Inter-Theoretic Reduction III: Recent Views from Biology (Kitcher) and Physics (Batterman)

Some Preliminary Remarks

- We've covered Nagel's derivational (logical) notion of intertheoretic reduction (**Lectures XXV, XXVI**) as well as Nickles' critiques of Nagel and his versions (domain-combining; i.e. derivational, versus domain-preserving; i.e. justificatory and heuristic.) Perhaps one can ask now, and as was discussed in class (**Lecture XXVI**)with especial thanks to questions/comments from Stephen Mahanes and Leonard Goff: What do we call a general failure of reduction, in other words what do we with a case of two related theories *T* and *T* ' that *won't* exhibit a reduction relation in *any* theory of intertheroetic reduction? How can we distinguish such a failure from a *in principle* failure versus *in practice*? (Are there *absolute limits* to reduction or only *practical limitations*?)

- Generally a failure of reduction in a particular domain is denoted as a form of **emergence.**[1] **Weak emergence** is usually (but not always) thought of as **epistemic, reflecting inherent limits or practical limitations in cognitive resolving power.**[2] **Strong emergence** is usually (but not always) though of as

[1] The topic has been receiving much renewed attention, though the notion is found already in the writings of Aristotle. John Stuart Mill (1850s) revived the notion, and relatively recently it has become an area of active research, thanks to the developments in cognitive science, complexity theory, neural nets, etc. See for instance, Tim O'Connor's & Hang Yu Wang's 2002 review article of "Emergent Properties" in the *Stanford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/properties-emergent/
See also:

Clayton, Philip D. (2004). "Emergence: Us from It," in *Science and Ultimate Reality*, eds. J. D. Barrow, P. C. W. Davies and C. L. Harper. Cambridge: Cambridge University Press, 577-606.

Clayton, Philip (2006). "Conceptual Foundations of Physical Emergence Theory," from *The Re-emergence of Emergence,* Clayton & Davies, eds. Oxford: OUP Press, 1-31.

Silberstein, Michael & McGeever, John. "The Search for Ontological Emergence." *The Philosophical Quarterly*. Vol 49, n195 (April 1999), 182-200.

[2] A classic case of weak emergence includes the **three-body central force problem** in classical Newtonian mechanics. When three or more bodies possessing a central force potential (like Coulomb/electrostatic or Newtonian gravitational, etc) interact locally, the mathematical problem to specify precisely their trajectories becomes impossible to solve. The differential equations describing their dynamic behavior cannot be solved by exact means. Hence we'd say that the motion of the three bodies is **epistemically emergent** from their net mutual forces. This is not to say that one cannot *approximate* the solution by perturbation methods and asymptotic analysis. More importantly, the strong metaphysical reductionism (atomism + materialism) tells us that nothing strange is going on metaphysically: In principle, the motion of the three particles is reducible to the mutual forces they feel on one another. In practice, however, there's a limitation concerning how precisely can one resolve such motion.

ontological, i.e. reflecting real cases of emergent relations among objective properties occurring *independently* of our cognitive activity.[3] In addition, a 'wishy-washy' notion denoting something between the extremes of emergence (whether strong or weak) and reduction, is **supervenience.** Recall: B supervenes on A whenever any change in A produces a change in B **but not vice versa.**[4] This 'wishy-washy', 'neither fish nor fowl' notion has served itself well, especially in some of the recent developments of science in the last several decades.[5]

- Recall from **<u>Lecture XXVI:</u>** Nickles elaborates more on his notion of T '≈≈> T by presenting a scheme of reduction $O_n \ldots O_1 T'$ ≈≈> T where $O_1, \ldots, O_n$ represent a list of n intertheoretic operations "which are reductive under certain conditions.[6]"(963) In addition, the operations $O_n \ldots O_1$ on T' need not cover all of the aspects of T ' let alone T..." [T'] and [T] will stand for theory-parts. Nevertheless partial reduction of this sort remains an indispensable conceptual tool in theoretical research." (963) He then consider a toy example involving the following two 'theory' parts:

  (A): $w = ax + 2y + g$ (B): $z = bx + ey + d$

  where x, y are (independent) physical variables while w,z are (dependent) physical variables and a, b, d, e, g are constants. Suppose (B) is the 'new' theory while (A) is the 'old' theory, in which $g = 0$. Futhermore, suppose that $a = b$, and that $0 < d \ll 1$.[7] "Is it surprising to say (B) reduces$_2$ to (A) in the limit as $d \to 0$? …[W]hy is it not equally legitimate to say that (A) reduces$_2$ to (B) in the limit as $g \to d$?" (964) His answer is that "letting numerical constants change value is mathematically illegitimate." (ibid) Nickles uses a *reductio ad absurdum* here to argue why he thinks so: One could, *mutates mutandis* end up asking what

[3] For instance, Cartesian metaphysical dualists would argue that mind is **strongly emergent** with respect to matter. Cartesian dualists are those who believe that there are fundamentally two modes of being in ultimate terms: mind versus matter. According to Descartes, mind lakes the property of not being spatially extended or located, while it is essential for matter to be spatially extended and localized.

[4] This definition can also be phrased in **contrapositive** form (recall **<u>Lecture II</u>**) as mentioned for instance by Leonard Goff after class (**<u>Lecture XXVI</u>**): B supervenes on A if no change in B can occur without a change in A.

[5] To name one instance: the nascent research tradition of *Complexity Studies* (based for instance at the Santa Fe Institute). Whether examining protein folding and other complex biophysical phenomena characterized as being far from thermodynamic or mechanical equilibrium, or inorganic correlates exemplified in rotor cell-formation in turbulent fluid dynamics, the macrolevel properties (temperature, pressure, density, viscosity, large-scale structure, etc.) are best suited as characterized in terms of supervening on the properties of their microlevel constituents. We have no story for *how* such macroproperties are exactly characterized or fully reduced to the properties on the microlevel, (the mathematics, even with some of the best computers, remains intractable) but this doen't imply that something metaphysically novel or epistemically intractable is occurring. In other words, in the case of supervenience, it's correct to assume *some* causal dependence of the macroproperties on the microproperties.

[6] Nickles presents two, but of course his point can be generalized to finitely many (n in this case). Note also that $O_n \ldots O_1 T'$ is shorthand for nesting, and should be read in parenthetical order from right to left ("first do O_1, then do $O_{2,\ldots}$") i.e.: $O_n(\ldots (O_1 (T'))\ldots)$

[7] All of these moves can be considered cases of the operations Oi as discussed above.

characterizes (A) in the "2 $\rightarrow$ 0" limit. Not only does this appear mathematically absurd, it would reduce (A) to an equation *qualitiatively different* from (A) and (B), i.e. to an equation involving *one* variable alone.[8]

- However, physicists *do* talk in such terms! (They allow constants like the speed of light $c \rightarrow \infty$ or Plank's constant $h \rightarrow 0$ when looking for heuristic justificatory reductions of SRD to CND, or quantum theory to classical theory, respectively, for example)[9]. What are we to make of this? We should think of cases like this that "*h* and *c* act as variables in a noncommital metalanguage." (966) Or (as Nickles paraphrases) "Strauss points out that when constants are taken to limits, they are being regarded as variables in the metatheory." (n. 37, 970) The fact that this occurs on a case-by-case basis in physics indicates that "there is [no] general formula for reductive relationships any more than there is an interesting common structure to all theories:…we must examine each case on its individual merits." (964)

- Robert Batterman (2001, rev. 2007) elaborates on this above theme by examining the heuristic, justificatory, domain-preserving case *T* '≈≈> *T* more closely. **Caveat: Notice that Batterman is adopting Feyerabend's convention[10] of assigning the prime superscript to the *preceding* theory! I'll stick with the uniform convention (assigning *T'* as the *successive* theory.)** Though he covers the same ground as in our previous readings on Nagel & Nickles in the first section, Batterman does offer more elaboration on Schaffer's notion concerning "correcting" a version of the predecessor theory *T* (to *T**) in order to effect a the possibility of a Nagelian domain-combining reduction: I.e. *T* reduces to *T'* if *T* has a corrected version (*T**) so that:

    1. The primitive terms of *T** are associated by …bridge laws…with various terms of *T* '.
    2. *T** is **derivable from** *T'*, when it is supplemented with the reduction functions [bridge laws] specified in 1.
    3. *T** **corrects** *T* in that it makes more accurate predictions than does *T*.
    4. *T* is **explained by** *T'* in that *T* and *T** are *strongly analogous* to one another … *T'* indicat[ing] why *T* works as well as it does in its domain of validity.

- Batterman characterizes more formally Nickles' sense of domain-preserving reduction (*T* '≈≈> *T*) by the **SchemaR:** $\lim_{\varepsilon \rightarrow 0} \boldsymbol{T'} = \boldsymbol{T}$. The 'equation' is basically shorthand for stating:

[8] Robert Batterman (Dec. 6th readings) looks at this issue more closely.
[9] In fact this limit process is so commonplace that mathematical phycisists usually refer to such 'constants' as 'parameters' which could be thought of as a type of variable.
[10] See n. 12, p. 2 **Lecture XXV.**

For some fundamental parameter ε *of* ***T'****, as it becomes negligible* (*as* $\varepsilon \to 0$[11]), *the behavior of some of the laws of* ***T' smoothly converge*** *to the limiting case of the laws of the older theory* ***T****.*

Examples are easy to recall (**Lectures XXV, XXVI**). As Batterman however mentions this must be "taken with a grain of salt" insofar as: a) One shouldn't expect this to occur for **all** the laws of ***T'***. b) (More mportantly) the limit must be "regular" (smooth approach).

- Recall an irregular limit suggested by Nickles' toy example: for theory-part (B): $z = bx + ey + d$, letting $e \to 0$ indicates that the **"limiting behavior" is not the same as the behavior "*in* the limit."** For as long as e is nonzero, no matter how negligibly small, then the dependent variable z acts logically like a two-place predicate: i.e. $z(x,y)$ (z is a function of **two** independent variables). However, when e reaches 0, z discontinuously switches to becoming a one-place predicate: i.e. $z(x)$ (z is a function of **one** independent variable). Batterman echoes a similar notion with his toy example: Note that the $\varepsilon \to 0$ behavior for the 'law'

$$x^2 + x - 9\varepsilon = 0$$

is obviously regular. (In the $\varepsilon = 0$ limit we still have a quadratic equation

$$x^2 + x = 0$$

…with two roots.) On the other hand, for the 'law' $\varepsilon x^2 + x - 9 = 0$ the $\varepsilon \to 0$ behavior is irregular! (In the $\varepsilon = 0$ limit we discontinuously switch to a **linear** equation with only one root.)

- A paradigm case of a regular limit is discussed by Batterman (in more explicit detail) the example of momentum in SRD reducing to CND.[12] Batterman expands the gamma factor as a Taylor series[13] (centered at $\varepsilon \equiv {}^{v}/_{c} = 0$):

$$\gamma(v) = [1 - ({}^{v}/_{c})^2]^{-1/2} = 1 - {}^{1}/_{2}({}^{v}/_{c})^2 + O(({}^{v}/_{c})^{2n})$$

where: $O(({}^{v}/_{c})^{2n})$ are higher-order even powered terms of $({}^{v}/_{c})$ that are all 'big-oh', i.e. $\lim_{v/c\to 0} O(v^{2n}) = 0$.

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[11] With no loss of generality, one could just as well say that for some fundamental paramter η in ***T'***, as η becomes **arbitrarily large,** i.e. $\lim_{\eta\to\infty} \boldsymbol{T'} = \boldsymbol{T}$. This is equivalent in meaning to **Schema R** as one could always re-define: $\eta \equiv {}^{1}/_{\varepsilon}$ hence, $\varepsilon \equiv {}^{1}/\eta$.

[12] Recall n. 19, **Lecture XXVI.**

[13] If you've had Calculus II, then you know better in this case **not** to derive the coefficients of that series on page 6 using first principles using Taylor's Theorem! It's a far too messy procedure. It's easier to expand a Binomial series (which in this case is infinite, since the exponent is not a positive integer quantity.) The generalized Binomial coefficients in this case simply become: (for the k th term in the series)

$$\binom{-1/2}{k} = {}^{[(-1/2)(-3/2)\ldots(-1/2\,-\,k+1)]}/_{k!}$$

This is emblematic of a ***regular*** perturbation pattern.[14]

- On the other hand, when the limiting behavior *isn't regular* "it is best to speak of intertheoretic relations rather than intertheoretic reductions." Though the techniques of renormalization can serve to temper such discontinuities—by bounding *T* or *T* ' within a certain range of energies, for instance. However, in general, according to Batterman, asymptotic analysis (examining the *approximate* behavior of *T* '*near* the limit indicates that the old theory *T* is essentially utilized in the explanation of the phenomenon. For example: optical caustic surfaces (rainbow phenomena) produce a singular limit in the case of the wave theory *T'* , so one must resort to the older geometric optics theory *T* of ray-tracing to qualitatively describe such phenomena.[15]

- Further driving home the pluralist theme of Nickles, Kitcher (1984) points out that in the case of the reduction of classical genetics *T* to molecular biology *T'*, the three *prima facie* plausible conditions (expanded from Nagel's schema):

  R1: Genetics contains laws which act as conclusions to molecular biology's laws.
  R2: Bridge principles can link extensions of terms/predicates in genetics with those in molecular biology.
  R3: Deriving general principles of gene transmission form molecular biology would underwrite the laws of gene transmission.

  …Are all inapplicable! **R1** cannot hold because nothing like reliable laws (not subject to continuous *ceteris paribus* modification) have been shown to hold in classical genetics.[16] **R2** cannot hold because there remains no logical procedure (short of exhaustively listing all sufficiency condition) for fixing stable predicates to genes. **R3** is untenable as even if one assumes in principle such general laws can be derived, "th[e] obscurity is an artefact of our limited cognitive abilities…there are no general constraints of molecular structures that can be paired or on how forces combine to pair or separate them." (1033)

- Borrowing from Kuhn (science as complex practice) as well as his unification account of explanation, Kitcher replaces the above three notions with *presupposition, conceptual refinement, explanatory extension* as the three necessary forms of intertheory relations for reduction to hold. All three epistemic notions aren't simple, logical, 'global' methodological rules, but rather function locally in their particular historical and reductive context.

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[14] "Perturbing" means how 'coarse' or fine we set $\varepsilon \equiv {}^{v}\!/_{c}$. For example, if $v = 0.1c$, this is a 'coarse' pertubation term, so the 2nd order, 4th order contribute quantities that have a notice deviation on γ (away from 1) to a certain order of magnitude. In Calculus II terms, the measure of the order of magnitude of deviation (perturbation) is marked by the 'big-Oh' expression which can be written in terms of a **Remainder formula.**

[15] Batterman's thesis is controversial. He has met many criticisms (G Belot (2003), Cohnitz (2003))…including yours truly (see my homepage ☺).

[16] Linley Darden argues that *mechanisms* should be the epistemic and ontological unit, not laws.

- *T* presupposes instantiations of problem-solving patterns. *T'* derives the possibility of a previous problematic presupposition of *T*..

  [W]here the reductionist looks for a global relation between *T* and all the fundamental laws of *T*' Kitcher's account…**focuses on particular derivations of problematic presuppositions in classical genetic theory. (1037)**

- **Conceptual refinement:** *T'* fixes entitites within extensions of predicates of *T* that alters the way of fixing referents of the predicates in *T*.

- **Explanatory extension:**

  Kitcher proposes that we understand the relation between the patterns of reasoning found in different theories by means of the notion of explanatory extension…*T'* provides an explanatory extension of *T* only if one of the premises of some problem-solving pattern of *T* can be generated as a conclusion of some new problem-solving pattern of *T* '. (1038)