BIOLOGICAL EMERGENCE: AN INTRODUCTION

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Three claims undergird emergence theory:

1) Empirical reality divides naturally into multiple levels. Over the course of natural history, new emergent levels evolve.

2) Emergent wholes that are more than the sum of the parts require new types of explanation adequate to each new level of phenomena.

3) Such emergent wholes manifest new types of causal interactions; they include irreducibly biological interactions and must be explained in biological terms.

- Philip Clayton
• “There is only one science, physics: all else is social work.”
  - James Watson

• “Physics is the only real science. The rest are just stamp collecting.”
  - Ernest Rutherford
“A full understanding of organisms cannot be secured through the theories of physics and chemistry alone.” . . . “[T]he patterned complexity of living systems is hierarchically organized and . . . higher levels in the hierarchy are characterized by the emergence of novelties. . . . When a well-known Nobel laureate in biochemistry said, 'There is only one biology, and it is molecular biology,' he simply revealed his ignorance and lack of understanding of biology.” - Ernst Mayr
Kinds of Emergence

- Strong and Weak Emergence
- Synchronic and Diachronic Emergence
- Emergence and Hierarchy
  - Parts and Wholes
  - Organizational Levels
- Mechanisms
Conclusions

• Emergence helps us to understand biological (and other?) complexity and reflects the diversity in nature.

• Emergence can add to a Christian understanding of biological evolution.
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For more details on my thoughts on Emergence, see Perspectives on Science and Christian Faith, December, 2013.
Categories of Emergence

- **Diachronic**
  - historical; development over time
  - emergence of new features of…
    - the universe (e.g. atoms, life, humanity)
    - individuals (e.g. embryonic development, becoming conscious)

- **Synchronic**
  - snapshot, ontological, “at this moment”
  - functioning of the cell

“Emergence in Physics: Signposts of Creativity”
Sikkema, ASA 2013
Categories of Emergence

- **Strong**
  - inter-disciplinary
  - life: physics to biology
  - mind: biology to psychology

- **Weak**
  - intra-disciplinary
  - physics: phase transition
  - biology: swarming

Sikkema, ASA 2013
Emergence and Science & Faith

- Origins
- Laws of nature
- Divine action
- Multi-faceted creation
- Creativity of the creator
- Expectation of continued unfolding of creation
- Emergence as description and/or explanation

Sikkema, ASA 2013
Collective animal motion

- “active matter”, “self-propelled particles”
- leaderless swarming

Ballerini et al., PNAS 105 (2008) 1232
Emergence, physics, and life: Physics “anticipates” biology

- How are electrons (e.g.) open to the biotic?
- Their physical properties allow them to be “parts of” a greater whole with supra-physical properties.
- Indeterminism is fruitful.
- The scale of electron, atom, molecule is…
  - small enough to experience quantum openness
  - large enough for biochemical processes
Clouser on Dooyeweerd on Aspects & Emergence

“Nonliving things that combine to form a living one already have the potentiality of (passive) biological functions. Thus it is not correct to understand the integration of nonliving things into a living thing as the ‘emergence’ of the biotic aspect from a reality which is solely physical. Nothing is solely physical, and aspects do not emerge. It is only a thing’s acquisition of a new active function which emerges, and that is possible only because the thing is already passively governed by the laws of the aspect in which the new active function is acquired.”
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<th>Aspects of Reality</th>
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<td>Self-giving love</td>
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<td>Creedal</td>
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<td>Vision, commitment</td>
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For much more on this, see www.dooy.salford.ac.uk
“Entire aspects do not emerge into being as products of some one or two [aspects] taken to be ‘substance,’ but all exist in mutual correlation with one another and with the entities they qualify.”

- “A Sketch of Dooyeweerd’s Philosophy of Science”, Facets of Faith & Science v. 2, ch. 4, van der Meer, ed. (1996) [see www.AllOfLifeRedeemed.co.uk/clouser.htm ]
Emergence & Idionomy

- How do new kinds of entities respond to new kinds of laws?
- Klapwijk on the limits of scientific theorizing:
  - “a believer has good reason to confess that the idionomy that we encounter in distinct levels of being...is, in the final analysis, grounded in...laws of the creator God... [W]e see a world that is open to its Creator, [which] shows a fundamental receptivity to laws of a higher.... The world of becoming...is responding to divine orderings.” Phil. Ref. 76 (2011) 27

Sikkema, ASA 2013
Information & Physicality

- Is information separate from matter & energy or is it physical?
- No, information is not physical.
- No, information is not separate from the physical.
- But information has:
  - a physical aspect
  - a numerical aspect
  - a lingual aspect
  - a social aspect
  - a biotic aspect
DNA & Information

- DNA is actively subject to numerical, spatial, kinematic, physical laws.
- DNA is passively subject to biotic laws.
- DNA has a lingual aspect.
- These can be studied (e.g.):
  - Numerical aspect of DNA’s lingual aspect
  - Numerical aspect of DNA’s biotic aspect
  - Numerical aspect of DNA’s physical aspect
- None of these is in any meaningful way the “information” of DNA.
- Laws of physics exist for DNA’s physical aspect but not for the lingual or biotic.
Additional remarks on...

- downward causation, or top-down causality
- self-organisation
- computations of & mechanisms for emergence
The Challenge of Emergence

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The Challenge of Emergence

Definition and Implication

Emergence is the appearance of something new in a process with two characteristics:

(1) rule-governed interaction among parts produces a system with properties that do not occur in the parts

(2) the rules use only local information and do not refer to or originate in the emerging system

The Challenge of Emergence

Implication: Parts properties are sufficient to produce a system with new properties and new rules

Test 1: Kinetic Molecular Theory.
Test 2: Operon.
Test 3: Selfreflecting Person.
Test 1: Kinetic Molecular Theory

Lower average kinetic energy
Lower absolute temperature

Higher average kinetic energy
Higher absolute temperature
The Challenge of Emergence
Test 1: Kinetic Molecular Theory

(1) rule-governed interaction among parts produces a system with properties that do not occur in the parts.
(2) the rules use only local information and do not refer to or originate in the emerging system

Parts property: kinetic energy
System property: temperature = average kinetic energy

Rule of interaction: collisions are elastic = no loss of kinetic energy
Ad (2) satisfied
Ad (1) not satisfied: Rule of interaction does not produce system properties because temperature is a system property
Conclusions

Test 1: Conclusions Kinetic Molecular Theory

Conclusion 1: no theory reduction, epistemic cut.
Conclusion 2: ontological emergence
Conclusion 3: non-reductive physicalism applies
What is Emergence?

Test 2: Operon
Monod (1971)
What is Emergence?

Test 2: Operon

“There is no chemically necessary relationship between the fact that β-galactosidase hydrolyzes β-galactosides, and the fact that its biosynthesis is induced by the same compounds.”

What is Emergence?

Test 2: Operon
No chemically necessary relationship of structure or reactivity between activator and substrate; the causal relationship is contingent (Monod, 1971)
(1) The causal relation between activator (inhibitor) and substrate is contingent. It is not due to chemical necessity.

(2) The specificity of the relation between activator (inhibitor) and substrate is due to one of the structures adopted by the allosteric protein which is dictated by the structure of a gene.

Two complementary explanations of specificity are needed:

(A) mechanisms of chemical reaction using physical law and bottom up causation explain the chemical synthesis of the enzyme.

(B) mechanisms of biological information processing using downward causation from organism level to explain the specificity of enzyme action.
What is Emergence?

Test 2: Operon (Monod 1971)

(3) Any relationship between activator (inhibitor) and substrate is possible.

(4) Actual relationships between activator (inhibitor) and substrate evolve due to selection from unlimited possibilities

Two complementary explanations are needed:

(A) mechanisms of chemical reaction in terms of physical law and bottom up causation to explain the chemical synthesis of the enzyme

(B) mechanisms of natural selection in terms of downward causation from the population level to explain selection of the enzyme
## The Challenge of Emergence

### Application 2: Selective Combinatorics

| 
| 
| $10^{543}$ codon sequences  |
| (~300 codons/average gene) |
| 
| $10^{260}$ proteins (~200 aa average) |
| 
| 64 Codons |
| 
| 20 coded Amino Acids |
| 
| 4 nucleotides |
| 
| 100s Amino Acids |
| 
| 100s Nucleotides |
| 
| 6 Chemical Elements |
| 
| 6 Chemical Elements |
| 
| 117 Chemical Elements |
| 
| 3 Elementary Particles |

Fig. 5: Selective Combinatorics: the selection of entities at a given level and their combination producing an expanded number of entities one level up.
The Challenge of Emergence

Test 2: Interim Summary of Theory

Theory: New modes of existence may emerge by selective combination of entities at a lower level.

Theory: The number of possible combinations at the threshold to life may be so large that the crossing event cannot be identified.
The Challenge of Emergence

Test 2: Interim Summary of Facts & Conclusions

Fact 1: No empirical support for transition non-life to life.

Fact 2: Molecules do not organize themselves into systems because the system is required to organize the molecules via downward causation.

Fact 3: No theory reduction: epistemic cut.

Conclusion 1: Downward causation makes emergence impossible.

Conclusion 2: Non-reductive physicalism does not apply here.

Conclusion 3: Ontological gap b/w non-life and life cannot be excluded.
“With me the horrid doubt always arises whether the convictions of man’s mind, which has been developed from the mind of the lower animals, are of any value or at all trustworthy. Would any one trust in the convictions of a monkey’s mind, if there are any convictions in such a mind?”

“If my mental processes are determined wholly by the motions of atoms in my brain, I have no reason to suppose that my beliefs are true … and hence I have no reason for supposing my brain to be composed of atoms.”

Test 3: Molecule to Selfreflecting Person

Conclusion

Causal Continuity Between Lawful Orders of Nature Produces Selfcontradiction

Therefore, to avoid selfcontradiction, there should be causal discontinuity between lawful orders of nature
Overall Conclusions

(1) There is emergence within modes of existence (Test 1).

(2) Intramodal emergence produces levels of composition.

(3) There is no emergence between modes of existence (Tests 2, 3).

(4) We cannot exclude the possibility of intermodal emergence.

(5) Intermodal emergence is a metaphysical research program.