes happen. Secondly, beyond serving as models for unobservable phenomena inside the body, certain fermentations are literally carried over from the natural world into the human body. Because many of the foods we ingest are the ones in which fermentations occur, physiology itself continues the work of nature. This is not a metaphor. Descartes writes of bread, beer, wine, “from

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- 8 *Discours*, AT VI 45-46: “que je ne conçois point d'autre nature que celui qui échaufe le foin, lorsqu'on l'a renfermé avant qu'il fust sec, ou qui fait bouillir les vins nouveaux, lorsqu'on les laisse cuver sur la rape.” [Translation is mine.] CSM I 134 renders this as “no different from that of the fire which heats hay when it has been stored before it is dry, or which causes new wine to seethe when it is left to ferment from the crushed grapes.” However, I here distance myself from this translation insofar as Descartes does not use the verb “ferment”; Descartes’ “cuver” is, in my view, best rendered as “to mature”. For more on this terminological issue see CARMEN SCHMECHEL, “Descartes and fermentation in digestion: iatromechanism, analogy and teleology,” *The British Journal for the History of Science* (2021), p. 101-116, here p. 107-108.
- 9 Importantly, while Descartes makes use of fermentation analogies, he rejects the analogy of innate heat with solar heat, in order to avoid association with Fernel and others in the idea of the origin of innate heat being divine. Cf. ANNIE BITBOL-HESPÉRIÈS, “Cartesian Physiology,” in *Descartes' Natural Philosophy*, ed. by S. Gaukroger, J. Schuster, and J. Sutton, London and New York, Routledge, 2000, p. 349-382, p. 363-364.
- 10 For the particular analogy of innate heat with external heat, see EVERETT MENDELSON, *Heat and Life*, Cambridge, Harvard University Press, 1964, p. 3-4.
- 11 THOMAS FUCHS, *The Mechanization of the Heart: Harvey and Descartes*, transl. by Marjorie Grene, Rochester, University of Rochester Press, 2001, p. 127; Fuchs refers to the *Description*, AT XI 228, as well as to the *Discours* 5, AT VI 46-47.
- 12 Descartes to the Marquis de Newcastle, April (?) 1645, AT IV 189.
- 13 I rely on the concept of an explanation model in science, and especially in biology, as exposed by the following sources: MANFRED LAUBICHLER and GERD MÜLLER, ed., *Modeling Biology: Structures, Behavior, Evolution*, Cambridge, Mass., MIT Press, 2007; LINDLEY DARDEN, “Mechanisms and Models,” in *The Cambridge Companion to the Philosophy of Biology*, ed. by D. L. Hull and M. Ruse, Cambridge and New York, Cambridge University Press, 2007, p. 139-159; JAY ODENBAUGH, “Models,” in *A Companion to the Philosophy of Biology*, ed. by S. Sarkar and A. Plutynski, Malden, Blackwell Publications, 2008, p. 506-524. See also, for descriptive models, ROMAN FRIGG and STEPHAN HARTMANN. “Models in Science,” in *Stanford Encyclopedia of Philosophy*, Stanford: The Metaphysics Research Lab, 2020, p. 19-20.

which a great part of our blood arises [is made].”¹⁴ Hence, what happens *in* the body is a continuation and/or a reiteration, under new environmental conditions, of what happens outside of it. Food thus becomes the literal and direct source of the fermentational fire and heat. This point is important because it serves to distance¹⁵ Descartes from the claim of coeval chymical theories about the origin of innate heat being celestial and/or divine (such as with Fernel and his followers.)¹⁶ It also marks the beginnings of thinking about physiology in terms of literal chemical reactions conceptualized mechanistically, an approach continued by Borelli.

Descartes’ ideas on heat coming from food resonate with a line of ancient authors such as the Hippocratic writers, Galen and even — in part, and controversially — Aristotle. A relationship between nutriment and the innate heat¹⁷ was established already in the Hippocratic corpus. The text on “Nutriment” claims that “[p]ower of nutriment reaches to bone and to all the parts of bone, to sinew, to vein, to artery, to muscle, to membrane, to flesh, fat, blood, phlegm, marrow, brain, spinal marrow, the intestines and all their parts; it reaches also to heat, breath and moisture.”¹⁸ As for Aristotle, while a famous passage¹⁹ courted by Renaissance Neoplatonists seems to suggest that innate heat may be celestial²⁰ due to being analogous with solar heat, several other Aristotelian passages either state or at least imply that the heat comes from food.²¹

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- 14 Descartes to Plempius, 15 February 1638, AT I 530; this part is not translated in CSMK.
- 15 For Descartes’ positioning towards coeval chymistry, the most helpful resource remains BERNARD JOLY, *Descartes et la chimie*, Paris, Vrin, 2011. See also JEAN-FRANÇOIS MAILLARD, “Descartes et l’alchimie: une tentation conjurée?,” in *Aspects de la tradition alchimique au XVII^e siècle: actes du colloque international de l’Université de Reims-Champagne-Ardenne*, ed. by F. Greiner, Paris, SEHA [u.a.], 1998, p. 95-109.
- 16 For Fernel’s position on this issue see HIRO HIRAL, “Alter Galenus: Jean Fernel et son interprétation platonico-chrétienne de Galien,” *Early Science and Medicine* 10 (2005), p. 1-35, p. 26 *et passim*.
- 17 On innate heat see MENDELSON, *Heat and Life*; FRIEDRICH SOLMSEN, “The Vital Heat, the Inborn Pneuma and the Aether,” in *The Journal of Hellenic Studies* 77 (1957), p. 119-123; for a recent short overview, ELISABETH MOREAU, “Innate Heat,” in *Encyclopedia of Renaissance Philosophy*, ed. by M. Sgarbi, Cham, Springer, 2015, DOI: 10.1007/978-973-319-02848-4_399-391.
- 18 HIPPOCRATES, *Ancient Medicine; Airs, Waters, Places; Epidemics I and III; The Oath; Precepts; Nutriment*, translated by W. H. S. Jones. Vol. 1. Loeb Classical Library, London, Heinemann, 1958, p. 345.
- 19 ARISTOTLE, *De generatione animalium*, 736a-737a: “the semen contains within itself that which causes it to be fertile — what is known as ‘hot’ substance, which is not fire nor any similar substance [...] this substance is analogous to the element which belongs to the stars;” also later “the heat which is in animals is not fire and does not get its origin or principle from fire.”
- 20 However, there was pushback from other commentators underlining that Aristotle had only made an analogy, not stated an identity. Joachim Cureus, a German theologian and an old-school Aristotelian, writes: “Non fuit ita incogitans Aristoteles, ut aeterna & incorruptibilia misceret cum caducis & corruptibilibus, sed facit collationem ex analogia, sicut manifeste ostendunt verba.” CUREUS, *Lib. Ph.*, p. 264-265, quoted after D. P. WALKER, “The Astral Body in Renaissance Medicine,” *Journal of the Warburg and Courtauld Institutes* 21 (1958), p. 119-133, esp. p. 129: “Aristotle was not as thoughtless as to mix up eternal and incorruptible things with those that are perishing and corruptible; instead he made a comparison by analogy, as [his] words explicitly reveal” [my translation.]
- 21 ARISTOTLE, *De partibus animalium*, 650a1-5; *De sensu*, 442a4; *De respiracione*, 473a10: “Further, how are we to describe this fictitious process of the generation of heat from the breath? Observation shows rather that it is a product of the food.”

Galen, on the other hand, explicitly and repeatedly endorsed a vision of food as a source of heat in the body: "All nutriment [...] increases the heat of the animal [...] and likewise it truly heats the body which it nourishes;"²² food also serves as fuel for physiological processes: "Whatever in the blood is fatty, light, and tenuous, becomes in the warmer bodies a kind of fuel for heat, in the colder it is stored [...] but in the parts warmer by nature such as the fleshy ones, it is taken up by the heat itself and carried off."²³

While not directly derivative from these Ancient sources, Descartes' own project remains largely compatible with them. For Descartes, the fire in the heart comes from the blood, which in turn is a distilled and fermented form of chyle, meaning that the fire comes ultimately from food; additionally, the fire comes from the air by means of respiration. Thus while Descartes explains the micro-process differently, the larger contours of his theory follow Ancient sources including in the issue of the origin of fermentational heat.

3. The 'Heat-Rarefaction' Model: A Mechanist Version of Fermentation

Beyond being the source of all innate heat, this fermentation is also the efficient cause of the beating of the heart, by driving the expansion of the blood matter: "it is this rarefaction of the blood alone that is the cause of the movement of the heart."²⁴ Descartes exposes this in most detail in *La description du corps humain*, Part Two ("Concerning the Motion of the Heart and Blood").²⁵

Without dwelling here on the debate about the movement of the heart as it relates to the circulation of the blood,²⁶ I will focus on how exactly Descartes claims that fermentation works at a microscopic level to further the physiological processes necessary for the beating of the heart. This approach will reveal the main features of Descartes' model of how fermentation happens, and will shed light on his 1638 disagreement with Plempius. The reason I understand this as an analogical scientific model is because Descartes uses it to explain not just everyday fermentations, but also processes in the body, transferring onto physiology the blueprint of how he understands everyday fermentations to be working. This will be explained in detail in the following.

22 Galen (Kühn), I, 660.

23 Galen (Kühn), I, 606.

24 *La Description du corps humain*, AT XI 244; G 182.

25 For Descartes, the issue of what causes the movement of the heart is not a marginal debate, but one that he considers central to the whole of medicine, since "without it, we cannot know anything about the theory of medicine, because all the other functions in the animal depend on it." *Ibid.*, AT XI 245; G 182.

26 This has received much attention, mainly due to the Descartes-Harvey controversy; see, among others: FUCHS, *The Mechanization of the Heart*; LUCIAN PETRESCU, "Descartes on the Heartbeat: The Leuven Affair," *Perspectives on Science* 21 (2013), 397-428; FABRIZIO BALDASSARRI, *Il metodo al tavolo anatomico. Descartes e la medicina*, Rome, Aracne, 2021, esp. p. 74-82; BITBOL-HESPÉRIÈS, "Cartesian Physiology".

In the *Description*,²⁷ Descartes argues that the undoubtedly existing heat in the heart is of the same nature as “that which is caused by the addition of some fluid, or yeast, which causes the body with which it is mixed to expand.”²⁸ It is this fermentative expansion at micro-level which holds the key to the circulation of blood, in Descartes’ view. The blood expands, growing in volume and becoming rarefied as its particles move away from each other. In addition, the mechanical movement is imparted to adjacent particles. Thus, even a small quantity of such rarefied blood can animate an incoming larger quantity into the same expansion behaviour:

the small amount of rarefied blood that remains in these ventricles, mixing straightaway with the fresh blood coming in, is like a kind of yeast [*comme vne espece de leuain*], which causes it to heat and expand immediately, and by these means the heart swells, hardens, and becomes a little squatter in shape [...]²⁹

The analogies regarding this phenomenon had been laid out more explicitly and vividly in the 1638 correspondence with the physician, Plempius,³⁰ where Descartes claimed that the small quantity of blood that remains in the heart “performs a fermentation” much like the fermentations observable in nature:

we see that certain liquids, when mixed with certain others, by this very act they heat up and inflate; in the same way, indeed in the recesses of the heart some humour could reside, like a ferment [*instar fermenti*], whose admixture causes another incoming humour to swell up.³¹

Since he knew that Plempius was suspicious of how this rarefaction happens, Descartes explains in more detail:

As the blood swells up in the heart, indeed the larger part of it exits violently through the aorta and the arterial vein, yet another [part] in fact remains inside, which, filling the inner ventricles of the heart, through a new degree of heat takes over, as it were, the nature of ferment (*veluti fermenti naturam adipiscitur*); and immediately afterwards, as the heart deflates, anew the blood that glides in through the vena cava and the arterial vein mixes itself up quickly, in order to

27 The text, said to have been composed around 1647-1648, was published posthumously by Clerselier in 1664. See the Introduction to this volume.

28 DESCARTES, *La Description du corps humain*, AT XI 228; G 172.

29 *La Description du corps humain*, AT XI 231; G 174.

30 For the debate with Plempius see also ETIENNE GILSON, *Études sur le rôle de la philosophie médiévale dans la formation du système cartésien*, Paris, Vrin, 1951, p. 84-91; BALDASSARRI, *Il metodo al tavolo anatomico*, p. 74-82.

31 Descartes to Plempius, 15 February 1638, AT I 523. Original Latin is “denique vt videmus quosdam liquores quibusdam alijs admistos hoc ipso incalescere atque inflari, sic forte etiam in recessibus cordis nonnihil humoris instar fermenti residere, cuius permistione alius humor adueniens intumescit.” Cf. existing translation at CSMK 80 which renders “instar fermenti” as “yeast-like” although such a term is absent in the original (‘yeast’ usually translates the French *levain* or the Latin *levamen*, both terms used by Descartes in other places).

quickly grow in volume and depart for the arteries; yet another part of it is left behind, which acts like a ferment (*fermenti vice*).³²

Descartes is here showing caution when mentioning the ferment — he never says it is a ferment, but that the liquid 'acts like', or 'serves as' a ferment, or is endowed with 'the nature of a ferment'. This caution is indicative of Descartes distancing himself in this respect from the coeval chymical philosophy. He does not mean the fermentation such as the chymists understand it, but he means something *similar* or *analogous* to it as to the manner of action. He does believe that these processes are actual fermentations, but he lays stress on the precise manner in which he conceptualizes them, and which is different from the understanding that was current among chymical philosophers.

But Plempius' response is unexpected. He fears that the ferment may be a 'figment' of Descartes' scientific imagination: "Confugis deinde ad fermentum cordiale, quod rarefaciet sanguinem, quod fermentum vereor ne figmentum sit. Et vt non sit, quomodo, inquam, tam celeriter rarefaciet?"³³ The disagreement concerns the issue of how the rarefaction of the blood in the heart happens; Plempius doubts that fermentation could effect such a powerful motion by itself. Descartes in turn expresses that he is "extremely surprised" that no one had hitherto had the insight that it is "this rarefaction of the blood alone that is the cause of the movement of the heart,"³⁴ including Aristotle. He is attempting to draw attention away from the 'ferment' issue, and onto his own ideas about the rarefaction of blood. The 'ferment' is in fact secondary, he suggests.

The key to understanding the stakes of this passage is that Descartes employs here a mechanistic model of fermentation which I will call the 'heat-rarefaction' model. Fermentation, in this Cartesian version, uses heat as a means to increase space between particles of matter, hence to 'rarefy' and 'subtilize' it, leading to the mass of matter taking up more space and hence its parts being propelled through various channels as are available (such as the vein structure in the case of the blood). This model is ontologically different from how coeval chymists understood fermentation to be working. Chymists relied on a medieval tradition which saw fermentation as the process through which a 'ferment' transforms a given mass into the ferment's own nature.³⁵ This tradition, which reached the Latin West along

32 Descartes to Plempius, 15 February 1638, AT I 530; CSMK 83 omits this fragment. Original: "Cum sanguis in corde intumescit, maxima quidem eius pars per aortam & venam arteriosam foras erumpit, sed alia etiam intus manet, quae intimos eius ventriculorum recessus replens, nouum ibi caloris gradum & quamdam veluti fermenti naturam adipiscitur: statimque postea, dum cor detumuit, nouo sanguini per venam cauum & arteriam venosam illabenti celerrime se admiscens efficit, vt celerrime turgescat, in arteriasque discedat; sed relicta rursus aliqua sui parte, quae fermenti vice fungatur." [Translation is mine.]

33 Plempius to Descartes, March 1638, AT II 54.

34 *Description*, AT XI 244; G 182.

35 For an excellent treatment of 'ferment' in medieval alchemy and medicine see SÉBASTIEN MOUREAU, "Elixir atque fermentum: New investigations about the link between Pseudo-Avicenna's alchemical 'De anima' and Roger Bacon: Alchemical and medical doctrines," *Traditio* 68 (2013), p. 277-325.

lines of transmission from medieval Islamic medicine and alchemy, emphasized the qualitative³⁶ change of the nature of matter, as opposed to a simple dilution or expansion. For example, in Pseudo-Avicenna's influential treatise *De anima*, the ferment is said to be that which transforms the thing into the nature of the ferment itself: "Fermentum non est aliud nisi hoc quod revertaris causam de illa natura de qua est ad naturam fermenti;"³⁷ it acts like the leaven in bread (*levamen* being used as a synonym for *fermentum* in this work). While *levamen*, by way of its etymology, does suggest 'rising' (a term used in baking until today), the focus was not on the rarefaction of existing matter (and consequent increase in volume) as much as on the transformation of its nature. For Descartes, however, there seems to be no question of a qualitative transformation of matter at microscopic level; it is a *rearrangement of particles* at microscopic level, which *only apparently* leads to a transformation at macroscopic level. In other (Aristotelian) words, fermentation for chymists was a substantial change, while for Descartes it could be subsumed under accidental change.

Descartes' fermentation hence creates heat and an agitation³⁸ of particles, promoting further movement and rarefaction. As Justin Smith also emphasizes, the change taking place is solely quantitative: "it is clear that Descartes conceives fermentation as a straightforwardly microstructural process, and that he conceives the changes it brings about not in terms of the emergence of new forms but in terms of the quantitative alteration of preexisting corpuscles."³⁹ Marina Banchetti-Robino argues similarly: "the Cartesian account would not accept that chemical qualities are higher-level properties that have any causal power unto themselves, since all causal efficacy was attributed only to mechanistic properties and to primary causes."⁴⁰ In the case of fermentative processes, these primary causes acted at the level of particles; whatever happened macroscopically was a result of microscopic rarefaction. Hence, with fermentation, Descartes employs a bottom-up (or: upward) model of causation.⁴¹

At this point an objection might be raised. When it comes to the blood remaining in the heart which 'acts like a leaven' or a 'ferment,' Descartes would seem to be using the old fermentation model, because the remaining drop of blood confers its 'nature' to the incoming blood. Yet I argue that what exactly it conveys in Descartes' understanding is not a different *nature*, but a *property*: heat and agitation of particles

36 In the sense in which we understand 'qualitative' now. For the scholastics this would have been a change of substantial form.

37 PSEUDO-AVICENNA, *De anima*, 363; apud MOUREAU, "Elixir atque fermentum," p. 292.

38 For an explanation of how for Descartes the expansion by heat occurs through violent motion, see J. R. PARTINGTON, *A History of Chemistry*, London, Macmillan St Martin's Press, 1969, vol. II, p. 435.

39 JUSTIN E. H. SMITH, *Divine Machines: Leibniz and the Sciences of Life*, Princeton, Princeton University Press, 2011, p. 78-79.

40 MARINA PAOLA BANCHETTI-ROBINO, "Mechanism and Chemistry in Early Modern Natural Philosophy," in *Encyclopedia of Early Modern Philosophy and the Sciences*, ed. by D. Jalobeanu and Ch. T. Wolfe, Cham, Springer, 2020, p. 3. DOI: 10.1007/978-973-319-20791-9_145-141.

41 For more on causation, including in Descartes, see Jaegwon Kim's work, esp. JAEGWON KIM, "Mental Causation in a Physical World." *Philosophical Issues* 3, Science and Knowledge (1993): 157-176.

(motion). The matter remains the same: blood. This means that Descartes interprets mechanistically even those fermentations which at first glance seem to be working after a chymical model. This mechanist functionality of Cartesian fermentation as 'heat-rarefaction' is focused on processes that, in their macroscopic manifestations in the natural world (as opposed to inside the human body), can be observed and even measured externally (such as ebullition or effervescence, as well as thermal changes). It is an instrumental model of fermentation: fermentation serves a certain goal of transforming matter, but it does not have its own mysterious agenda. Therefore, this model is incompatible with any occult powers, hidden virtues, or other types of obscure agencies that elicited caution on the part of more hardline mechanist philosophers. The 'heat-rarefaction' model of fermentation will have some success with followers such as Borelli, before merging with its chymical counterpart in the work of English physicians such as Thomas Willis or William Simpson.

My hypothesis, hence, is that in their letters of 1638 Descartes and Plempius are in fact talking about different things. What Plempius understood by fermentation was not what Descartes meant. While Descartes makes use of analogies with common fermentations, his underlying stance still entails that such fermentations act by 'heat-rarefaction'. Plempius, however, reads quickly and assumes that Descartes has in mind the fermentation of the chymists, and *this is what he refutes*. The matter is not helped by the fact that Descartes does in fact say that chymistry ('Chymia') provides many examples of the processes he discusses.⁴² Left unconvinced, Plempius accused Descartes of a suboptimal choice of words as regards 'fermentation'; the debate, which turned rather sour,⁴³ is likely to have contributed significantly to Descartes' later avoidance of the term fermentation.⁴⁴ Descartes never stopped employing his comparisons with (fermentative) wine and hay, but ceased to call them explicitly fermentations, resorting instead to describing the phenomena every time in what looks like contrived paraphrases of 'fermentation' ("such as happens with new wines when they are left to mature"). As for the noun 'ferment,' the word later virtually disappeared from his vocabulary, being replaced by 'yeast' (*levain*) which was functionally identical but rhetorically a better option, since as a term in everyday usage it was less likely to conjure alchemical associations.

Fermentation for Descartes, therefore, is a process of heating, rarefaction and subtilization of matter. When blood ferments repeatedly, due to its rarefied state it becomes prone to generating animal spirits which are a more subtle form of matter. In this transformation Descartes claims that there is, again, no qualitative change involved. In Aristotelian terms:

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- 42 Descartes to Plempius, 15 February 1638, AT I 530 (absent in CSMK): "At quid opus est alienis exemplis, quorum magnam multitudinem Chymia posset suppeditare..."
- 43 Plempius mounted an attack at Descartes and petitioned to exclude his teachings from the university. See Descartes to Plempius, 15 February 1638, AT I 534-535; also PETRESCU, "Descartes on the Heartbeat," p. 421.
- 44 In "Descartes and fermentation in digestion," I show how (and why) Descartes grew reluctant to use both fermentation and concoction, all the while still employing the images of natural processes which were, then as now, classified as fermentations.

there is a change in qualities or properties (*ἀλλοίωσις*, *alloiosis*, alteration) but no *substantial* change (*γένεσις*, *genesis*, coming-to-be).⁴⁵ As Descartes insists in *Passions de l'ame*, “elles [les *Esprits animaux*] n'ont besoin à cet effect de recevoir *aucun autre changement* dans le cerveau, sinon qu'elles y sont séparées des autres parties du sang moins subtiles.”⁴⁶

To trace back some of the heritage of Descartes' ideas of medical spirits, it is worth making a short incursion into the medieval philosophies of spirit and medical spirits.

4. Descartes' 'Animal Spirits' and their Medieval Historical Background

For Descartes, the 'animal spirits' in human bodies were “a certain very fine wind, or rather a very lively and very pure flame”⁴⁷ produced by the parts of blood that “penetrate as far as the brain,” thanks to being particularly volatile; these were the “most agitated and most active parts of this blood.”⁴⁸ Such 'spirits' enter the nerves, and from there, they move the limbs of the body-machine.⁴⁹ The production of spirits presupposes the rarefying action of heat;⁵⁰ yet their engendering from the most subtle parts of blood is not a qualitative (substantial) transformation of blood, but a mechanical sieving.⁵¹

Descartes employed his version of the 'animal spirits' in *L'Homme, A Description of the Human Body*,⁵² as well as in the *Passions*. In a comparison of the nerve system of the human body, in this respect, with the mechanical pipe system of the “grottoes and fountains in the royal gardens,”⁵³ the 'animal spirits' corresponded to the water moving through these pipes.

45 ARISTOTLE, *De generatione et corruptione* (On Coming-to-Be and Passing-Away), 319b6-320a5. However, because the process of generating animal spirits as an elevated form of matter is clearly teleological, this poses a problem for Descartes' system; on teleology in Cartesian physiology see: KAREN DETLEFSEN, ed. *Descartes' Meditations: A Critical Guide*, Cambridge, Cambridge University Press, 2013, chapter “Teleology and natures in Descartes' Sixth Meditation;” also DETLEFSEN, “Descartes on the Theory of Life and Methodology in the Life Sciences;” PETER M. DISTELZWEIG, “The Use of *Usus* and the Function of *Functio*: Teleology and Its Limits in Descartes's Physiology,” *Journal of the History of Philosophy* 53/3 (2015), p. 377-399.

46 *Passions de l'âme*, art. X, AT XI 335, my emphasis.

47 *L'Homme*, AT XI 129; G 104-105.

48 *Description*, AT XI 227; G 172.

49 *L'Homme*, AT XI 134; G 107.

50 *Passions*, X, AT XI 334: “toutes les plus vives & plus subtiles parties du sang, que la chaleur a rarefiées dans le coeur, entrent sans cesse en grande quantité dans le cavitez du cerveau.”

51 *L'Homme*, AT XI 130: “ainsi, sans autre preparation, ny changement, sinon qu'elles sont séparées des plus grossieres, & qu'elles retiennent encore l'extreme vitesse que la chaleur du coeur leur a donnée, elles cessent d'auoir la forme du sang, & se nomment les Esprits animaux,” my emphasis. See also *Passions*, X, AT XI 334: “a cause qu'il n'y a que des passages fort estroits, celles de ses parties qui sont les plus agitées & les plus subtiles, y passent seules, pendant que le reste se respand en tous les autres endroits du corps. Or ces parties du sang tres-subtiles composent les esprits animaux.”

52 *Description*, AT XI 227; G 172.

53 *L'Homme*, AT XI 131; G 107.

Importantly, Descartes' animal spirits retain a material nature: "ce que je nomme icy des esprits, ne sont que des corps, & ils n'ont point d'autre propriété, sinon que ce sont des corps tres-petits, & qui se meuvent tres-viste, ainsi que les parties de la flame qui sort d'un flambeau."⁵⁴ They are immanent in living matter — not divine, celestial, or otherwise occult. In animals, including humans, they are transmitted from mother to foetus through the umbilical cord, and while they do not interfere with the rational soul in humans, they act rather as its instruments. A certain time after digestion is achieved, "le mesme sang, ayant passé & repassé plusieurs fois dans le coeur, est deuenue plus subtil."⁵⁵ As the blood is passed repeatedly through the heart, it undergoes every time a process of fermentation, which includes rarefaction. As an effect, the animal spirits, too, become stronger as the blood from which they are produced becomes more purified.⁵⁶ Hence the repeated fermentation leads to production of purer animal spirits. Together with the fermentation in the heart, the 'animal spirits' — ultimately the most refined⁵⁷ form of blood — replace the Aristotelian vegetative and sensitive souls.⁵⁸

I argue that Descartes' 'spirits' and the operations correlated with them (such as the fire of fermentation) are modelled after the 'spirits' of a medical tradition rooted in antiquity and transmitted throughout the Middle Ages.⁵⁹ In particular, Galen had posited very similar spirits of an airy, subtle nature, that originate in respiration and in the blood.⁶⁰ As James Bono notes, Galen's *pneuma* is 'of a corporeal, that is material, nature, though the matter in question is of an exceptionally fine and rarified sort, rather like hot vapor'.⁶¹ Much like Descartes' fire in the heart, this Galenic *pneuma* has a double source in air and blood.⁶² Such spirits were active in all areas where a more subtle, rarefied type of matter was called for, such as in the nerves and the brain.

Throughout the Middle Ages, the idea of *spiritus* underwent gradual changes along different schools of thought. One strand in medieval Arabic medicine brought

54 *Passions*, art. X, AT XI 335.

55 *L'Homme*, AT XI 168, see also AT XI 199.

56 *L'Homme*, AT XI 199: "cependant ces esprits se trouuent estre plus forts, d'autant que le sang qui les produit, s'est purifié, en passant & repassant plusieurs fois dans le cœur," see also AT XI 168.

57 *L'Homme*, AT XI 128.

58 See *Description*, AT XI 202; G 169.

59 For a detailed history of medical spirits, from Antiquity throughout the Middle Ages, see JAMES BONO, "Medical Spirits and the Language of Life," *Traditio*, 40 (1984), p. 91-130. In what follows in this section I am highly indebted to Bono's work. Another notable account of spirit from Antiquity into the seventeenth century is that of MARIELENE PUTSCHER, *Pneuma, Spiritus, Geist: Vorstellungen vom Lebensantrieb in ihren geschichtlichen Wandlungen*, Wiesbaden, Franz Steiner Verlag, 1973.

60 BONO, "Medical Spirits," p. 92.

61 BONO, "Medical Spirits," p. 92. On Galen's *pneuma* see, among others: OWSEI TEMKIN, "On Galen's Pneumatology," *Gesnerus* 8 (1951): p. 180-189; L. G. WILSON, "Erasistratus, Galen, and the Pneuma," *Bulletin of the History of Medicine* 33 (1959): p. 293-314; JULIUS ROCCA, "Chapter 11 Pneuma as a Holistic Concept in Galen," in *Holism in Ancient Medicine and Its Reception*, ed. by C. Thumiger, Leiden: Brill, 2020, p. 268-291; PHILIP VAN DER EIJK, "Galen on Soul, Mixture and Pneuma," in *Body and Soul in Hellenistic Philosophy*, ed. by B. Inwood and J. Warren, Cambridge: Cambridge University Press, 2020, p. 62-88.

62 BONO, "Medical Spirits," p. 92, adding on p. 97 that "[t]here is some question whether Galen considered spirits to have an origin which is internal (derived from the blood) or external (derived from the air)."

it from a fine sort of matter to representing a divine essence. This line harked back to some ideas of Stoic and Neoplatonic heritage. Another school constituted itself along a medieval corpuscular tradition rooted in Aristotle. Within the latter, the spirits retained their material character and medical role, while the immortal soul was retained as transcendent; this forms the contours of a dualism that survived until and beyond Descartes. Costa ben Luca (Constantinus Africanus), in *De animae et spiritus discrimine*,⁶³ claims that the spirits are material while the soul is incorporeal.⁶⁴ He also differentiates between two kinds of corporeal spirits: vital (in the heart), related to respiration and circulation — this one being the source of life; and animal (related to the soul, *anima*), which resides in the brain and feeds on the vital spirit. The *animal* spirit operates the thinking, memory, and the nerves and movement of the muscles.⁶⁵ How exactly the *vital* spirit, on the other hand, functions as a cause of life — whether it has inherent activity or whether it is moved by an external principle — remains unclear; Constantinus does not address this.⁶⁶

This ontological ambiguity is present with Descartes as well. Descartes posits only one type of spirits (the animal spirits), which derive from the fermentational fire in the heart. But while we know that this fire comes to the heart from nutriment via blood, its ultimate origin is shrouded in some obscurity. Descartes does not address the final cause of fermentations in the natural world (presumably, it belongs to the inscrutable will of God). He relies on them as analogies to explain physiology, and explains how he believes that they happen at a microscopic level (which is a speculative hypothesis). But the ultimate question of why fermentations happen at all remains largely beyond the scope of the mechanist endeavour.

These tensions are relevant for Descartes' positioning in terms of the debate regarding the role of the soul (or of other agents, internal or external) in moving the body. While in Aristotle's more immanent biology and teleology, soul and body had been inseparable,⁶⁷ for the medieval scholastics a rift took shape between mortal matter (flesh) and a divine, transcendent soul. The distance between them was connoted

63 COSTA BEN LUCA, "De animae et spiritus discrimine liber" in CONSTANTINUS AFRICANUS, *Opera*, Basel, 1536, p. 308-317. See the reprint in PUTSCHER, *Pneuma, Spiritus, Geist*, p. 145-150.

64 "Dicamusque quod prima differentia haec est, videlicet, quod spiritus est corpus. Anima vero res incorporea est." -PUTSCHER, *Pneuma, Spiritus, Geist*, p. 150.

65 Costa ben Luca, in PUTSCHER, *Pneuma, Spiritus, Geist*, p. 147: "In humano corpore sunt *duo* species: Unus, qui vocatur *vitalis*, cuius nutrimentus vel sustentatio est aer, et eiusdem animatio [*sic: for emanatio*] est ex corde, et mittitur per pulsus ad reliquum corpus, et operatur vitam, pulsum atque anhelitum. Est et alter, qui ab anima, dicitur *animalis*, qui operatur in ipso cerebro, cuius nutrimentum est spiritus vitalis, et eius emanatio est ex cerebro, et operatur in ipso cerebro cogitationem, et memoriam, atque providentiam, et ex eo mittitur per nervos ad caetera membra, ut operetur sensum, atque motum."

66 See BONO, "Medical Spirits," p. 95.

67 For Aristotle soul and body formed a whole; ARISTOTLE, *De anima* 412a28-29; "neither the soul nor certain parts of it, if it has parts, can be separated from the body" (413a4-5). However, 429b-430a may be (and was) taken as a suggestion that the rational soul is, after all, separable from the body. See also KATHARINE PARK, "The Organic Soul," in *The Cambridge History of Renaissance Philosophy*, ed. by C. B. Schmitt *et al.*, Cambridge, Cambridge University Press, 2007, p. 468.

morally. Under these auspices, spirits, which had started out in Galenic tradition as a rarefied, subtler form of matter, gradually were reconceptualized to fit the dichotomy between the material body and the more transcendent component that had begun to take hold; within this dichotomy, on the one side, spirit(s) approached the soul and its incorporeal nature, and on the other side might still be found performing physiological functions (hence retaining material character). Alain de Lille, for example, found the compromise of positing two kinds of spirit: rational (incorporeal, immortal) and physical (natural and perishing with the body):

There is in fact in man a double spirit, the rational and incorporeal spirit, which does not perish with the body; and another one, which is called physical or natural, by whose mediation the rational soul is united with the body, and this spirit is more subtle than air and even than fire, and it mediates sense perception and imagination: and that [spirit] perishes with the body.⁶⁸

As Bono shows, the issue at hand was the transition of the human being from its mortal condition in the flesh towards a more spiritualized state (the eschatological narrative). In other words, at the more 'spiritual'⁶⁹ end of this continuum salvation had to be possible, while at the more corporeal end (where spirits were still understood as material) the natural philosophy had to provide medical explanations about how the human body works.

Regarding Descartes, my thesis is that while the sixteenth century's revival of Renaissance Neoplatonism and of natural magic would later blur these differences, Descartes, interestingly, reverted in part to earlier medieval traditions of thought in which spirits were still entirely corporeal (material) and fulfilled medical and physiological functions. The rationale for this might have been that if Descartes had wished to uphold the dichotomy between the body and the rational soul, another non-corporeal item (of the type of Alain de Lille's *spiritus incorporeus*) would have been in the way.⁷⁰ Thus with regard to this particular issue Descartes replaced Aristotle's framework of 'souls' with an updated version of Galenic *pneuma* in the form of 'animal spirits.' It is to be noted that such 'animal spirits' are, in principle, compatible with both Descartes' more restricted mechanist view, and with the new

68 ALAIN DE LILLE, *Contra haereticos* I, 28, in M.-D. CHENU, "Spiritus: Le vocabulaire de l'âme au XII^e siècle," *Revue des Sciences Philosophiques et Théologiques* 41 (1957), p. 209-232, p. 215: "Est namque in homine duplex spiritus, spiritus rationalis et incorporeus, qui non perit cum corpore; et alius qui dicitur physicus sive naturalis, quo mediante anima rationalis unitur corpori, et hic spiritus est subtilior aere, et etiam igne, quo mediante fit sensus et imaginatio: et ille perit cum corpore." [Translation is mine.]

69 I here use 'spiritual' rather anachronistically, in a modern sense, which is itself the result of this historical process of semantic transformation.

70 Descartes will have been aware of the troubles into which Fernel had run due to positing two kinds of immortal agents in the body. Criticizing the doubling of soul and spirit in Fernel's embryology, Cureus had written: "since the heavenly bodies are exempt from the mutability of generation and corruption, you will have to imagine that the heat from the heavens is infused into bodies by a miracle, as St Thomas wished for the soul, and thus in man there will be two immortal bodies, the soul and the innate heat; which everyone, I think, will admit is absurd." CUREUS, *Lib. Ph.*, p. 262, in D. P. WALKER, "The Astral Body," p. 130.

chymical philosophy; the difference lies in the explanation of the cause of movement of particles, but the particulate nature and the role of these spirits in physiology is preserved in both versions.

One position not too far from Descartes' in this particular regard was that of Alfred of Sareshel (Alfredus Anglicus), a thirteenth century monk (active between 1180 and 1217) and one of the earliest commentators of Aristotle in the medieval Latin West. In his work *De motu cordis*,⁷¹ which treats of medical spirits, the heart plays a central role as the site of such spirits.⁷² As the seat of life, the heart also imparts life throughout the body by means of its motion, the heartbeat: "Virtus cordis in motu est; motu enim vitam distribuit."⁷³ But for Alfred, the source of the heartbeat, a violent motion, had to be an *external agent* — which he located in an external heat, as opposed to the innate heat of the Ancients. The heat did reside in the heart, but its ultimate source was extrinsic and divine — the soul: "exterius est principium [...] Extrinseco igitur principio [...] movetur."⁷⁴ However, the heat was nevertheless for him the immediate, efficient cause of the heartbeat, which it produced by means of the dilation and rarefaction of the blood. Thus it is possible that Alfred ascribes to a similar model of 'heat-rarefaction.' There are, however, two main differences to consider. First, Alfred does not call this principle 'fermentation,' nor does he write of a ferment. Second, for Descartes, the heat-rarefaction process (which he understands as a fermentation) is a wholly inherent principle, not an extrinsic one. The fermentation in the heart creates its heat spontaneously, and does not need heat from an external source, just as in the natural world where the fermenting masses normally heat up of their own accord: "neither beer, nor wine, nor bread, from which a great part of our blood arises [is made], require intense heat in order to ferment, but indeed they spontaneously warm up of their own accord."⁷⁵ Descartes claims that the process of rarefaction effected in the body by this immanently generated heat is, if not identical, very similar to the analogous processes in the natural world: "I am not maintaining that the rarefaction of the blood that takes place in the heart is similar in all respects to the rarefaction which is brought about by artificial means. All the same, to be quite frank, I do think it comes about in that way."⁷⁶ In more than one sense, this echoes Aristotle's discussion of 'concoction by boiling' in the *Meteorology* IV, where the Stagirite had argued that "it makes no difference whether it takes place in an artificial or a natural vessel, for the cause is the same in all cases."⁷⁷ Though what Descartes envisages in the blood is a fermentation, Descartes' idea of fermentation

71 See the complete edition by C. BAEUMKER, *Des Alfred von Sareshel (Alfredus Anglicus) Schrift De motu cordis* (BGPhMA 23.1-2), Münster, 1923. On Alfred see the bibliography in BONO, "Medical Spirits," p. 112, note 63.

72 Cf. BONO, "Medical Spirits," p. 113.

73 *De motu cordis*, cap. 5 (Baumker p. 17). [Paraphrase is mine.]

74 *De motu cordis*, cap. 9 (Baumker p. 36 f.): "the principle is external ... Hence, it is moved by an extrinsic principle." [Translation is mine.]

75 Descartes to Plempius, 15 February 1638, AT I 530. [Translation is mine.]

76 Descartes to Plempius, 15 February 1638, AT I 530; CSMK 83.

77 ARISTOTLE, *Meteorology* IV, 381a9-12.

parallels Aristotle's 'boiling' (ἐψῆσις) firstly in a functional sense (fermentation, just as boiling, could happen in different kinds of vessels) and secondly, in content: Since Aristotle's boiling included the natural processes undergone by milk and must, it makes sense to consider it related to fermentation.⁷⁸

Another point in which Descartes' project exhibits some similarity with that of Alfred is the *spiritus*. For Alfred, the spirit was ontologically intermediate between the organic body and the soul (*anima*). Although it was ultimately the soul from whence all motions in the body, as well as life, originated, the soul itself remained an external principle. It lived in the heart conceptually but not physically. But how could the soul then act on and from the heart, and perform actions like moving the limbs? The answer is that this happened with the help of spirit, which played the role of instrument of the soul. The (vital) spirit was a 'virtue' distributed (irradiated, as Alfred writes) throughout the body from its center, the heart. But while the ultimate cause remained the soul, the local efficient cause of this movement of irradiation was heat. In a similar way, for Descartes, the fermentational fire in the heart drives the production of animal spirits,⁷⁹ which in turn play a key role in muscle movement. A salient difference, however, is that Descartes' spirits are material, while Alfred's tended towards preternaturality.

Another significant voice in medieval natural philosophy, Albert the Great, sides with Alfred as to the heart being the domicile of the soul in the body, as well as to the spirits performing physiological functions. Yet Albert does not mention any celestial origin for such spirits,⁸⁰ promoting a view of spirit as a fine vapor⁸¹ (thus closer to Galen). Albert defines the spirit, which is found in the bodies of the animals, as the "vehicle of life," adding that "that which is the seminal moisture in the bodies of the living should be more mixed in with the airy, spiritual moisture and a heat should be in it, making the spirit in it frothy."⁸² For otherwise, this moisture would not be rendered the principle of life.⁸³

However, the Albertian spirit functions, like for Alfred, as a mediator between the soul and the body and as the direct instrument of the soul. Only that instead of an ontological mediator, it is a functional one, whose own nature remains material.

Descartes, I believe, is to be seen as a heir of this tradition, which from his own vantage point is an older one when compared to the more recent developments of the sixteenth century. Unlike for Renaissance Neoplatonists such as Fernel or Severinus,⁸⁴ Descartes' animal spirits are not produced in the stars, but wholly immanent to the

78 However, while boiling has some overlap with fermentation in terms of how it works on matter, the concept of concoction (πέψις, *pepsis*) may be even more closely related to fermentation.

79 For Alfred, the spirits "irradiated" from the heart were vital spirits which were close to the very principle of organic life. Alfred also posited animal spirits which were more concrete. We shall not delve into detail here.

80 See Albertus. *On Animals: A Medieval Summa Zoologica*. Translated by Kenneth F. Kitchell and Irven Michael Resnick. Vol. 2. Baltimore: Johns Hopkins University Press, 1999, here Chapter XX, 1.4.

81 See BONO, "Medical Spirits," p. 121, p. 124 f.; cf. ALBERT, *On Animals* XX.1.7.

82 This is likely an Aristotelian reference, see *De gen. anim.* 3.11, 762a13-27.

83 *On Animals*, XX 1.1 (p. 1358).

84 See D. P. WALKER, "The Astral Body," *passim*.

body and purely material. In this respect, other aspects of Descartes' heritage may also be traced back to one particular "corpuscular theory" which, as William Newman has noted, was derived from Aristotle's *Meteorology* IV's "corpuscular proclivities."⁸⁵ This version of Aristotelian corpuscularism later "became a mainstay of medieval alchemy,"⁸⁶ only to merge, in the seventeenth century, with Paracelsianism and iatrochemistry. In my view, this tradition supplies another apt framework of thought for Descartes' 'heat-rarefaction' model of fermentation. Notably, Descartes does not join the step of merging corpuscularism with iatrochemistry. He reverts to the older, medieval version, exemplified by writers such as Albert the Great; while this tradition itself was not without affinities with chemistry, the stage that Descartes is most closely related to is the one *before* this tradition's definitive "marriage," as Newman calls it, with Paracelsian iatrochemistry. This is not to say that Albert was a foreigner to alchemy,⁸⁷ only that, as Newman notes, he was "willing to entertain corpuscular ideas when framing his explanations of phenomena."⁸⁸ Thus Albert's ideas on the microstructure of matter turn out more compatible with Cartesian mechanism than later mergings which included occult forces, pulsific faculties, or other formative powers or virtues.

Descartes' animal spirits do replace the Aristotelian vegetative and nutritive souls, which were immanent faculties. Importantly, however, they do not replace all the souls — the *ame*, rational soul,⁸⁹ remains; but this soul is transcendent, divine, and put into the body by God. Descartes hence solves the dilemma by positing a dualism in which the transcendent soul stays, while matter itself moves fueled by fermentation, which becomes the most prominent efficient cause of physiology: the force that fuels the production of blood, its circulation, and hence also the production of animal spirits. This dualism is not unlike some of the solutions found to this problem by medieval physician scholars — like Alfred of Sareshel — who preferred to keep the 'soul' as an external principle while at the same time having to account for how the body performs the motions of living, but crucially, without granting matter an intrinsic moving agency.

The final cause of fermentation, however — and the origin of the motion which it produces — must be said to rest with divine causation. In other words, why the fermentational fire exists at all in bodies — which is the same as asking 'why is there organic life' — is, for the medievals, left to God. That does not mean that the fire itself has a literal celestial origin; as argued in the previous section, heat could very well constitute a local, efficient cause of movement. Descartes' fermentation, too, is a 'heat-rarefaction' process with no occult powers partaking in it.

85 NEWMAN, "Corpuscular Alchemy," p. 145.

86 *Ibid.*

87 See, among others, ROBERT HALLEUX, "Albert le Grand et l'alchimie," *Revue des Sciences philosophiques et théologiques* 66/1 (1982), p. 57-80.

88 WILLIAM R. NEWMAN, *The Summa Perfectionis of Pseudo-Geber: A Critical Edition, Translation and Study*, Leiden-New York, Brill, 1991, p. 189.

89 The rational soul remains the ultimate *movens* of the body. For how the mind moves the body as an occasionalist cause see DANIEL GARBER, "Mind, Body, and the Laws of Nature in Descartes and Leibniz," in DANIEL GARBER, *Descartes Embodied: Reading Cartesian Philosophy through Cartesian Science*, Cambridge, Cambridge University Press, 2010, p. 133 ff.

We shall now take a look at how Descartes implements his theory in two physiological realms: muscle movement and generation.

5. Animal Spirits and Fermentation in Muscle Movement

For Descartes, both animal spirits⁹⁰ and fermentation (as their driving force) play a role in muscle movement.⁹¹ From the brain, the animal spirits travel along the nerves, descending and ascending⁹² across a network compared with trees and their branches.⁹³ Through their movements, they “have the power to change the shapes of the muscles into which these nerves are embedded, and in this way to move all the limbs.”⁹⁴ The mechanism through which this happens entails the contraction and inflation of muscles and their opposites, due to a higher or lower quantity of spirits entering the muscles and combining with spirits that are already present.⁹⁵ While spirits are in movement all the time, even a small differential quantity suffices in order to move a certain muscle.⁹⁶

The direction into which the animal spirits move is determined by two factors, both geometrical: the size and shape of the animal spirit particles themselves, and the size and shape of the pathways they take.⁹⁷ The pathways are predetermined by God;⁹⁸ the movement of the animal spirits, while fueled by the fire in the heart, obeys the predetermined rules of geometry. The spirits' own shapes cause an “unequal agitation”⁹⁹ (*inegale agitation*) due to differences such as in speed or force: the smaller, subtler ones move faster. The causes of these inequalities may be either in the “diverse dispositions” of the organs which contributed to their generation, or in the “diverse types of matter of which they are composed;”¹⁰⁰ an example of the latter case are ‘vapours of wine’, which, after drinking, convert into stronger and more abundant spirits¹⁰¹ which “move the body in several strange ways” — perhaps as a result of wine already being a fermentative liquid, hence, containing the principle of movement.

Descartes' account is reminiscent of Plato's account of the structure of matter in *Timaeus*. For Plato, the subtlest particles of matter were those of fire, whose shape

90 For an account of the workings of Cartesian animal spirits, see also BALDASSARRI, *Il metodo al tavolo anatomico*, p. 106-110.

91 For an overview of the philosophies of muscular movement, see DOROTHY M. NEEDHAM, *Machina Carnis: The Biochemistry of Muscular Contraction in Its Historical Development*, Cambridge, Cambridge University Press, 1971, esp. p. 1-27 for early developments.

92 *Primae Cogitationes*, AT XI 530.

93 *Primae Cogitationes*, AT XI 532.

94 *L'Homme*, AT XI ; G 106-107; see also *Description*, AT XI 227; same idea in *L'Homme*, AT XI 132; *Passions*, AT XI 332; *Passions*, AT XI 335.

95 *Passions*, art. XI, AT XI 335-336.

96 *Primae Cogitationes*, AT XI 518.

97 *L'Homme*, AT XI 189-190.

98 *L'Homme*, AT XI 192.

99 *Passions*, art. XIV, AT XI 339.

100 *Passions*, art. XV, AT XI 340.

101 *Passions*, art. XV, AT XI 340.

was a pointy tetrahedron endowed with a “cutting quality.”¹⁰² This is compatible with the rarefaction role of heat in Descartes’ natural philosophy.

Importantly, the *movens* of the spirits is an immanent principle in the body — the heat in the heart.¹⁰³ In fact, the fire from the heart constitutes the corporeal principle of fermentation and of muscle movement. “For as long as we live,” Descartes writes, “there is a continual heat in our heart, which is a kind of fire maintained by the blood in the veins, and this fire is the corporeal principle of all the movements of our limbs.”¹⁰⁴ Hence movement of muscles is indirectly owed to the fermentational fire, through the mediation of animal spirits.

Later mechanical philosophers largely adopted Descartes’ explanation, further emphasizing fermentation as a chemical reaction at particle level.¹⁰⁵ Many of them did, however, employ a less restrictive version of mechanism in which mechanical laws were acknowledged but the animal spirits were considered the instruments of souls, including in non-human animals.¹⁰⁶ As regards muscular movement, a common modification was that they claimed fermentation happened locally, in the muscle, as a swelling that provoked the movement directly, in addition to having been triggered by the animal spirits traveling along the nerves. Such is the case in the works of Giovanni Alphonso Borelli (1608-1679), who, like Descartes, employs fermentation analogies from the natural world as well as from chemical experiments to account for physiological processes. For Borelli, as for Descartes, fermentation was a process or mechanism defined by heat and a subsequent expansion in volume. Noting that “all acid spirits mixed with fixed salts suddenly boil by fermentation,” he concludes that “in muscles some similar mixing may occur,” entailing a “sudden fermentation and ebullition which fill and expand the pores of the muscles, resulting in turgescence and contraction”¹⁰⁷ — a mechanism “not different from that of common fermentation.”

Many other seventeenth-century thinkers similarly held that fermentation triggered muscle movement by happening locally, in the muscle. For some, such as William Croone¹⁰⁸ (1633-1684), the animal spirits had a character similar to

102 Cf. PLATO, *Timaeus*, transl. by Donald J. Zeyl, Indianapolis/Cambridge: Hackett Publishing Company, 2000, p. 47 (56a6-56b2): “the body with the sharpest edges belongs to fire, the next sharpest to air, and the third sharpest to water. Now in all these cases the body that has the fewest faces is of necessity the most mobile, in that it, more than any other, has edges that are the sharpest and best fit for cutting in every direction.”

103 *Passions*, XVI, AT XI 342: “les esprits excitez par la chaleur du coeur.”

104 *Passions*, art. VIII, AT XI 333: “pendant que nous vivons, il y a une chaleur continue en nostre coeur, qui est une espece de feu que le sang des venes y entretient, & que ce feu est le principe corporel de tous les mouvemens de nos membres.” [Translation is mine.]

105 For instance Borelli; see GIOVANNI ALFONSO BORELLI, *De Motu animalium*, Jo. Alphonsi Borelli, ... *opus posthumum*, Rome, ex typographia Angeli Bernabo, 1680-1681; English translation in GIOVANNI ALFONSO BORELLI, *On the Movement of Animals*, transl. by Paul Maquet, Berlin, Heidelberg, Springer 1989.

106 See DES CHENE, “Mechanisms of Life,” p. 251.

107 BORELLI and MAQUET, *On the Movement of Animals*, 232.

108 See L. G. WILSON, “William Croone’s Theory of Muscular Contraction,” *Notes and Records of the Royal Society of London* 16 (1961), p. 158-178, esp. p. 160.

wine — again, likely related to wine being itself already a fermentative liquid, hence carrying over the fermentative expansion force into the body. Croone understood animal spirits as a “subtle, active and highly volatile liquor of the nerves, in the same way as we speak of spirit of wine or salt or others of this kind.”¹⁰⁹ Like Borelli, he presumed that animal spirits travel along the nerves, but that they also produce a local fermentation in the muscles by their interaction with blood. For John Mayow (1640-1679), similarly, muscle contraction was the result of a local fermentation or ebullition in the muscle; interestingly, this fermentation is caused by a different chemical reaction. Instead of indigenous animal spirits and blood, Mayow here presumes a mixing of ‘nitro-aërial spirits’ derived from air through respiration, with a locally extant sulphureous fuel; the reaction provokes contraction. Somewhat later along a similar pathway of reasoning, oxygen would be discovered.¹¹⁰ While this is far from anything Descartes himself imagined, his model of fermentation as ‘heat-rarefaction’ may have been one of the factors that nudged his followers into this direction of thinking.

6. Fermentations in the Formation of the Embryo

In his theory of generation,¹¹¹ Descartes reserves for fermentation two kinds of roles. The first one refers to the fermented, i.e. heated and rarefied animal spirits, the second subtlest blood particles (after the first ones going to the brain)¹¹² flowing to the vessels of reproduction¹¹³ prior to generation. The second one refers to the fermentative mixing of seeds which gives rise to the embryo; here fermentation plays a direct role, non-mediated by any animal spirits. In broad lines, Descartes claims that the male and female¹¹⁴ seed mixing together in the uterus engender a fermentation, which, as expected, entails heat;¹¹⁵ the heat then pushes the seeds

109 Quoted after WILSON, “Muscular contraction,” p. 160, note 11. Wilson notes that the analogy between *spiritus animae* or *spiritus vitae* and the spirit of wine is supported by both van Helmont and Sylvius. See JAN BAPTISTA VAN HELMONT, *Ortus medicinae*, Leyden, 1655, p. 122, and FRANS DE LE BOË (FRANCISCUS SYLVIUS), *Disputationem medicarum* 4. 29 in SYLVIUS, *Opera medica*, Coloniae Allobrogum, 1680, p. 8.

110 SIDNEY OCHS, *A History of Nerve Functions: From Animal Spirits to Molecular Mechanisms*, Cambridge, Cambridge University Press, 2004, p. 81, note 50.

111 For an account of Cartesian generation see also BALDASSARRI, *Il metodo al tavolo anatomico*, p. 191-197.

112 *L’Homme*, AT XI 128; *Primae Cogitationes*, AT XI 507.

113 *L’Homme*, AT XI 128; G 104. Original: “apres celles qui entrent dans le cerveau, il n’y en a point de plus fortes ny de plus vives, que celles qui se vont rendre aux vaisseaux destinez à la generation.”

114 For the background of the contribution of the female seed to generation in Antiquity see SOPHIA M. CONNELL, *Aristotle on Female Animals: A Study of the Generation of Animals*, Cambridge, Cambridge University Press, 2016, Chap. 3, “Menstrual blood and female semen,” p. 93-120; and Chap. 4, “Matter,” p. 121-160.

115 For the role of heat in generation in Ancient theories, see GIANNA POMATA, “Innate Heat, Radical Moisture and Generation,” in *Reproduction*, ed. by N. Hopwood, R. Flemming, and L. Kassell, Cambridge, Cambridge University Press, 2018, p. 195-208.

upwards, leading to the formation of the individual organs — first of all the heart, afterwards the brain, and so forth.

But how does this fermentation work? It seems like a fermentation without a ferment, in the sense that no external element has to be added. Here, too, fermentation acts as ‘heat-rarefaction.’ The formation of the embryo is, of course, a qualitative transformation (in the sense of substantial); and yet there is no process in which an ‘embryo ferment’ would transform an amorphous mass into itself. Instead, the two seeds serve as ‘a kind of yeast’ to one another. Because it is not a chymical type of fermentation, none of the seeds has to impose its own nature upon the other one; instead they propel each other into agitation, “heating one another so that some of the particles acquire the same degree of agitation as fire, expanding and pressing on the others, and in this way putting them gradually into the state required for the formation of parts of the body.”¹¹⁶ Central to this process is a kind of heat that Descartes compares, again, to fermentations of wine or hay (which he cautiously refers to by paraphrase in order to avoid the loaded term):

Or ie croy que la première chose qui arriue en ce mélange de la semence, & qui fait que toutes les gouttes cessent d’estre semblables, c’est que la chaleur s’y excite, & qu’y agissant en mesme facon que dans les vins nouueaux lors qu’ils bouillent, ou dans le foin qu’on a renfermé auant qu’il fust sec, elle fait que quelques-vnes de ses particules s’assemblent vers quelque endroit de l’espace qui les contient, & que là se dilatant, elles pressent les autres qui les enuironnent; ce qui commence à former le coeur.¹¹⁷

Heat making an appearance in the process of generation is very common in the medical literature up to Descartes. Following Galen, this heat used to be ascribed to the menstrual blood of the mother.¹¹⁸ Yet Descartes assigns its origin elsewhere: namely, in the mutual fermenting of the seeds. Because it leads to the formation of the embryo’s heart, this process is likely also the source of the fire in the heart of the offspring individual.

Annie Bitbol-Hespériès writes that Descartes’ use of fermentation at this juncture of the argument “amounts to a total rejection of the previous medical tradition,”¹¹⁹ explaining it as a break from Fernel and the divine origin of heat.¹²⁰ I agree that Descartes’ fermentation, and the heat that it is correlated with, is not Fernelian i.e. does not have a divine origin; I have tried to show that it comes instead, along

116 *Description*, AT XI 253; G 187.

117 *Description*, AT XI 253-254. Cf. English translations in G 187 and CSM I 322. Note that the verb ‘ferments,’ introduced both in the CSM and in Gaukroger’s version, is markedly absent in the AT original, though the comparison is essentially about fermentation.

118 On this topic more extensively, see LINDA DEER RICHARDSON, *Academic Theories of Generation in the Renaissance*, ed. by B. Goldberg, Cham, Springer, 2018, p. 61-64. For a recent account of Galen’s theory of generation see REBECCA FLEMMING, “Galen’s Generations of Seeds,” in Hopwood, *Reproduction*, 95-108.

119 ANNIE BITBOL-HESPÉRIÈS, “Monsters, nature, and generation from the Renaissance to the Early modern period: The emergence of medical thought,” in *The Problem of Animal Generation in Early Modern Philosophy*, ed. by J. E. H. Smith, Cambridge, Cambridge University Press, 2006, p. 47-62, p. 61.

120 BITBOL-HESPÉRIÈS, “Monsters, nature, and generation,” p. 41.

Ancient lines, mainly from nutriment. Far from being divine, the spirit, for Descartes, is transmitted from mother to child through the umbilical cord: "Spiritus autem transit per arterias umbilicales."¹²¹

In the *Excerpta anatomica*, Descartes explains how the mixture of the seeds is performed by means of the rarefaction within the heat-rarefaction model:

animals are generated first from the seeds of the male and the female, which, mixed together and rarefied by heat, engender from one part the matter of the windpipe and of the lungs, and from the other part the matter of the liver; hereafter from the encounter of these two, the fire is enkindled in the heart.¹²²

The seeds need rarefaction in order to be able to mix ("sine rarefactione permisceri non possunt").¹²³ On the other hand, they do not need to be much different from one another:

And these two liquids need not be very different from one another for this purpose. For, just as we can observe how old dough can make new dough swell, and how the scum formed on beer is able to serve as yeast for making more beer, so we can easily agree that the seeds of the two sexes, when mixed together, serve as yeast to one another.¹²⁴

This might be another Cartesian departure from the ancient tradition. In Aristotle's theory of mixture, elements which combine have to be opposed to each other, or else one would speak of an increase and not a mixture: "only those agents are combinable which involve a contrariety, for these are such as to suffer action reciprocally."¹²⁵ While the analogy with dough and beer prompts the question of how exactly this reciprocal action is possible, the answer might be found in the same idea of a heated agitation of particles. The moving particles would impart their motion to adjacent particles until the whole quantity would be encompassed by this agitation. From the particles that have fermented from the mixed seeds, some turn into blood, some into animal spirits; depending on the path taken, and on their own constitution, they engender the individual organs.¹²⁶ The very first one is the heart, the future seat of innate heat and fermentational fire. This was an Aristotelian idea, exposed in *De generatione animalium*¹²⁷ where Aristotle argued that this is because the heart functions as the seat of the nutritive soul. The next organ to be formed is the brain,¹²⁸ made from the subtler particles of blood: "les plus subtiles,

121 *Primae Cogitationes*, AT XI 511.

122 *Excerpta*, AT XI 599 (Dec. 1637): "animalia generentur primo ex eo quod semina maris & foeminae permista & calore rarescentia excernant ex una parte materiam asperae arteriae & pulmonum, ex altera materiam hepatis; deinde ex harum duarum concursu accenditur ignis in corde." [Translation is mine.]

123 *Primae Cogitationes*, AT XI 507.

124 *Description*, AT XI 253; G 187 (my emphasis).

125 ARISTOTLE, *De generatione et corruptione*, 328a32-328a33. The secondary literature on Aristotle's theory of mixture abounds and is beyond the scope of this paper.

126 *Primae Cogitationes*, AT XI 508. See also *Description*, AT XI 260.

127 *De generatione animalium* II 4 (esp. 740a).

128 *Description*, AT XI 261.

qui composent les esprits, s'aucent vn peu dauantage, & se mettent en la place ou doit estre apres le cerueau."¹²⁹ Yet the animal does not yet have an existence ("nondum est animal"¹³⁰); its life only begins with the enkindling of fire into the new heart: "Hicque incipit animal esse, quoniam ignis vitae accensus est in corde."¹³¹ In other words, it is only with (and through) the fire in the heart that the new animal comes into being as such. This seems problematic, as the very juncture when the fire is enkindled may not be explainable by the fermentative heat-rarefaction motions that preceded this moment.

Briefly, in his embryology Descartes employs broadly the same model of fermentation as 'heat-rarefaction,' yet this time within the potentially problematic framework of a non-Aristotelian theory of mixture. Though his description of how the male and female seed serve as yeast to one another may also be interpreted mechanistically, it remains difficult to uphold that transformations of motion and heat alone may result in a new being. At the point where the fire is enkindled in the heart, a metaphysical dimension enters the stage. The fermentation of seeds in embryology is hence a process of substantial transformation, which possibly goes one step beyond the heat-rarefaction model that Descartes uses in all other instances. After Descartes, mechanist philosophers continued to ascribe a similar role to fermentation in their embryologies.¹³²

7. Conclusion

I have argued that when Descartes uses the term 'fermentation,' he does so in a purely mechanist manner, or at least as pure as he can achieve.¹³³ Reconceptualizing fermentations as processes of 'heat-rarefaction,' as opposed to their chymical version entailing qualitative (substantial) change, Descartes employs analogies with the natural world to describe human physiology. The 'heat-rarefaction' model of fermentation would later be taken up by Borelli and other continental mechanists. The more chymical one would be adopted in England by the chemical physicians who tended to integrate mechanism with occult powers such as that of a ferment. As Des Chene succinctly put it, in the aftermath of Descartes "[m]echanism as ontology failed, but mechanism as method succeeded."¹³⁴

Even if later conceptualizations of fermentation in physiology departed from the Cartesian perspective, it remains the case that Descartes gave a decisive impetus to the use of the fermentation concept within the mechanical medical philosophy of

129 *Description*, AT XI 261.

130 *Primae Cogitationes*, AT XI 508.

131 *Primae Cogitationes*, AT XI 509.

132 For instance Borelli; see BORELLI AND MAQUET, p. 375-380.

133 In "Descartes and fermentation in digestion," I attempt to describe an inherent problem with Descartes' otherwise mechanist account of fermentation. Whether they act chymically or by 'heat-rarefaction,' fermentations do yield ameliorated products, thus entailing a natural teleology which poses a problem for Descartes' philosophical system.

134 DES CHENE, "Mechanisms of Life," p. 249.

the seventeenth century. It can be argued that he turned a controversial concept with alchemical overtones into something that more restrictive mechanists such as Borelli were more likely to adopt.¹³⁵ This in turn opened up the way for further discoveries related to respiration, circulation, digestion, and metabolism.



135 This accords with Antonio Clericuzio's argument about the circle of Hartlib which reinterpreted chymical theories in a corpuscular framework. See ANTONIO CLERICUZIO, *Elements, Principles and Corpuscles*, Dordrecht, Springer Netherlands, 2000, p. 90.