Theoretical Relicts: Progress, Reduction, and Autonomy

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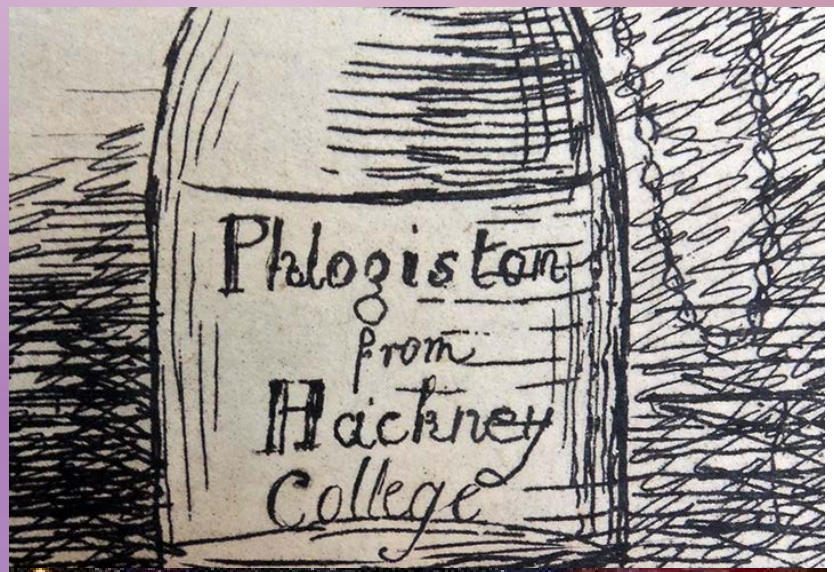
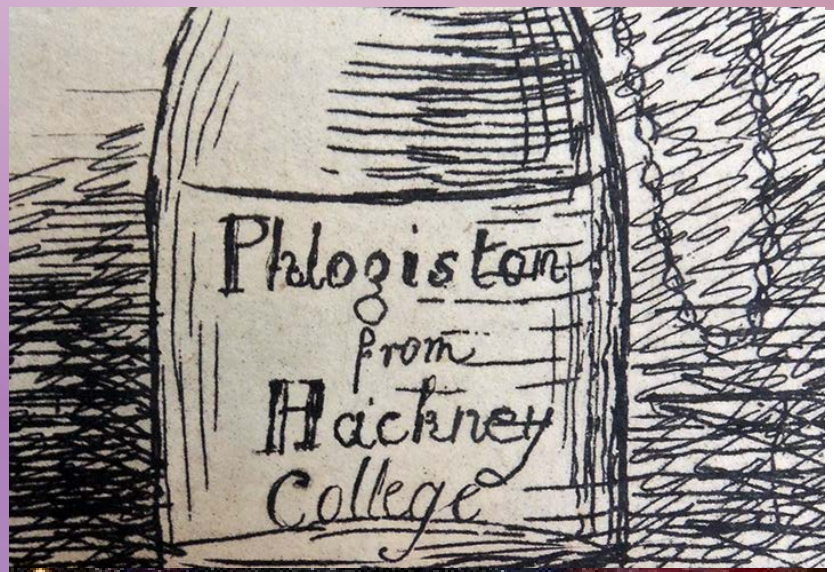


Introduction: progress in ontology

- When once-successful physical theories are superseded, common wisdom has it that their key theoretical entities are abandoned.
- Classic examples: caloric, phlogiston.
- But sometimes entities are retained in scientific descriptions despite being relegated from a fundamental role.
- Classic examples: heat, light rays, atoms, Newtonian forces, Euclidean space.



The puzzle of theoretical relicts

- A *theoretical relict* is a theoretical entity posited as basic by a previously successful scientific theory, but which is retained as non-basic in the scientific worldview after the theory is superseded.
- Our puzzle: why are some theoretical entities abandoned and others retained as relicts?
- Disclaimer: we aim to set aside issues about reference of theoretical terms (cf. inter alia Ladyman 2011, Myrvold 2020).

The plan

+ Distinguish two types of reduction: horizontal and vertical.
+ Outline a 'verticalization' procedure which transforms horizontal reductions into vertical reductions.
+ Identify a sense in which verticalized theoretical entities, as higher-level abstractions, remain distinct from their lower-level realizers.
+ Suggest that entities from old theories should be retained in a scientific realist worldview just when, understood as higher-level abstractions, they perform distinctive explanatory work.

  In slogan form: a good relict is an emergent verticalized relict.

Two types of theory reduction

- A theory T_t is reduced to T_b if the equations/quantities/variables of T_t can be *constructed* from the equations/quantities/variables of T_b (cf. Robertson 2020)

Contrast two types:

- Horizontal reduction: old-new theory reduction. (T_b = "better")
- Vertical reduction: big-small theory reduction. (T_b = "bottom")

Related terminology: diachronic vs synchronic reduction (Crowther 2018).

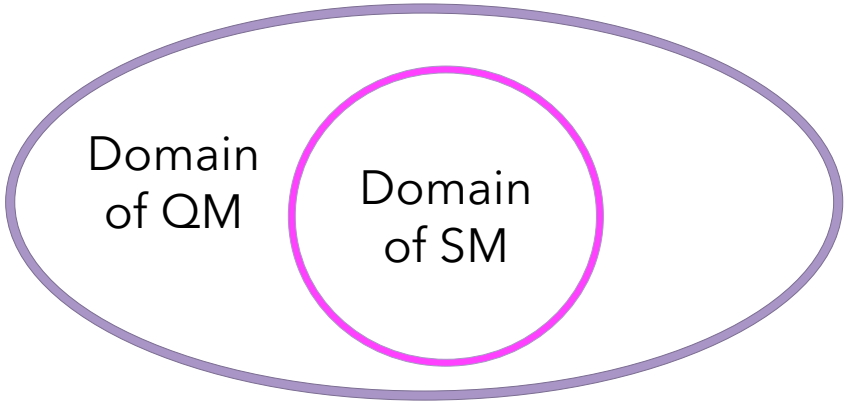
Horizontal reduction

Target phenomena of NM
=
Target phenomena of SR.

- If T_t is horizontally reduced to T_b, then the success of the older theory T_t is explained by its relation to the better theory T_b.
- T_b is typically more *accurate*.
- But to compare accuracy of description, the two theories need to describe the same phenomenon.
- As a description of that phenomenon, T_t *approximates* T_b.

  Example: Newtonian mechanics and special relativity in the low-velocity limit.

Vertical reduction

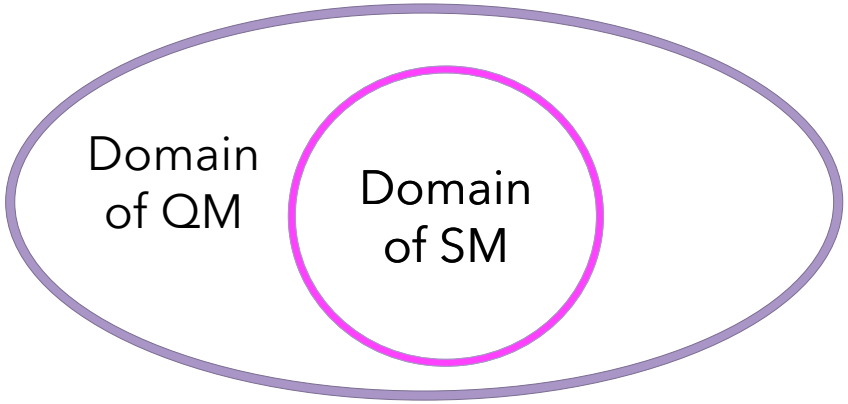


Is hydrodynamics less accurate than particle mechanics?

Is biology less accurate than chemistry?

- In order to compare theories with respect to accuracy, they need to make predictions about the same phenomena.
- But: in cases of vertical reduction, T_t describes a different set of phenomena from T_b even when it reduces to T_b.
- Statistical mechanics is *about* bulk properties such as mean kinetic energy and answers questions about these properties.
- The underlying quantum microdynamics is *about* the detailed state of the system and answers questions about that state.

Vertical reduction and abstraction



- Higher-level theories have distinct subject-matters from the lower-level theories which feature in the reduction of the higher-level theories.
- Strong Cartwrightian version: SM describes phenomena that QM doesn't describe (Hartmann, 2000).
- Uncontroversial version: QM describes phenomena that SM doesn't.
  - what happens at the recurrence time.
  - what happens with unusual initial conditions.
  - what happens to systems that do not fulfil the conditions of applicability of SM.
- T_t doesn't *approximate* T_b, but instead *abstracts away* from some of the microdetails and focuses on a *restricted range of possibilities*.

Distinguishing horizontal and vertical

Horizontal reduction

- The older theory *approximates* the newer theory, which gives a more *accurate* description of their *common subject matter.*

Vertical reduction

- The higher-level theory *abstracts* away from the more detailed lower-level theory and describes a *distinct subject matter.*

What is a theory's subject-matter?

- Some accounts are too fine-grained for our purposes; each theory will have a different subject matter. (cf. Hawke 2018).

We understand subject-matter in terms of:

- target phenomena – whatever causes/explains the observational data that are used to test the theory (cf. Bogen and Woodward 1988)
- the partitions on possibilities induced by the questions we associate with those target phenomena (cf. Lewis 1988).

Target phenomena

+ Examples of target phenomena:
  - Newtonian mechanics aimed to describe the same phenomena as special relativity: matter in motion.
  - Phlogiston theory aimed to describe the same phenomena as oxygen theory: combustion and suffocation.
  - The ray theory of light aimed to describe the same phenomena as the wave theory of light: optical phenomena like rainbows.

Phenomena, partitions and questions

- Target phenomena generate a range of questions:

  At what temperature does the kettle boil?

  Why does the flame turn green when this ionic compound is added?

  Why does the football follow this trajectory?

- The connection to subject matters a la Lewis:

  A question defines a partition over possible worlds (each cell corresponds to one possible answer).

  The subject matter of a theory is how things stand with respect to the conjunction of questions connected to the target phenomena.

Subject-matters at different levels

- The questions that an old theory aims to answer are the same as the new theory: they have the same target phenomena.
- Higher-level theories and lower-level theories aim at different sets of questions: they have different target phenomena.
  - In the latter case, the set of questions answered by the higher-level theory T_t overlaps with T_b 's set.
  - This is to be expected: the subject matters are not orthogonal (compare: the number of universities / the number of jellyfish) since there are supervenience relations between levels.

Verticalization – *how?*

- Restrict the domain of the old theory such to limit it to the circumstances in which it gets some nomological structure right, and so latches onto genuine dependencies.
- This gives T_t a distinct subject matter from T_b
  - N.B. this is distinctness in the 'not exactly the same' sense which permits partial overlap, rather than distinctness in the sense of disjointness.
- T_t is now understood an *effective theory* (in the sense of an effective field theory: cf. Williams 2019)

Verticalization: an objection

- Q: Can't we *always* vindicate any old theory by reinterpreting it, to understand it as applying only within certain domains and/or to certain degrees of accuracy?

- A: Yes.
  But that doesn't mean verticalization opens the floodgates to just any old entities: there are restricted circumstances in which we should verticalize.

Verticalization – *when?*

- Some entities are rightly abandoned! We need limits on when to verticalize.
- Phlogiston theory got *some* nomological structure right.
- Noretta Koertege (1968) argues that phlogiston theory can be *reduced* to redox theory (cf. Ladyman 2011).
- So: does phlogiston exist after all?
- If not, what is the difference between this theory and other examples? (TD-SM, or NM-SR?)

Verticalization – a suggestion

- Guiding thought: there are no explananda for which phlogiston theory does better than redox theory, but some explananda for which Newtonian mechanics does better than special relativity:

  Why did my ball miss the goal?
  Is this pendulum's motion chaotic?

- **Our suggestion: verticalize just when T_t gives better explanations than T_b for some explananda, so T_b does not strictly dominate T_t wrt to explanatory power.**

  (Contra Frigg and Werndl 2019, this assumes effective theories can explain).

Verticalization – further questions

- What restrictions on explanatory questions are required?
  - The questions can't be purely theoretical (how much phlogiston? Which is the frame of absolute rest?)
  - These questions seem to have have no *empirical* basis since they were generated not by the phenomena but only by the theory.
- Will Kuhn losses mean the 'does not strictly dominate' condition is always satisfied? Cf. Hartmann (2000).
- Most pressingly: how to understand 'better explanation'?
  - More calculationally tractable?
  - More proportionate explanation?

Verticalization and emergence

- Suggestion: link the explanatory role distinctive of genuine relicts with existing conceptions of weak emergence.
- Various alternative accounts of emergence are open, e.g.:
  - J. Wilson - entities are (weakly) emergent if their states can be specified using strictly fewer degrees of freedom.
  - Franklin and Robertson - entities are emergent if they enter into novel laws/macrodependencies that screen off the microdetails.

- ***Slogan:* a good relict is an emergent verticalized relict.**

Conclusion: resolving the relicts puzzle

- Horizontal reductions can be verticalized, with the older theory restricted to apply in some domain to some degree of accuracy.
- Verticalization turns old theories into *effective theories* and old theoretical entities into *higher-level entities*.
- Verticalization is apt just when it gives rise to distinctively explanatorily powerful – *emergent* - higher-level entities.
- Verticalization rehabilitates the old theory: from being merely wrong, to being wrong about the fundamental but right about something emergent.

Thanks for listening! - & References

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