Chapter 1

Molecule/idea code expression in layered networks

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Given that gene-expression informed to multiple scales of organization is key to development and operation of individual metazoans, how may we better inform idea-expression to multiple layers of community structure? Thermodynamic views of e-mergence in natural history suggest an integrative approach, focused on a hierarchical series of physical gradients and boundaries. We argue here that the physical boundaries that define metazoan communities beyond the skin are code-pool boundaries of two types: molecular and memetic. Metazoan niches that serve to buffer correlations focused in/out with respect to these physical boundaries comprise a layered niche-network. Simplex models of such networks, and niche level multiplicity in particular, may help construct robust monitors of community health in non-human and human communities.

1.1 Introduction

Only eukaryotes can assemble a bobcat from a single cell, in part thanks to the fact that their expression of nucleic and amino acid sequences can be informed to processes on multiple scales of organization. Idea "expression" in the same sense translates memetic codes, e.g. a blueprint, into behaviors or possibly even into a building. Newspapers, for example, transcribe stories for distribution

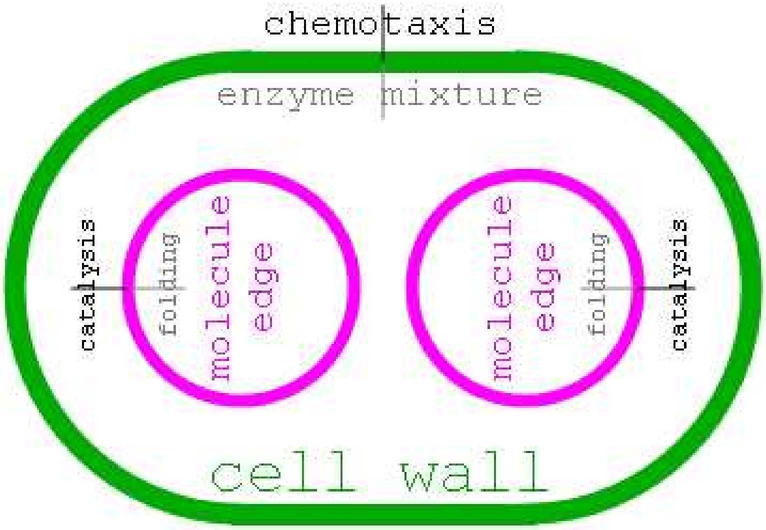

Figure 1.1: Correlation examples for layers 1 and 2: molecule edges and cell walls.

while the translation itself is done by their readership one sentence at a time. This similarity between genes and ideas is not just metaphorical. To wit, the 2nd law of thermodynamics applies to both types of expression by prescribing a minumum energy cost for each step in the process[1, 2].

As for nucleic acid and other molecular codes, so with ideas an ability to guide which codes get expressed (i.e. translated into structure or action) on the basis of inputs from more than one level of organization seems crucial to community well-being, e.g. to recovery from disaster or resource depletion. Ideologues might in that sense serve as "prokaryotes in the idea pool", less able to inform their songs to issues on more than one scale but more likely to be "all that's left" when we're confronted with decreasing thermodynamic availability. Thus in the stuggle against devolution for our descendants, the past century's advances in electronic communication[3] may be magnifying the impact of ideologies systematically uninformed to a subset of the correlations on which high-population human communities are built.

Here we discuss ways that cross-disciplinary study of physical complexity and its emergence might help inform our idea codes to correlations on multiple scales of space, time, and organization. Long-term objectives in this context might include:

- (i) protocols to acquire data for models of community health e.g. in terms of correlations focused in/out-ward from the physical boundaries of skin (self), gene-pool (family), and idea-pool (culture),
- (ii) quantitative dynamical models of the impact of policy changes and

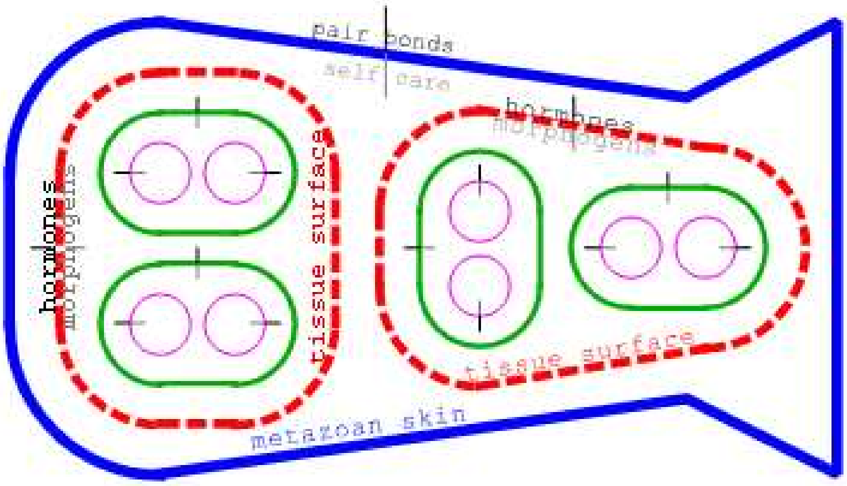

Figure 1.2: Correlation examples for layers 3 and 4: tissue surfaces and metazoan skins.

media perturbations on those correlations, and

- (iii) guidelines for use of language, particularly in electronic media, in ways which respect correlations on more than one level.

Data acquisition alone, for example, might allow one to put questions about the impact of policy changes (like immigration reform) into a quantitative context that considers issues of importance across cultures, like the opportunity for children to be long-term participants in a community. We show further that such tools could facilitate a rigorous scientific dialog about living ideas and community health, which up front integrates independent respect for observation, belief, consensus, family, friendship, and healthcare into a unified whole.

1.2 Correlations with respect to gradients and boundaries

In examining correlations in living systems, it's natural to start with the contemporary understanding of thermodynamic emergence in physical systems[4]. Thermodynamic emergence, like Chaisson's "cosmic evolution"[5] or the natural history of invention (from the first three minutes to the present day), generally involves reversible thermalization of available work to support the formation of subsystem correlations with respect to a set of physical gradients and boundaries. The correlation between idea codes and the excitations to which they

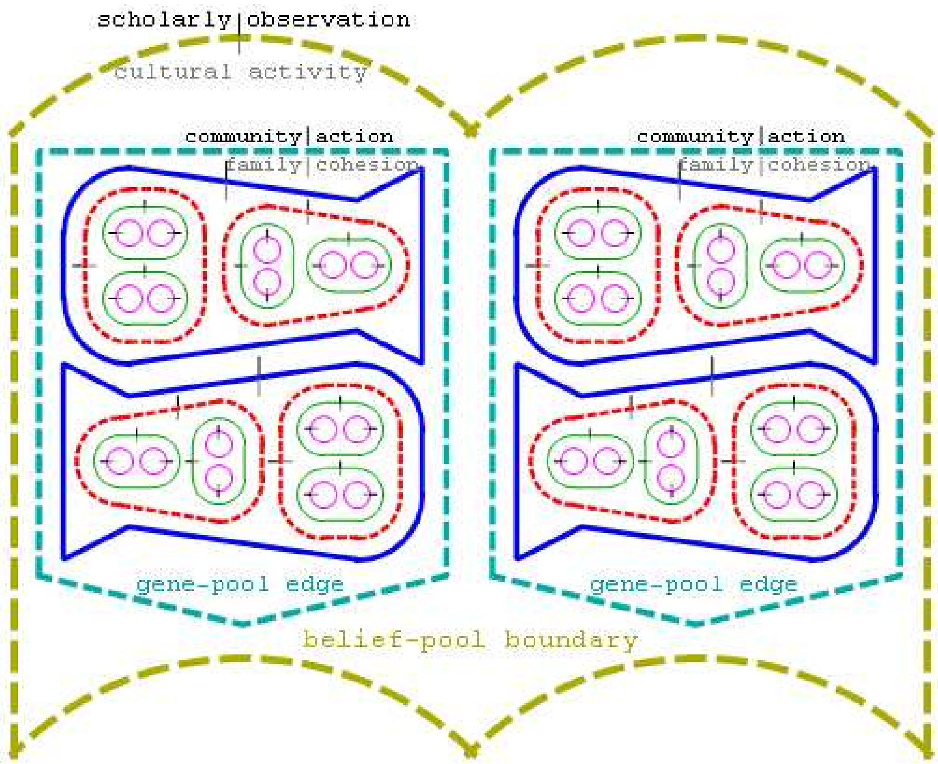

Figure 1.3: Correlation examples for layers 5 and 6: molecular and memetic code pool boundaries.

refer is an important subset of the larger collection of subsystem correlations associated with this evolving complexity[6].

The radial structure of a star, for instance, emerges from less well-defined structure in the cloud of gas and dust from which it forms. Thus stars and planets emerge in the presence of density and thermal gradients in their respective nurseries, eventually making possible biochemical cycles on planetary surfaces that emerge in the presence of composition gradients. Thanks to those sunlight-driven biochemical cycles, molecule surfaces and cell membranes define the inward and outward looking correlations that describe microbial life (Figure 1.1), just as organ surfaces and skins predicate the correlations that describe metazoan individuals (Figure 1.2).

We argue that, in a similar sense, the physical boundaries that define metazoan communities beyond the skin are code-pool boundaries of two types (Figure 1.3): molecular (e.g. family gene-pools) and memetic (e.g. cultural idea-pools). In each case, correlations with respect to these latter boundaries (often ferociously complex in a geometric sense) can facilitate quantitative as well as conceptual inventories of the subsystem correlations that we think of as community life.

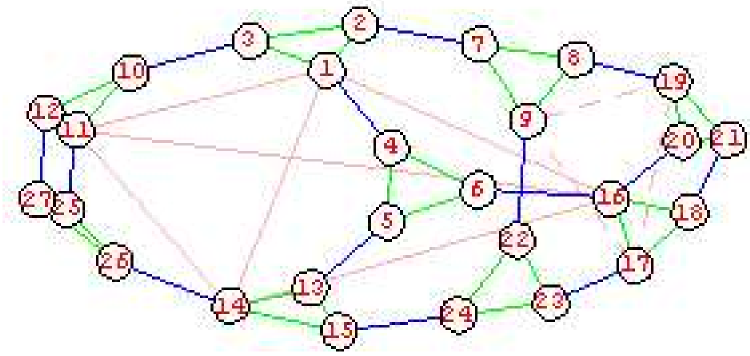

Figure 1.4: Layered niche network: This one shows four layers of correlation: self (number), friends (blue), family (green) and teams (light red).

1.3 Layered-niche networks and the attention-slice simplex

Given a picture of subsystem correlations with thermodynamic roots, we now focus on the role of metazoans in developing and maintaining these correlations. Attempting to quantify individual metazoan connections across a layered niche network, like the 4-layer network depicted in Figure 1.4, would be difficult in most cases even ignoring questions of appropriateness and measuring-instrument-induced perturbation. However, data on the multiplicity of levels in which individuals participate appears to be both accessible, and potentially useful.

By making the Laplace-prior assumptions that we treat individual metazoans on the same par, we've proposed a simplex model of niche multiplicity[7] that associates six positive numbers (resource fractions directed toward the buffering of correlations in/out relative to skin, family and culture) with each metazoan. These numbers characterize a community's correlation network only in terms of the fraction of an individual's time and/or energy resources allocated to each level.

Suppose you are given the fraction f_j of an individual's attention and/or resource allocation to correlations inward and outward looking with respect to skin, gene-pool, and idea-pool, respectively. By definition the f_j sum to 1 for j=1,6. A simple measure of that individual's multi-level involvement is their niche-multiplicity between 1 and 6, given by $\Omega_i \equiv 2^{S_i}$ where the average niche-level surprisal is, as usual, given by

$$S_i \equiv -\sum_{j=1}^{6} f_j \log_2(f_j). \tag{1.1}$$

By averaging the surprisal over a number (say i=1,N) of individuals, one can

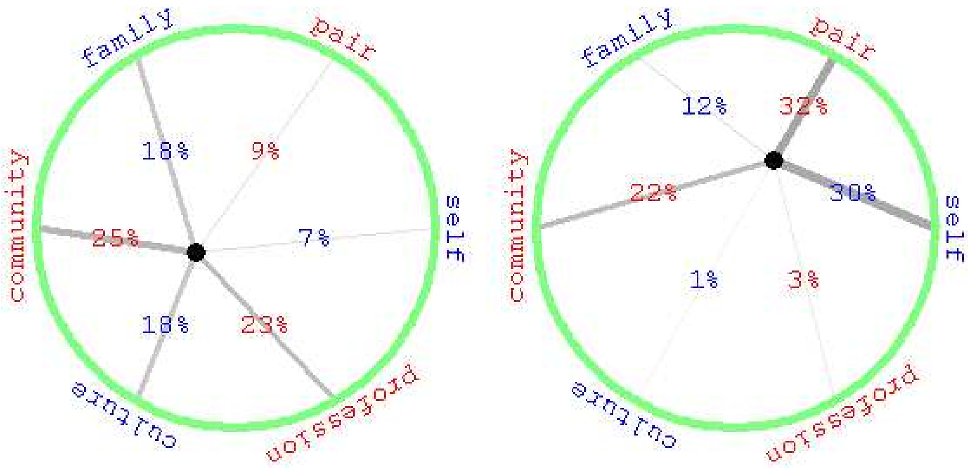

Figure 1.5: Spider representations of the correlation focus of one individual.

also find the community's niche-level surprisal

$$S_{community} \equiv (\frac{1}{N}) \sum_{i=1}^{N} S_i, \tag{1.2}$$

and niche-multiplicity

$$\Omega_{community} \equiv 2^{S_{community}}. \tag{1.3}$$

This latter, a geometric average of individual multiplicities, has the advantage of lying between one and six as does the individual multiplicity.

An economical way to depict these connection parameters for a single individual uses the spider web schematic shown in Figure 1.5. Objectively determining these six numbers for a population individuals is a separate story, although each of us can probably estimate how many of our past 100 waking hours involved a focus on self, friends, family, community/consensus, culture/beliefs, and profession/observations. The color of the numbers in the figure reflects one's emphasis on inward-looking (blue) versus outward-looking (red) foci. This brings to mind the ancient distinction between yin and yang i.e. between nurturer and adventurer, as well the history of pair-bond role specialization in some metazoan communities.

We also argue that the niche-multiplicity of a community may serve as a robust measure of community health. Consider for example quantifying the niche structure of a given metazoan community, along with the geographic distribution of the subsystems with which it correlates. In behavioral ecology, the approach might facilitate quantitative comparison of the extent and nature of community cultural-correlations, from one species to another or from one time to another for a given species[8]. Particularly important questions arise when comparing the correlation networks operational in communities where humans evolved, to those networks that humans are being asked to participate in today. Such measures might also serve as complement to GDP as human communities transition toward sustainability, and as a yardstick for the impact of programmatic decisions as well as disasters on non-human as well as human communities. Measures like this could also help deconstruct extremist programs that disrespect correlations on one level or another.

1.4 Measurement and informed expression

The first cross-disciplinary task is to find ways to gather high-quality experimental data on the scale of niche structures in a given metazoan community. This might develop e.g. in non-human communities via direct observation of behaviors[9], and in human communities via development of survey instruments and statistical analysis and/or the monitoring of communication traffic. For example, survey instruments like those developed to assess feelings about words in affect control theory[10] might also work in asking about the slicing of attention across levels, since both are difficult to check independently but there may also be little incentive to falsify information. Similarly, programs to assess the relative focus of web traffic from communities as a function of time, on subjects of healthcare, pair bonding, family matters, politics/consensus, culture/beliefs, and technical observation may be relatively easy to implement.

If these measures correlate with community health in a more robust sense than more monochromatic indicators (e.g. life span, appetite, or economic activity), the challenge of putting them to use e.g. in monitoring the effect of policy changes, media perturbations, or climate change on a given commmunity can begin in earnest. In preparation for the availability of such data, quantitative dynamical models of the impact of these things on niche multiplicity are already being considered. For example, the recent paper by Lin et al[11] explores the modeling of data on the spatial distribution of violent incidents e.g. situations in which the physical space of individuals are violated. The formalism discussed here suggests that information on the disruption of friendships, families, social hierarchies, local cultural activities and professions might also be worth examining in this context.

This brings us back to the original subject, namely ways to inform the expression of idea codes to organization on all levels of importance to communities. The ability of ideas to replicate themselves electronically across the planet in seconds very likely has a profound effect not just on the global spectacle, but on the local unfolding of events as well. The conceptual framework described here, with deep roots in all of the more fundamental sciences, suggests a way to integrate observations in those sciences as well as in more humanitarian and economic pursuits toward shared objectives. The most immediate bottleneck at this point is our need to work together, across disciplines, on objective measures of multiscale community health that we can put to use toward these ends.

1.5 Acknowledgments

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Bibliography

[1] JAYNES, Edwin T., "Information theory and statistical mechanics", *Phys. Rev.* **106** (1957), 620–630.

[2] LLOYD, Seth, "Use of mutual information to decrease entropy", *Phys. Rev. A* **39** (1989), 5378–5386.

[3] MCLUHAN, M., *The Gutenberg galaxy*, U. Toronto (1962).

[4] BAR-YAM, Yaneer, *Dynamics of Complex Systems*, Perseus Books, Reading MA (1992).

[5] CHAISSON, Eric J., "The cosmic environment for the growth of complexity", *BioSystems* **46** (1998), 12–19.

[6] FRAUNDORF, P., "Thermal roots of correlation-based complexity", *Complexity* **12** (2007), in press.

[7] FRAUNDORF, P., "A simplex model for layered niche networks", *Complexity* (2007), submitted (arXiv:physics/0603068).

[8] REEVE, Hudson Kern, "In search of unified theories in sociobiology", *Model systems in behavioral ecology* (Lee Alan DUGATKIN ed.), Princeton University Press (2001), 57–71.

[9] VAN SCHAIK, C. P., M. ANCRENAZ, G. BORGEN, B. GALDIKAS, C. D. KNOTT, I. SINGLETON, A. SUZUKI, S. S. UTAMI and M. MERRILL, "O-rangutan cultures and the evolution of material culture", *Science* **299** (2003) 102–105.

[10] FRANCIS, Clare Anne, "Introduction to Affect Control Theory", *Purpose, meaning and action* (Kent A. MCCLELLAND and Thomas J. FARARO eds.), Palgrave MacMillan (2006), 139–162.

[11] LIM, M., R. METZLER and Y. BAR-YAM, "Global pattern formation and ethnic/cultural violence", *Science* **317** (2007), 1540–1544.