Biological Circularchy

Ellis D. Cooper, Ph.D. 1973

1942 - TBD

June 26, 2021 2021-CONTENTS-ZD.docx

"Circularchy" is supposed to be an adjustable formal framework with enough expressive power to articulate biological theory about

Earthly Life

in the sense of multi-scale biological autonomy constrained by thermodynamics.

"Formal framework" means specifically a multi-sorted first-order-theory with equality (for each sort). Philosophically, such a theory is one kind of "microlect," which means a "way of speaking" (or, more generally, a "way of behaving") for overtly expressing a "mental model" of some "referent." Other kinds of microlect include "natural microlect," "diagrammatic microlect," and "behavioral microlect," with examples such as "political theory," "Euclidean geometry," and "dance choreography," respectively. These are all describable in terms of a vocabulary conforming to a grammar. As aspects of human culture they are possibly reminiscent of Ernst Cassirer's idea of "symbolic form;" as vocabularies they are akin to Richard Rorty's idea of "final vocabulary" for expressing a mental model of one's life.

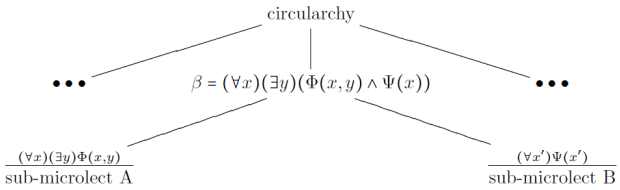
A formal microlect is presented by stipulating *sorts*, *variables*, *calculations*, *predicates*, and *postulates*. Calculations (a.k.a., "terms") may be composed to form more complicated calculations; predicates (a.k.a., "relations") may be logically combined to form more complicated predicates; and *statements* (a.k.a., "sentences") are grammatically correct expressions which are true or false. *Conclusions* are statements derived using logical rules of deduction from postulates, other assumed statements, or previously derived conclusions. A *circularchy* is a formal microlect constituted by two or more sub-microlects, each with its distinct stipulations of sorts, variables, calculations, predicates and postulates. Within a sub-microlect some postulates or conclusions are *equations* which are statements that declare equality of specified calculations. An *equational bond* between an equation in one sub-microlect and an equation in either the same sub-microlect or in another sub-microlect, is a predicate that declares equality of symbols occurring in a side of one equation with symbols occurring in a side of the other equation. Briefly, a circularchy is a network of equational bonds between sub-microlects.

A circularchy is *solvable* if there exist solutions for all equations that satisfy all equational bonds. If a circularchy is not solvable, then a challenge would be to discover the *obstruction* to solvability, and then conjecture what adjustments might remove the obstruction. *Adjustment* means changes in stipulated ingredients (sorts, etc.) of sub-microlects, or changes in equational bonds between sub-microlects, or introduction of new sub-microlects and new equational bonds. A circularchy is modular insofar as each sub-microlect is a node in a network of equation bonds.

Solvability of a circularchy may be conjectured. Efforts to prove solvability may be thwarted by a counter-example, or may lead to construction of a solution. An automated theorem-proof assistant would likely be necessary for investigating a substantial circularchy, such as one purported to represent

Earthly Life.

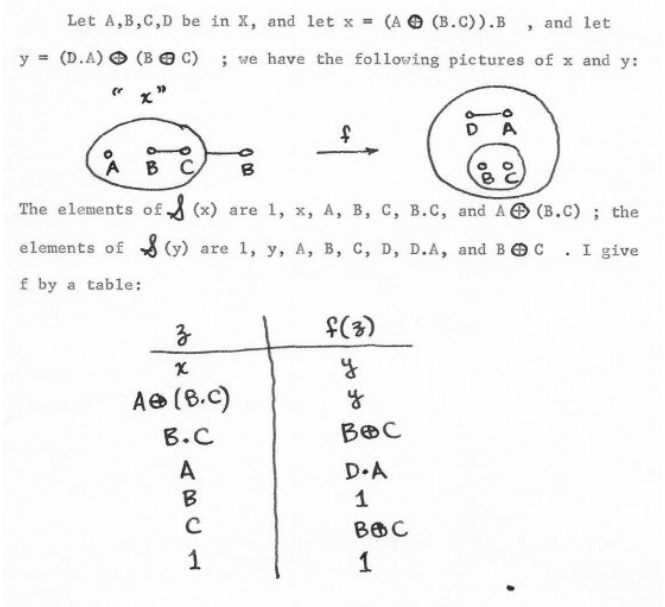
Such investigations (chains of statements) would be concurrent with and no substitute for simulations (chains of numbers).



Conventions:

1. As the symbols ‘English,’ ‘Spanish,’ ‘Swedish,’ and so on, are names of *natural* languages, if *X* is the topic of a formal microlect (multi-sorted first-order-theory with equalities), then the symbol ‘Xish’ shall be the name of the formal microlect. For example, the formal microlect for the BioNetGen language BNGL is “BNGLish.” Other formal microlects are CARTOONish, KINETish, and TINYish.
2. Closed bullets (·) associate with linked documents; open bullets (∘) associate with quotations from within linked documents.
3. Framed entries are *original* documents by Ellis D. Cooper, and the latest ones (2021) are scans of handwritten notes of partial thoughts, dead ends, mystifications, occasional insights, and proofs of theorems.
4. Commentary by Ellis D. Cooper on documents is dated, e.g., 21.06.26, and displayed in *italics*.

A Way of Speaking about Ways of Speaking

1. 1965 “Mentamatics”
   a. “April 5, 1965 The near edge of chaos is where one’s doubts and confusions hold sway, but not yet tumbling one into the chasm of futilism. I have lived here for long, master of my gestures, of my muscles, merely aware of the unseen brink. And from the midst of the sulfured fumes arises Mentamatics, one limited attempt to spring from the thanatoxic vapors.”
   b. 

   Compare to (61.d,e) in 2021!
2. 1973 “Way of Speaking”
   a. “So-called languages are averages of many dialects, which in turn are averages of many idiolects, which are themselves averages of what I call ways of speaking, or microlects. A way of speaking is an average computed over individual acts of communication about a particular topic. On the largest scale the study of ways of speaking, microlectics, is the study of the state and growth of communication between cities and nations. On the smallest scale it is the study of the fine processes of thought (formal theory of the history of ideas). Since speaking is one way to be, among countless others, it appears that there is a separate study to be made for each way of being. A sufficiently abstract theory of microlects, however, would abstract from the traits peculiar to ways of speaking, and be therefore a theory of all ways of being. Such a theory could only be called Mathematical Metaphysics.”
3. 1989 “Contingency, irony, and solidarity” Richard Rorty
   a. “All human beings carry about a set of words which they employ to justify their actions, their beliefs, and their lives. These are the words in which we formulate praise of our friends and contempt for our enemies, our long-term projects, our deepest self-doubts and our highest hopes. They are the words in which we tell, sometimes prospectively and sometimes retrospectively, the story of our lives. I shall call these words a person's "final vocabulary." It is "final" in the sense that if doubt is cast on the worth of these words, their user has no noncircular argumentative recourse. Those words are as far as he can go with language; beyond them there is only helpless passivity or a resort to force. A small part of a final vocabulary is made up of thin, flexible, and ubiquitous terms such as "true," "good," "right," and "beautiful." The larger part contains thicker, more rigid, and more parochial terms, for example, "Christ," "England," "professional standards," "decency," "kindness," "the Revolution," "the Church," "progressive," "rigorous," "creative." The more parochial terms do most of the work.”
4. 2006 “Is chemistry ‘The Central Science’? How are different sciences related? Co-citations, reductionism, emergence, and posets” Alexandru T. Balaban *et al*

5. 2015 “Microlects of Mental Models”

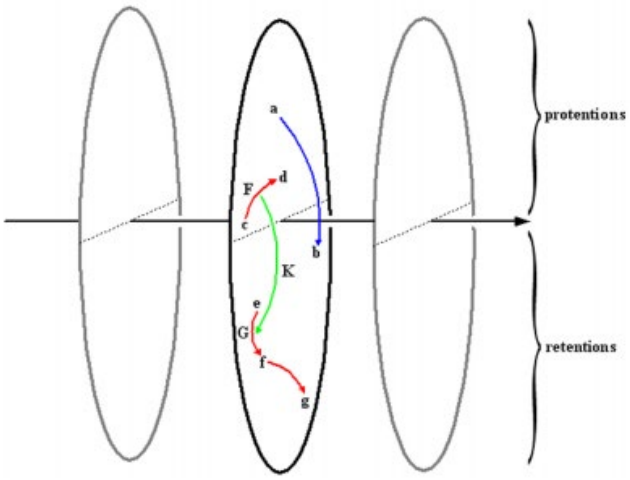


Figure 6.5: Diagram of a synthesis and extension of the Bergson-Husserl-Miller mental models of temporal awareness.

a.

6. 2018 Diagrammatic Microlect of Microlects

The Story to Tell $\xrightarrow{\text{Language to Tell the Story}}$ What the Story is About

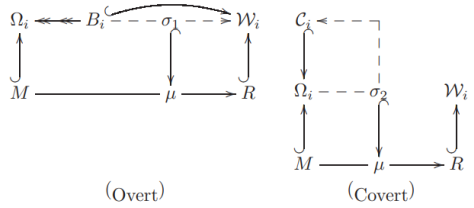


Figure 1.1: (Overt) The mind Ω_i of subject i supervenes on body B_i in the **Quotidian World** of i. Microlect μ expresses mental model M of of the part R of the **Quotidian World**. Signal σ_1 is a particular overt expression by i about R. Presumably some object or subject in that **Quotidian World** receives the signal. (Covert) Signal σ_2 is a particular covert expression about R in conscious thought $\mathcal{C}_i$ of i.

a.

7. 2021 Circularchy

a. “Mathematical logic must start with intuitive, naïve set theory.”
b. “Syntactic-substitution is a meta-syntax operation.”
c. “Take into account, for a model of Life, that a model should break if any of these is omitted:
    i. Energy
    ii. Entropy (Boltzmann vs. Clausius)
    iii. Closure-of-constraints
    iv. Entity
    v. Activity
    vi. Organization
    vii. Multi-scale
    viii. Stochastic
    ix. Persistence
    x. Death
d. “A circularchy is a finite set of equations that relates variables, their finite differences, and their tiny differences.”
e. “A circularchy may include uniformly distributed random variables, hence, *any* variable with a specified (cumulative) probability distribution function. A bond between members of a circularchy is a predicate that relates their variables.”

f. "What do you, a categorist, call it when…"
g. "Directed versus Un-directed graph"
h. "Hierarchy is to Circularchy as Tangent Line is to Circle"
i. "Crowd computing in *Coq*"
j. "What is a solution to that groupoid?"

8. 2021 *Earthly Life* is a Circularchy
9. 2021 Non-Circularchy Charts

10. Up with Downward Causation

11. 2012 "Downward causation without foundations" Michel Bitbol
12. 2012 "Top-down causation: an integrating theme within and across the sciences?" George F. R. Ellis *et al*
13. 2012 "A theory of biological relativity: no privileged level of causation" Denis Noble
14. 2013 "Emergence, Closure and Inter-level Causation in Biological Systems" Matteo Mossio *et al*
15. 2016 "Theoretical principles for biology: organization" Matteo Mossio *et al*

16. Autopoeisis and Autonomy

17. 2002 "Life after Kant: Natural purposes and the autopoietic foundations of biological individuality" Andreas Weber *et al*
18. 2013 "Perspectives on Organisms, Biological Time, Symmetries and Singularities" Giuseppe Longo *et al*
19. 2004 "A universal definition of life: autonomy and open-ended evolution" Kepa Ruiz-Mirazo *et al*
20. 2015 "Biological organization as closure of constraints" Maël Montévil *et al*
    a. "ABSTRACT: We propose a conceptual and formal characterisation of biological organisation as a closure of constraints. We first establish a distinction between two causal regimes at work in biological systems: processes, which refer to the whole set of changes occurring in non-equilibrium open thermodynamic conditions; and constraints, those entities which, while acting upon the processes, exhibit some form of conservation (symmetry) at the relevant time scales. We then argue that, in biological systems, constraints realise closure, i.e. mutual dependence such that they both depend on and contribute to maintaining each other. With this characterisation in hand, we discuss how organisational closure can provide an operational tool for marking the boundaries between interacting biological systems. We conclude by focusing on the original conception of the relationship between stability and variation which emerges from this framework." 21.06.26 *This article is the "formal cause" of the "biological circularchy" project, which may be considered to have as its "final cause" a comprehensive, expandable, mathematical framework for explaining "processes," "closure of constraints," and "time scales" in biology.*
21. 2016 "Theoretical principles for biology: Organization" Matteo Mossio *et al*

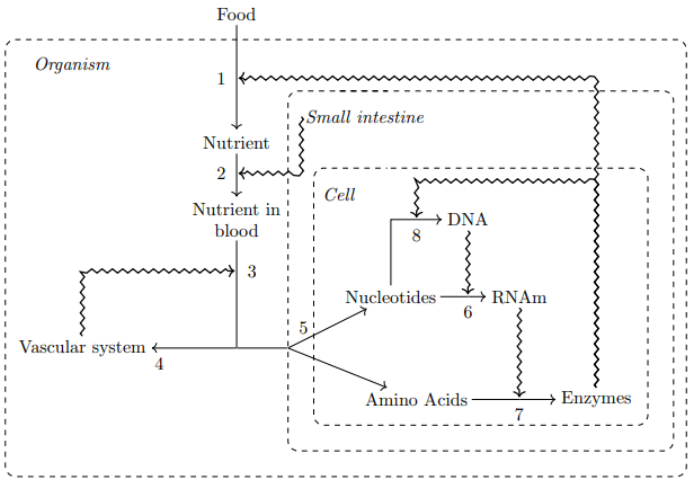


Figure 1: *Schematic illustration of the organizational closures between the vascular system and the small intestine in a mammal, and within a single cell.* After ingestion, food is broken down in the gut (1) and transformed into nutrients, which are absorbed into blood (2) through the mucosa of the small intestine. Nutrients are transported to all the cells of the organism through the vascular system (3). In particular, the absorbed nutrients feed the cells of the whole organism, including those of the vascular system (4), and those of the small intestine (5). Within each cell, the nutrients include nucleotides that are assembled into mRNA in accordance with DNA sequences (6). In turn, mRNA mediates the synthesis of enzymes from amino acids (which are also nutrients) (7). There are enzymes specifically involved in DNA repair mechanisms (8); as a result, DNA, RNA and enzymes realize organizational closure in the cell. A subset of the small intestine's cells secretes enzymes that contribute to the breaking down of food mentioned above (1). As a result, the vascular system and the small intestine realize closure by jointly contributing (through the transport and breaking down of nutrients, respectively) to maintaining their own cells. As discussed in the preceding sections, all entities from which a zigzag arrow originates are constraints, by hypothesis.

a.

22. 2018 "Autopoeisis, Biological Autonomy and the Process View of Life" Anne Sophie Meincke

23. Ignoring Details

24. 2002 "Simplifying and reducing complex models" Bard Ermentrout
    a. "The multiple time and space scales in biological systems force one to generally focus on some particular level using often heuristic approximations for the finer details which are neglected. The hope is that the knowledge of the finer levels suggests the correct heuristics for modeling and understanding the higher levels of the system. This principle of reductionism has served the sciences well."
    b. "In many models, there are diverse time scales and space scales. Extreme time differences often allow one to assume that during the changes in a fast quantity, a slow quantity can be considered constant. On the other hand, if the slow quantity is of interest, then the fluctuations or changes in the fast quantity occur so fast, the the slow quantity only "sees" the mean or average of them. This intuitively appealing idea can be made rigorous by a procedure called averaging. Related to this is the idea of "spatial averaging" in which one assumes individual influences of one system on another are small but manifold. Thus, one averages over these; such an average or approximation is often called the "mean field approximation."
25. 2021 "Ignoring Details" 21.06.26 *This is an assortment of pertinent quotations without attribution. The sources are available on request.*
    a. "[P]robabilistic description and Waage-Guldberg's law of mass action are also two parts of a same dynamic theory: The latter is the limit of the former if fluctuations are sufficiently small, when the volume of the reaction system, V, is large."
    b. "Effective noise terms can be introduced to account for a variety of ill-identified external influences, for instance an high-dimensional input that we do not want to describe in detail."
    c. "Bottom-up approaches aim at determining the collective behavior of an assembly of elements. Effective parameters play an essential role in this integration, in reducing a wealth of complicated and possibly not fully know microscopic ingredients to a single effective one, *having the same*

impact at higher scales." "this noise term appears as the net result of microscopic degrees of freedom that we do not intend to take into account."

d. "One consequence of the "multi-valuedness" of multi-scale systems is that different details must be ignored by models operating at different spatial and temporal scales."
e. "Continuum models are typically used at higher scales where the effects of many constituents average out, and the models aggregate discrete entities in a continuous variable (typically via partial differential equations)." "At higher scales, coarser-grained deterministic models typically give more robust predictions." "[T]he success of coarser-grained macroscale models suggests the relative independence of some macroscopic properties on lower-scale details."

26. Biology Cartoons

27. 2008 "The EXACT description of biomedical protocols" Larisa N. Soldatova *et al*
    a. "EXACT provides a model for the description of experiment actions and it can be used for the fully formalized representation of protocols." 21.06.26 "*Experimental actions" are motions of human beings in laboratories. There must be a "vocabulary and grammar" of laboratory routines for performing experiments. In other words, there is a behavioral microlect of experimentation. These authors appear to be offering steps towards a formal microlectic translation of experimental protocols.*

28. 2021-CARTOONish 21.06.26 *Biology textbooks and research publications freely use "cartoon" diagrams to express mental models of biological phenomena at multiple scales of time and space. There is no uniform diagrammatic microlect that subsumes these expressions. Labeled Hasse diagrams of partially-ordered sets (including temporal coloring of cover relations) correspond to logical formulas for expressing all such cartoons.*
    a. "tRNA synthetase: tRNA Aminoacylation and beyond" Yan Ling Joy Pang *et al*
    b. "The Function and Synthesis of Ribosomes" Denis L. J. Lafontaine *et al*
        i. "Key steps in eukaryotic ribosome synthesis"
    c. "Assembly of MHC Class I Molecules within the Endoplasmic Reticulum" Yinan Zhang *et al*
        i. "Assembly and trafficking of peptide-MHC I complexes."
    d. "A model of malignant inflammation."
    e. "A JAK/STAT miR-155 model" of mycosis fungoides malignant inflammation.
    f. "T-cell inflammatory recruitment cascade."
    g. "A "road-map" of the secretory and endocytotic pathways."
    h. "Coevolution of key machineries in the pathway of major histocompatibility complex (MHC) I antigen processing."
    i. "Current model of the translocation cycle of peptides by transporter associated with antigen processing."
    j. "Amino acid attached by carboxyl group to ribose of last ribonucleotide of tRNA."
    k. "Multi-sorted First-Order Theory"
    l. "Formation of an amino acid-tRNA pair by an aminoacyl tRNA-synthetase."
    m. "Labeled poset and linear expression translated cartoons:"
    n. "The Container Axiom"
    o. "SARS-CoV-2 T cell immunity: Specificity, function, durability, and role in protection" Daniel M. Altmann *et al*
        i. "Hypothetical interactions between SARS-CoV-2-infected cells, antigen-presenting cells, and CD4 and CD8 T cells."

29. Tiny or Finite or Infinite or Random Number

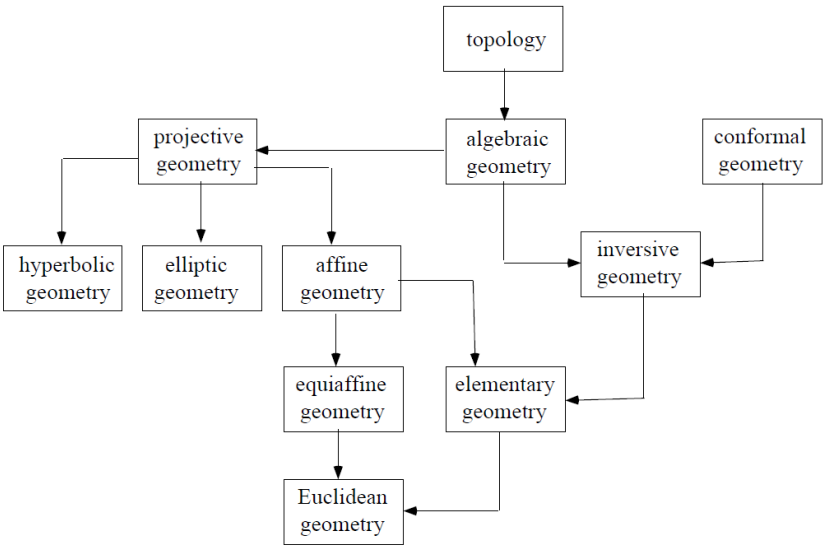
30. 2020 "A Meditation on Patterns of Mathematical Notation"
31. 2021 TINYish, The Numbers Microlect
32. 2021 Rational Calculations 21.06.26 *Equation bonds are constraints on pairs of equations, equations which may be expressions of distinct sub-microlects of a circularchy. These equations are statements that declare equality of two calculations. Throughout science, these calculations express algorithms for calculating values based on numbers and ratios between numbers. "Numbers" include the usual finite natural, rational, real (or complex) numbers, or tiny numbers (officially, "infinitesimals" of one flavor or another, e.g., "epsilonics," "infinitesimal hyperreal numbers," "nilsquare infinitesimals," etc.), infinite numbers (reciprocals of tiny numbers), and (uniformly distributed) random numbers.*

33. Multi-Scale Science

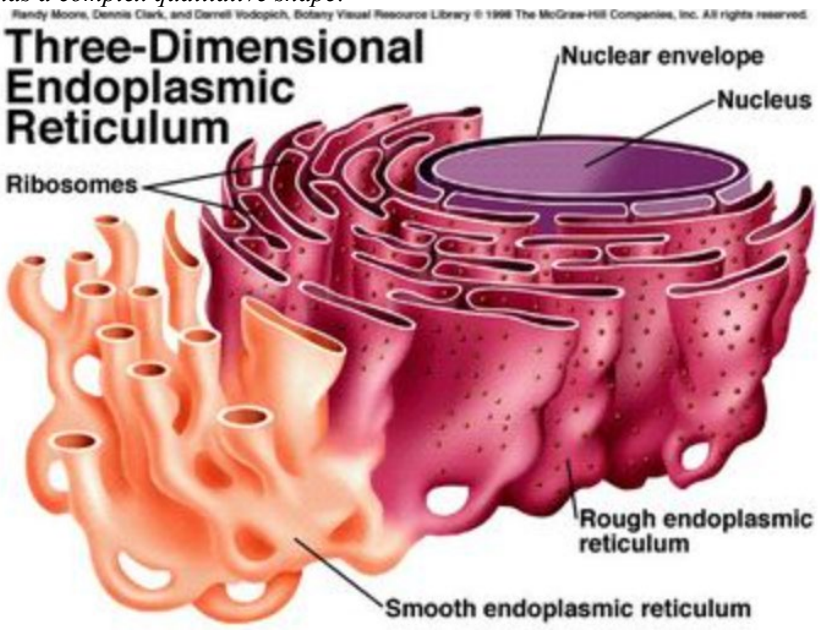
34. 2007 "Multi-scale computational modelling in biology and physiology" James Southern *et al*
35. 2008 "Scale relativity theory and integrative systems biology: 1 Founding principles and scale laws" Charles Auffray *et al*
36. 2010 "Biophysics and systems biology" Denis Noble
37. 2011 "Multi-scale Modeling in Biology: How to Bridge the Gaps between Scales?" Zhilin Qu *et al*
38. 2013 "Multiscale Analysis of Biological Systems" Annick Lesne
39. 2014 "Modeling Biology Spanning Different Scales: An Open Challenge" Filippo Castiglione *et al*
40. 2015 "The Partial Differential Equations of Biology: Signals and Patterns or Biology in Time *and* Space" James P. Keener
41. 2016 "Biology meets Physics: Reductionism and Multi-scale Modeling of Morphogenesis" Sara Green *et al*
42. 2017 "The Sum of the Parts: Large-Scale Modeling in Systems Biology" Fridolin Gross *et al*
43. 2021 Equation Bonds
    a. Equation bonds express cross- (or within-)microlect
        i. Scale relationships (rate ratios)
        ii. Constraints (multiple-place predicates)
        iii. Coupling of thermodynamic processes
        iv. Mutual connections
        v. Initial and boundary conditions
        vi. Prequels to unification algorithm

44. Shape and Container

45. 1980 "Geometric Vision Theory"
46. 1997 "A Global Framework for Qualitative Shape Description" Eliseo Clementini *et al*

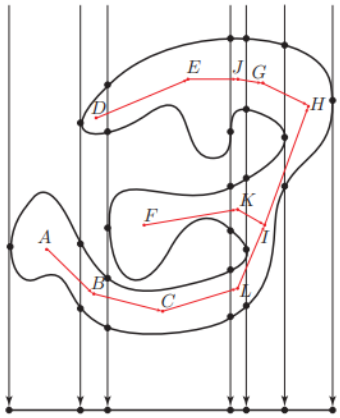


a. 21,06.26 *Where the geometry of "qualitative shapes" fits into this hierarchy of geometries is not obvious. It is more restrictive than topology, yet more "flexible" than the next row down. An endoplasmic reticulum has a complex qualitative shape:*

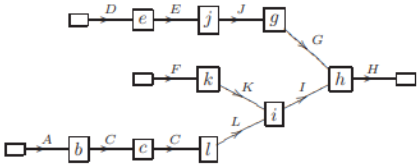


b. 21.06.26 *Perhaps Morse theory is relevant, but that would not capture metric information of this qualitative shape.*

47. 2008 "Bitonal membrane systems Interactions of biological membranes" Luca Cardelli
48. 2012 "Qualitative Smooth Shape in the Plane"



(34)



(35)

$$A \xrightarrow{\Delta_A} A \otimes A \xrightarrow{\Delta_A \otimes 1_A} A \otimes A \otimes A \xrightarrow{\circ_A \otimes \circ_A \otimes 1_A} \mathbf{I} \otimes \mathbf{I} \otimes A \xrightarrow{\square_D \otimes \mathbf{1} \otimes b} \quad (36)$$

$$D \otimes \mathbf{I} \otimes B \xrightarrow{e \otimes \square_F \otimes c} E \otimes F \otimes C \xrightarrow{j \otimes k \otimes l} J \otimes K \otimes L \xrightarrow{g \otimes i} G \otimes I \xrightarrow{h} H \quad (37)$$

a.

49. 2015 “Infinitely Far X-Ray View of a Shape”

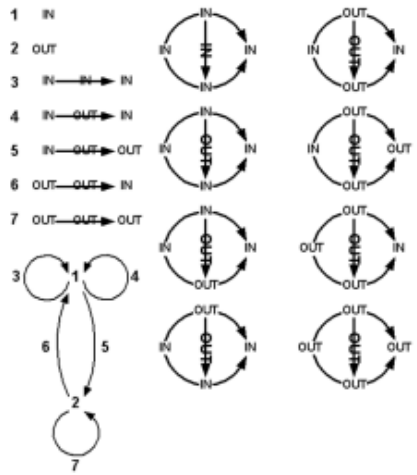


Figure 7.6: Subobject classifier in the presheaf topos of 2-graphs. Upper left: all possible 0-cells and 1-cells in a subgraph of a 1-graph. Lower left: 1-graph of the subobject classifier of 1-graphs [LS97]. Right: all possible 2-cells in a subgraph of a 2-graph.

a. “algorithm for constructing a diagram of 2-graphs of a smooth shape in the plane”

b. “for shapes in three dimensions, partial views involve elements of the 1st homology group of the partial view”

50. 2020 “Applications of Categorical Meriology to Metaphysics and Theoretical Biology”

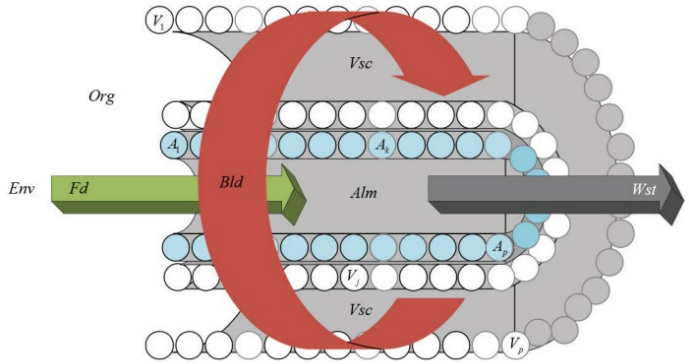


Figure 7: An environment with an organism.

a. 21.06.26 *Compare to the Figure at (21.a.).*

51. 2021 Formal Microlect of Shape and Container
    a. Container Predicates
    b. Substance in Container
    c. Contact, Attach, Rupture
    d. "Container Algebra"?
    e. Formal Microlect of Joint, Strut, Plate, and Tetra
    f. Simplicial Shapes, Surfaces, and Curves

52. Thermodynamics

53. 1977 "Exact Stochastic Simulation of Coupled Chemical Reactions" Daniel T. Gillespie
54. 1992 "A rigorous derivation of the chemical master equation" Daniel T. Gillespie
    a. "Since the chemical master equation and the stochastic simulation algorithm are derived from the same set of theorems, then they are logically equivalent to each other. In more precise terms, the stochastic simulation algorithm produces exact "realizations" of the jump Markov process X(t) whose initially conditioned density function is determined by the chemical master equation. In essence, we have proved here that both the chemical master equation and the stochastic simulation algorithm are rigorous consequences of premises (I) and (II)."
55. 2001 "Use of Legendre Transforms in Chemical Thermodynamics" Robert A. Alberty
56. 2009 "Rule-based Modeling of Biochemical Systems with BioNetGen" James R. Faeder *et al*
57. 2015 Timing Machine for Gillespie Stochastic Simulation Algorithm
    a. transition propensity

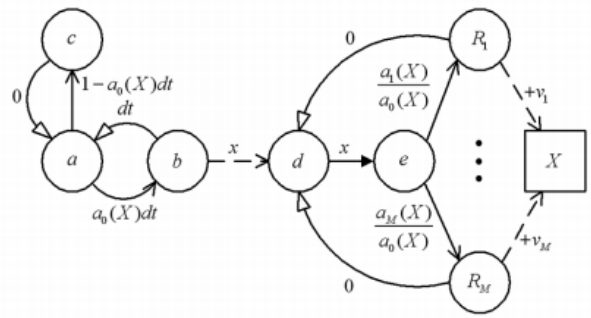


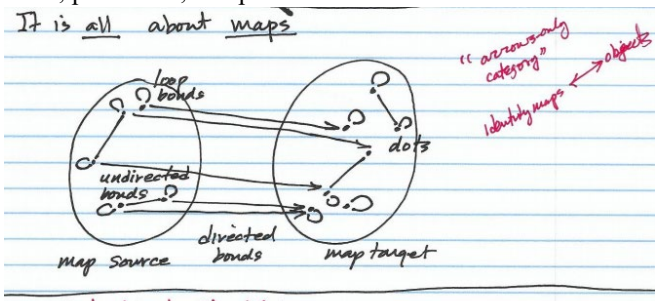
Figure 2.21: Timing Machine diagram of Gillespie Stochastic Simulation Algorithm.

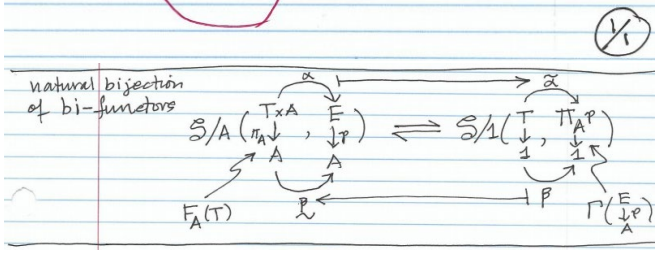
b.

58. 2018 "Biochemical Coupling Through Emergent Conservation Laws" John C. Baez *et al*

a. “It is impossible for ATP to turn into ADP+Pi without X+Y also turning into XY.”

59. 2019 “Coordinate-Free Derivation of the Heat Equation”
60. http://www.cognocity.org/circularchy/ORIGINAL/2021-BIONETGEN-SYNTAX-SEMANTICS.pdf
61. 2021 BNGLish: Towards a Formal Microlect of BioNetGen

a. Category theory of Dependent Products to model states of sites of molecules
b. “Arrows-only” category of molecules using undirected and directed graphs
c. Sub-object Classifier of sub-molecules
d. Sorts, predicates, and postulates of BioNetGen
e. 

f. 

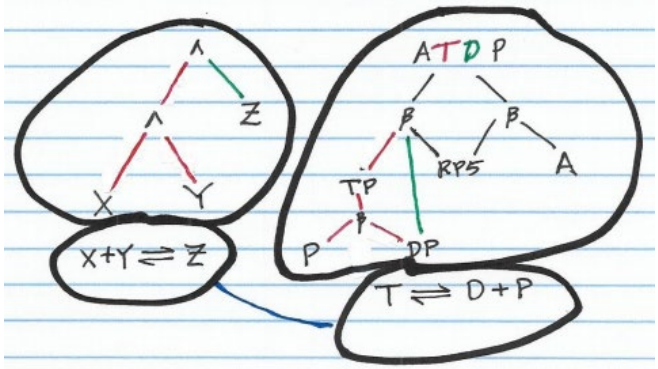
Compare to (1.b.) in 1965!

62. 2020 “Newton, Lagrange, Hamilton, and Noether”

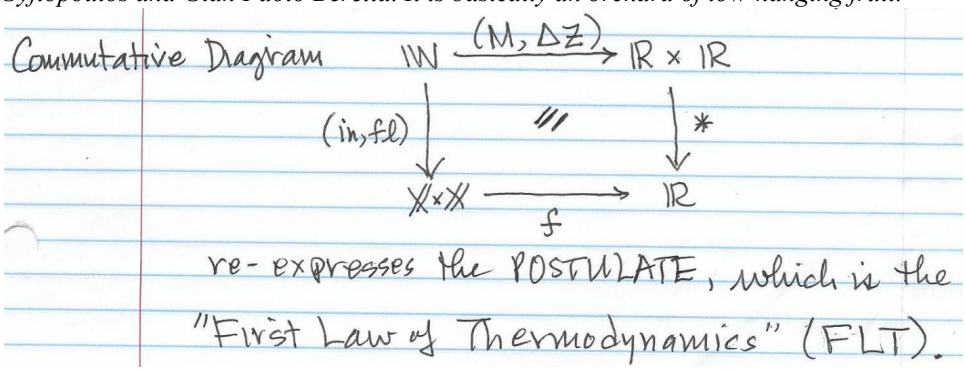
a. Newton and Lagrange
b. Hamilton’s Variational Principle
c. Noether’s Theorem via Rund-Trautman Identity

63. 2021 Gillespie Stochastic Equation and Algorithm
64. 2021 “KINETish”

a. Formal microlect for chemical kinetics
    i. Rate equation
    ii. Theorem on ATP hydrolysis
    iii. “Coupling of chemical reactions is an equation bond.”
    iv. “Kinetic Diagrams”

b. 

65. 2021 THERMish: First Law and Energy Additivity 21.06.26 *Of all thermodynamics textbooks the one which lends itself best to re-expression by a formal microlect is "Thermodynamics, Foundations and Applications" Elias P. Gyftopoulos and Gian Paolo Beretta. It is basically an orchard of low-hanging fruit.*

a. 

b. "Theorem. If two weight processes with the same weight have the same initial height, and the same state change, then they have the same final height."

c. "That energy is additive follows from considering systems as objects in a strict monoidal category."