LSU PHIL 4941 Spring 2018

Pamela Lyon, "The Cognitive Cell: Bacterial Behavior Reconsidered," Frontiers in Microbiology 6.24 (published 14 April 2015). doi: 10.3389/fmicb.2015.00264

ABSTRACT: Signal transduction is foundation of information-processing approach in cog sci; ST appears in bacteria. But cognitive scientists don't know about research into ST in bacteria and microbiologists don't appreciate that their work might be relevant to cog sci in more complex organisms. Article reviews research on bacterial cognition and shows parallels in function, mechanisms, evolution, and ecology, all of which offer hope for cross-fertilization of future research.

BACKGROUND: the idea has been around for some time but not taken up in detail recently.

PART I: Cognition as "biological function." Cognition is polysemic and you can define it narrowly to (mostly) pick out only humans or more broadly. Most cog sci ignores bacteria research or is explicitly human chauvinist (not Lyon's term, but see "phylogenetic snobbery" on p 14). But this ignores a key Darwinian principle that functions differ in form but not in kind. (Analogy, as opposed to homology [= resemblance due to common descent].)

Biological Cognition: Lyon first gives an information-processing view of "cognition," but when she comes to the real-life biological instantiations of cognition, note that in Table 1 and elsewhere she includes "valence," "salience," "discrimination," "existential opportunity," "teleonomic striving," and other more or less enactivist terms. (See Di Paolo 2005, who adds adaptivity to autopoiesis as elements of enaction; adaptivity means ability to sense approaches or retreats from homeostasis, as well as entry into "danger zones." This ability to discriminate needs to be added to the binary logic of autopoiesis [survive or die].)

She also points to von Uexküll, Gibson, and Maturana among others to include "interacting with its environment in order to meet existential goals." (Note that you might want to distinguish "world" as the limited set of agent-relative or first-person aspects of the "environment" [=that which a 3rd person objective observer might identify].)

Traditional view is that bacteria have only inflexible mechanisms to adapt to world changes, but new view sees them as "highly social, flexible responders," with mechanisms that show "non-linear responsivity, integration from multiple sources, and habituation and adaptation.

PART 2: Bacterial Cognitive Toolkit: see Box 1 for list. Lyon stresses valence, agent-relative and context-dependent significance. Obstacle to seeing bacterial cognition is lack of specialized structures and difficulty in separating metabolism and cognition. But that's only a lack if you require a linear model of input / processing / output.

Sensing: ST systems can be one-component or multiple components.

Autoinduction: indirect sensing via proxies. Organisms produce molecules that stimulate change in gene expression when hitting a threshold. The gene expression might then produce other molecules for functions, or even a global transformation as in "sporulation" (= production of a dormant form [very, very slow metabolism] that protects genetic material by being resistant to extreme environments in hopes that later on things will change enough to allow restoration of "normal" form; more discussion on p 11 of Lyon.)

"Quorum sensing" is when bacterial autoinduction occurs due to population density (hence it's a form of "sensing" agent-relative aspects of world). QS facilitates cooperative behavior such as "social motility" / swarming; … chromosomal replication … lateral gene transfer … symbiotic mutualism … biofilm formation (= 3-dimensional sticky structure or "bacterial city.")

Autoinduction producing meaning for the organism in sensing world, allowing protein interactions that are "pushmi-pullyu" or info that is both constative and directive – what is the case and what should be done.

Communication and Sociality: debates here about expansion of term are related to individual vs group level selection. Distinction was proposed between "signals" (evolved to mediate sender and recipient) and mere "cues." Evolution of prosociality is huge debate in evolutionary theory; Lyone thinks we can justify group selection at bacterial level. Political implications here are massive.

Lifestyle Complexity = Signaling Complexity. Complexity of niche drives selection for complexity of cognition.

Motility. Chemotaxis requires assessment of valence.

Predicting: Bacteria are "dynamic predictors actively oriented to what comes next"; requires memory and learning;

Memory: protein dynamics in bacteria; changes in neuronal structure for mammals. DNA methylation is mechanism here; methylation and chromatin remodeling are mechanisms of epigenetic learning.

Learning: non-associative learning (indistinguishable from long-term memory) shows sensitization and habituation. Experiments try to show this with bacteria.

Prediction: evolution for both "public and private goods" (p 13). "return to homeostasis" paradigm is not powerful enough to explain bacterial behavior; need "predictive-dynamic framework" such that gene-protein regulatory networks in bacterial are functional analogues of neural networks. The attempted reductio warning that this research implies presence of representations qua internal models in bacteria should be taken in context of complaints about such reps and models in humans.

Signal Integration: we don't really know how this works, but we should be investigating it.