

# Teaching and learning guide for: Duality and ontology

Baptiste Le Bihan\* and James Read†

## 1 Authors' introduction

Dualities are a pervasive phenomenon in contemporary physics, in which two physical theories are empirically equivalent, yet *prima facie* make different ontological claims about the world (potentially *very* different claims—differing in e.g. the number and radius of dimensions of the universe). Dualities thus present a particular instantiation of the well-known notion of underdetermination of theory by evidence. Many different philosophical proposals have been made for how such putative underdetermination might be resolved—this continues to be a programme of active research. In addition, dualities raise many other philosophical questions, for example: (a) What is the most appropriate technical definition of a duality? (b) What is the connection between dualities, and the more familiar notion of symmetry transformations? (c) Should duality-related theories *always* be interpreted such that they make the same ontological claims about the world (*pace* the naïve ontological picture with which they present us), or is the situation more subtle? (d) What is the connection between dualities, and notions of (metaphysical) emergence? (e) What is the connection between dualities and the metaphysics of fundamentality? (f) Can the study of dualities benefit from philosophical work on ‘theoretical equivalence’? (g) Can we draw novel lessons from dualities on the nature of spacetime?

---

\*baptiste.lebihan@unige.ch

†james.read@philosophy.ox.ac.uk

## 2 Authors recommend

Below, we provide (with brief descriptions) some valuable papers on a number of topics in the nascent philosophy of dualities. (This list is certainly not to be regarded as exhaustive.) For introductory classes in philosophy of science, philosophy of physics or metaphysics, one could make use in particular of the works listed in §2.1 and §2.2. In in masters- or research-level seminars, one could use the references listed in all the following sections.

### 2.1 Introductions to dualities

- Dean Rickles, “A Philosopher Looks at String Dualities”, *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 42, pp. 54-67, 2011.

*An excellent, philosophically-accessible introduction to dualities.*

- Joseph Polchinski, “Dualities of Fields and Strings”, *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 59, pp. 6-20, 2017.

*An introduction to dualities written for philosophers by a titan of theoretical physics.*

- Dean Rickles, “AdS/CFT Duality and the Emergence of Spacetime”, *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 44, pp. 312-320, 2013.

*An accessible philosophical introduction to one of the most famous dualities—the so-called ‘AdS-CFT correspondence’.*

- Dean Rickles, “Mirror Symmetry and Other Miracles in Superstring Theory”, *Foundations of Physics* 43, pp. 54-80, 2013.

*A philosophical introduction to a duality called ‘mirror symmetry’, which holds between theories defined on topologically inequivalent manifolds.*

### 2.2 Dualities and underdetermination

- Keizo Matsubara, “Realism, Underdetermination and String Theory Dualities”, *Synthese*, pp. 471-489, 2013.

*One of the first papers to present dualities as a case of underdetermination of theory by evidence.*

- James Read, “The Interpretation of String-Theoretic Dualities”, *Foundations of Physics* 46(2), pp. 209-235, 2016.

*A paper which develops on the theme of underdetermination in the context of dualities in more fine-grained detail.*

### 2.3 The definition of dualities

- Sebastian de Haro, “Spacetime and Physical Equivalence”, 2017. Available at [arxiv.org/abs/1707.06581](https://arxiv.org/abs/1707.06581).

*A paper presenting a technical definition of dualities, as well as drawing many useful distinctions regarding dualities.*

- Sebastian de Haro and Jeremy Butterfield, “A Schema for Duality, Illustrated by Bosonization”, 2017. Available at [arxiv.org/abs/1707.06681](https://arxiv.org/abs/1707.06681).

*The gold standard in technical definitions of dualities, developing on the above in significantly greater detail.*

### 2.4 The interpretation of dualities

- Dean Rickles, “Dual Theories: ‘Same but Different’ or ‘Different but Same’?”, *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 59, pp. 62-67, 2017.

*A paper arguing that duality-related theories should invariably be interpreted as being physically equivalent.*

- James Read and Thomas Møller-Nielsen, “Motivating Dualities”, *Synthese*, 2018. (Forthcoming.)

*A paper resisting the above conclusion.*

### 2.5 Dualities and fundamentality

- Edward Witten, “Reflections on the Fate of Spacetime”, *Physics Today*, April 1996, pp. 24-30, 1996.

*A paper by the world’s leading string theorist, in which it is argued that dualities raise complications for the naïve idea that there could be an arbitrarily small fundamental length.*

- Elena Castellani, “Duality and ‘Particle’ Democracy”, *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 59, pp. 100-108, 2017.

*A paper discussing how to interpret situations in which what is viewed as 'elementary' in one theory gets mapped to what is viewed as 'composite' in its dual.*

## 2.6 Dualities and emergence

- Dennis Dieks, Jeroen van Dongen and Sebastian de Haro, "Emergence in Holographic Scenarios for Gravity", *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 52, pp. 203-216, 2015.

*A paper analysing whether dualities can be understood as cases of 'metaphysical emergence'.*

- Nicholas Teh, "Holography and Emergence", in *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 44, pp. 300-311, 2013.

*A further study of the relations between dualities and emergence.*

## 2.7 Dualities and spacetime

- Nick Huggett, "Target Space  $\neq$  Space", *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 59, pp. 81-88, 2017.

*A paper arguing that dualities render subtle how we are to read off spacetime structures from the mathematics of our physical theories—the focus is on one particular duality, known as 'T-duality'.*

- Keizo Matsubara and Lars-Göran Johansson, "Spacetime in String Theory: A Conceptual Clarification", *Journal for General Philosophy of Science*, 2018. (Forthcoming.)

*An extension of the above to other dualities.*

# 3 Sample syllabus

## Week 1: Dualities and underdetermination

Baptiste Le Bihan and James Read, "Duality and Ontology", *Philosophy Compass*, 2018.

### **Week 2: The interpretation of dualities**

James Read and Thomas Møller-Nielsen, "Motivating Dualities", *Synthese*, 2018. (Forthcoming.)

### **Week 3: Technical definitions of dualities**

Sebastian de Haro and Jeremy Butterfield, "A Schema for Duality, Illustrated by Bosonization", 2017. Available at [arxiv.org/abs/1707.06681](https://arxiv.org/abs/1707.06681).

### **Week 4: Dualities and emergence**

Dennis Dieks, Jeroen van Dongen and Sebastian de Haro, "Emergence in Holographic Scenarios for Gravity", *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 52, pp. 203-216, 2015.

### **Week 5: Dualities and fundamentality**

Elena Castellani, "Duality and 'Particle' Democracy", *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 59, pp. 100-108, 2017.

### **Week 6: Dualities and spacetime**

Nick Huggett, "Target Space  $\neq$  Space", *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 59, pp. 81-88, 2017.

### **Week 7: Theoretical equivalence**

James Owen Weatherall, "Are Newtonian Gravitation and Geometrized Newtonian Gravitation Theoretically Equivalent?", *Erkenntnis* 81(5), pp. 1073-1091, 2016.

## **4 Focus questions**

See questions (a)-(g) in the authors' introduction.