

## Philosophy Faculty Reading List and Course Outline 2018-2019

### PART II PAPER 06: PHILOSOPHY OF SCIENCE

#### SYLLABUS

- **Philosophy of Physics I:** the metaphysics of space and space-time: absolute and relational theories of space and space-time; geometry and conventionalism.
- **Philosophy of Physics II:** the interpretation of quantum mechanics; non-locality.
- **Philosophy of Biology:** biological kinds, the nature of species; biological laws; functional and causal explanation in biology.
- **Philosophy of Economics and Social Science:** social science versus natural science; rational choice theory and social science; social ontology.
- **Special topic (2018-19): Philosophy of cognitive science:** folk psychology; eliminative materialism; explanation in psychology and neuroscience; embodied and extended cognition.

#### COURSE OUTLINE

Philosophy of science at Part IB studied philosophical problems that arise when we think about scientific method in general. This Part II focuses on philosophical problems connected with particular branches of science.

**Philosophy of Physics** concentrates on overlaps between metaphysical questions and those at the foundations of physics, addressing such questions as the reality of space and measurement-independence.

**Philosophy of Biology:** examines such questions as does biology seek natural kinds, and do kinds have essences? How do biological explanations differ from physical ones? Does any contingency in evolutionary processes undermine biological laws?

**Philosophy of Economics and Social Science** considers whether these disciplines differ in some basic and interesting way from natural sciences; whether it is appropriate to model human behaviour using the tools of rational choice theory (including 'game theory'); and whether there is a 'social reality' over and above what depends only on individuals.

**Special topic (2018-19): Philosophy of Cognitive Science** critically examines key research strategies employed in cognitive science, addressing such questions as: What constitutes a good explanation in cognitive science? Is cognition a property of only the brain or does it extend to the body and world?

#### READING LIST

Readings are divided into (A) and (B) lists below. Some attempt is made to put material in the basic (A)-lists in a sensible *reading* order. (B)-lists are in *alphabetical* order, and for dipping into (no-one expects you to read everything).

#### PHILOSOPHY OF PHYSICS

It is an uplifting experience, for both the spacetime and the quantum parts of the course, to read some philosophical writings by the giants of twentieth-century physics. For example:

- EINSTEIN, Albert, 'Autobiographical Notes', in P.A. Schilpp, ed., *Albert-Einstein: Philosopher-Scientist*. 3rd ed. (La Salle, IL.: Open Court, 1970). [this and other essays therein, written in Einstein's honour, e.g. by N. Bohr]
- WEYL, Hermann, *Philosophy of Mathematics and Natural Science* (Princeton, NJ: Princeton University Press, 1949; new ed. 2009), ch. II.1 on space and time.

A historically oriented survey of the philosophy of physics, which is especially strong on the space and time part of the syllabus is:

- TORRETTI, Roberto, *The Philosophy of Physics* (Cambridge: Cambridge University Press, 1999). Also available online at: <https://doi.org/10.1017/CBO9781139172981>

Space-time and quantum mechanics are both addressed by particle physicists. Their work on gravity embodies conventional wisdom among many physicists, but is insufficiently considered in philosophy. Particle physics provides perspective on substantivalism vs. relationalism and on conventionality and gives a distinctive justification for Einstein's field equations akin to eliminative induction. The following selections are all short.

- GUPTA, Suraj N., 'Einstein's and Other Theories of Gravitation', *Reviews of Modern Physics*, 29 (1957): 334-36.  
<https://journals.aps.org/rmp/pdf/10.1103/RevModPhys.29.334>
- FEYNMAN, Richard P., Fernando B. MORINIGO, and William G. WAGNER, *Feynman Lectures on Gravitation* (Boulder, CO: Westview Press, 2002), pp. vii-xv, xxv-xxviii, 112-3, 166-7, 219-20.
- SCHUCKING, Engelbert L., 'The Introduction of the Cosmological Constant', in A. Zichichi, V. de Sabbata and N. Sánchez, eds., *Gravitation and Modern Cosmology: The Cosmological Constant Problem* (New York, NY: Plenum, 1991), pp. 185-87.
- BOULWARE, David G., and Stanley DESER, 'Inconsistency of Finite Range Gravitation', *Physics Letters B*, 40 (1972): 227-29.  
[https://doi.org/10.1016/0370-2693\(72\)90418-2](https://doi.org/10.1016/0370-2693(72)90418-2)

## PHILOSOPHY OF PHYSICS I

It is well worth reading some accessible introductions to relativity. Note that you do not need a very deep mathematical understanding of the theories in order to engage with the chosen philosophical issues at a Part II level. But on the other hand, you do need some grasp of what is going on in the physics! For helpful introductions to relativity with low mathematical content, see:

GEROCH, Robert, *General Relativity from A to B* (Chicago, IL: University of Chicago Press, 1978).

SARTORI, Leo, *Understanding Relativity* (Berkeley: University of California Press, 1996).

Geroch explains the idea of 'space-time' very well, Sartori will tell you a little more about the physics. Those with a mathematical background will find the classic:

RINDLER, Wolfgang, *Essential Relativity*. 2nd ed. (New York: Springer, 1977).

Relatively approachable, and Rindler also pays more attention at the outset to the conceptual background than most textbooks. You'll find yards more of books on relativity on library shelves: browse till you find something that suits. A classic on the foundations and history of relativity theory is:

TORRETTI, Roberto, *Relativity and Geometry* (Oxford: Pergamon, 1983; New York, NY: Dover, 1996).

A good introduction to General Relativity that is also aware of the particle physics tradition is:

OHANIAN, Hans, and Remo RUFFINI, *Gravitation and Spacetime*. 3rd ed. (Cambridge: Cambridge University Press, 2013). Also available online at: <https://doi.org/10.1017/CBO9781139003391>

Three fairly recent books on cosmology that are worth mentioning are:

EARMAN, John, *Bangs, Crunches Whimpers and Shrieks* (Oxford: Oxford University Press, 1995).

HAKIM, Rémi, *An Introduction to Relativistic Gravitation* (Cambridge: Cambridge University Press, 1999). Also available online at: <https://doi.org/10.1017/CBO9781139174213>

LIDDLE, Andrew R., *An Introduction to Modern Cosmology* (Chichester: John Wiley, 1999).

Even a quick browse that ignores the mathematical detail will be quite instructive.

### The Metaphysics of Space and Spacetime

Two focal points of debate concern substantivalism and relationism (are all facts about space fixed by the facts about the spatial relations between actual-or actual-and-possible

objects?), and conventionalism about geometry and topology (is the choice of a geometrical framework within which to do physics ultimately a matter of convention?). For either topic you will find the following useful introductory reading:

SKLAR, Lawrence, *The Philosophy of Physics* (Oxford: Oxford University Press, 1992), ch. 2 'Space, time, and motion'.

NORTON, John, 'The Philosophy of Space and Time', in M. Salmon, ed., *Introduction to the Philosophy of Science* (Englewood Cliffs, NJ: Prentice Hall, 1992; Indianapolis, IN: Hackett, 1999), pp. 179-213. Reprinted in J. Butterfield, M. Hogarth and G. Belot, eds., *Spacetime* (Aldershot: Dartmouth, 1996), pp. 3-56.

A slower, fuller treatment of the issues is to be found in:

DAINTON, Barry, *Time and Space*. 2nd ed. (Montreal, QC: McGill-Queen's University Press, 2010), chs. 9-21.

The basic 'old' debate between Newton and Leibniz on absolute and relational theories is the topic in particular of Dainton's chs. 9–11. Historical material about this debate, indeed about the 'history of space' over two millennia, can be found in:

HUGGETT, Nick, ed., *Space: From Zeno to Einstein* (Cambridge, MA: MIT Press, 1999).  
JAMMER, Max *Concepts of Space* (Cambridge, MA: Harvard University Press, 1954; 1969, New York, NY: Dover, 1993).

But in this paper, we look at the 'new' debate, as it arises in the context of modern spacetime theories. This debate is also enriched by considering literature from particle physicists, pondering the century-long controversy about gravitational energy and conservation laws in General Relativity, and exploring the claimed absence of change in a formulation of General Relativity perhaps best suited for a merger with quantum mechanics.

### Absolute and Relational Theories of Space and Spacetime

For further reading, beyond Dainton, see:

#### (A)

BUTTERFIELD, Jeremy, 'The Hole Truth', *British Journal for the Philosophy of Science*, 40 (1989): 1-28. <http://www.jstor.org/stable/687461>. Reprinted in J. Worrall, ed., *The Ontology of Science* (Aldershot: Dartmouth, 1996).

EARMAN, John, 'Who's Afraid of Absolute Space?' *Australasian Journal of Philosophy*, 48 (1970): 287-319. <https://doi.org/10.1080/00048407012341291>. Reprinted in J. Butterfield, M. Hogarth and G. Belot, eds., *Spacetime* (Aldershot: Dartmouth, 1996).

EARMAN, John, and John NORTON, 'What Price Space-Time Substantivalism? The Hole Story', *British Journal for the Philosophy of Science*, 38 (1987): 515-25. <http://www.jstor.org/stable/687356>. Reprinted in J. Worrall, ed., *The Ontology of Science* (Aldershot: Dartmouth, 1996).

- SKLAR, Lawrence, *Space, Time and Spacetime* (Berkeley, CA: University of California Press, 1974), ch. 3 'Absolute motion and substantial spacetime', especially sects. D-F.
- TELLER, Paul, 'Substance, Relations and Arguments About the Nature of Space-Time', *Philosophical Review*, 100 (1991): 363-97. <http://www.jstor.org/stable/2185065>. Reprinted in J. Worrall, ed., *The Ontology of Science* (Aldershot: Dartmouth, 1996).

## (B)

- BELOT, Gordon, *Geometric Possibility* (Oxford: Oxford University Press, 2011), esp. chs. 1 & 2. Also available online at: <https://doi.org/10.1093/acprof:oso/9780199595327.001.0001>
- BRADING, Katherine, and Elena CASTELLANI, 'Symmetries and Invariances in Classical Physics', in J. Butterfield and J. Earman, eds., *Handbook of the Philosophy of Science: Philosophy of Physics* (Amsterdam: Elsevier, 2007), pp. 1331-67.
- CATTANI, Carlo, and Michelangelo DE MARIA, 'Conservation Laws and Gravitational Waves in General Relativity (1915-1918)', in J. Earman, M. Janssen and J.D. Norton, eds., *The Attraction of Gravitation: New Studies in the History of General Relativity, Einstein Studies*. Vol. 5 (Boston, NJ: Birkhäuser, 1993), pp. 63-87.
- EARMAN, John, 'Thoroughly Modern McTaggart: Or, What McTaggart Would Have Said If He Had Read the General Theory of Relativity', *Philosophers' Imprint*, 2, no. 3 (2002). <http://hdl.handle.net/2027/spo.3521354.0002.003> and see Maudlin below.
- EARMAN, John, *World Enough and Spacetime* (Cambridge, MA: MIT Press, 1989). [Especially chs. 1-3, 5, 6, 8 & 9]
- FRIEDMAN, Michael, *Foundations of Space-Time Theories* (Princeton, NJ: Princeton University Press, 1983), ch. 6 'Relationalism'.
- HOEFER, Carl, 'Energy Conservation in GTR', *Studies in History and Philosophy of Modern Physics*, 31, no. 2 (2000): 187-99. [https://doi.org/10.1016/S1355-2198\(00\)00004-6](https://doi.org/10.1016/S1355-2198(00)00004-6)
- KASTRUP, Hans A., 'The Contribution of Emmy Noether, Felix Klein and Sophus Lie to the Modern Concept of Symmetries in Physical Systems', in M.G. Doncel, ed., *Symmetries in Physics (1600-1980)* (Barcelona: Universitat Autònoma de Barcelona, 1987), pp. 113-41.
- KNOX, Eleanor, 'Newton-Cartan Theory and Teleparallel Gravity: The Force of a Formulation', *Studies in History and Philosophy of Modern Physics*, 42, no. 4 (2011): 264-75. <https://doi.org/10.1016/j.shpsb.2011.09.003>
- MAUDLIN, Tim, 'Thoroughly Muddled McTaggart: Or, How to Abuse Gauge Freedom to Generate Metaphysical Monstrosities, with a Reply by John Earman', *Philosophers' Imprint*, 2, no. 4 (2002): 1-23. <http://hdl.handle.net/2027/spo.3521354.0002.004>
- MAUDLIN, Tim, 'Buckets of Water and Waves of Space', *Philosophy of Science*, 60 (1993): 183-203. <http://www.jstor.org/stable/188350>. Reprinted in J. Butterfield, M. Hogarth and G. Belot, eds., *Spacetime* (Aldershot: Dartmouth, 1996).
- NOETHER, Emmy, 'Invariant Variation Problems', in Y. Kosmann-Schwarzbach, ed., *The Noether Theorems: Invariance and Conservation Laws in the Twentieth Century*, translated by B.E. Schwarzbach (New York, NY: Springer, 2011), pp. 3-24. Also available on [Moodle](http://Moodle)
- NORTON, John D., 'Did Einstein Stumble? The Debate over General Covariance', *Erkenntnis*, 42 (1995): 223-45. <https://doi.org/10.1007/BF01128809>

- PITTS, J. Brian, 'Change in Hamiltonian General Relativity from the Lack of a Time-Like Killing Vector Field', *Studies in History and Philosophy of Modern Physics*, 47 (2014): 68-89. <https://doi.org/10.1016/j.shpsb.2014.05.007>
- WILSON, Mark, 'There's a Hole and a Bucket, Dear Leibniz', *Midwest Studies in Philosophy*, 18 (1993): 202-41. <https://doi.org/10.1111/j.1475-4975.1993.tb00265.x>. Reprinted in J. Butterfield, M. Hogarth and G. Belot, eds., *Spacetime* (Aldershot: Dartmouth, 1996).

## Geometry and Conventionalism

### (A)

- CARNAP, Rudolf, *An Introduction to the Philosophy of Science* (New York, NY: Dover, 1995), chs. 13-18.
- DAINTON, Barry, *Time and Space* (Chesham: Acumen, 2010), ch. 13 'Curved space'.
- NAGEL, Ernest, *Structure of Science: Problems in the Logic of Scientific Explanation* (London: Routledge & Kegan Paul, 1961), chs. 8 & 9.
- NERLICH, Graham, *The Shape of Space*. 2nd ed. (Cambridge: Cambridge University Press, 1994). Also available online at: <https://doi.org/10.1017/CBO9780511621130>. [Especially chs. 6 & 7]
- REICHENBACH, Hans, *Philosophy of Space and Time* (New York: Dover, 1958), sects. 1-8 & 27.
- SKLAR, Lawrence, *Space, Time and Spacetime* (Berkeley, CA: University of California Press, 1974), ch. 2, 'The epistemology of geometry', especially sects. C, D, F-H; also ch. 4 sect. C.

### (B)

- BEN-MENAHM, Yemima, *Conventionalism: From Poincare to Quine* (Cambridge: Cambridge University Press, 2006), ch. 3 'Relativity: from "experience and geometry" to "geometry and experience"'. Also available online at: <https://doi.org/10.1017/CBO9780511584404.004>
- BROWN, Harvey R., *Physical Relativity: Space-Time Structure from a Dynamical Perspective* (Oxford: Oxford University Press, 2005), ch. 9 'The View from General Relativity'. Also available online at: <https://doi.org/10.1093/0199275831.003.0009>
- EINSTEIN, Albert, *Geometry and Experience*, Lecture before the Prussian Academy of Sciences, January 27, 1921. Available online at: [http://www.relativitycalculator.com/pdfs/einstein\\_geometry\\_and\\_experience\\_1921.pdf](http://www.relativitycalculator.com/pdfs/einstein_geometry_and_experience_1921.pdf)
- FRIEDMAN, Michael, *Foundations of Space-Time Theories* (Princeton, NJ: Princeton University Press, 1983), ch. 7 'Conventionalism'.
- GLYMOUR, Clark, 'The Epistemology of Geometry', *Noûs*, 11 (1977): 227-51. <http://www.jstor.org/stable/2214764>. Reprinted in J. Butterfield, M. Hogarth and G. Belot, eds., *Spacetime* (Aldershot: Dartmouth, 1996). Also in R. Boyd, P. Gaspar and J.D. Trout, eds., *The Philosophy of Science: The Central Issues* (Cambridge, MA: MIT Press, 1991). Or see his *Theory and Evidence* (Princeton, NJ: Princeton University Press, 1980), ch. 9.
- GLYMOUR, Clark, 'Topology, Cosmology and Convention', *Synthese*, 24 (1972): 195-218. <http://www.jstor.org/stable/20114832>. Reprinted in J. Butterfield, M. Hogarth and G. Belot, eds., *Spacetime* (Aldershot: Dartmouth, 1996).

- GRÜNBAUM, Adolf, 'Space, Time and Falsifiability: Critical Exposition and Reply to "a Panel Discussion of Grünbaum's Philosophy of Science", Part I', *Philosophy of Science*, 37 (1970): 469-588, excerpt of 70-73. <https://doi.org/10.1086/288327>
- NORTON, John D., 'Observationally Indistinguishable Spacetimes: A Challenge for Any Inductivist', in G.J. Morgan, ed., *Philosophy of Science Matters: The Philosophy of Peter Achinstein* (Oxford: Oxford University Press, 2011), pp. 164-76.
- PUTNAM, Hilary, 'The Refutation of Conventionalism', *Noûs*, 8 (1974): 25-40. <http://www.jstor.org/stable/pdf/2214643>. Reprinted in his *Philosophical Papers*. Vol. 2: *Mind, Language and Reality* (Cambridge: Cambridge University Press, 1975), pp. 153-91. Also available online at: <https://doi.org/10.1017/CBO9780511625251>
- TORRETTI, Roberto, *Relativity and Geometry* (Oxford: Pergamon, 1983; New York, NY: Dover, 1996), ch. 7.2 'Geometric conventionalism'.

## PHILOSOPHY OF PHYSICS II

### The Interpretation of Quantum Mechanics

We focus on three clusters of issues: why is the old orthodox interpretation of quantum mechanics (apparently) in trouble? What are the prospects for the Everett (many-worlds) interpretation? And how should we respond to non-locality results?

For helpful introductions to Quantum Mechanics with a very low mathematical content, see, for example, the following:

- ALBERT, David Z., *Quantum Mechanics and Experience* (Cambridge, MA: Harvard University Press, 1992).
- DAVIES, Paul C.W., and Julian R. BROWN, eds., *The Ghost in the Atom* (Cambridge: Cambridge University Press, 1986).
- RAE, Alastair I.M., *Quantum Physics: Illusion or Reality?* (Cambridge: Cambridge University Press, 1986; 2nd ed. 2004). Also available online at: <https://doi.org/10.1017/CBO9780511815676>
- RAE, Alastair I.M., *Quantum Physics: A Beginner's Guide* (Oxford: OneWorld Press, 2005).
- STYER, Daniel F., *The Strange World of Quantum Mechanics* (Cambridge: Cambridge University Press, 2000). Also available online at: <https://doi.org/10.1017/CBO9781107050709>

The Davies and Brown volume contains a series of interviews with 'big name' physicists who defend differing views of quantum mechanics.

- HUGHES, R. I.G., *The Structure and Interpretation of Quantum Mechanics* (Cambridge, MA: Harvard University Press, 1992).

Is written by a philosopher, and proceeds gently, explaining e.g. complex numbers and vectors. Those with a mathematical background who want a straight, non-philosophical, introduction to the physics will find the choice of texts almost limitless. It really is a

question of browsing to find a book that suits your mathematical level. One fine short book is:

- BOWMAN, Gary, *Essential Quantum Mechanics* (Oxford: Oxford University Press, 2008).

### (A)

- BELL, John Stewart, 'Six Possible Worlds of Quantum Mechanics', *Foundations of Physics*, 22, no. 10 (1992): 1201-15. <https://doi.org/10.1007/BF01889711>. Reprinted in his *Speakable and Unspeakable in Quantum Mechanics* (Cambridge: Cambridge University Press, 1987; 2nd ed. 2004), pp. 181-195.
- BOHR, Niels, 'Discussion with Einstein on Epistemological Problems in Atomic Physics', in P. Schilpp, ed., *Albert Einstein: Philosopher-Scientist* (Evanston, IL: Library of Living Philosophers, 1949), pp. 199-241. Also available online at: <http://minerva.tau.ac.il/bsc/3/3144/bohr.pdf>
- CUSHING, James T., *Philosophical Concepts in Physics* (Cambridge: Cambridge University Press, 1998), chs. 19-21. Also available online at: <https://doi.org/10.1017/CBO9781139171106>
- NAGEL, Ernest, *Structure of Science: Problems in the Logic of Scientific Explanation* (London: Routledge & Kegan Paul, 1961), ch. 10 'Causality and indeterminism in physical theory'. Also available on [Moodle](#)
- SKLAR, Lawrence, *The Philosophy of Physics* (Oxford: Oxford University Press, 1992), ch. 4 'The quantum picture of the world'. Also available on [Moodle](#)
- WHITAKER, Andrew, *The New Quantum Age* (Oxford: Oxford University Press, 2012).

### (B)

- BUB, Jeffrey, *Interpreting the Quantum World* (Cambridge: Cambridge University Press, 1997), sect. 7.1.
- CUSHING, James, *Quantum Mechanics: Historical Contingency and the Copenhagen Hegemony* (Chicago, IL: University of Chicago Press, 1994), chs. 2 & 3.
- HUGHES, R. I.G., *The Structure and Interpretation of Quantum Mechanics* (Cambridge, MA: Harvard University Press, 1992), chs. 6 & 7.
- REDHEAD, Michael, *Incompleteness, Nonlocality and Realism* (Oxford: Oxford University Press, 1987), ch. 2 'The interpretation of quantum mechanics'.
- RUETSCHKE, Laura, *Interpreting Quantum Theories* (Oxford: Oxford University Press, 2011). Available online at: <https://doi.org/10.1093/acprof:oso/9780199535408.001.0001>
- VAN FRAASSEN, Bas C., *Quantum Mechanics: An Empiricist View* (Oxford: Oxford University Press, 1991), chs.1, 6 & 8. Also available online at: <https://doi.org/10.1093/0198239807.001.0001>
- WALLACE, David, 'Philosophy of Quantum Mechanics', in D. Rickles, ed., *The Ashgate Companion to Contemporary Philosophy of Physics* (Aldershot: Ashgate, 2016). Also available online at: <https://www.routledgehandbooks.com/doi/10.4324/9781315612676.ch2>

## The Everett Interpretation

### (A)

- ALBERT, David Z., *Quantum Mechanics and Experience* (Cambridge, MA: Harvard University Press, 1992), pp. 112-125 (first part of ch. 6). Also available on [Moodle](#)
- BUTTERFIELD, Jeremy, 'Critical Notice Of: Many Worlds? Edited by J. Barrett, A. Kent, S. Saunders and D. Wallace', *Philosophy*, 86 (2011): 451-63. <http://www.jstor.org/stable/23014826>. Preprint available at: <http://philsci-archive.pitt.edu/10758/>
- BUTTERFIELD, Jeremy, 'Some Worlds of Quantum Theory', in J. Russell, *et al.*, eds., *Quantum Mechanics (Scientific Perspectives on Divine Action, Vol. 5)* (Vatican: Vatican Observatory Publications, 2002), pp. 111-40.
- DEUTSCH, David, 'Comment on Lockwood', *British Journal for the Philosophy of Science*, 47 (1996): 222-28. <http://www.jstor.org/stable/687943>
- WALLACE, David, 'Worlds in the Everett Interpretation', *Studies in the History and Philosophy of Modern Physics*, 33 (2002): 637-61. [https://doi.org/10.1016/S1355-2198\(02\)00032-1](https://doi.org/10.1016/S1355-2198(02)00032-1)
- WALLACE, David, 'Everett and Structure', *Studies in the History and Philosophy of Modern Physics*, 34 (2003): 87-105. [http://doi.org/10.1016/S1355-2198\(02\)00085-0](http://doi.org/10.1016/S1355-2198(02)00085-0)

### (B)

- ALBERT, David Z., and Barry LOEWER, 'Interpreting the Many Worlds Interpretation', *Synthese*, 77 (1988): 195-213. <http://www.jstor.org/stable/20116589>. [Another version of the Many Minds theory]
- BARRETT, Jeffrey A., *The Quantum Mechanics of Minds and Worlds* (Oxford: Oxford University Press, 1999), especially chs. 3 & 6. Also available online at: <https://doi.org/10.1093/acprof:oso/9780199247431.001.0001>. What is essentially a precis of ch. 3, with some added sections which precis other bits of the book, can be found in his article: 'Everett's Relative-State Formulation of Quantum Mechanics', in E.N. Zalta, ed., *The Stanford Encyclopedia of Philosophy* (Winter 2016 ed.) [Online] available at: <http://plato.stanford.edu/archives/win2016/entries/qm-everett> (a clear exegesis of Everett's original paper and a variety of comments on later versions of the interpretation).
- KENT, Adrian, 'Against Many-Worlds Interpretations' [Online]. Available at: <http://xxx.arxiv.org/abs/gr-qc/9703089> (Accessed: 21 September 2018). [Critical survey of Everett-type interpretations from a physicist's perspective] This is a 1997 update on Kent's paper of the same name in *International Journal of Modern Physics*, A5 (1990), 1745-62.
- LOCKWOOD, Michael J., '"Many Minds" Interpretations of Quantum Mechanics', *British Journal for the Philosophy of Science*, 47 (1996): 159-88. <http://www.jstor.org/stable/687940>. [Lockwood's version of the Everett interpretation, emphasizing considerations from the philosophy of mind. See also the many commentaries in the same issue]

- SAUNDERS, Simon, *et al.*, eds., *Many Worlds? Everett, Quantum Theory and Reality* (Oxford: Oxford University Press, 2010). [especially chs. 1,6,7,10,12 & 18, by (respectively) Wallace, Saunders, Papineau, Kent, Price and Deutsch]
- WALLACE, David, *The Emergent Multiverse* (Oxford: Oxford University Press, 2012) 125-42. Also available online at: <https://doi.org/10.1093/acprof:oso/9780199546961.001.0001>. [Especially Parts I & II (Part II, on probability, includes revised versions the following two items)]
- WALLACE, David, 'Epistemology Quantized: Circumstances in Which We Should Come to Believe in the Everett Interpretation', *British Journal for the Philosophy of Science*, 57 (2006): 655-89. <https://doi.org/10.1093/bjps/axl023>
- WALLACE, David, 'Quantum Probability from Subjective Likelihood: Improving on Deutsch's Proof of the Probability Rule', *Studies in the History and Philosophy of Modern Physics*, 38 (2007): 311-32. <https://doi.org/10.1016/j.shpsb.2006.04.008>

## Non-Localities

### (A)

- BELL, John Stewart, 'Bertlmann's Socks and the Nature of Reality', in his *Speakable and Unsayable in Quantum Mechanics* (Cambridge: Cambridge University Press, 1987), pp. 139-58. Also available online at: <https://doi.org/10.1017/CBO9780511815676>
- BUTTERFIELD, Jeremy, 'Bell's Theorem: What It Takes', *British Journal for the Philosophy of Science*, 43 (1992): 41-83. <http://www.jstor.org/stable/687884>
- CUSHING, James T., *Philosophical Concepts in Physics* (Cambridge: Cambridge University Press, 1998), ch. 22 'The EPR paper and Bell's theorem'. Also available online at: <https://doi.org/10.1017/CBO9781139171106>
- CUSHING, James, and E. McMULLIN, eds., *Philosophical Consequences of Quantum Theory: Reflections on Bell's Theorem* (Notre Dame, IN: Notre Dame University Press, 1989). [especially Chapters by Cushing, Shimony, Mermin Jarrett, van Fraassen and McMullin]
- MAUDLIN, Tim, *Quantum Non-Localities and Relativity: Metaphysical Intimations of Modern Physics* (Oxford: Blackwell, 1994), chs. 3-5.

### (B)

- BUB, Jeffrey, *Interpreting the Quantum World* (Cambridge: Cambridge University Press, 1997), ch. 2 'Bell's 'no go' theorem'.
- CUSHING, James, *Quantum Mechanics: Historical Contingency and the Copenhagen Hegemony* (Chicago, IL: University of Chicago Press, 1994), ch. 10 'An alternative scenario?'
- MERMIN, N. David, 'Is the Moon There When Nobody Looks', *Physics Today*, 38 (1985): 38-47. <https://doi.org/10.1063/1.880968>. Reprinted in R. Boyd, P. Gasper and J.D. Trout, eds., *Philosophy of Science* (Cambridge, MA: MIT Press, 1991).
- REDHEAD, Michael, *Incompleteness Nonlocality and Realism: A Prolegomenon to the Philosophy of Quantum Mechanics* (Oxford: Clarendon Press, 1987), chs. 3 & 4.

SHIMONY, Abner, 'Metaphysical Problems in the Foundations of Quantum Mechanics', *International Philosophical Quarterly*, 18 (1978): 3-17. <https://dx.doi.org/10.5840/ipq19781818>. Reprinted in R. Boyd, P. Gasper and J.D. Trout, eds., *Philosophy of Science* (Cambridge, MA: MIT Press, 1991).

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## PHILOSOPHY OF BIOLOGY

### General

There are two very good introductory texts on philosophy of biology:

SOBER, Elliot, *The Philosophy of Biology*. 2nd ed. (Boulder, CO: Westview, 1999).  
STERELNY, Kim, and Paul E. GRIFFITHS, *Sex and Death* (Chicago, IL: Chicago University Press, 1999).

There are also several very useful collections of classic articles:

HULL, David, and Michael RUSE, eds., *The Cambridge Companion to the Philosophy of Biology* (Cambridge: Cambridge University Press, 2007). Also available online at: <https://doi.org/10.1017/CCOL9780521851282>  
KELLER, Evelyn Fox, and Elisabeth A. LLOYD, eds., *Keywords in Evolutionary Biology* (Cambridge, MA: Harvard University Press, 1992).  
SOBER, Elliot, ed., *Conceptual Issues in Evolutionary Biology* (Cambridge MA: MIT Press, 1984; 2nd ed., 1994; 3rd ed., 2006). [The three editions all contain slightly different material, and all are useful]

### Biological Kinds and the Nature of Species

Two interleaved questions are treated by these readings. First, can standard accounts of the nature and role of natural kinds be applied to biology? More specifically, can they be applied to biological species? Second, what sorts of things are biological species? Is there, for example, any sense in which they have essences?

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OKASHA, Samir, 'Darwinian Metaphysics: Species and Question of Essentialism', *Synthese*, 131 (2002): 191-213. <http://www.jstor.org/stable/20117245>

SOBER, Elliot, 'Evolution, Population Thinking, and Essentialism', *Philosophy of Science*, 47 (1980): 350-83. <http://www.jstor.org/stable/186950>

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BOYD, Richard, 'Homeostasis, Species, and Higher Taxa', in R. Wilson, ed., *Species: New Interdisciplinary Essays* (Cambridge, MA: MIT Press, 1999), pp. 141-87.  
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DEVITT, Michael, 'Resurrecting Biological Essentialism', *Philosophy of Science*, 75 (2008): 344-82. <http://www.jstor.org/stable/10.1086/593566>  
GRIFFITHS, Paul E., 'Squaring the Circle: Natural Kinds with Historical Essences', in R. Wilson, ed., *Species: New Interdisciplinary Essays* (Cambridge, MA: MIT Press, 1999), pp. 209-28.

### Biological Laws

On the one hand, physics snobs have sometimes suggested that biology lacks laws, and as a result has the status of mere 'stamp collecting'. On the other hand, philosophers of biology have sometimes argued that only someone with an impoverished view of the sciences would think that it lacks laws. It is worth familiarising yourself with general material on laws of nature prior to looking at these biology-specific pieces.

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MITCHELL, Sandra D., 'Dimensions of Scientific Law', *Philosophy of Science*, 67 (2000): 242-65. <http://www.jstor.org/stable/188723>  
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LANGE, Marc, *Natural Laws in Scientific Practice* (Oxford: Oxford University Press, 2000).  
MITCHELL, Sandra D., *Unsimple Truths: Science, Complexity and Policy* (Chicago, IL: University of Chicago Press, 2009), ch. 3 'Complexities of evolved diversity: Laws'.  
TURCHIN, Peter, 'Does Population Ecology Have General Laws?' *Oikos*, 94 (2001): 17-26. <http://www.jstor.org/stable/3547251>

## Functional and Causal Explanation in Biology

Most items below concentrate on the puzzling teleological aspect of many biological explanations: dolphins are streamlined because it enables them to swim more efficiently. What is the nature of these explanations? Some of the items also concern the question of whether causal explanation in biology can be understood as a simple instance of causal explanation more generally.

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- ALLEN, Colin, Marc BEKOFF, and George LAUDER, eds., *Nature's Purposes* (Cambridge, MA: MIT Press, 1998). [This enormous collection contains a very large number of relevant papers. Focus on those by Cummins, Wright, Neander, Millikan, Griffiths and Godfrey-Smith. The papers by Cummins and Wright are classics, and are reprinted in many other places]
- LEWENS, Tim, 'Functions', in M. Matthen and C. Stephens, eds., *Handbook of Philosophy of Biology* (Amsterdam: Elsevier, 2007), pp. 525-47. Also available on [Moodle](#). [An overview of the modern debate on functions]
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- WRIGHT, Larry, *Teleological Explanations* (Berkeley, CA: University of California Press, 1976).

### (B)

- BOORSE, Christopher, 'A Rebuttal on Function', in A. Ariew, R. Cummins and M. Perlman, eds., *Functions* (Oxford: Oxford University Press, 2002), pp. 63-112.
- BULLER, David J., 'Etiological Theories of Function: A Geographical Survey', *Biology and Philosophy*, 13 (1998): 505-27. <https://doi.org/10.1023/A:1006559512367>. Reprinted in his *Function, Selection and Design* (New York: SUNY Press, 1999).
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## PHILOSOPHY OF ECONOMICS AND SOCIAL SCIENCE

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Many helpful papers are also available in:

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### Social Science vs. Natural Science

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## PHILOSOPHY OF COGNITIVE SCIENCE

Special topic (2018-19): Philosophy of cognitive science: folk psychology; eliminative materialism; explanation in psychology and neuroscience; embodied and extended cognition.

### General introductory texts

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CRANE, Tim, *The Mechanical Mind: A Philosophical Introduction to Minds, Machines, and Mental Representation* (London: Routledge, 2003). Also available online at: <http://lib.myilibrary.com/?id=2275>

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We welcome your suggestions for further readings that will improve and diversify our reading lists, to reflect the best recent research, and important work by members of under-represented groups. Please email your suggestions to [phillib@hermes.cam.ac.uk](mailto:phillib@hermes.cam.ac.uk) including the relevant part and paper number. For information on how we handle your personal data when you submit a suggestion please see <https://www.information-compliance.admin.cam.ac.uk/data-protection/general-data>.