



Alexandre Guay

Physics and Metaphysics: a Sellarsian project ... sort of

3 – Emergence, or changing laws

1. Varieties of emergence

Compartmentalization of the conceptual landscape of emergence

2. Transformational emergence: an account

The ontology/epistemology of transformational emergence

3. Transformational emergence: an exemplification

The fractional quantum Hall effect

4. The problem of the nature of the transformation

The metaphysics of changing laws





1. Varieties of emergence

Compartmentalization of the conceptual landscape of emergence

2. Transformational emergence: an account

The ontology/epistemology of transformational emergence

3. Transformational emergence: an exemplification

The fractional quantum Hall effect

4. The problem of the nature of the transformation

The metaphysics of changing laws



Every *bona fide* account of emergence is an account that makes sense of:

(DEP) E is dependent on – or determined by – its basis B; and yet

(NOV) E is novel with regard to – or autonomous from – its basis B.

Most pressing challenges that any account of emergence has to meet:

- (a) Provide a precise and positive characterization of (DEP) and (NOV);
- (a) Show that, under a given characterization, (DEP) and (NOV) are compatible;
- (a) Show that, under a given characterization, there is a non-trivial demarcation between what satisfies (DEP) and (NOV) (and hence counts as emergent) and what doesn't satisfy (DEP) and (NOV) (and hence doesn't count as emergent)

(i) Synchronic vs. diachronic emergence

Synchronic
emergence

(DEP_S) E is constitutively dependent on its (underlying and simultaneous) basis B; and yet

(NOV_S) E is constitutively novel with regard to its basis B.

Diachronic
emergence

(DEP_D) E is processually dependent on its (antecedent but not necessarily underlying) basis B; and yet

(NOV_D) E is historically novel with regard to its basis B.

(i) Synchronic vs. diachronic emergence

(ii) Epistemological vs. ontological emergence

Epistemological
emergence

(DEP) E is dependent on its basis B; and yet

(NOV_E) E is (*e.g.*) unexplainable, unpredictable, underivable
from complete knowledge of its basis B.

Ontological
emergence

(DEP) E is dependent on its basis B; and yet

(NOV_O) E (*e.g.*) exhibits new causal powers that are not
combinations of the powers of its basis B.



(i) Synchronic vs. diachronic emergence

(ii) Epistemological vs. ontological emergence

(iii) Weak vs. strong emergence

Weak
emergence

(DEP) E is dependent on its basis B; and yet

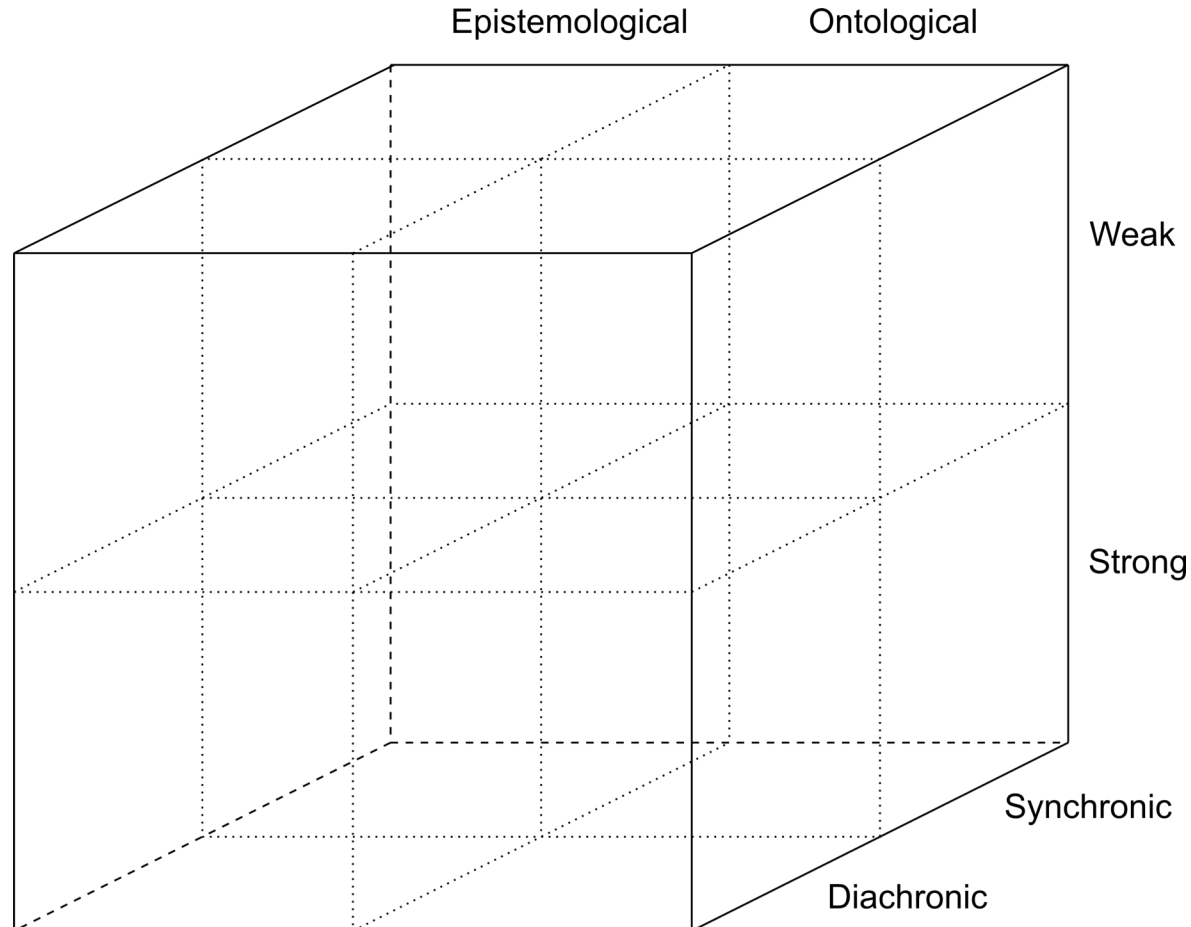
(NOV_w) E (*e.g.*) is unexplainable, unpredictable, underivable
in practice from complete knowledge of its basis B.

Strong
emergence

(DEP) E is dependent on its basis B; and yet

(NOV_{st}) E (*e.g.*) is unexplainable, unpredictable, underivable
in principle from complete knowledge of its basis B.

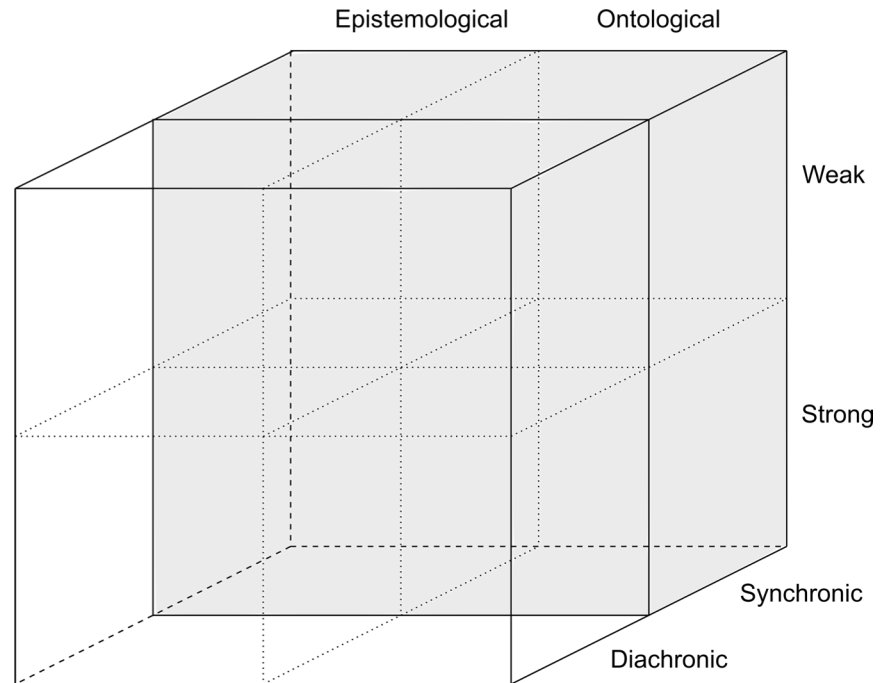
1. Varieties of emergence



1. Varieties of emergence

Emergence in the philosophy of mind

Essentially in the wake of Broad (1925)'s **synchronic** construal of the notion

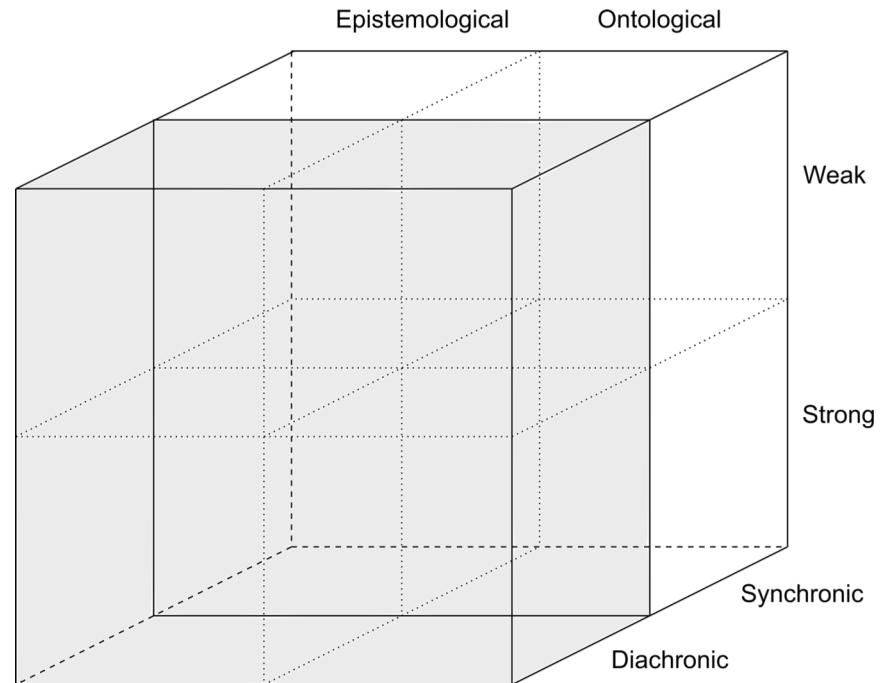


	Epistemological	Ontological
Weak	Nagel (1949)	Gillett (2003)
Strong	Searle (1992)	Popper (1977)

1. Varieties of emergence

Emergence in
philosophy of science

Essentially in the wake of
Morgan (1913)'s **diachronic**
construal of the notion



	Epistemological	Ontological
Weak	Rueger (2001)	Wilson (2010)
Strong	Bedau (1997)	Humphreys (1997)



1. Varieties of emergence

Compartmentalization of the conceptual landscape of emergence

2. Transformational emergence: an account

The ontology/epistemology of transformational emergence

3. Transformational emergence: an exemplification

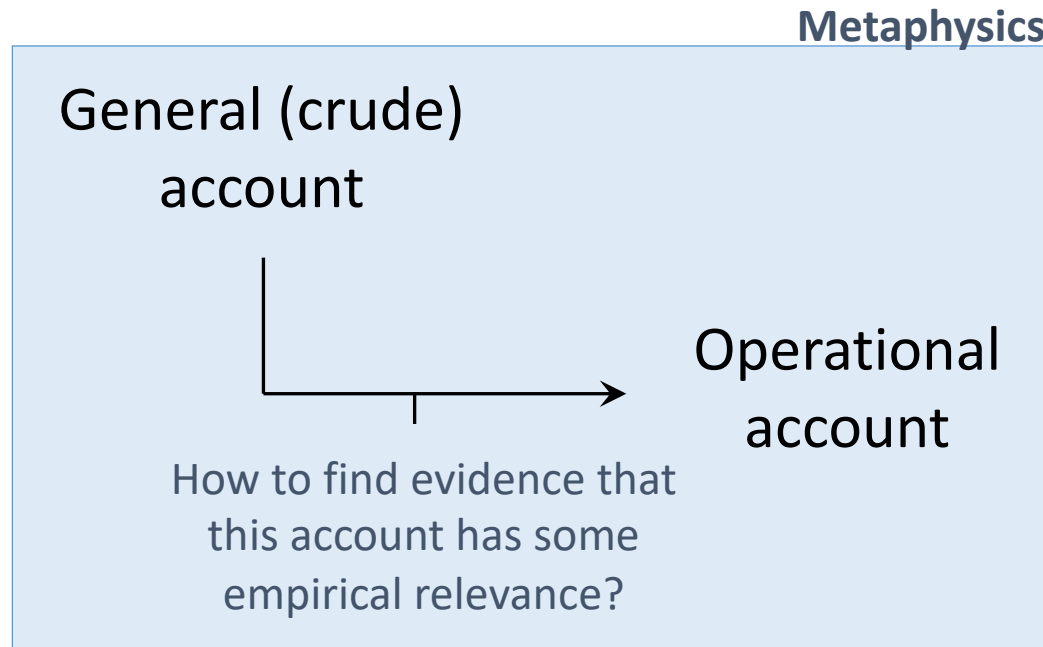
The fractional quantum Hall effect

4. The problem of the nature of the transformation

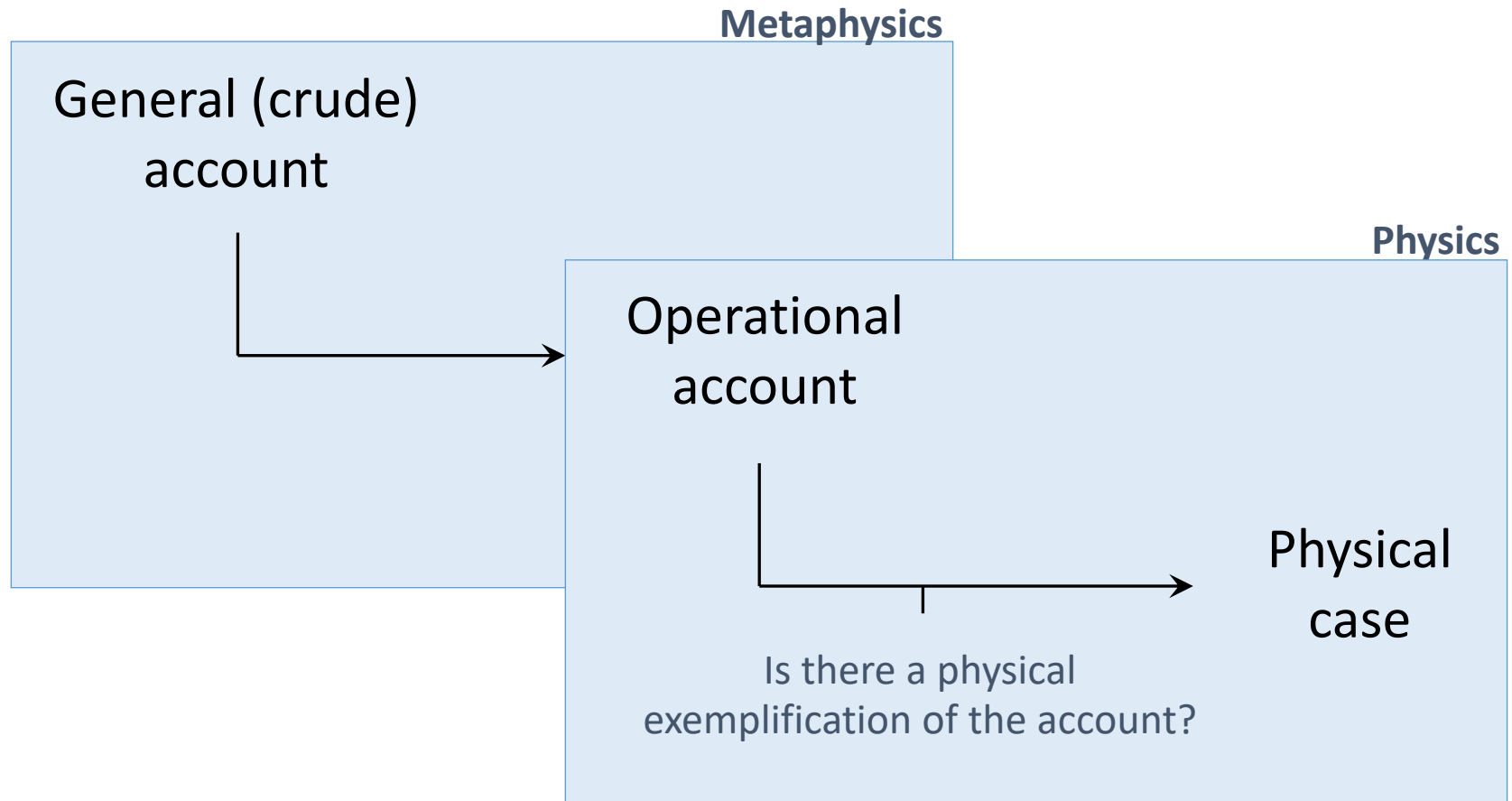
The metaphysics of changing laws



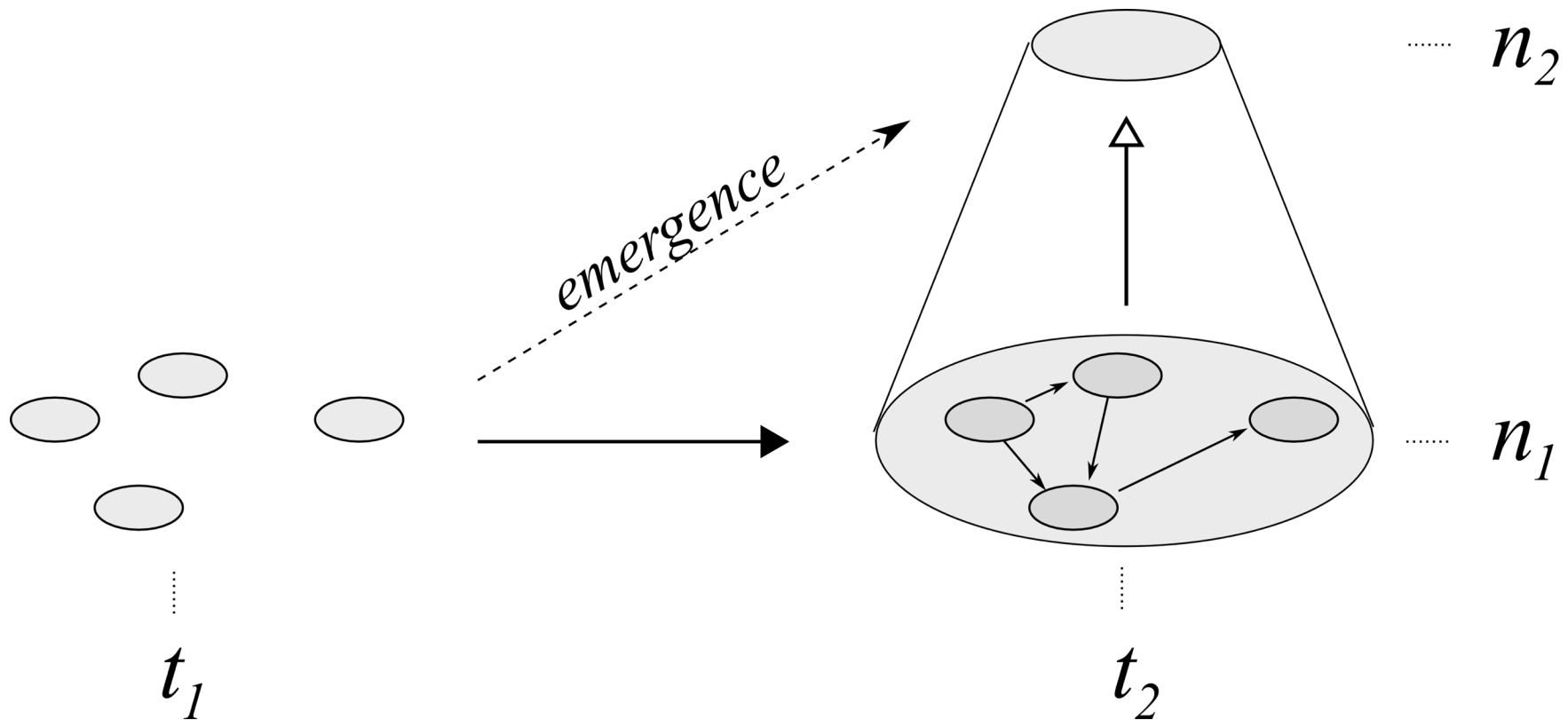
2. Transformational emergence: an account



2. Transformational emergence: an account



2. Transformational emergence: an account

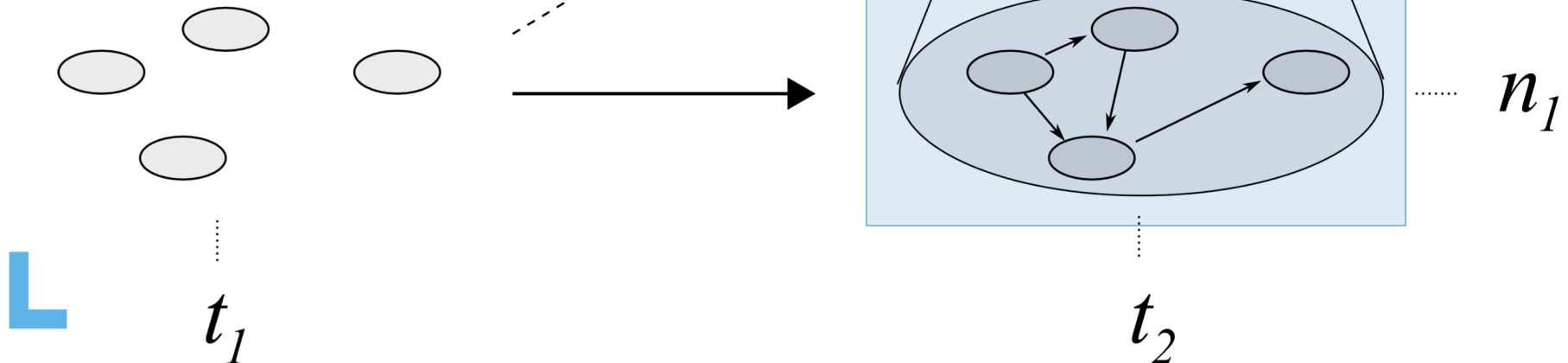


2. Transformational emergence: an account

Synchronic emergence

Drive = a specific constitutive relationship
[C] between levels n_1 and n_2 .

(*e.g.* supervenience + downward causation)
(DEP_S) (NOV_S)

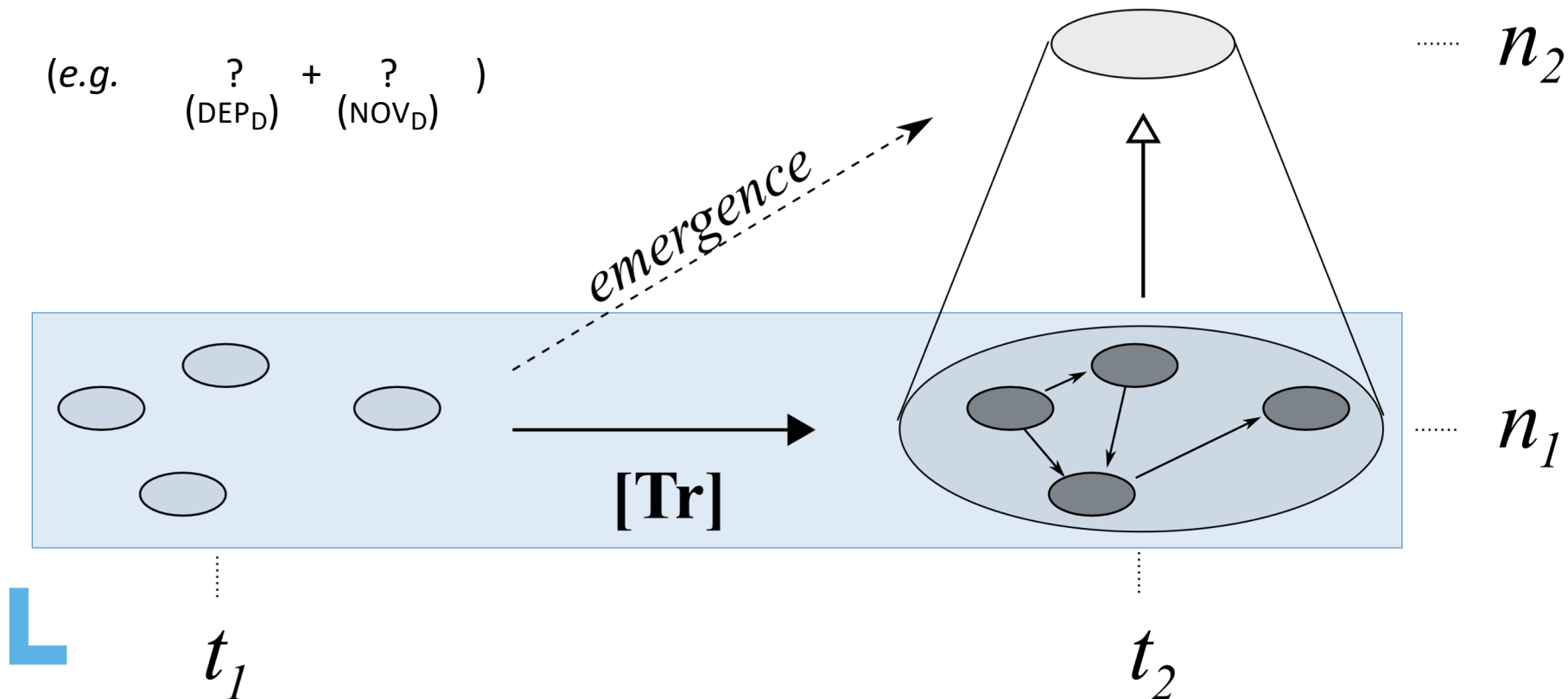


2. Transformational emergence: an account

Diachronic emergence

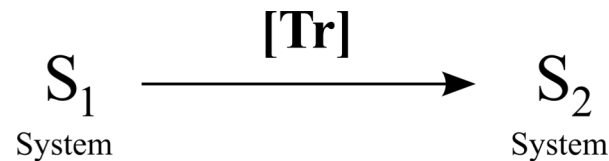
Drive = a specific transformational relationship
[Tr] between times t_1 and t_2 .

(e.g. $\begin{pmatrix} ? \\ (\text{DEP}_D) \end{pmatrix} + \begin{pmatrix} ? \\ (\text{NOV}_D) \end{pmatrix}$)



2. Transformational emergence: an account

General account

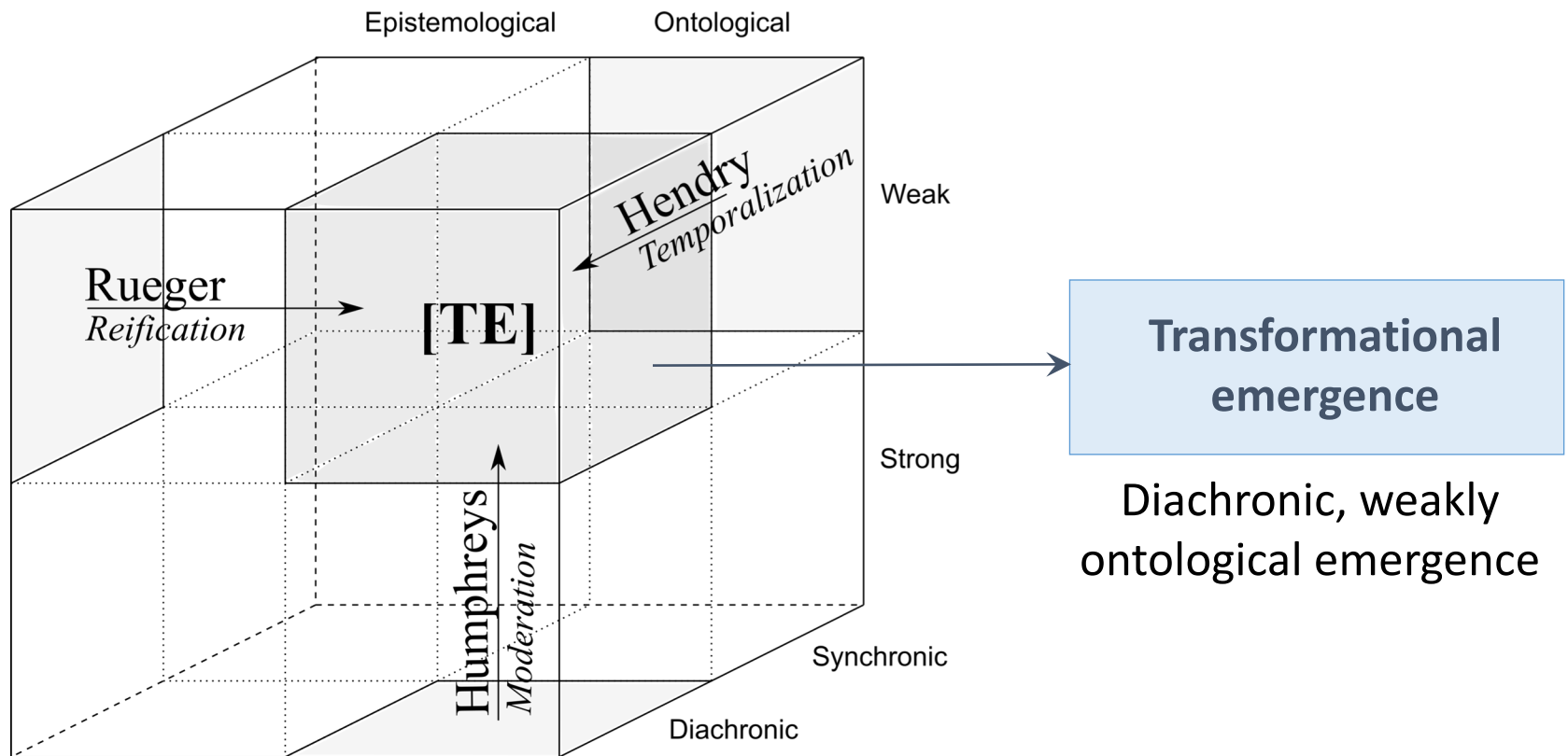


S_2 transformationally emerges on S_1 iff there exists a transformation **[Tr]** such that:

- (DEP_D) S_2 is the product of a continuous process going from S_1 (for example causal, and possibly fully deterministic). In particular, the “realm” R to which S_1 and S_2 belong (*e.g.* the physical realm) is closed, to the effect that nothing outside of R participates in S_1 bringing about S_2 .
- (NOV_D) S_2 exhibits new entities, properties or powers that do not exist in S_1 , and that are furthermore *forbidden* to exist in S_1 according to the laws governing S_1 . Accordingly, new laws govern S_2 .



2. Transformational emergence: an account



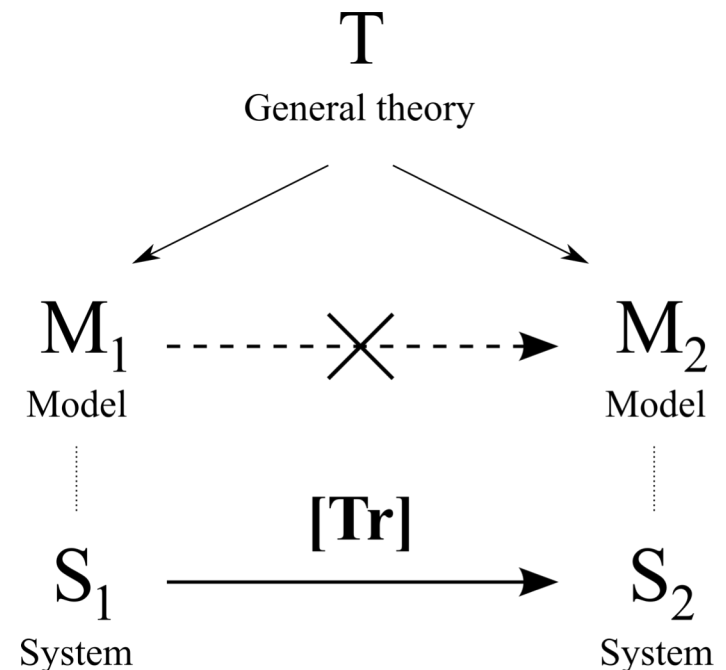
2. Transformational emergence: an account

Operational account

(DEP*_D) M_1 and M_2 are models of one and the same non trivial theory T .

(NOV*_D) M_2 is not derivable from M_1 as a matter of principle, for M_2 contains features that are forbidden in M_1 according to theory T .

More precisely, S_2 's dynamics as described by M_2 is not continuously deformable into S_1 's dynamics as described by M_1 .



2. Transformational emergence: an account

Some advantages:

- No need to have a metaphysical notion of “levels”. Transformational emergence can actually tolerate a deflationary account of levels grounded in notions like scale or composition.
- No need to posit a controversial, holistic and “downwardly oriented” causal influence (or a “configurational force”). Transformational emergence is actually immune to Kim-style exclusion and overdetermination problems.
- A sense is already given (though it will be refined) to the notion of “historical novelty” and is contrasted to mere (qualitative) difference.

Some (possible) issues:

- *Empirical issue*: are there transformationally emergent systems in the world? Put differently: is there an exemplification of **[Tr]** in the world?
- *Triviality / scarcity issue*: is the general account too liberal or too restrictive, so that transformationally emergent entities are either rather mundane or merely nonexistent?

1. Varieties of emergence

Compartmentalization of the conceptual landscape of emergence

2. Transformational emergence: an account

The ontology/epistemology of transformational emergence

3. Transformational emergence: an exemplification

The fractional quantum Hall effect

4. The problem of the nature of the transformation

The metaphysics of changing laws



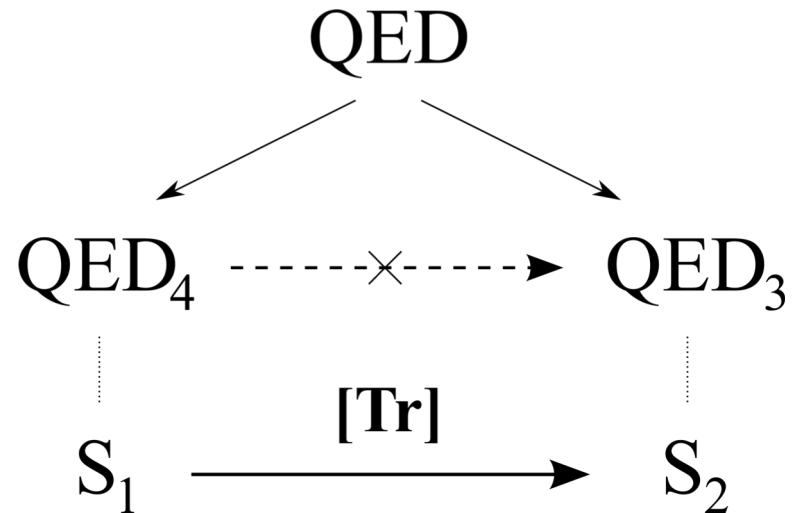
3. Transformational emergence: an exemplification

Physical case

(DEP^*_D) QED_3 and QED_4 are models of QED.
(S_2 and S_1 are “of the same kind”)

(NOV^*_D) QED_3 is not derivable from QED_4 as a matter of principle, for QED_3 contains features that are forbidden in QED_4 according to QED.

States of matter modelled by QED_3 can exhibit new topological orders compared to QED_4 .

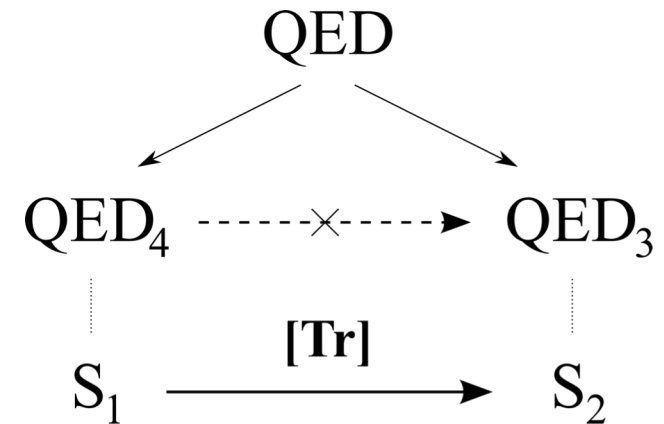


3. Transformational emergence: an exemplification

(DEP^*_D) QED_3 and QED_4 are models of QED.
(S_2 and S_1 are “of the same kind”)

QED is a quantum field theory with the following requirements:

- Poincaré invariance
- $U(1)$ local gauge symmetry
- Renormalizable
- Minimal coupling: $L_I = -J^\mu A_\mu$ (A_μ acts like a connection)
- The equations of motion and the Bianchi identity for the gauge field are of “Maxwell type” (they do not refer to the vector potential).
- L_{matter} is analogue to L_{matter} in 3+1 dimensions.



3. Transformational emergence: an exemplification

(DEP*_D) QED₃ and QED₄ are models of QED.
(S₂ and S₁ are “of the same kind”)

QED₄

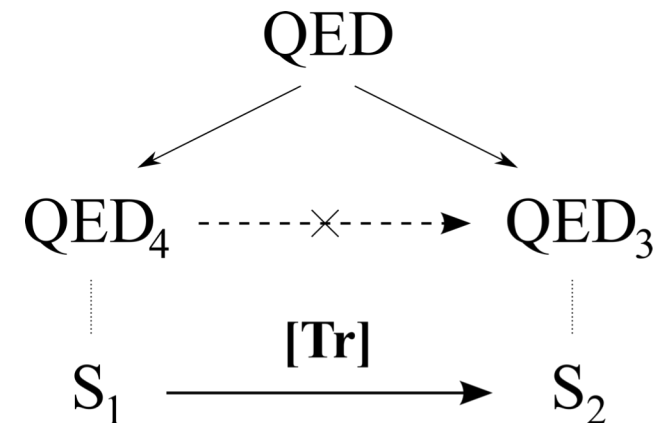
$$L = L_{\text{matter}} + L_{\text{Maxwell}} + L_{\text{interaction}}$$

QED₃

Analogue L but

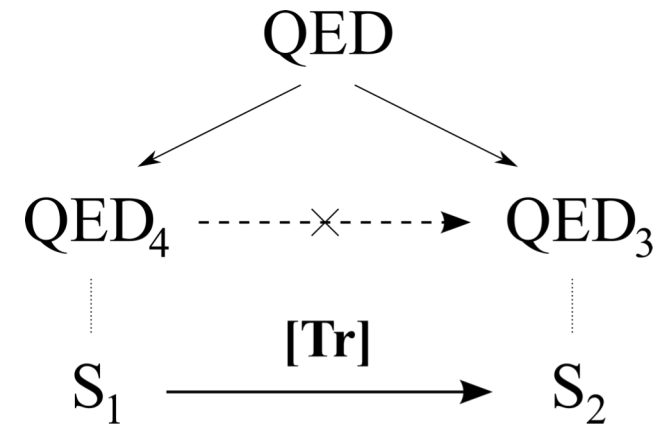
$$L_{\text{Maxwell}4} \rightarrow L_{\text{Maxwell}3} + L_{\text{Chern-Simons}} = L_M + \gamma \epsilon^{\mu\nu\alpha} A_\mu \delta_\nu A_\alpha$$

Under a gauge transformation $L_{\text{QED}3}$ changes by a total derivative.



3. Transformational emergence: an exemplification

(NOV*_D) QED₃ is not derivable from QED₄.
States of matter modelled by QED₃
can exhibit new topological orders
compared to QED₄.

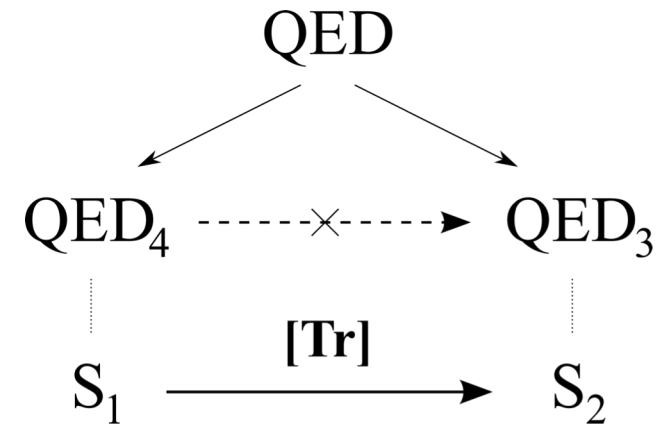


- L_{CS} is topological. It does not depend on the space-time metric. It does not contribute to the Hamiltonian.
- L_{CS} generates a topological mass to the photons (spin 1 excited states of the gauge field).
- L_{CS} endows “charged particles” with magnetic flux $\rightarrow$ new field solutions exhibiting fractional statistics are allowed.

[Note: this effect is the result of a long range interaction of the Aharonov-Bohm type. In consequence, there is no conflict with the fact that photons are massive]

3. Transformational emergence: an exemplification

(NOV*_D) QED₃ is not derivable from QED₄.
States of matter modelled by QED₃
can exhibit new topological orders
compared to QED₄.

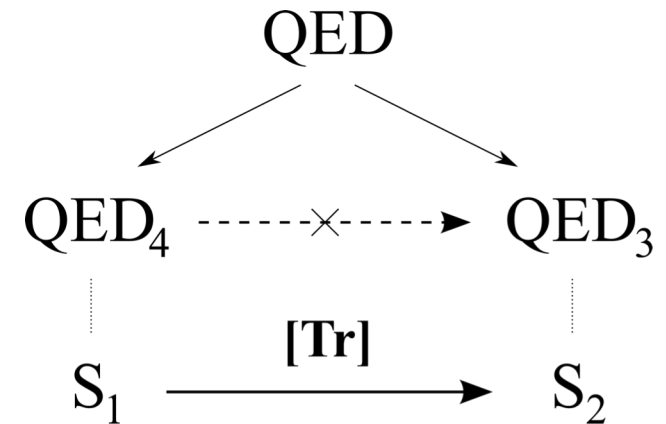


Topological order: a state of matter that cannot be characterized by symmetry breaking and (local) order parameters (*e.g.* Laughlin states or superconducting states).

Topological order is (partially) defined by ground-state degeneracy, which is robust against any perturbations that can break all of the symmetries (Wen 2004; *e.g.* The ground state degeneracy of a Hall fluid depends on the topology of the manifold it lives on, a dependence group theory is incapable of accounting for (Zee 2010)).

3. Transformational emergence: an exemplification

(NOV*_D) QED₃ is not derivable from QED₄.
States of matter modelled by QED₃
can exhibit new topological orders
compared to QED₄.



As shown in the case of the pure Chern-Simons theory (Witten 1989), even if the CS term does not contribute to the Hamiltonian, it contributes significantly to the ground state degeneracy.

Consequently, some states accessible to S_2 , modelled by QED₃, are not topologically possible for S_1 , modelled by QED₄.

3. Transformational emergence: an exemplification

Exemplification

Fractional Quantum Hall Effect

Different FQH states (different fractional charges and fractional statistics) belong to different quantum phases, but with all the same symmetry → Different topological orders (Wen 2004).

The low-energy effective theories of FQH states are the pure Chern-Simons theories to which we add that electron or hole should appear in the excitation spectrum.

We can understand these effective theories as low-energy special cases of QED_3 .

The existence of the FQHE is a 3+1 dimensional physical exemplification of a phenomenon modelled essentially by QED_3 .

3. Transformational emergence: an exemplification

“The fractional quantum Hall state is not adiabatically deformable to any noninteracting electron state. I am always astonished at how upset people get over this statement, for with a proper definition of a state of matter and a full understanding of the integral quantum Hall effect there is no other possible conclusion. The Hall conductance would necessarily be quantized to an integer because it is conserved by the adiabatic map and is an integer in the noninteracting limit by virtue of gauge invariance and the discreteness of the electron charge. So the fractional quantum Hall state is something unprecedented—a new state of matter”.

(Laughlin’s Nobel lecture 1998)

1. Varieties of emergence

Compartmentalization of the conceptual landscape of emergence

2. Transformational emergence: an account

The ontology/epistemology of transformational emergence

3. Transformational emergence: an exemplification

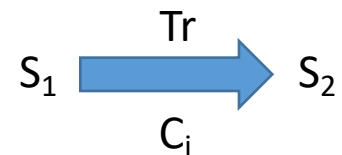
The fractional quantum Hall effect

4. The problem of the nature of the transformation

The metaphysics of changing laws

4. The problem of the nature of the transformation

- R cannot be defined as obeying to the same physical laws.
 - In the case of the FQHE, it was defined by a kind of interaction, QED_n physics. A constraint on laws, a metalaw, a metaproperty?
- In this context, how could we define the identity of the system through the transformation?
 - Apparently incompatible with the position that to be is to be subject of a law (Newton).
 - Goes against the current trend to classify physical ontologies.
 - The identity is defined by a causal relation?



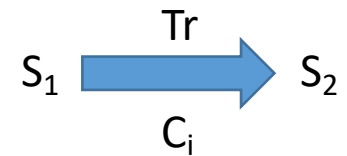
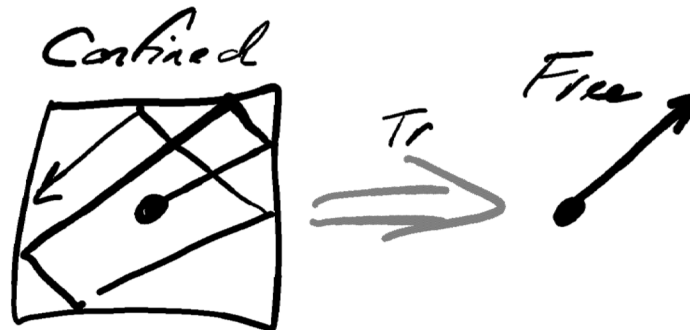
4. The problem of the nature of the transformation

- Related point, the conditions C_i necessary for the transformation to happen should not be “solely responsible” for the new behaviour.
 - Example: the inclusion of charges to generate electromagnetic phenomena.
- The emergence of S_2 is regular. This could be explained by the existence of a disposition D of S_1 triggered by C_i .
 - But if D is essential it should ground a related law that allow the passage from S_1 to S_2 .
 - But if D is non essential how could it be that regular?
 - Is the causal a broader category than the nomological?

UCLouvain

4. The problem of the nature of the transformation

- S_2 should not be just new, but modally new compare to S_1 . We want to avoid contingent novelty. See the box example.
 - In a certain sense, something like the laws has to change between the two states.
 - This necessitates a good distinction between laws and initial conditions.
 - A transformation of the domain of what is possible is required.



4. The problem of the nature of the transformation

- A well known analogous case in the history of metaphysics: the transubstantiation.
 - One of the possible “solutions” to avoid to invoke a brute fact is to introduce another kind of the necessity responsible for the change.
- Let us imagine there are second order natural laws, the laws of emergence. These are not just constraint on possible laws, by dynamical laws of emergence.
 - Is it a coherent position?



4. The problem of the nature of the transformation

Dispositionalism

Dispositionalism asserts that the laws derive from the necessary behavior of objects and that the source of this necessity is internal to things.

For example, Mumford (2006) and Bird (2005) tells us that at least some fundamental properties, like P , are *essentially* dispositions D to yield certain manifestation or output M , given a certain stimulus or input S ,

$$\text{i.e., } Px \rightarrow D_{(S,M)}x.$$

4. The problem of the nature of the transformation

Could the laws of emergence be meta-laws, in other words the result of a disposition of a disposition, $D_{(D(S,M),E)}x$?

A problem for meta-dispositionalism is that if the disposition to M is at least part of the nature of S (and this is something that every dispositionalist believes), so the meta-disposition to exhibit the emergent behavior E. In other words to cause E is one of $D_{(S,M)}x$'s causal powers.

But if this is so, $D_{(D(S,M),E)}x$ is not a meta-law, but an accidental byproduct of law, given that it is derived from the nature of $D_{(S,M)}x$.

4. The problem of the nature of the transformation

Governism

A law of nature is an objective necessitation relation among universals or properties. It *governs* its instances. For example, a genuine law connecting the two universals, F and G, would be represented by $N(F, G)$, where N is a necessitation relation.

Emergence: $L_B \Rightarrow L_E$

4. The problem of the nature of the transformation

**Does L_E exist before the first instantiation of L_E ?
Is the first instance of L_E the emergent moment?**

According to Armstrong, there is no uninstantiated law, because there is no real uninstantiated universal.

In a block universe, it is legitimate to assert that a universal exists if it is instantiated anywhere in the block.

In a growing block universe, the answer is more controversial.

4. The problem of the nature of the transformation

Could the laws of emergence be meta-laws, in other words the result of a law $N_E(L_B, L_E)$?

Is N_E distinct from the usual N ?

The main difficulty of having formulas with two N s is that we would have to say that the two N s are N s inasmuch as they are instances of some other N_3 ; but then we would have three N s that can only be identified as N inasmuch there is a N_4 from which all of the others are instances; *ad infinitum*...

4. The problem of the nature of the transformation

Could the laws of emergence be meta-laws, in other words the result of a law $N(L_B, L_E)$?

If there is only one kind of N then the L_i in $N(L_B, L_E)$ are not just symbol representing sets of laws, they refer to universals, to natural properties.

These properties are necessary relational properties between basic natural properties.

4. The problem of the nature of the transformation

But in this case, $N(L_B, L_E)$ would be a necessary change among necessary relations among natural properties.

To restore the coherence of the account, we have to argue that L_B and L_E are not different necessary relations among the same universals.

They must be relations among quasi-universals.

4. The problem of the nature of the transformation

They must be relations among quasi-universals.
They are not genuine natural laws.

The natural laws are the ones relating the universals
to which the quasi-universals refer.

4. The problem of the nature of the transformation

Another puzzle

Does $N(L_B, L_E)$ exist before the first instantiation of L_E ?

If $N(L_B, L_E)$ does not fully exist before the instantiation of L_E the explanation of the transformation collapses to the action of disposition.

So it must exist before the first instantiation.

4. The problem of the nature of the transformation

Regularism

Regularism tells us that laws are Humean regularities. They supervene on facts. Nevertheless, it is not necessarily a no-laws approach. For example, according to David Lewis:

What we value in a deductive system is a properly balanced combination of simplicity and strength-as much of both as truth and our way of balancing will permit [...] a contingent generalization is a law of nature if and only if it appears as a theorem (or axiom) in each of the true deductive systems that achieves a best combination of simplicity and strength. (1973 [2001], 73)

4. The problem of the nature of the transformation

According to Sartenaer, BSA/humeanism implies

- 1) Fundamentalism – Natural properties form a unique and finite set of properties
- 2) Physicalism
- 3) Mereological reductionism
- 4) Eternalism – Past, present and future facts are on a par
- 5) Universalism – BS-laws are universal
- 6) Optimism – “Nature is kind to us”

4. The problem of the nature of the transformation

Against 5

To verify if this conception can accommodate changing laws, we have to discuss two cases:

A) The BSA treats the mosaic of facts as disjoint regions.

The BS has a disjunctive structure.
The regularity of emergent phenomena is understood as a brute fact.

4. The problem of the nature of the transformation

B) The BSA contains regional laws and laws of transition between regions/contexts.

The structuration of natural laws will be similar as in the case of governism.

4. The problem of the nature of the transformation

Primitivism

Primitivism, in the words of Maudlin (2007, 17), is:
To the ontological question of what makes a regularity into a law of nature I answer that lawhood is a primitive status. Nothing further, neither relations among universals nor role in a theory, promotes a regularity into a law. [...] If a law governs a particular space-time region then the physical states there will so evolve.

Conclusion and things I did not discuss

- Transformational emergence is promising but the modal nature of the transformation is still not clear.
 - If we want diachronic emergence not to be the result of a brute fact of nature, more metaphysical exploration must be done.
- To resist the problem of time, all conceptions of emergence will have to be modified.



Paul Humphreys



Olivier Sartenaer