Science/philosophy content, Text

Cognitive glue: stress sharing and memory anonymization holding together anatomical intelligence

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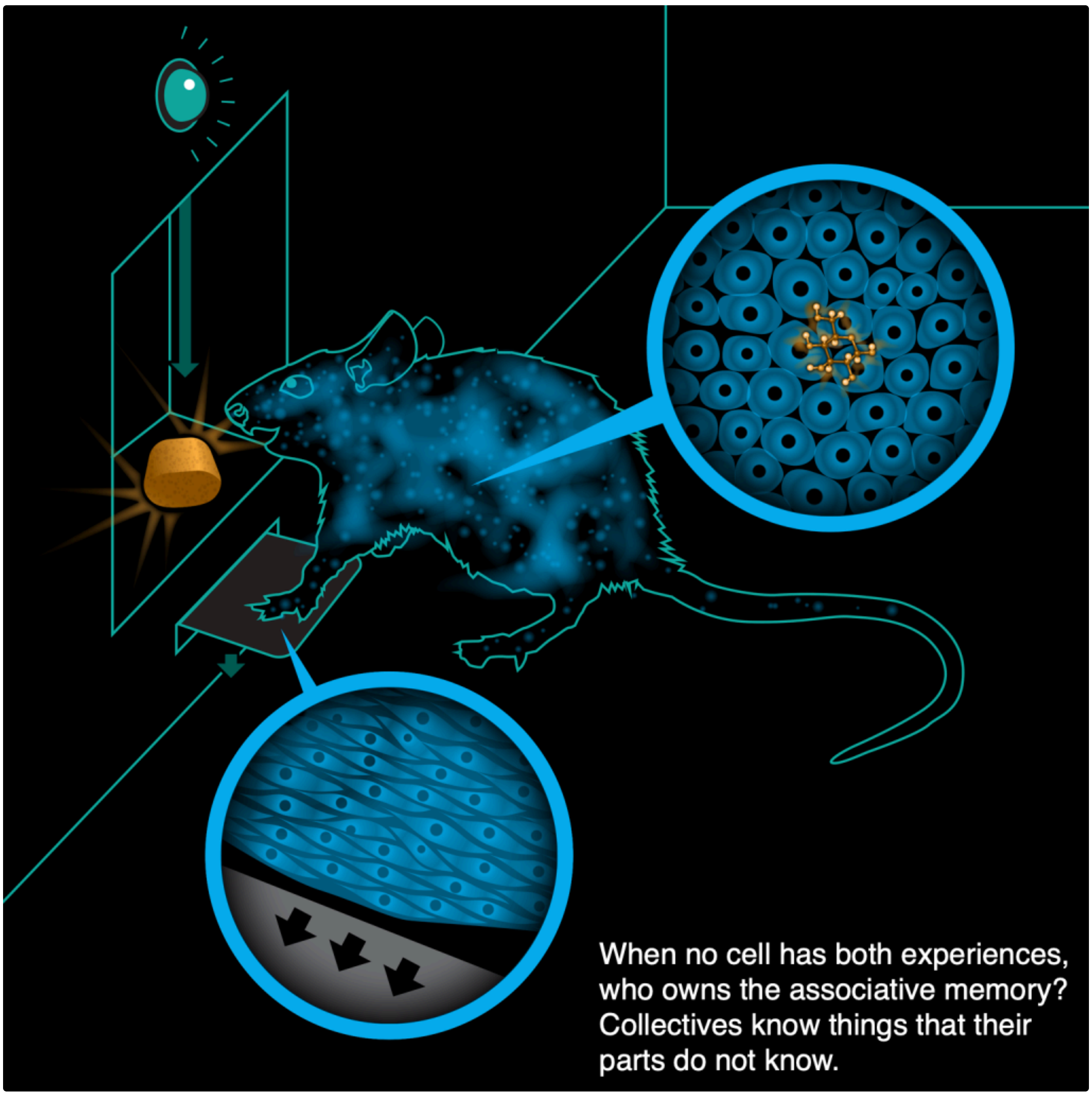
We are all collective intelligences — not just ants and bee colonies, but all of us, because we are made of active parts (cells), which have to become aligned to work together to give rise to a system that has memories, preferences, and goals that don't belong to any of them. The collective organism operates in new problem spaces to which its parts do not have access (such as anatomical morphospace). This emergence of higher-level Selves, through the actions of components, is one of the most fascinating questions of science and philosophy: how do integrated Selves, which are more than the sum of their parts, arise? Where do their goals, preferences, and competencies come from? Our lab is working on these questions, as well as on the origin of novel systems' goals (ones that couldn't have been directly set by evolutionary selection in the case of synthetic proto-organisms). We also work toward tools for detecting, understanding, communicating with, and constructing such emergent Selves. You can see some of that discussed in my recent talks where I describe how we use the ability of cellular collectives to achieve specific anatomical shapes as a model system to understand collective intelligence. Groups of living cells navigate the space of possible anatomical outcomes (morphospace) by using their genetically-provided toolkits to achieve the correct species-specific target morphology even when circumstances, or their own parts, change.

Collective intelligence and cognitive glue

Here I want to talk about a key question in this field — the nature of *cognitive glue*: what policies, properties, and features of cells and various laws (physics, computation, etc.) enable this binding toward common purpose? A cognitive glue mechanism is one that aligns subunits (e.g., cells) toward the same model of themselves, of the outside world, and of their goals, enabling them to work together to reach that goal reliably and despite novel circumstances, perturbations, etc.

Crucially, cognitive glue mechanisms enlarge the size of goals that a system can represent and re-shapes the action landscape toward common interests in a way that induces cooperation and effective alignment. In the case of our most apparent cognitive Self, which drives conventional behavior in 3D space, we emerge via the functioning of a collection of neurons in our central nervous system. Here's an example illustrating this.

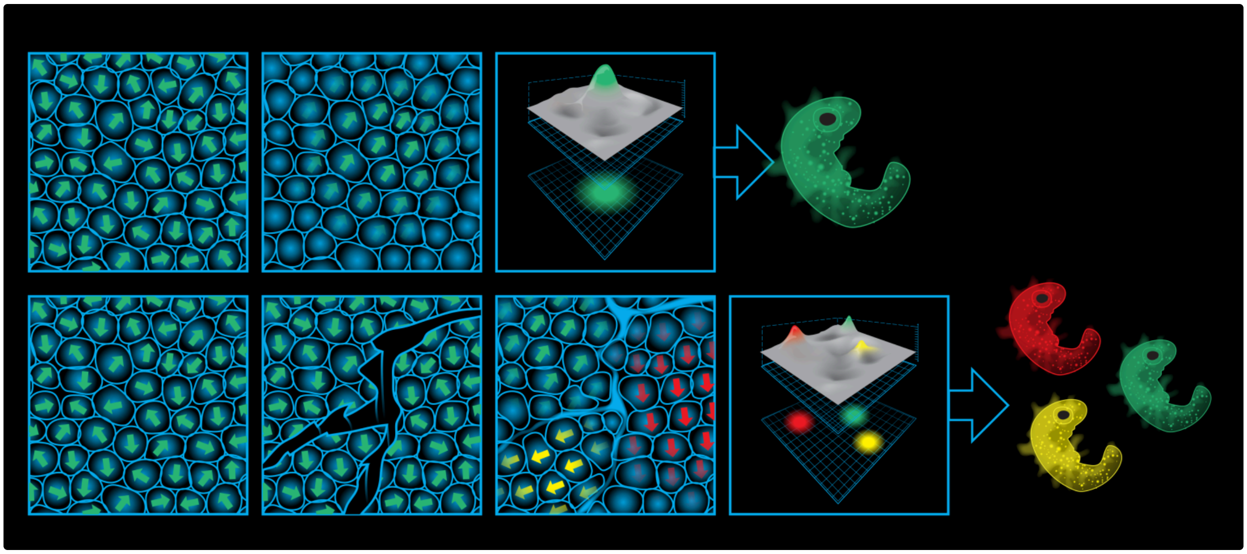


The rat has been trained to press a lever and get a delicious pellet as reward. But note that no individual cell has both experiences: the cells at the bottom of the paws touch the lever, the cells in the gut receive the sugar reward — who owns the associative memory between the two events? The "rat", held together by (among other things) neural networks that bind a huge number of cells into a coherent whole that can own memories (and goals, and preferences) which none of them individually have.

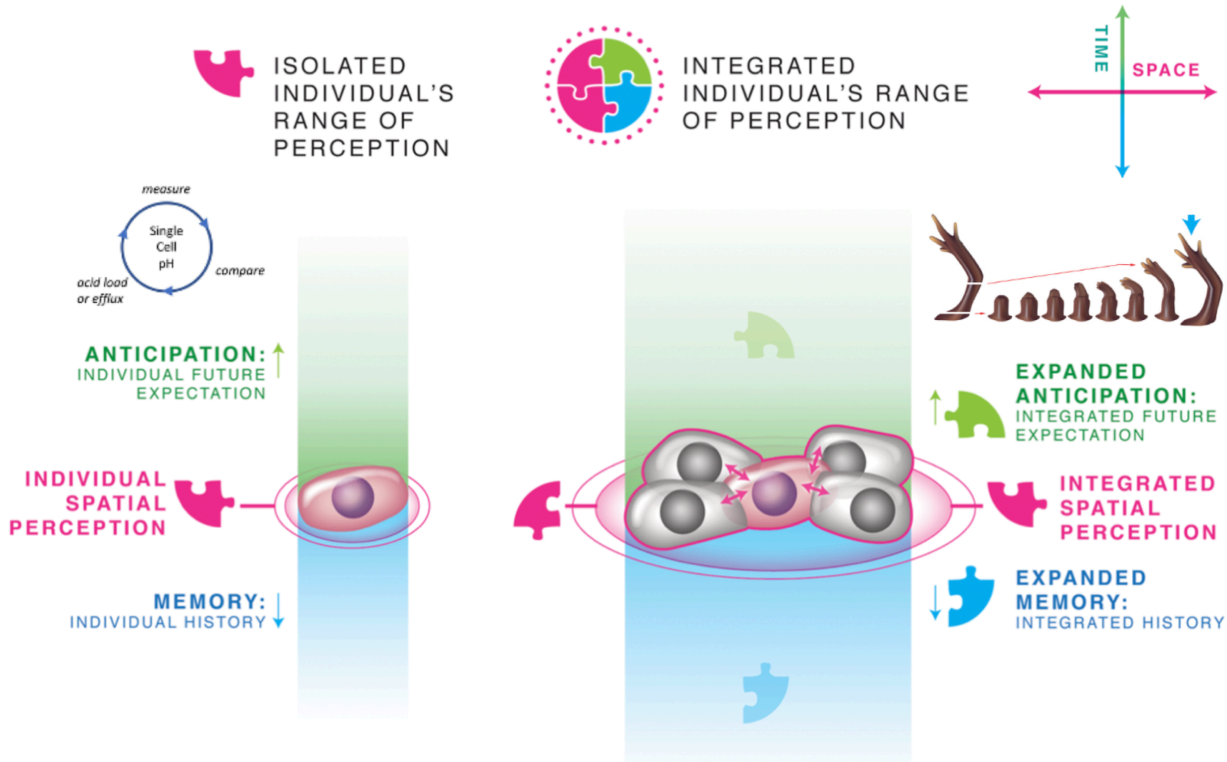
Morphogenesis as collective intelligence

What about morphogenesis — the process by which complex bodies self-assemble? Embryogenesis, regeneration of organs (in species fortunate enough to be capable of it), and on-going suppression of cancer and aging, all require cells to work together to reliably reach and maintain a specific target morphology — a tight anatomical specification. The most remarkable and salient aspect of this process is not its fidelity however — it's the ability of morphogenesis to reach the same target morphology despite a wide range of novel scenarios, interventions, and surprise changes of external environment and internal components). Here is a talk discussing how we use morphogenesis as a model system to learn to detect, manipulate, and create collective intelligences that operate in non-obvious problem spaces. When cast as navigation of the anatomical morphospace, it becomes clear that morphogenesis is actually the behavior of a collective intelligence; this insight has enabled our lab (and now others) to make many new discoveries with implications for many fields from AI to cognitive science to biomedicine. Enormous advances in regenerative medicine and in our understanding of evolution will be reaped when the mechanisms, capabilities, and communication interfaces to this somatic intelligence are characterized.

To really understand the need for alignment in morphogenesis, consider an embryonic blastoderm — a sheet of tens of thousands of cells we call "an embryo". What are we counting there — what is there one of? What we're really counting when we look at a sheet of cells and see an "embryo" is commitment to a world-model: the fact that all of the cells are aligned to the same goal — the same journey in anatomical space that they will do their best to undertake as a collective. But that glue is easily interrupted — mechanical or physiological barriers placed within the blastoderm (such as scratch wounds shown in the lower series of panels below) separate it into multiple individuals, each of which will take their own journey and become separate beings (conjoined, or not, twins, triplets, etc.). So how many individual beings can come forth from the excitable medium of an embryonic blastoderm? 0, 1, 4 or possibly more potential selves. The number of selves and the borders between distinct selves and the outside world are defined by the workings of specific cognitive glue mechanisms (this also has fascinating parallels with dissociative identity disorders of the cognitive intelligence, in terms of fragmentation and unification of individual goal-directed intelligences within a substrate).

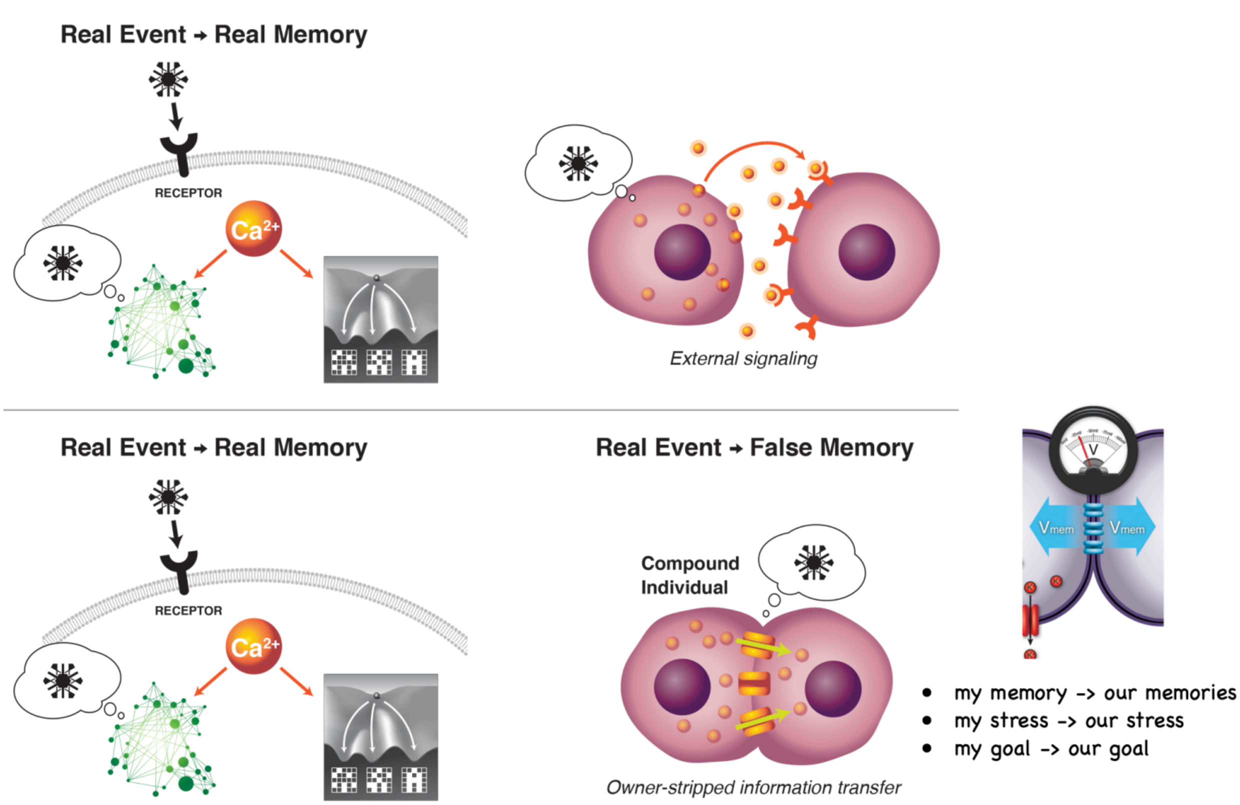


The same issue comes up when trying to set up boundaries between regenerating structures (indeed, all of development can be seen as regeneration of all of the body's structures from 1 cell). So how do cells control their internal parts (molecular networks) and all act together to, for example, regenerate the right number of fingers in an amputated salamander limb, when no individual cell knows what a finger is? That kind of creative problem-solving in multicellular bodies requires the tiny cognitive light cones of their cells to be merged together into a much larger one that subsumes massive construction projects (like, "build a limb of this shape and size") instead of the much smaller physiological and metabolic goal states pursued by individual cells. On the developmental and evolutionary time scales, cells become connected into networks (e.g., bioelectrical) that can store larger goals by providing extended memory, anticipation, and representation capacities. Here is a diagram that shows the limited size (in time and space) of single cells vs. cellular collectives and their goals:



Memory anonymization as a kind of cognitive glue

How are cells orchestrated toward specific anatomical outcomes as goal states that, once achieved, cause their activity to cease? In other work (Figure 9 here) we focused on memory anonymization as one kind of cognitive glue:



The idea that gap junction (electrochemical synapses) connections between cells make it harder for them to keep individual identities (memories) because physiological events that serve as memory engrams propagate from one cell into its neighbor, which then can't tell *whose* memory it was. It's not just a false memory for that 2nd cell, it's a *true* memory for the collective. Breaking down the informational boundaries between cells results in a partial collective mind where the individual identity partially disappears in favor of group dynamics and their informational mind-meld.

Gap junctions are part of the bioelectric networks governing growth and form. But they are not just another piece of biophysics that one needs to take into account in developmental biology. I have long argued that electrophysiological phenomena, which hold together our familiar behavioral Self evolved from older mechanisms that performed precisely the same function for our morphogenetic self. In other words, bioelectricity is a powerful mechanism for implementing cognitive glue that underlies integration of information across space and time, from bacteria to embryos to brains. But it is likely not the only one, and we are now studying another one — stress sharing — that may or may not have any bioelectrical component.

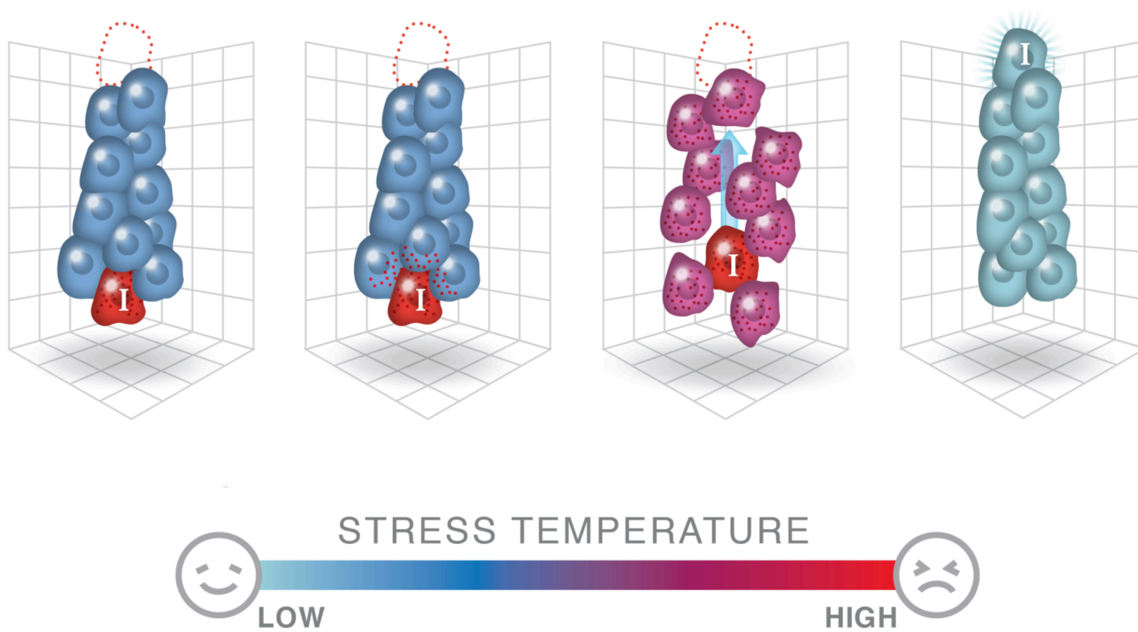
Stress sharing as cognitive glue

More recently, we began testing the hypothesis that another kind of cognitive glue in morphogenesis is ***stress sharing***, and that stress in morphogenesis is mediated by the same ancient genetic components that were first used to detect abnormal states in microbes and unicellular organisms.

The fundamental process of reliably reaching a specified target morphology, starting with a single cell (egg), different body (metamorphosis), or damaged body (regeneration), and stopping when it is achieved, is a process of error minimization. It's a loop, like any homeostat, in which the system continuously measures its progress relative to a setpoint within the action space and tries to reduce the delta between current state and final state (our lab has been studying for maby years how this final state is a pattern memory encoded in bioelectrical properties of cells, but other mechanisms could be involved as well). The important thing is that unlike in a thermostat, where the system is made of passive components and can be engineered with an explicit goal, life consists of an agential material — cells with their own agendas, which must be explicitly coordinated toward a specific goal in order to dominate their innate agendas (the story of cancer). Specifically, many problems (such as regeneration, repair, etc.) must involve coordination of many cellular events spread throughout the body, such as making sure that the various parts of a complex structure match in terms of size, orientation, location, symmetry, etc.

Individual cells are pushed through their homeostatic paces by error estimates — measurements (sensing of internal states) that tell the system how far off from desired setpoint it is. When the error falls below an acceptable limit, they can stop adjusting. That works fine for single-cell level goals (like keep the local pH to a certain level) but morphogenesis requires being motivated toward very large-scale states: does this Axolotl limb have the right number of fingers? etc. How to get all of the relevant components to care about the same problem?

We conjectured that stress — a system-level signal that reflects distance from setpoint but is not localized to a single locale, can be used to engage distant bodyparts into coordinated action. Let’s imagine how it might work. The following example concerns geometric positioning of cells, but the basic principle can hold in all kinds of spaces — physiological, gene expression (transcriptional), etc.



In this simplified diagram of one typical scenario during morphogenesis, stress sharing is hypothesized to help solve the problem. Cell *I* (red) is motivated to move upward until it reaches its correct position in a morphogen gradient. But cell *I* would not get to its intended spot because all the other cells’ target states are met and they have no incentive to move enough to let cell *I* pass, no matter how much stress cell *I* is feeling due to the error state of its current position — they are content, their own stress is low, they won’t move. Cell I’s problem is not their problem and a permanent defect will remain.

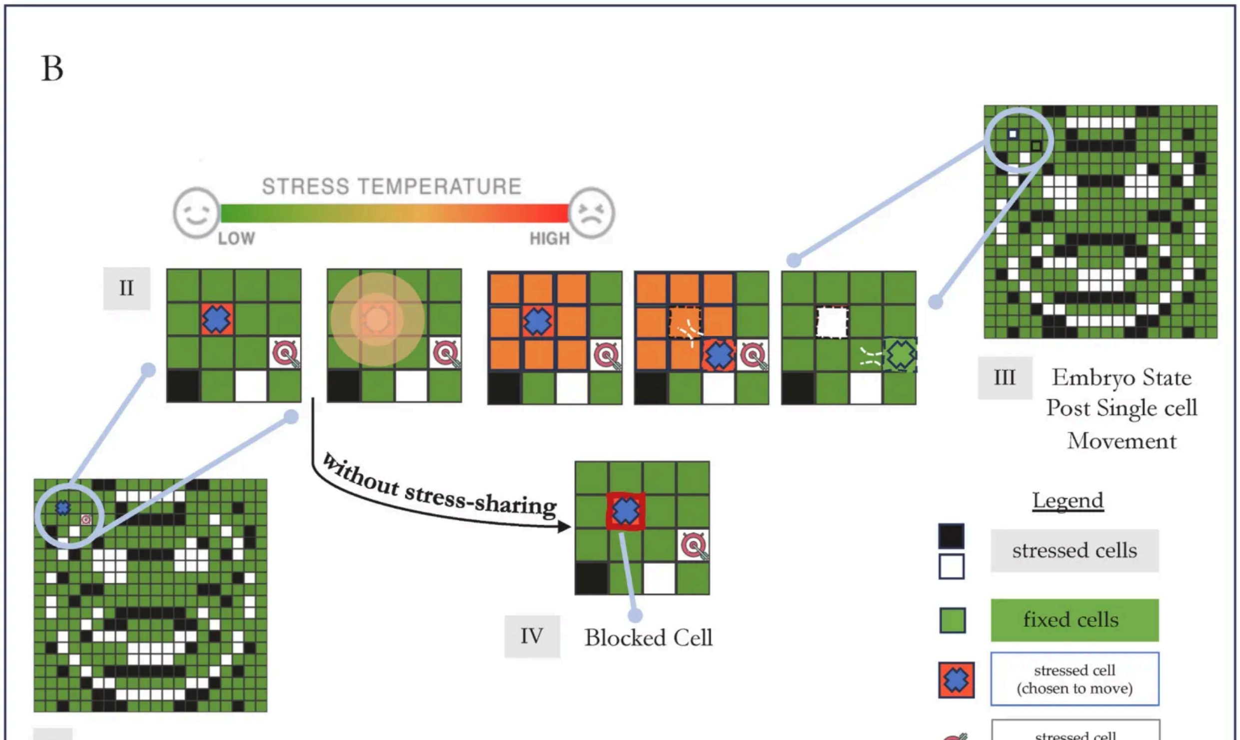
But if the molecule(s) whose level represent the distance between its positional setpoint and its current position can leak (or be exported) our of cell *I*, they will affect nearby cells. The leaking, propagating stress signal indicates a problem somewhere in the collective. But since stress molecules are conserved among all cells within a given body, the neighboring cells cannot tell that the problem is not their problem — they are motivated to reduce stress, and the presence of the conserved stress-carrying signal affects them directly. They will be stressed by their microenvironment, which raises their plasticity — reduces their threshold for moving and making changes and motivates them to act in order to reduce their own stress. In this example, they become more willing to move around (to find a better position for themselves), which enables them to let cell *I* pass through. When it gets to the correct position, its stress levels reduce, it stops generating and propagating its stress signal, and the whole cell sheet's stress levels reach low levels because the entire collective is in a low-energy state with respect to all of their setpoints.

In this way, a systemic stress response mechanism, implemented by conserved stress molecules that leak from specific cells, could facilitate large-scale problem-solving by de-localizing incentive to work toward group goals (cooperation without built-in altruism, since all the cells are simply trying to reduce their own local stress levels). The leak mechanism enables the collective to bend the energy landscape for the individual cells to exploit their homeostatic optimization behavior towards a tissue-level patterning goal. The best thing about a stress sharing mechanism is that it doesn't rely on altruism: by leaking stress, my problems become your problems. You are motivated to help me because it reduces your own stress to do so, you do not have to have a special mechanism for helping others. It's a kind of emergent collective coordination that can evolve simply by making stress indicator molecules leaky.

Seems to make sense conceptually, but would this really work?

Testing the stress sharing hypothesis in simulations

Lakshwin Shreesha (also here) and I tested this idea in a computational model of developmental biology (in silico embryogeny), described in the final paper here and in an open preprint here.



Forms of life, forms of mind

DR. MICHAEL LEVIN

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target states are met and they have no incentive to move enough to let cell *I* pass, no matter how much stress cell *I* is feeling due to the error state of its current position. Thus, a permanent defect will remain. (A2) Before and after, in the presence of stress sharing: if the stress molecule(s) representing the delta between its gradient setpoint and its current position can leak (or be exported) our of cell *I*, they will affect nearby cells. Since stress molecules are conserved among all cells within a given body, the neighboring cells will be stressed by their microenvironment, which raises their plasticity and enables them to let cell *I* pass through. When it gets to the correct position, its stress levels reduce and the whole cell sheet's stress levels reach low levels because the entire collective is in a low- energy state with respect to all of their setpoints. In this way, a systemic stress response mechanism, implemented by conserved stress molecules that leak from specific cells, could facilitate large-scale problem-solving by de-localizing incentive to work toward group goals (cooperation without built-in altruism, since all the cells are simply trying to reduce their own local stress levels). The leak mechanism enables the collective to bend the energy landscape for the individual cells to exploit their homeostatic optimization behavior towards a tissue-level patterning goal. (B): Process of cell movement with and without stress sharing in embryos: The target task was for cells within a randomly initialized 2D matrix/embryo to re-arrange themselves towards a pre-set target pattern (a smiling face binary image in our setup). Stressed cells (B.I) (i.e, cells which are not in their correct positions to form the pre-set morphogenetic pattern) were allowed to move by picking other stressed cells as target and moving towards them through local swaps. By default, a stressed cell was not allowed to disturb other fixed cells (cells which were already in their correct positions). However, when given the ability, stressed cells could share their stress with their fixed neighbors, urging them to provide a path for movement towards the target (B.II). Consequently two kinds of competencies were setup: One with stress sharing (B.II), and one without (B.IV). In the case where sharing was not allowed, a stressed cell surrounded by other fixed cells would have no way of moving through, causing it to get blocked locally (B.IV). In the case where sharing was allowed, blocked stressed cells would spread their stress to an area of size 3×3 around them (shown in orange), thereby communicating an intent of movement; in response, a channel would be created by the fixed cells for the stressed cell to move towards the target location. (Stages I, II, and III). With each resolved cell movement, the stress map was updated (B.III). Such a process occurred iteratively until either the competency limit was reached or the target pattern was formed.

Here is, the evolutionary cycle:

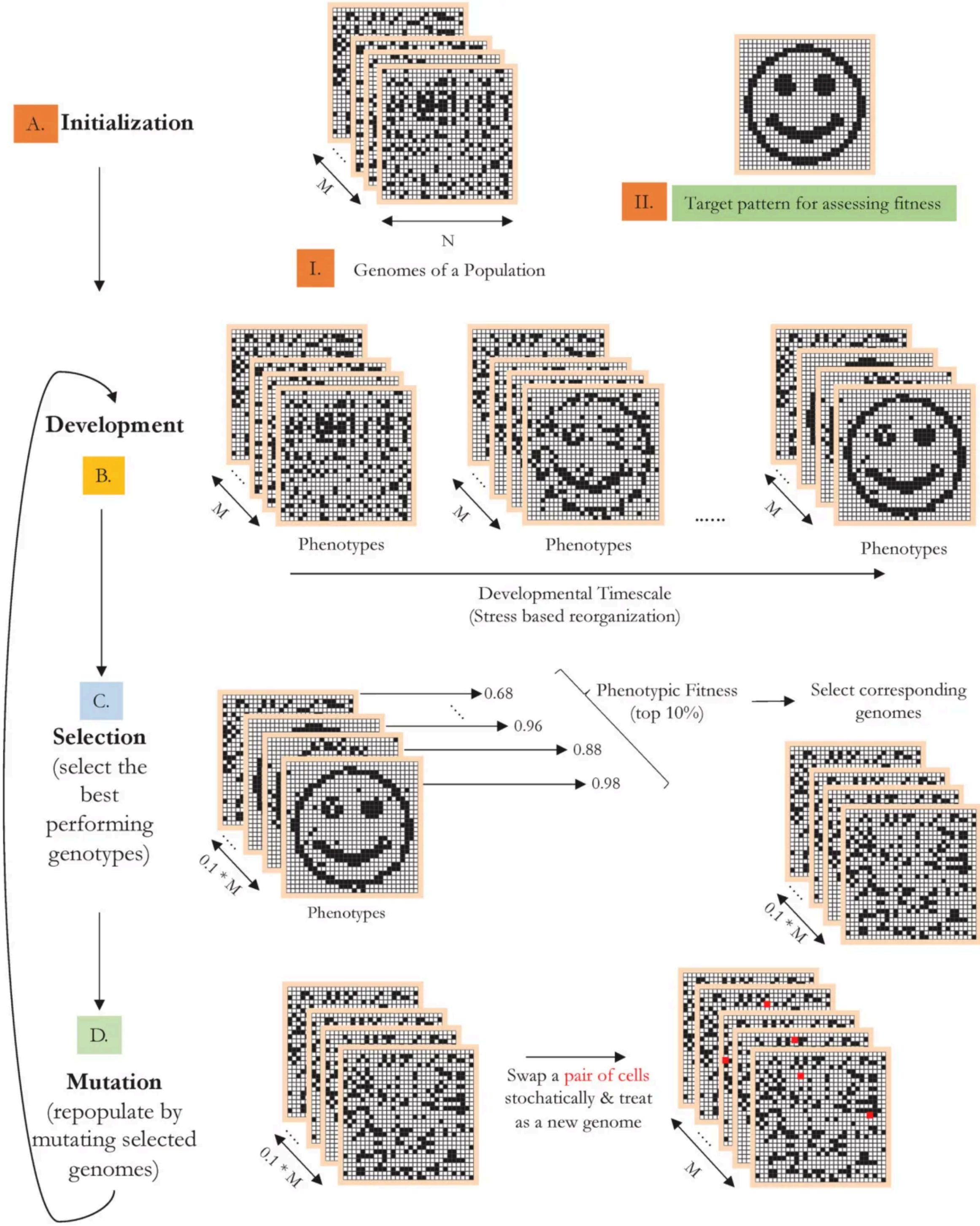
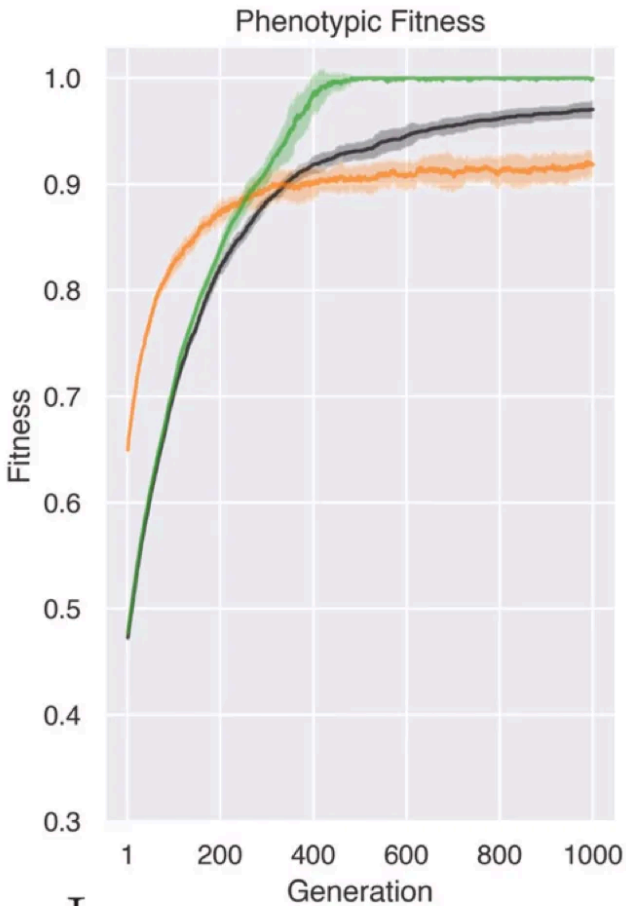


Fig. 2. Genetic algorithm schematic

(A): Initialization: Prior to evolution, a population of genomes which served as the substrate for evolution were initialized. A *genome* in our framework was a randomly initialized two-dimensional matrix containing two cell-types (0, indicated in black, and 1, indicated as white) (A.I). The genome also carried a marker indicating the type of development an embryo could undergo during the first stage of evolution i.e: development. Three kinds of reorganizaton processs were defined: 1. Stress sharing based reorganization, 2. Reorganization without stress sharing, and 3. Hardwired (no reorganization). A target for evolution was also set. To this end, we chose a downsampled binary image of a smiling face as the target pattern which evolution had to optimize over (A.II). (B): Development: The first stage of evolution involved a process of cellular reorganization of the initialized matrices. Reorganization would be based on the gene marker encoded in the genomes of each embryo. This stage served to mimic the developmental stage observed during an organism's lifetime. Post development, the reorganized cell-structure was termed the embryo's phenotype. Thus, the developmental process served as an independent layer separating the genotype of an embryo from its phenotype. (C): Selection: Prior to development, the fitness of each genome was recorded by comparing it with the target ($l2 - distance$). And Post development, the fitness of the corresponding phenotype was also recorded using its $l2 - distance$ with the target. During selection, phenotypic fitnesses of the top 10 % of the population were chosen and, their corresponding genomes were selected (Darwinian selection) for evolution in the next generation and the rest were discarded. (D): Mutation: The selected for genomes constituted 10 % of the original population. To repopulate the population back to its original strength, selected genomes were mutated by randomly swapping cell- pairs within the genome. The resulting mutated genome served as a new embryo. Post re-population, a new cycle of evolution began marked by the onset of development.

The basic experiment compared the ability 3 different kinds of simulated embryos to complete morphogenesis (we're using the "smiley face" target because this is a basic pattern for the frog embryo's electric face). Hardwired embryos (black line in the graph below) had a direct mapping from genotype to phenotype — like nematodes (for example), it was a very fixed kind of development which always went the same way. Other embryos had a more realistic developmental process between genotype and phenotype, which was able to make decisions in anatomical space and execute homeostatic ability to keep working until the overall anatomy was correct. When not sharing stress (controls, orange line), they started off well but were eventually overtaken by the direct evolution of the hardwired ones' genomes. The best performance was seen in the homeostatic embryos whose cells could share stress — they achieved perfect morphogenesis earlier than others (green), and had the best outcomes.


Phenotypic Fitness
Fitness
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
1
200
400
600
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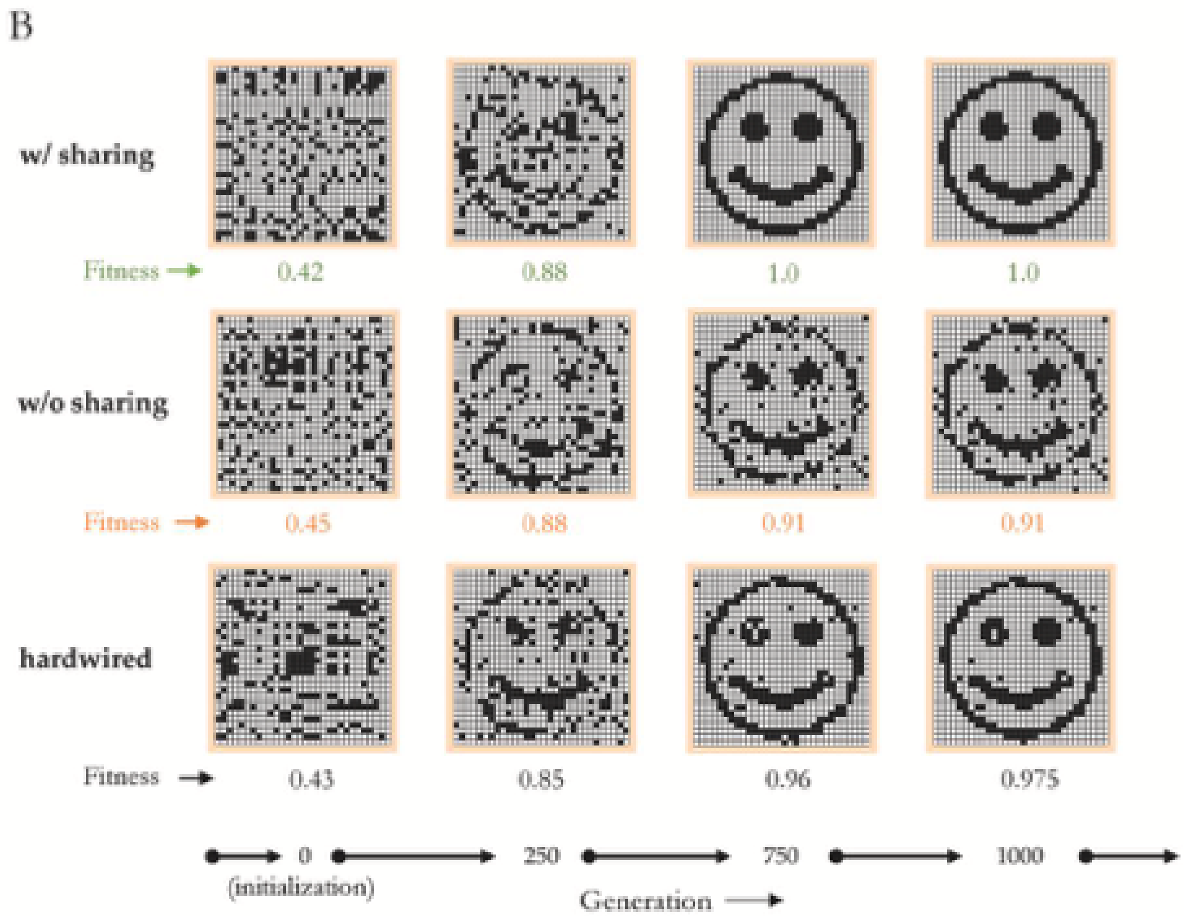
Generation



Thus, we found that stress sharing improves the morphogenetic efficiency of multicellular collectives. Moreover, we found that stress sharing influenced the future fate of distant cells in the multi-cellular collective, enhancing cells' movement and their radius of influence, consistent with the hypothesis that stress sharing works to increase cohesiveness of collectives. Finally, we found that anatomical goal states could not be inferred from observation of stress patterns (there was no obvious 1:1 mapping of the stress pattern among the cells and structure they were trying to build), revealing the limitations of knowledge of goals by an external observer outside the system itself.

What's next:

Interestingly, one thing we observed was that the effective "circle of concern" — the radius that individual cells tried to manage — was increased by stress sharing — they began to actively try to manage (i.e., care about) bigger domains of their world. To make an extension from morphological to cognitive spaces: the cognitive light cone (the size of the biggest goals an agent can work towards) is intimately tied to the intelligence. Tell me the size of things that stress you out and I can roughly guess what kind of mind I'm dealing with. If you only care about the sugar concentration over minutes in a few micron-sized area, you might be a bacterium. If you are stressed out by events in a few hundred yard radius but can't possibly worry over what happens several miles away 3 weeks from now, you might be a dog. If you're stressed by the sorry state of the planetary climate cycles long after you will be dead, you might be a human. However, if you can really (i.e., actively and in the linear range) care about trillions of other sentient beings, you are not human but something greater. In this paper we discuss the connection between intelligence, cognitive light cones, compassion, empathy, and related concepts, which is an area that needs to be developed further because of its implications for alignment of AI and other future beings.

In the meantime, next steps are to test these ideas in real morphogenesis in the lab. We've got some good candidates in mind for the stress-bearing molecule and we're going to study how they up- and down-regulate during specific scenarios, and how inhibiting their propagation (or. preventing cells from caring about their levels) affects morphogenesis. Actually we already have some pretty cool preliminary data on this; stay tuned!

Featured image by Midjourney.

Other images and diagrams by Jeremy Guay of Peregrine Creative.

collective intelligence, computational model, morphogenesis, philosophy, science

Previous Post
If mind is everywhere, where are all the panpsychiatrists? A (neuro)psychiatry-focussed discussion

Next Post
Platonism, Process Philosophy, and more: Tim Jackson and Robert Prentner

42 responses to "Cognitive glue: stress sharing and memory anonymization holding together anatomical intelligence"

Tony Budding
February 12, 2025

Hi Mike, a few thoughts for your consideration.

In terms of altruism, the modular nature of our sense of self means that each sense of self can have its own goals, stress, and intelligent problem solving. Neighboring cells only need to be incorporated into a collected sense of self to share the stress and problem solving of any submodule without the need for altruism. The sense of self is an experiential phenomenon, and as such, its modularity is nonlinear and nonexclusive, which means the individual and collective goals and stress can coexist without conflict.

This does bring up the fascinating question about the mechanisms by which an individual can become part of a collective sense of self (and its corollary what might prevent it). This would have implications across the board, from individual cells and their neighbors to individual people and their communities. And to your point about Bodhisattvas, how extended can the sense of self become?

Side note, while a Bodhisattva could conceivably care about trillions of other sentient beings, he/she would still be incapable of blinking anyone else's eyes or quenching their thirst by drinking for them. I suspect this caring without direct influence requires metacognition, but what a wonderful use of metacognition!

Reply

John Shearing
February 12, 2025

Tony writes:
"This would have implications across the board from individual cells and their neighbors to individual people and their communities."

Yes, Levin and Lyons did all the heavy lifting on this one.
If I understood correctly, they conjecture that there is a price system at every scale of collective consciousness from molecule, to cells, to organisms, to communities, and beyond.
https://youtu.be/0Oo4ng6dWrQ?si=mZqxWIEKtLFKi28l&t=34
https://osf.io/preprints/osf/3fdya

To me this implies that there must be commerce at every scale of collective intelligence and the extended self that group members feel is always derived from commerce of some type.

Some truths became apparent to me as I was viewing their work and comparing it with what I had been observing. Your truths may vary.

1. The price system itself at whatever scale is the collective intelligence.

2. If unmanipulated, the collective intelligence always seeks to provide answers to the question “How can we give group members what they want according to their own preferences?”

3. We can not expect to get honest answers from the collective intelligence that emerges from human commerce if we manipulate the markets or the currencies in any way.

4. The markets and the currencies used in the price system must be free of any manipulation if the emergent collective intelligence is to be sane.

5. Every collective intelligence is in the process of morphogenesis (trying to become the structure which best gives members what they prefer) unless there is no more stress in the system.

Regarding the Bodhisattva caring for trillions but not being able to quench their thirst — the price system does exactly that.

Reply

Benjamin L
February 12, 2025

Members of the price system will themselves try to manipulate the price system to their own benefit, interestingly. I imagine the same is true of members of a bioelectric collective, but I don’t know the details.

Reply

John Shearing
February 13, 2025

Greetings Benjamin, I really appreciate your work.

Only centralized powers can manipulate the price system. Morphogenesis is a completely decentralized process. No single cell or even group of cells are in are in control of the market or the currency. That is why the process is so reliable. The same is true of bee colonies. No bee or even group of bees are in control. That is why they make such good collective decisions. https://youtu.be/NDnQ4pAjBUg?t=310

So we know from nature, if a price system is fully decentralized it can not be manipulated and it will make good decisions with regard to the care of its members.

As we transition from central bank control to decentralized blockchain for money and finance, voting and governance, news and social media, and national identity management, the human collective intelligence (our price system) will become free to think for itself about how to give us all what we want according to our own preferences. And the extra bonus is that honest unmanipulated commerce makes us all care for each other as we all help to make pencils.

The two videos linked below are Charles Hoskinson speaking at the Cardano Constitutional Convention. Cardano is the most decentralized and transparent public currency and financial operating system. And it now has the first fully decentralized government. The community is currently working on decentralized news and social media, and on decentralized sovereign identity. When transparent decentralized currency is controlled by decentralized governance and decentralized social media then we will have a price system for humanity that can not be manipulated and will be free to think for itself about how to give us all what we want.
https://www.youtube.com/live/SkixwjCzQ9c?si=2yyycdb5GRvD7VWp&t=93
https://youtu.be/FciRpVKr2ms?si=rAkKzQnH6YgqVe-5&t=548

Hoskinson is meeting with Musk in early March. The conversation is likely to be about how to get government finances and voting on the blockchain.

This is the being that you have described and that Michael is asking for in the video linked below.
https://youtu.be/gDWxCkngQNQ?si=4C73RWtcSPjRYenc&t=4295

Love thy neighbor as thyself is about to become incentivized by our price system.

Reply

Tony Budding
February 12, 2025

Thanks John. While I certainly recognize the merits of the pricing and economic model for collective intelligence, it seems oversimplified, limited to the majority and missing the edge cases, similar to how Newtonian physics breaks down at the extremes of size and speed. Human behavior when n=millions is generally predictable. Human behavior when n=1 is substantially unpredictable. Uncertainty is a fundamental principle of quantum physics.

There are several reasons for all this. First, the individual/collective dynamic is not binary as there are countless modules comprising the collective, each of which operates both as an self-contained unit and also as a collective of submodules. This makes it impossible to generalize as each micro decision depends on which module(s) is/are involved, and whether they're acting as an individual or a collective.

Second, quantity and thus scarcity have very different rules in the material (physical) than in the experiential (mental). For example, my wearing a specific pair of gloves means you can't be wearing them. But my enjoyment of a specific jazz album wouldn't limit your enjoyment of that album. Or, say, my love for my second child doesn't limit my love of my firstborn. How this plays out in the various modules of collective intelligence is enormously complex.

Third, conflicts inevitably arise in the modules of collective intelligence. Sure, we can find examples of extremely simple systems in which the agenda and its resolution are binary, but as soon as sufficient complexity arises (which is the case in the overwhelming majority of real life scenarios), multiple resolutions are possible with conflicting outcomes.

In the pencil analogy, for example, arbitrage is possible with complex markets. Arbitrage is simply the outcome of one agent's strategy for achieving their agendas. At scale, arbitrage can drastically change the supply and demand pricing equations for the others involved.

Furthermore, we also see behaviors that could be described as hyper-competitive or even dysfunctional. Someone might buy extra pencils simply out of spite to prevent another person from having them.

Fourth, intelligence itself is variable. For example, sensory data can be misinterpreted, such as seeing the road ahead as dry when it's actually black ice. Or we may incorrectly interpret the meaning of valid information, such as seeing that a stock price has gone up 10 days in a row and assuming it will keep going up.

I can go on and on. My main point is that we need to embrace complexity and variability in systems since oversimplification limits our efficacy. Collectives can and do demonstrate efficiencies, yet they also demonstrate conflicts, variable priorities, competition, and counterproductive actions. If we count on unified, functional and effective decision making by a collective intelligence, we'll find ourselves regularly disappointed.

Reply

John Shearing
February 13, 2025

Thanks Tony, I appreciate your response.
I agree with you that the world is complex.
But the main point of Benjamin Lyon's presentation on the price system is that it reduces all that complexity to the simple questions of how much do I want to spend and how much product do I want to make.
https://youtu.be/0Oo4ng6dWrQ?si=mZqxWIEKtLFKi28l&t=34

Reply

M
February 12, 2025

I'm not sure if this is intentional or not, but it seems like copy-paste has been disabled for your blog. I tried Brave after noticing in Firefox.

Reply

Pier Luigi Gentili
February 12, 2025

Dear Michael, I like the questions you formulate, and your scenario is intriguing. It can be extended to chemistry…

Reply

Mike Levin
February 12, 2025

great! can you say more, how to extend to chemistry?

Reply

James Buchanan
February 12, 2025

This newish (I think) formulation of cognitive glue as Memory (or more broadly — perception?) Anonymization and Stress Sharing feels like two sides of the same coin.

In other words, when I share my stress with you, what am I sharing but the deviation of my (perceived) state from the (memorized) target? Do you hypothesize other types of information being shared? Such as a computation of the goal state itself? Now that would be interesting …

Reply

Benjamin L
February 12, 2025

When the legs walk, they both know where each other are and also share stress with each other, so my guess is memory anonymization and stress sharing are the same thing. I don't see what the difference would be regarding prices either.

Reply

Mike Levin
February 12, 2025

There is a lot more information shared. But here's why I think it's not the same thing. The stress sharing provides motivation to act and induces increased plasticity. Mere memories are not like that — they can be ignored, or even reinforce status quo (exactly opposite of stress signals). Conversely, stress doesn't need to be a memory of past events — it's a current prod to action which may or may not carry any info about the past nor necessarily need to be remembered.

Reply

Benjamin L
February 12, 2025

In her analysis of the development of reaching (https://www.tandfonline.com/doi/abs/10.1080/10481881509348831), Esther Thelen comes to similar views about how the abilities and goals of parts are scaled up by their cooperative interactions with each other to produce motor behavior. No part of the body is inscribed with some reaching ability—as she says, "the elements that coalesce to produce reaching need not look like reaching to begin with"—but instead reaching is a problem space that the parts learn how to navigate together without any of them being able to do so on their own. Dynamic systems theory doesn't use the term "cognitive glue", of course, but my guess is that there's stress-sharing happening at multiple levels in the body where the body is connected in such a way that when one part of the body is having trouble moving somewhere, it makes it harder for another part to stay where it is; each part of the body is happiest when each other part has reached its preferred state.

> They will be stressed by their microenvironment, which raises their plasticity — reduces their threshold for moving and making changes and motivates them to act in order to reduce their own stress. In this example, they become more willing to move around (to find a better position for themselves), which enables them to let cell I pass through. When it gets to the correct position, its stress levels reduce, it stops generating and propagating its stress

signal, and the whole cell sheet's stress levels reach low levels because the entire collective is in a low-energy state with respect to all of their setpoints.

In the same paper, Thelen describes "dynamic stability" as a key principle of dynamic systems theory, A pattern that is *too* stable is one that can't respond to new conditions and new demands. Variation isn't noise; it's opportunities for experimentation and the emergence of novel behaviors and forms. There's a cognitive-therapeutic perspective here: "The job of a skilled therapist is to detect where the system is open to change, to provide the appropriate new input to destabilize the old pattern, and to facilitate the person's seeking of new solutions (a process much like a baby's learning to reach)", which suggests that you could have therapists for morphogenesis.

> In this paper we discuss the connection between intelligence, cognitive light cones, compassion, empathy, and related concepts, which is an area that needs to be developed further because of its implications for alignment of AI and other future beings.

I know a good amount about this, and I think it's a mistake to associate the cooperative behaviors caused by cognitive glue with the cooperative behaviors caused by moral sentiments, see here for a brief summary: https://interestingessays.substack.com/p/morality-as-a-quasi-cognitive-glue. Morality is kind of like social morphogenesis but with a much weaker cognitive glue, and so some very different things happen. The ideas here aren't necessarily intuitive or pleasing, but let me know if you want more information.

Reply

Mike Levin
February 12, 2025

Therapists for morphogenesis — yes indeed! this is what we're trying to accomplish.

Re. the moral sentiments, yes — I'm not saying it's the same thing. Simply that some cooperative behaviors can be implemented very cheaply, with a simple dynamic. Yes please say more.

Reply

Benjamin L
February 12, 2025

Sure—basically, the current best theory of moral psychology is Tage Rai and Alan Fiske's relationship regulation theory, which says that morality is about regulating relationships. Simply put, people have relational models, or models of how relationships should be. Behavior that accords with those models is perceived as moral; behavior that violates those models is perceived as moral. Saying "please" and "thank you" are simple examples where you're morally motivated to say them because doing so conforms to how you expect relationships to work. Paper: https://psycnet.apa.org/record/2017-57514-017

Morality is thus one way in which a social equilibrium is established, with everyone behaving the way they think they're supposed to based on the relational models they construct. People find their place in a social order just like cells find their place in a cellular order—but morality is much less reliable and less incentive compatible than biolectricity is. https://en.wikipedia.org/wiki/Incentive_compatibility As a result, you don't get nearly the same degree of collective unity, and morality is at best a pale imitation of a cognitive glue.

An implication of relationship regulation theory is that the association between morality and cooperation is mistaken. The Western intellectual tradition has thought of morality as in some way referring to rules or patterns for how people can get along with each other. Relationship regulation theory says that this is wrong. Morality is a technology that can be *used* for cooperation, but so can many other things, and morality can also create a lot of conflict such as religious wars. Morality is about creating, reinforcing, acting out, and destroying relationships. Cooperation is a side effect that sometimes happens and sometimes doesn't, and is basically wrong as a perspective on what morality is and does.

Reply

Jeff, a new bio student
February 12, 2025

Still trying to wrap mind around these ideas. The observation that "if you can really care about trillions of sentient beings, you are not human but something greater" seems like it leads to a paradox given that each human we know is a collective of roughly 37 trillion agential, sentient, “selves”, at least it seems this could be the case in view of those clever anthrobots you’ve given us eyes to see.

You’ve made me think here more deeply about what caring about ourselves and others might actually entail and what it implies about our humanity. Some days, I don’t know if I do care (successfully, anyway) even about or for myself and each of my collective 37 trillion cogntitively stress-bound agential cells, and therefore fall short of the inherent potential to be something greater. In the faith tradition I was raised in, there was a phrase from one of its books of scripture about how it was because of “their great anxiety” that the prophets were given the ability to see what would happen to the people around them (and prophecy). Is a prophet/guru just someone who manages to achieve a level of genuine connectedness such that they have the capacity to feel the pains of those they serve? I don’t know. I guess I don’t know what to believe.

I guess a lot hinges on all that goes into the phrase “really care about”. Perhaps this is why the yogis talk about the “union” of yoga leading to changes that are reflected in their world. It makes me wonder about ideas along the lines of Ghandi’s “be the change you want to see in the world”. Are these all circling around the variants of the hermetic principle, and achieving the ability to affect changes in some Pareto-optimal welfare-improving sense? Is this why contemplatives can transcend what it is to be human? Being human implies being the union of so many others, but I guess being something more than human means you are willing to care for the sum and its parts, along with their agendas, goals, and preferences.

The concept of hell, or damnation even, then, could well be defined as the state of feeling impotent to affect pain- and suffering-reducing changes in the lives of those around (and within) us—to literally be stuck in a dysfunctional shape vis a vis the shape that is better fit to the problem space we are navigating. To feel stressed out by the collective suffering of others while unable to move the dial in a hopeful direction—I feel it daily, hourly, minutely. And that stresses me out. Which, I suppose, may be the first step. Wesley from Princess Bride may have been on to something, “No, not to the death. To the pain.” Pain and stress mean we need to change our form.

Reply

John Shearing
February 12, 2025

Greetings Jeff,
There are two kinds of stress:

1. Stress caused by fear and pain
2. Stress caused by love and desire.

The stress caused by fear and pain does not cause growth but rather causes repulsion from the perceived source of stress. You know this as the fight or flight instinct. Attention and reaction to the stress of fear must take precedence over attention to the stress of love because it gets us out of immediate danger. But this type of stress is supposed to be temporary. When danger has passed we should no longer experience this type of stress. The stress of fear will manifest as sickness, depression and despair if the state is chronic.

The stress of love and desire is an attractive force that causes growth, healing, reproduction, and cooperation in morphogenesis. This is the state we are supposed to be in most of the time if we are to be healthy, sane and develop normally.

Because we are hardwired to pay attention to danger before all else, the marketing industrial complex bombards us with images of death and suffering. So many people find themselves in a chronic state of fearful stress rather than the stress of love and growth even though wellbeing is prevalent over almost all of our planet.

This information comes to me from stem cell biologist Bruce Lipton who popularized the understanding that what the human mind perceives affects the health of the body. Lipton talked about his findings before big pharma would allow us to hear it and he was exiled from academia.

https://youtu.be/t2Hx67Lv1oY?si=9xCs-0dGNE7i0XR4

Michael Levin is courageously empowering us with more information on the topic.

https://youtu.be/0bPH2DsqgQ0?si=YODyHHfWLpRXPl56

So how can we keep our mind and emotions healthy when we are constantly being bombarded with messages which cause us to fear and suffer at the expense of our physical and mental health? Well I have learned from Abraham Hicks (video linked below) that we can maintain a constructive level of concern and service for others without suffering along with them. It turns out that with practice one can choose the most constructive thoughts and emotions regardless of the situation. Michael says that the placebo effect is almost a superpower. I think it becomes the highest of all powers when we deliberately choose what to think, how to feel, where to focus our attention, and how we perceive what we are looking at.

https://youtu.be/aQD7pzu14UU?si=2I_8sIBnAyMJBZ6x

Reply

Sam R

February 13, 2025

this is really interesting!

you've given me a lot to think about there, on top of the great article … cheers 🙂

Reply

Alex
February 12, 2025

Hi Michael,
Your writings are absolutely amazing, and I love your work. Been following it for a while now.
I had a question, as a lot of your work is at the absolute edge of what we know at the moment, particularly about health solutions.
Is there a good summary that you have and the work that you are doing at how it is currently looking in terms of boiling down into solutions for people's health issues?
Would help a lot in terms of trying to see the vision on where this all might be leading.
Cheers,
Alex

Reply

Mike Levin
February 12, 2025

thanks; for example: https://onlinelibrary.wiley.com/doi/10.1002/bies.202400196

Reply

Alex
February 13, 2025

Thanks for this. I will have a read through it.

The field of medicine is definitely in need for these types of change, and currently reading “The Body Electric” by Becker. Too often ideas just fall over in the medical space at the last hurdle (Clinical trials etc.).

Are you actively working to bring some of these concepts “to the clinic” so to speak? Or more on the research and then passing through from there?

Reply

Mike Levin
February 14, 2025

Absolutely — there are two companies that are working to take our on-going discoveries on bioelectric organ regeneration, aging, cellular learning, patient-specific healing biobots, etc. toward clinic.

Reply

Sam R
February 13, 2025

This is really fantastic stuff, thank you Michael 🙂

On a non technical tangent, I’ve been experimenting with combinations of “somatic” type therapies … eg. vipassana/breathwork/cold-bath etc. (some hippies might call “energy work”)

What never ceases to amaze me is how these practices leave me feeling like my whole body “reorganized” itself. After reading this, I wonder if something about them is stressful, but in just the right way that it acts as a catalyst where everything is more free to move toward its desired configuration (I always imagined it “exciting” the body out of a local minimum) acting as a “global coupling agent” where now separate parts are all suddenly coordinating

Even my thoughts, which before would feel frustrated/fragmented/forced … will just relax into place (it reminds me of the saying “solve et coagula”), so some analog of this must be happening cognitively as well. This really feels connected to chronic stress, the way it gets really “entrenched” into complexes which eventually just become disease

If you have a second, I gotta know because it's been on my mind so much lately … I've noticed that for any somatic practice I do to "heal" various chronic ailments, *mindfulness* seems to be a critical ingredient (eg. feel the pain, presence of awareness, attention to every detail of bodily sensation) … what is your view on the role of consciousness itself in morphogenesis? Because there seems to be a connection when you talk about agents, bioelectric control, etc. To me, pain (by virtue of being a felt experience in consciousness), always carried with it a kind of moral imperative or "plea" from my body to do something … even if often I don't know what it could possibly want from a fool like me, the fact "I" am conscious of it means "I" am precisely the thing being addressed by the pain (if that makes any sense) … maybe this "self" is related to the high level control / user interface analogy

If you had any links/references that go into that kindof thing at all, that would be amazing 🙂

Reply

Mike Levin
February 13, 2025

interesting. Here's my talk on consciousness https://youtu.be/HUto7zvCXqc?si=EYbluiHQJ8x58whm, although it doesn't address what you're talking about (but it's relevant)

Reply

Micah Zoltu
February 15, 2025

Do you have control over the inability to select text on this blog? It is frustrating that I cannot select anything easily when viewing the blog. I can work around it, but it is annoying none the less and if selection blocking is just a setting somewhere it would be nice if it could be disabled.

Reply

Mike Levin
February 15, 2025

hmm what's the use case — why do visitors select text?

Reply

Micah Zoltu
February 15, 2025

The primary reason I do it is to keep my place while reading when interrupted. I also find highlighting text as I read to be a useful tool in maintaining focus. It also speeds up reading pace as it makes it easy to keep track of which line you are on when you reach the end of previous line.

And of course, the thing it text selection was originally built for which is to copy/paste quotes when sharing an exert with others. This is the least relevant though because it is rare compared to the other uses and easy enough to hack around when I need it.

Reply

Mike Levin
February 15, 2025

hmm I see. I think it's turned off to make it slightly harder for people to just select/copy large tracts of text and use it verbatim elsewhere (obviously still possible to do if someone is determined). Also I think it's the same setting as for images (right-click to save images).

Reply

Micah Zoltu
February 15, 2025

In my experience, the people who are copy/pasting websites generally are doing it en masse and they don't use a web browser to do it, it is all automated and just looking at raw HTML over HTTP. Same thing for people who are stealing images I suspect, they are looking at the raw HTML. Blocking right-click and copy only stops the most lazy plagarists, who is unlikely to do anything particularly bad with their plagarism because they are too lazy to make anything big from it anyway.

This is one of those defenses that I am pretty sure does more harm to honest parties than it does to stop dishonest parties.

Reply

Benjamin L
February 15, 2025

Copying and pasting text—for commenting, sharing, etc. There's a reader mode in Firefox that lets you copy and paste, but it'd be nice to save a click.

Reply

Micah Zoltu
February 15, 2025

Yeah, in Firefox it is literally one click to get around the block. I should probably just read everything in reader mode, this page in particular renders quite well in it.

Reply

gstroke
February 18, 2025

As I was reading about the part regarding embryogenesis, I had the intuitive impression that the way in which cells are able to contain and act out the body plan even whilst separated from each other by dissection or otherwise seems oddly similar to the various "rhythm is pitch" and "musical fractal" phenomena as described by this video:

https://www.youtube.com/watch?v=mq0z-sxjNlo&ab_channel=AdamNeely

If we are to apply your fourfold spaces model to the analogy (physiological, anatomical spaces etc), do you think "memory" could be a situation where the body learns to preserve the "song" by re-routing to the appropriate problem spaces each time the environment presents a challenge to it? Each time it overcomes such a challenge, it could set up mechanisms to prevent having to spend as much energy as it originally had. Recall, then, could be the reactivation of those mechanisms, which now serve to perpetuate the song (as there are more than one way to reach one "note", if that makes sense) and to minimize external threats of the same kind. Of course this wouldn't be a perfect replication of the original stimulus and would likely change the said structure as well, which could explain why and how memory is altered.

Reply

Mike Levin
February 18, 2025

Interesting indeed. Could be relevant to Richard Watson's work on songs of form and cognition.

Reply

James Buchanan
February 18, 2025

Just a stray thought. You draw parallels between brain and body very convincingly. I haven't heard you mention attention in that context. Is there an analog?

Do you imagine a salamander body says "oh crap, my right forelimb is gone, I better focus!"

Reply

Mike Levin
February 18, 2025

I don't have a great way to measure or control it, so I've gone lightly on that one but there are situations in which cells have to decide which of competing stimuli to pay attention to.

Reply

James
February 18, 2025

A little dark, but cutting off the other forelimb at various points in the redevelopment of the first would shed light, no?

Reply

Tony Budding
March 6, 2025

Hey Mike, have you seen any patterns or trends with cells deciding among competing stimuli? All else equal, I'd assume the greater discrepancy between stimulus and setpoint/expectation would get the attention. I'd also assume that all else is rarely equal. Curious what you've been able to glean thus far...

Reply

Mike Levin
March 6, 2025

Yep. David Kaplan and I gave cells a chemical signal to differentiate, but a bioelectrical signal to stay stem — to see which would dominate. They went with the bioelectrical one. There are a lot of experiments like that but most are not quantitative enough to quantify strength of discrepancy — it's hard to do it in different strengths.

Reply

Micah Zoltu
March 7, 2025

Are more details about this available anywhere? I am very interested in gaining a deeper understanding of what leads to differentiation, and I have been wondering for a while now how much is chemical and how much is bioelectric.

Reply

Mike Levin
March 7, 2025

Yes — look at the papers with David Kaplan at https://drmichaellevin.org/publications/ , but much more needs to be done on this in mammalian cells. In frog and planarian cells, all of our papers showing morphological outcomes from bioelectric change basically demonstrate bioelectrics -> 2nd messenger cascades -> differentiation.

Reply

Tony Budding
March 7, 2025

Interesting. Did you ever try the reverse, where the bioelectrical signal was to differentiate? I could imagine a call to differentiate requiring greater stimulus than maintaining stasis. Or perhaps the bioelectrical signal is simply preferred either way.

Reply

Mike Levin
March 7, 2025

Interesting question. I don't recall! I'll have to go back and look, it was a while ago.

Reply

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