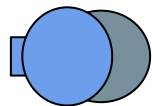
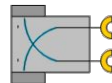


Observer-dependent Models



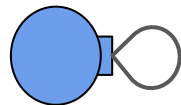
Morphogenetic Agent
(Inky)



Braitenberg
(Pinky)

Vehicle

Starring



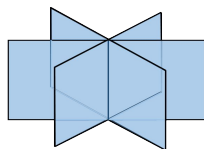
Morphogenetic Agent
with a Visual
Envelope (Blinky)



Genotype-to-Phenotype
Agent (Clyde)

Obscure Reference: [https://en.wikipedia.org/wiki/Ghosts_\(Pac-Man\)](https://en.wikipedia.org/wiki/Ghosts_(Pac-Man))

Bradly Alicea



Orthogonal Research and
Education Laboratory



“The observer registers decisions, which produces a registration (transition from the possible to the actual) is absolutely necessary and cannot be omitted”

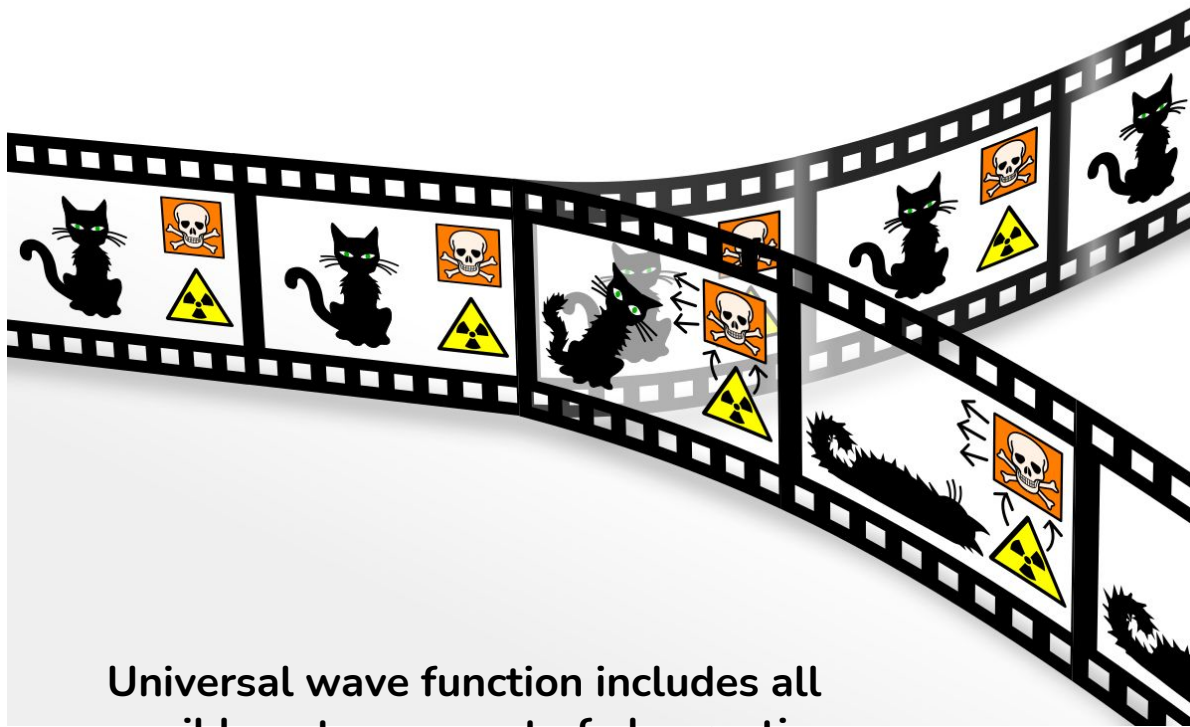
Paraphrase from Werner Heisenberg, Physicist

“The observer registers decisions, which produces a registration (transition from the possible to the actual) is absolutely necessary and cannot be omitted”

Paraphrase from Werner Heisenberg, Physicist



“Many Worlds” Quantum Theory



Universal wave function includes all possible outcomes, act of observation makes one of these outcomes distinct



The Many Hugh Everett Worlds

“The observer registers decisions, which produces a registration (transition from the possible to the actual) is absolutely necessary and cannot be omitted”

Paraphrase from Werner Heisenberg, Physicist

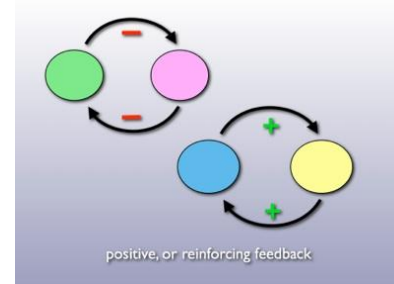
Second-order cybernetics focuses on the role of the observer (as agent), and the Every Good Regulator Theorem (EGRT) requires an observer to access the full scope of a system's variety.

“The observer registers decisions, which produces a registration (transition from the possible to the actual) is absolutely necessary and cannot be omitted”

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Second-order cybernetics focuses on the role of the observer (as agent), and the Every Good Regulator Theorem (EGRT) requires an observer to access the full scope of a system's variety.

Kirschfeld (1976). The Resolution of Lens and Compound Eyes. *Neural Principles in Vision*, 354-370.



Every Good Regulator Theorem

"Every good regulator of a system must be a model of that system"
Conant and Ashby, 1970.

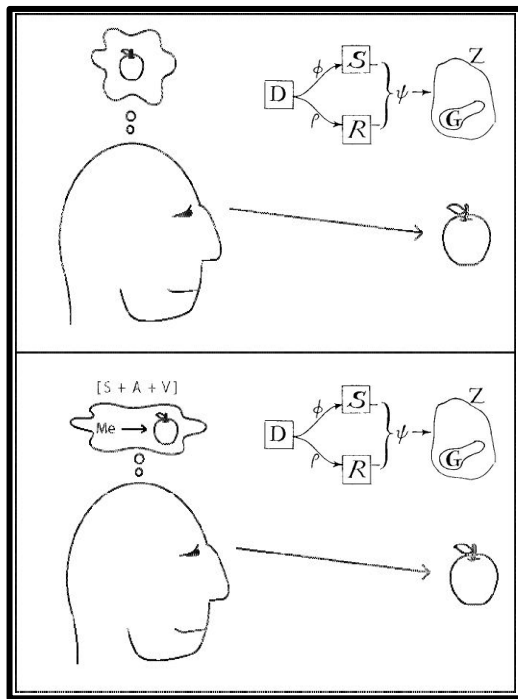
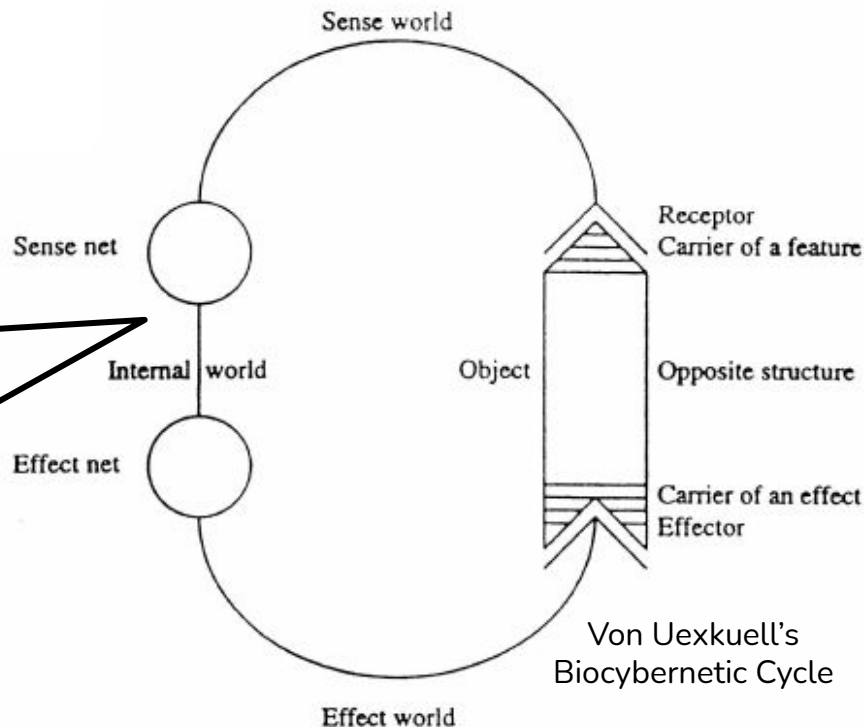


IMAGE: Graziano and Webb, The attention schema theory: a mechanistic account of subjective awareness. *Frontiers in Psychology* (2015).



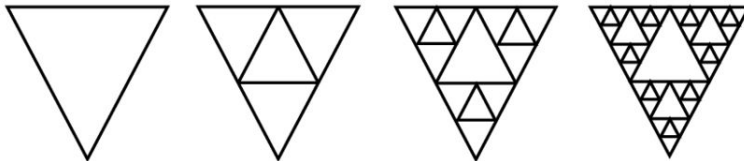
“The observer registers decisions, which produces a registration (transition from the possible to the actual) is absolutely necessary and cannot be omitted”

Paraphrase from Werner Heisenberg, Physicist

Second-order cybernetics focuses on the role of the observer (as agent), and the Every Good Regulator Theorem (EGRT) requires an observer to access the full scope of a system's variety.

Self-similarity: persistence of a pattern across scales.

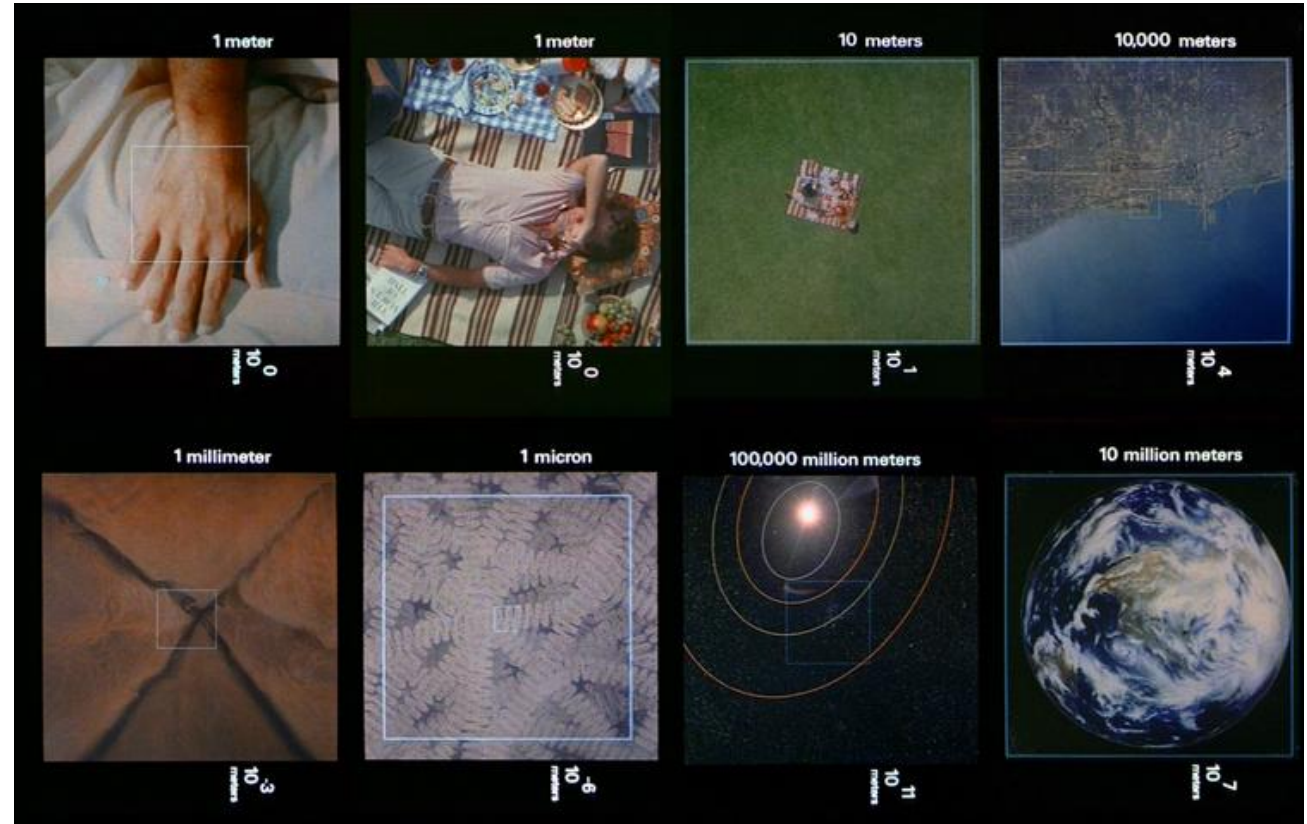
Example: Barnsley fern (right), triangle fractals (bottom).



Conceptual Integration Between Scales

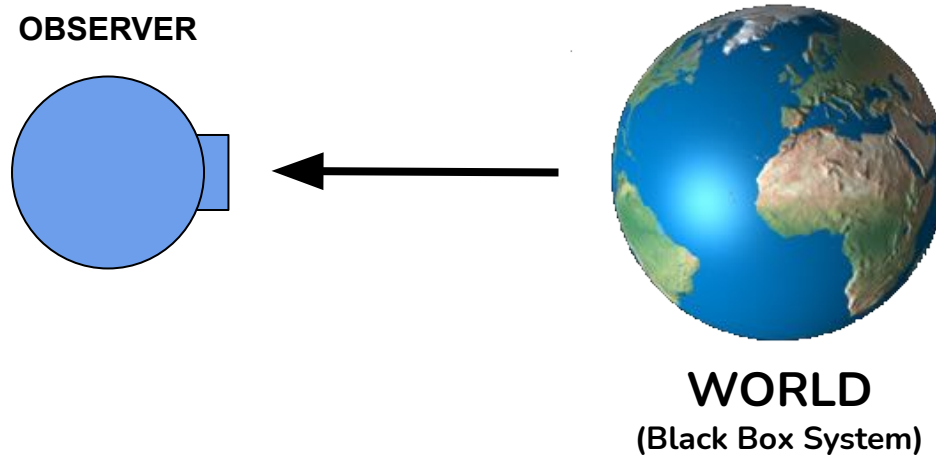
Powers of 10

COURTESY: Eames Office
<https://www.youtube.com/watch?v=0fKBhvDjuy0>



How does a single observer acquire an object?

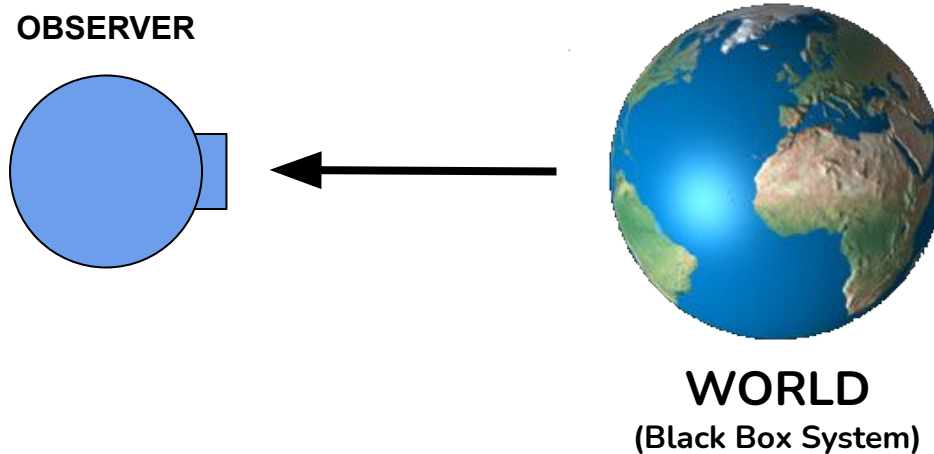
What information is contained in the world¹?



¹ Fields, C. (2016). Building the Observer into the System: toward a realistic description of human interaction with the world. *Systems*, 4, 32.

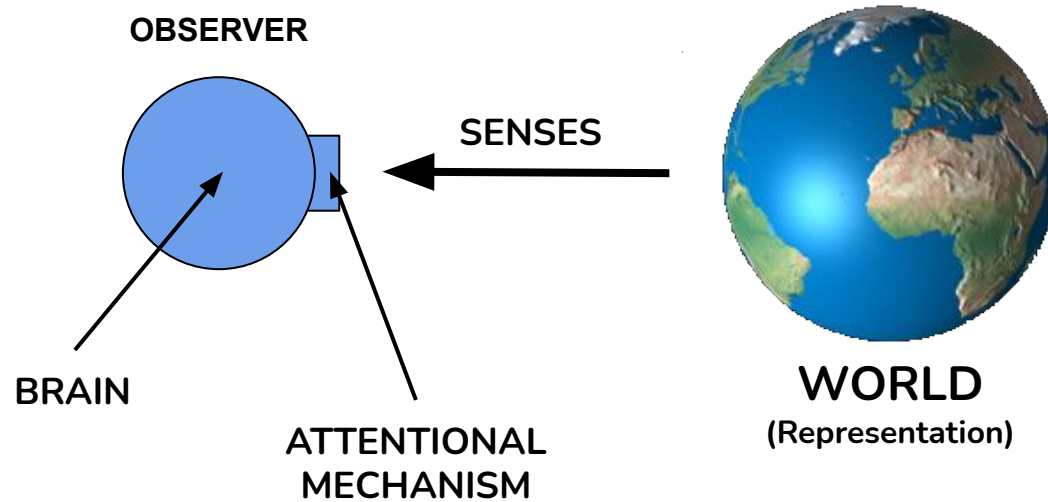
Black Boxes: unknown system.

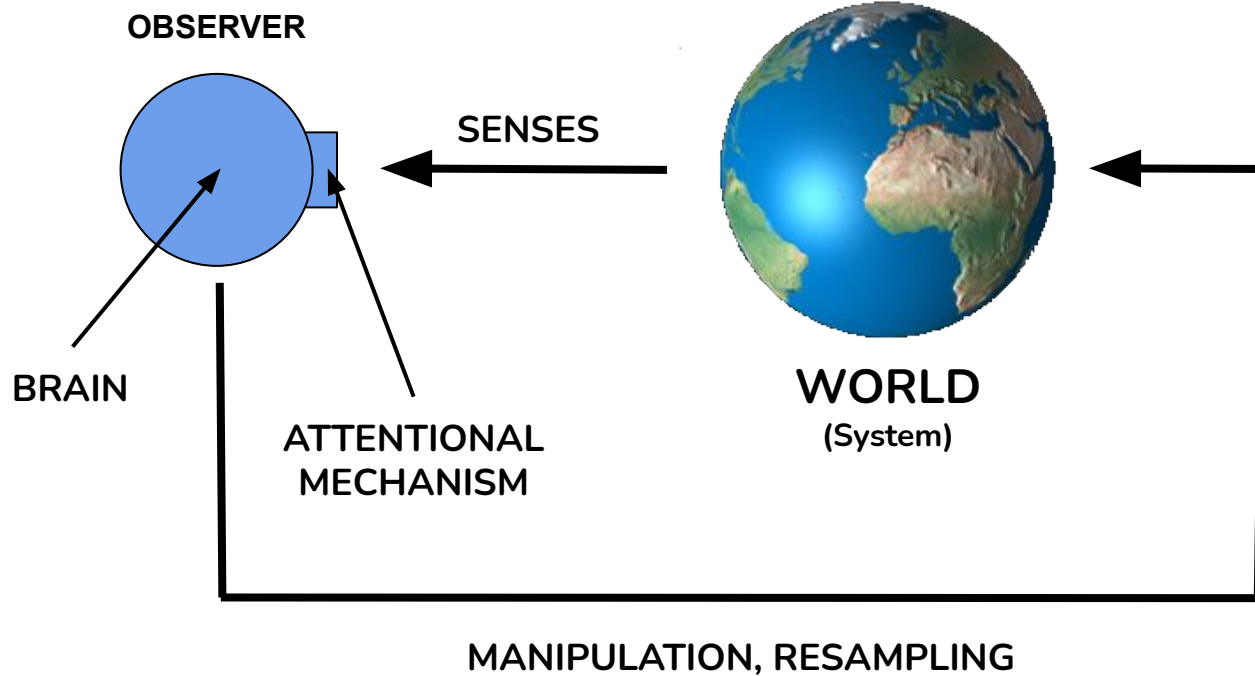
White boxes: inferring the composition of black boxes².



² Glanville, R. (1982). Inside every white box there are two black boxes trying to get out. *Behavioral Science*, 27.

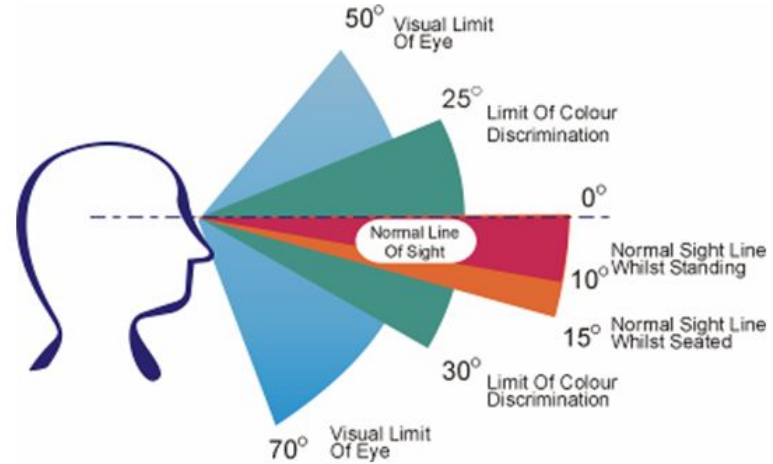
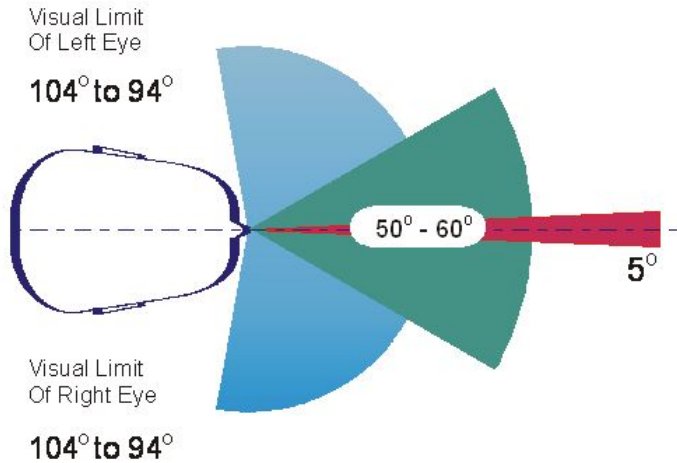
World as a representation of a system, observer (agent) as a heterogeneous embodied nervous system.





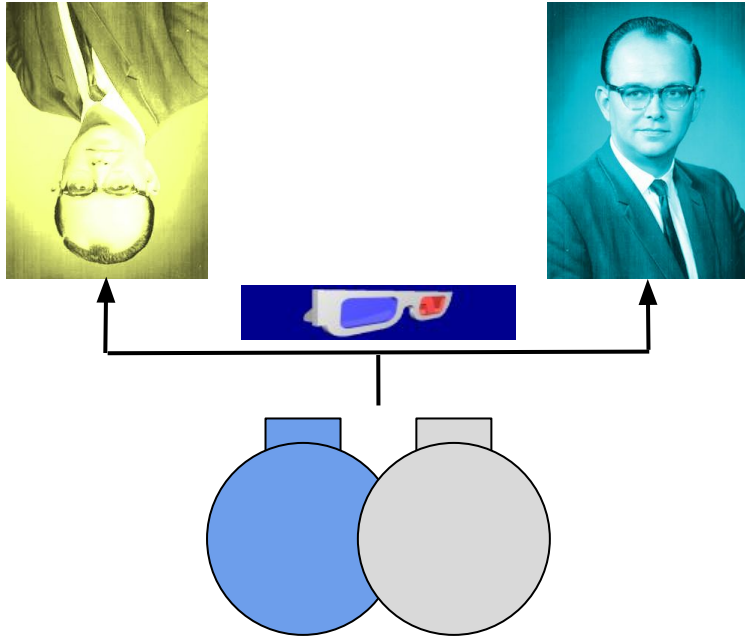
Observing the world as a white box (or series of black boxes). Need feedback to ensure a veridical representation. Feedback provides a sense of embodiment, but the senses are still a bottleneck.

Observer Embodiment

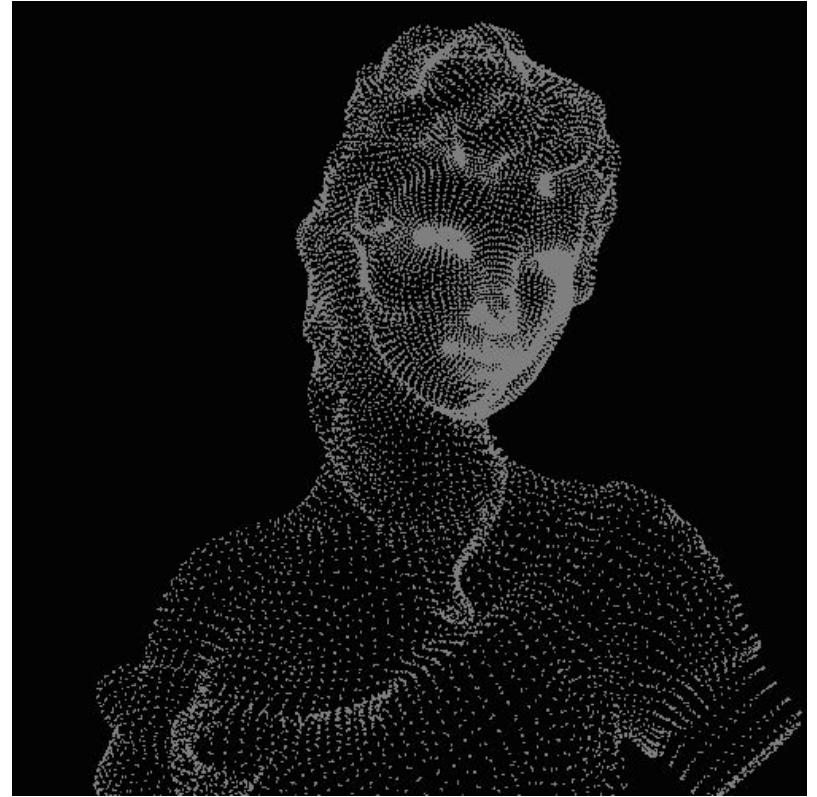


Example of the visual envelope in humans. Eye physiology and anatomy constrain information intake, which shape internal representation.

Multistable Perception

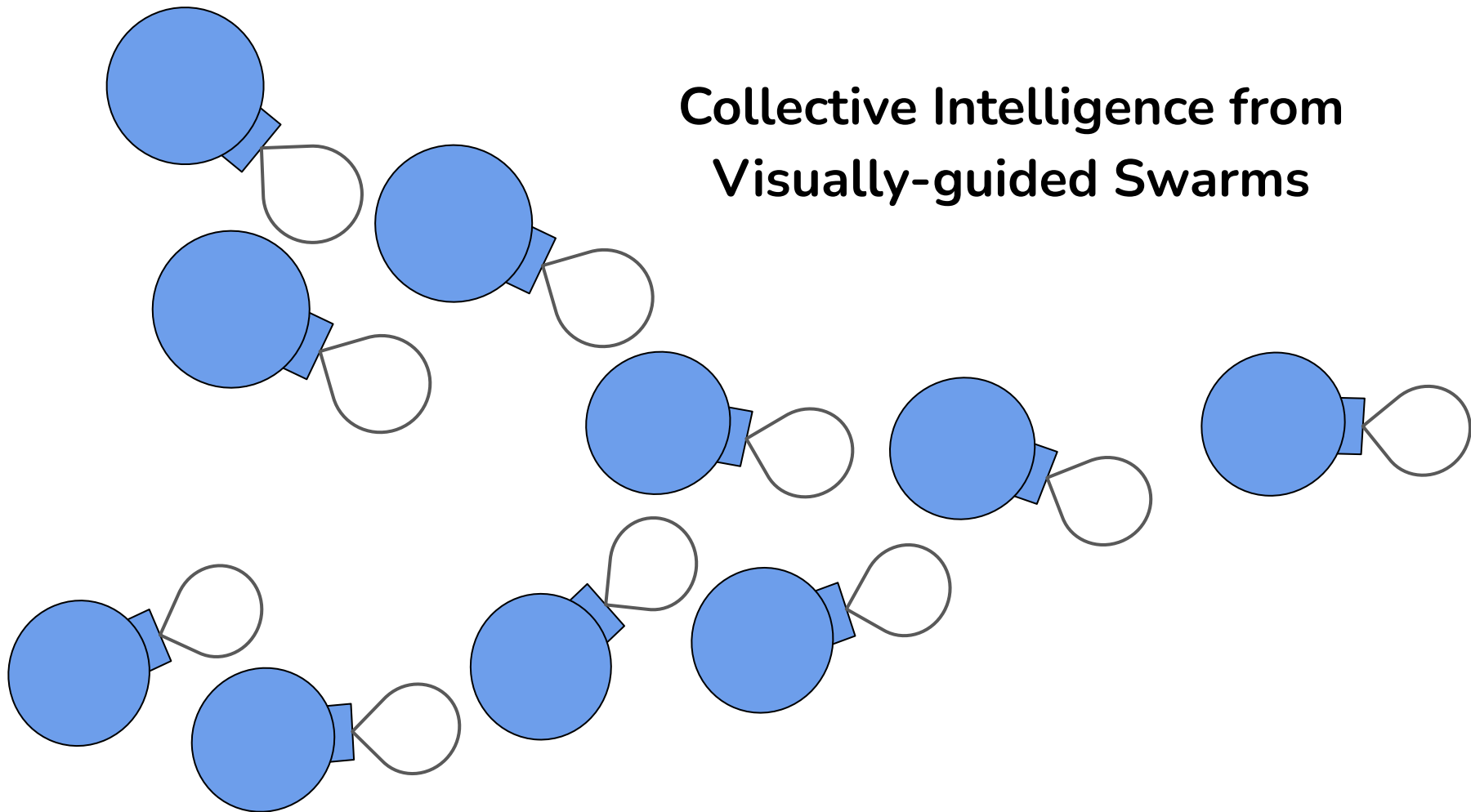


Loose connection in the literature between bistable perception and binocular rivalry.



COURTESY: Icedtorch on Imgur

Collective Intelligence from Visually-guided Swarms



Movement parameters are controlled by visual cues, produce many modes of collective motion (population of agents).

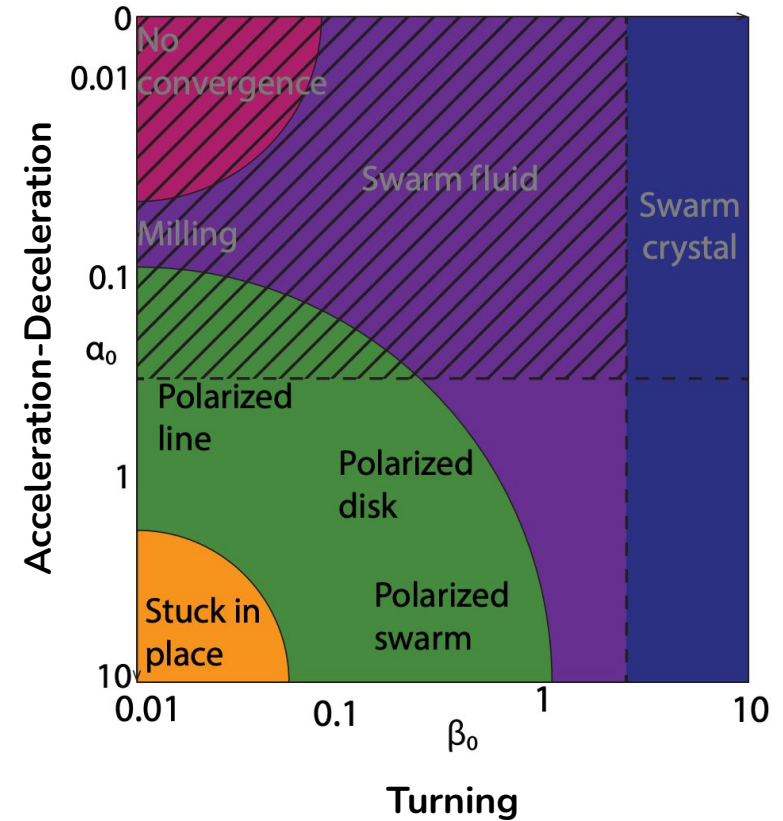


Figure 4 in Bastien, R. and Romanczuk, P. (2020). A model of collective behavior based purely on vision. *Science Advances*, 6, eaay0792.

Movement parameters are controlled by visual cues, produce many modes of collective motion (population of agents).

Ankit Gupta
Dynamic demos of Braitenberg Vehicle collectives.
Figshare, doi:10.6084/m9.figshare.11906847

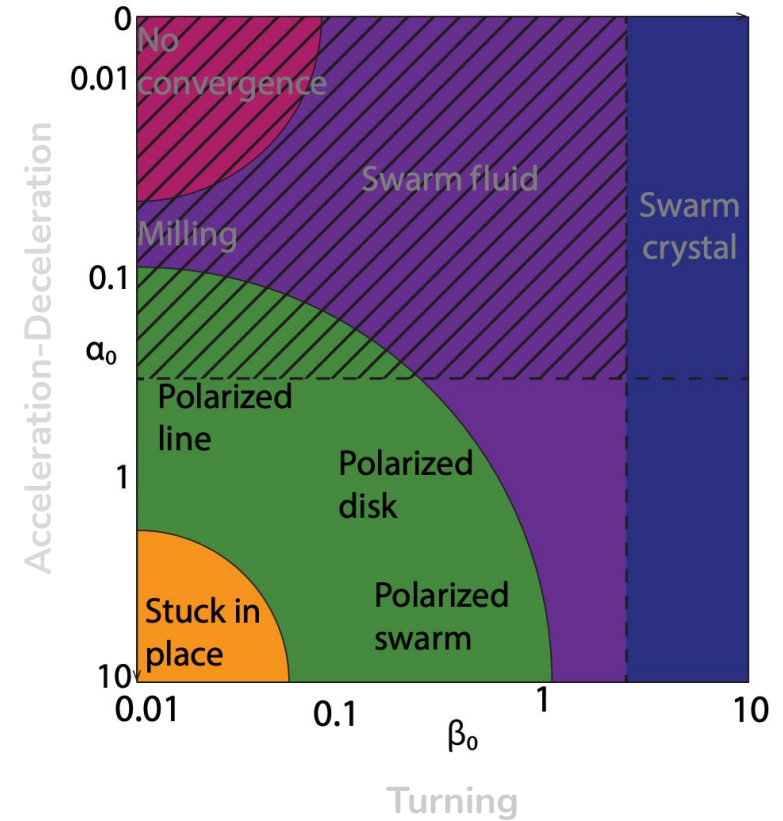
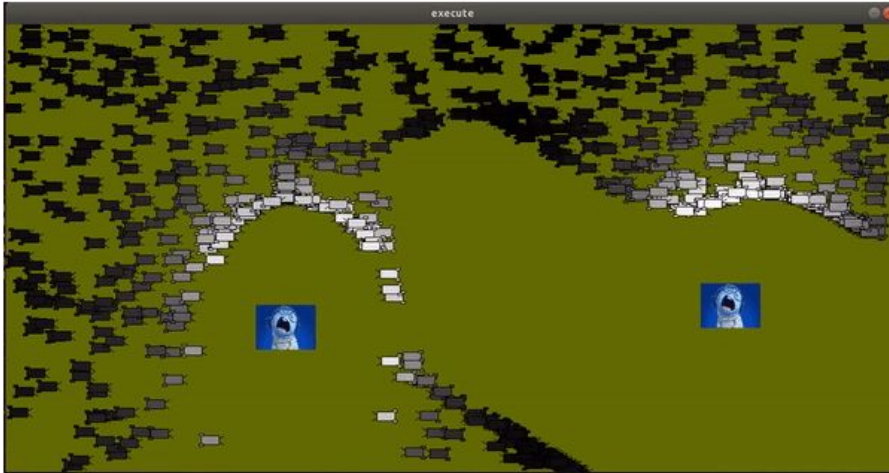
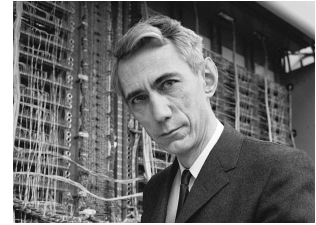
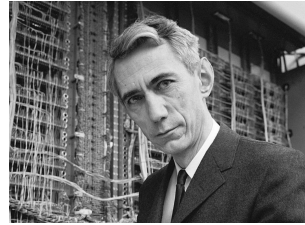
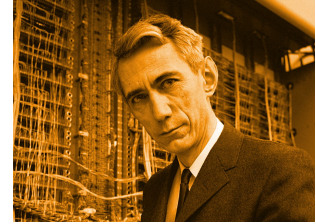
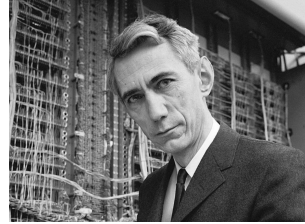
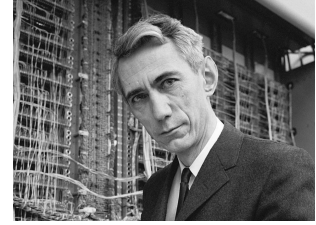
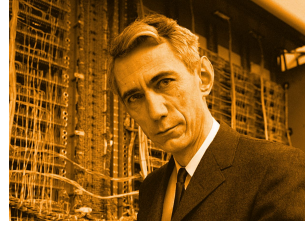
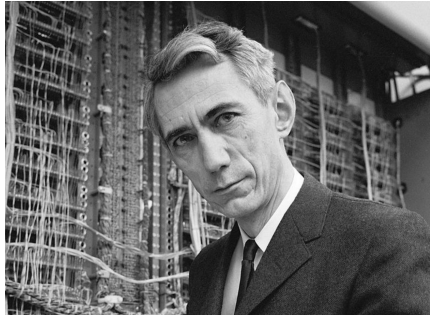


Figure 4 in Bastien, R. and Romanczuk, P. (2020). A model of collective behavior based purely on vision. *Science Advances*, 6, eaay0792.

Shannon Information



Variety provides information!

Probability of one state in a set of states, structure versus randomness

Gibsonian Information



Motion provides information!

Optical flow, relative motion between object and observer, structure from motion

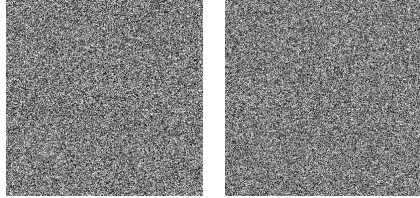
Observer Embodiment



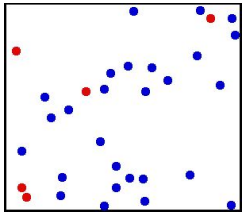
Direct multisensory perception (visual, proprioceptive) in addition to motion information.

Observer experience determines richness and detail of the internal representation.

Gibsonian Information and the Observer



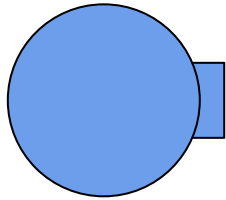
Disjoint distributions (top), contingent action (center), and coherent movement (bottom).



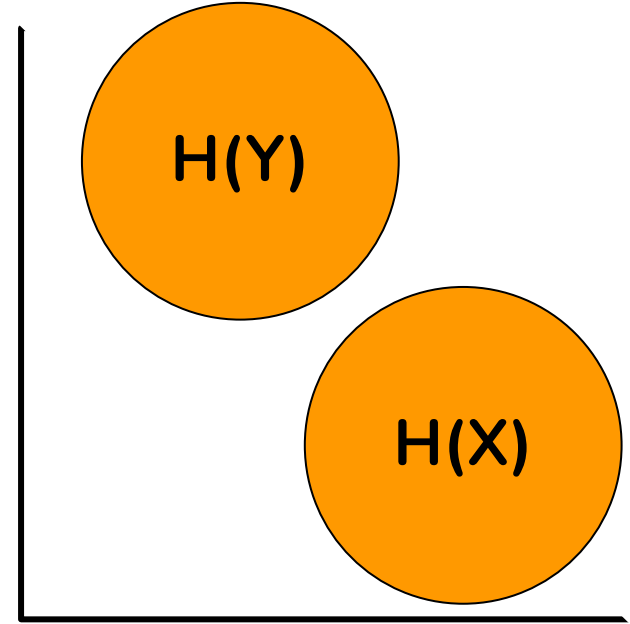
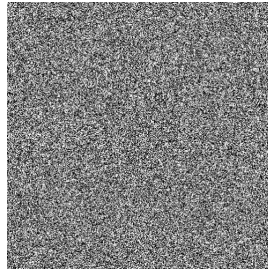
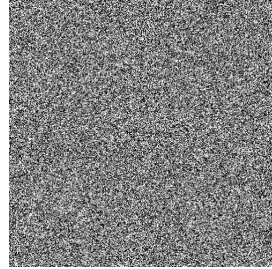
Each measurement gives us a quantitative approximation of motion information relative to stasis.

Gibsonian Information and the Observer

Disjoint distribution



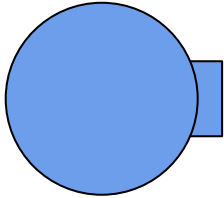
Gibsonian Information
 $G = H(X) - H(Y)$



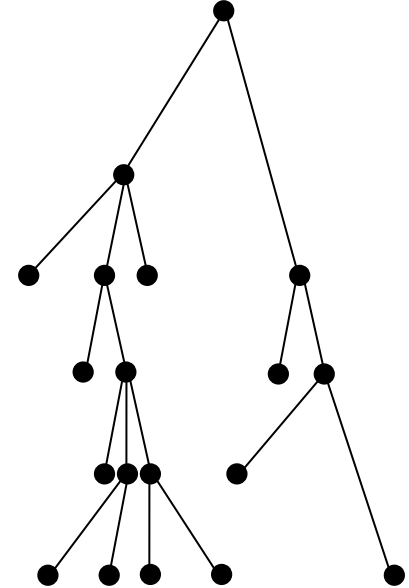
Shannon Information
 $H(X,Y) = 0$

Gibsonian Information and the Observer

Contingent Action

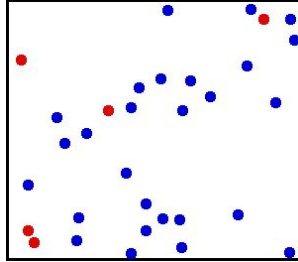
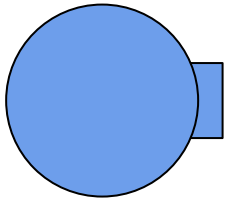


Each node has information is
the previous node (frame of
action) is consistent

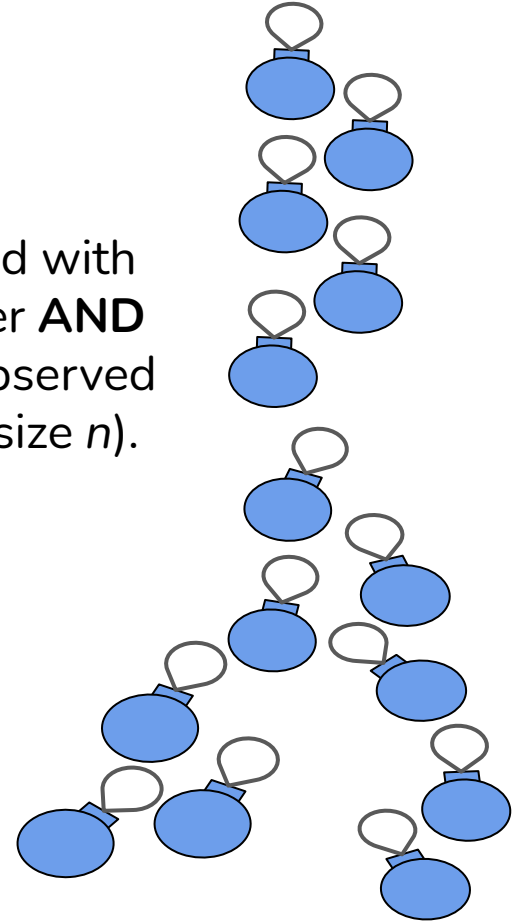


Gibsonian Information and the Observer

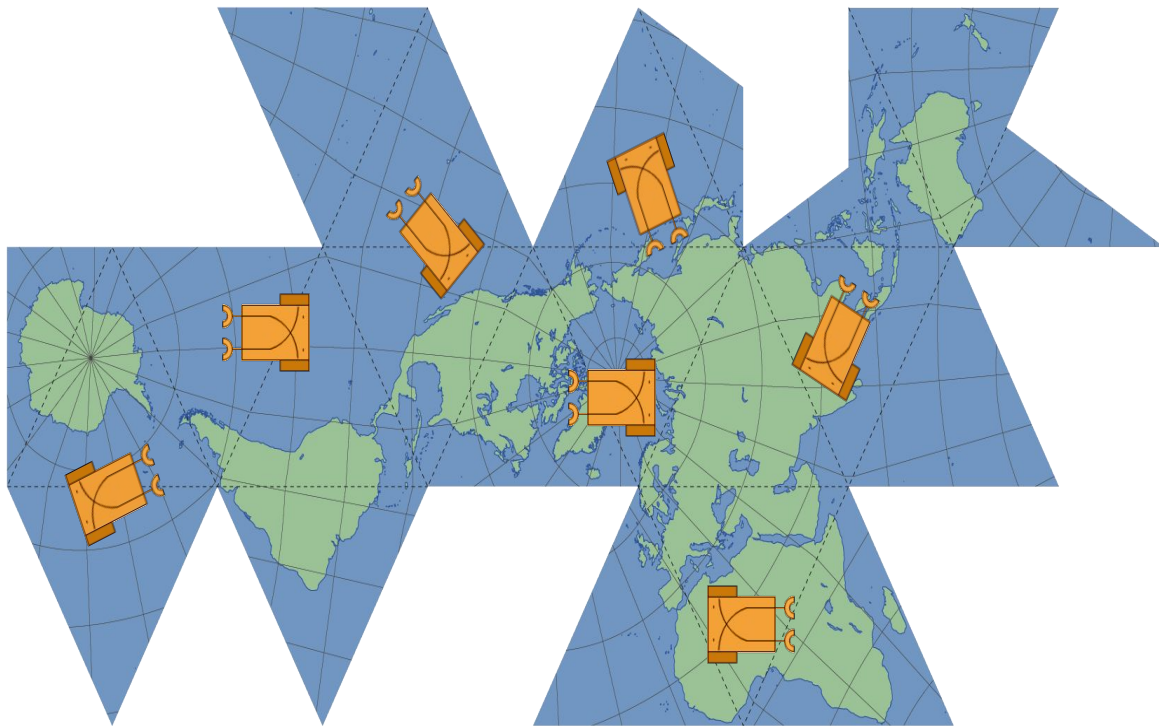
Coherent Movement



Previous heading is aligned with current heading of observer **AND** mean current heading of observed neighbors (neighborhood size n).



Touch and Multisensory Observations

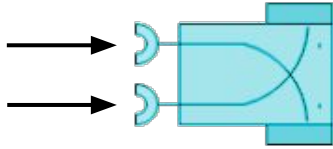


Our examples of Gibsonian Information have been limited by vision.

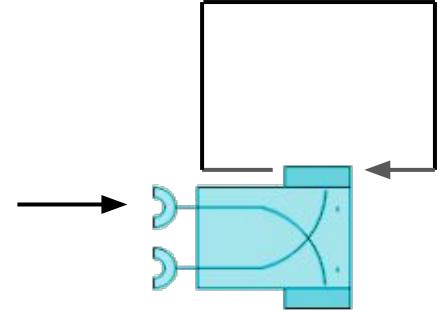
- in an embodied agent, we can also measure other sensory modalities such as touch.
- multimodel combinations of information, such as touch + vision.

Braitenberg Vehicles exploring a Dymaxion Map of Earth.

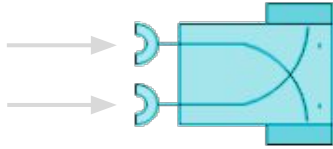
Touch and Multisensory Observations



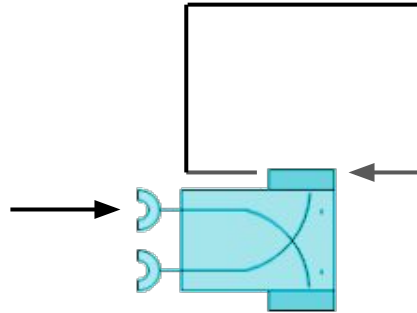
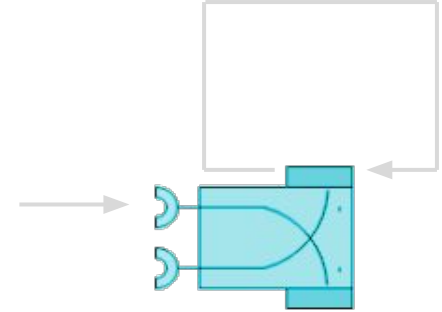
Braitenberg Vehicle with only light (visual) input, or visual + displacement (touch) input.



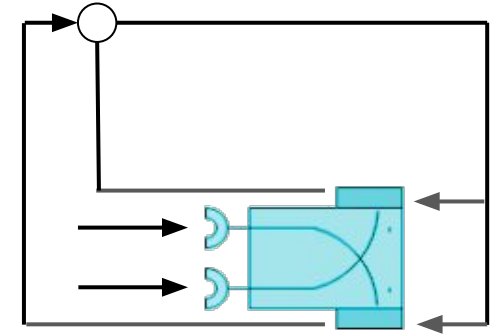
Touch and Multisensory Observations



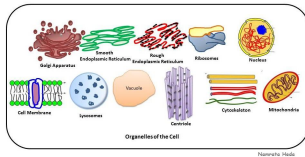
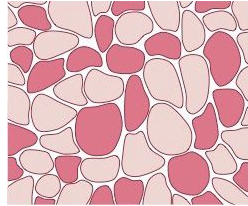
Braitenberg Vehicle with only light (visual) input, or visual + displacement (touch) input.



Braitenberg Vehicle touch (displacement) and vision (light) inputs serving to determine future positional (location) states.



Genotype-to-Phenotype Mapping



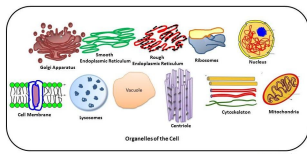
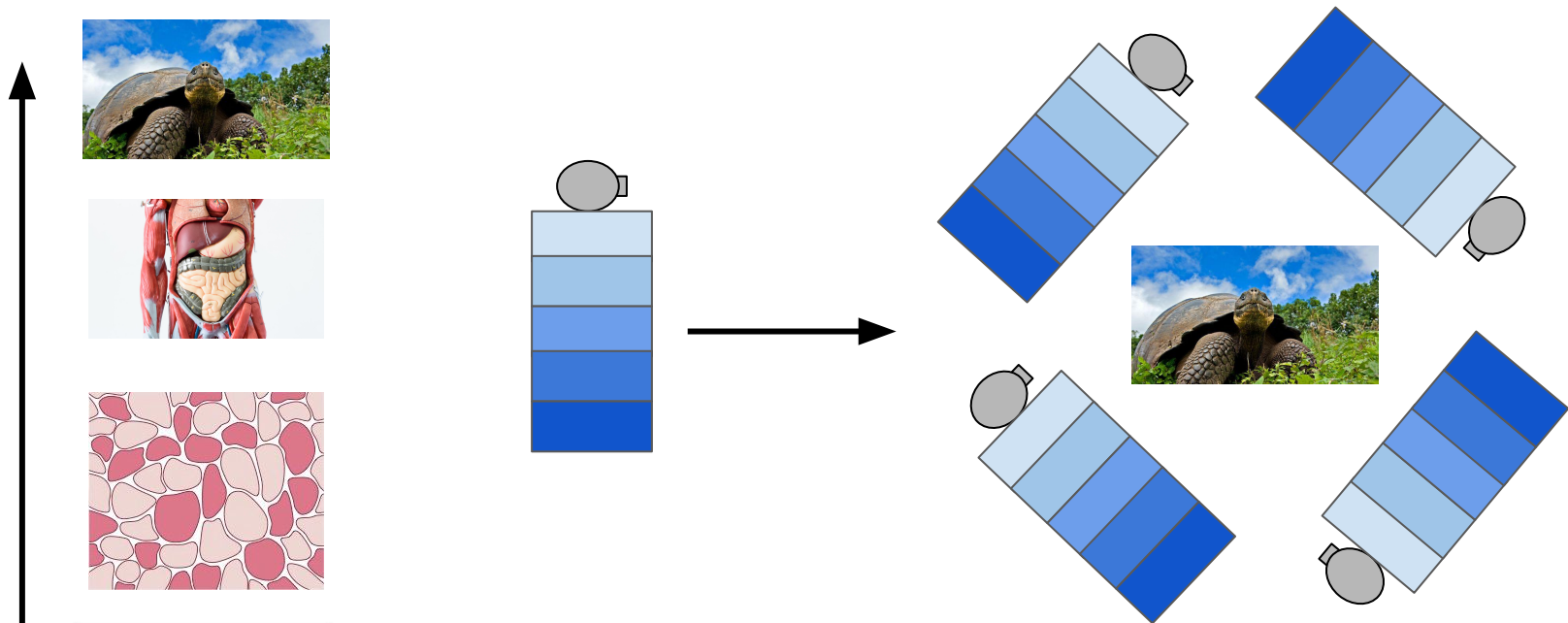
From “toy” embodiment to biologically-relevant?

If agent possesses analogues to a brain and perceptual system, then they must also possess a genotype-to-phenotype (G-to-P) mapping.

In biology: principle of vertical organization (organisms build complexity from genomes to organisms).

Agents should include these features into a representation of embodied action as well.

Genotype-to-Phenotype Mapping



Alicea, B., Parent, J., and Singh, U. (2020). Observer-dependent Collective Behavior For Biologically-inspired Processing Models. OpenReview.net: <https://openreview.net/forum?id=FiwgkEEemXOq>

Representational Biology of Intersubjectivity

G-to-P mapping in embodied agents allow us to build a representational biology of intersubjectivity.

Intersubjectivity: agent capable of “full and equivalent observation³” of what all other agents observe and know. Population of agents, each agent knowing a component of x , with mutual information H .

- population of agents can share genotypes (or variants of the same descendent).
- Innate ability to share perspectives on knowledge gained from different perspectives (viewpoints).
- Shared knowledge is a white box (agent share perspectives, shared processing, but do not possess individual experience).

³ Fuchs, T. and De Jaegher, H. (2009). Enactive intersubjectivity: Participatory sense-making and mutual incorporation. *Phenomenology and Cognitive Science*, 8, 465–486.

Representational Biology of Intersubjectivity

Creating intersubjective (shared) experience: how are different sensed perspectives able to be communicated⁴ (between agents).

Integrating individual behavior with collective (social) behavior allows us to move from second- to third-order cybernetics⁵.

Multi-view Learning⁶: using multiple feature sets to learn from empirical world.

⁴ Reich, W. (2010). Three Problems of Intersubjectivity—And One Solution. *Sociological Theory*, 28(1), 40-63.

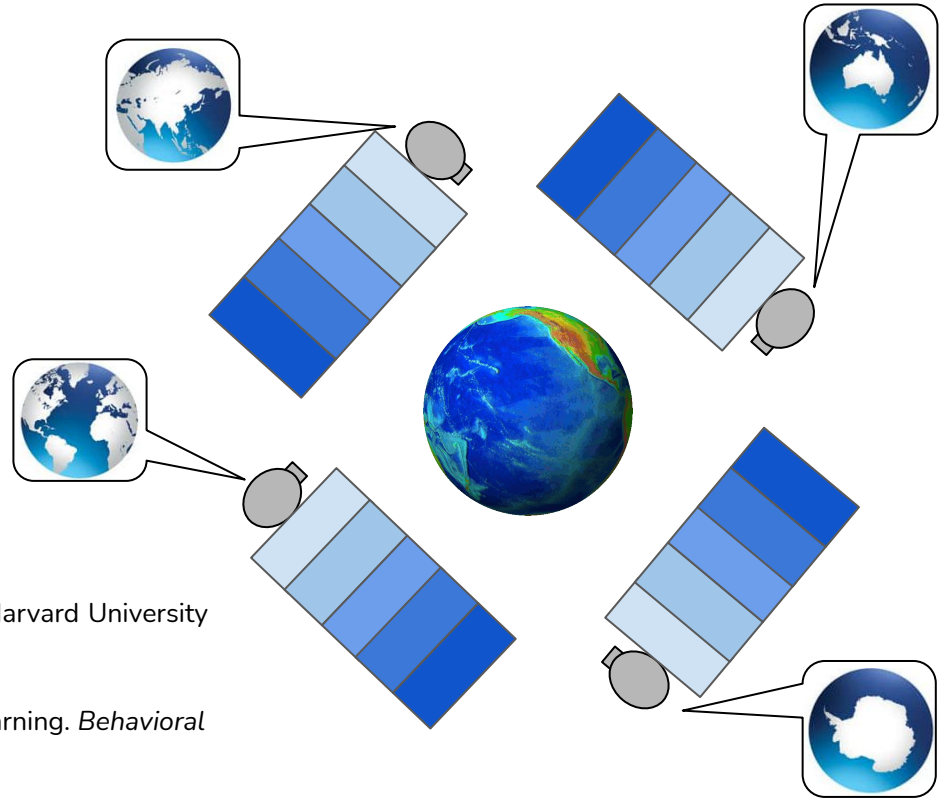
⁵ Gustavo Mancilla, R. (2011). Introduction to Sociocybernetics (Part 1): Third Order Cybernetics and a Basic Framework for Society. *Journal of Sociocybernetics*, 9, 35-56.

⁶ Zhao, J., Xie, X., Xu, X., and Sun, S. (2017). Multi-view learning overview: recent progress and new challenges. *Information Fusion*, 38, 43-54.

Representational Biology of Intersubjectivity

Consensus through argumentation theory⁷:

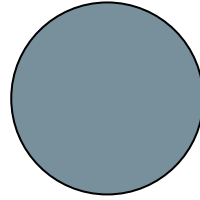
- interchange of information.
- coordinated perspective-taking⁸.



⁷ Mercier, H. and Sperber, D. (2017). *The Enigma of Reason*. Harvard University Press.

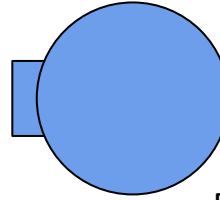
⁸ Tomasello, M., Kruger, A., and Ratner, H. (1993). Cultural Learning. *Behavioral and Brain Sciences*, 16(3), 495-511.

EMITTER



Produces pattern
(morphogenesis)

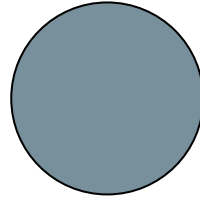
OBSERVER



Reconstructs pattern
(perception)

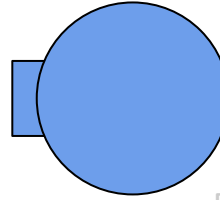
What is the relationship between morphogenesis and perception?

EMITTER



Produces pattern
(morphogenesis)

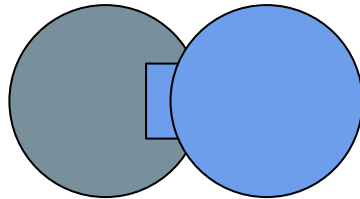
OBSERVER



Reconstructs pattern
(perception)

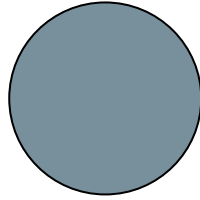
What is the relationship between morphogenesis and perception?

Morphogenesis



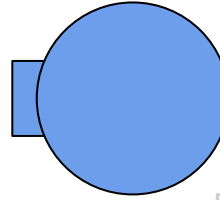
Perception

EMITTER



Produces pattern
(morphogenesis)

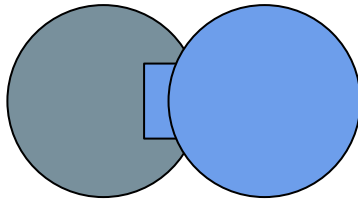
OBSERVER



Reconstructs pattern
(perception)

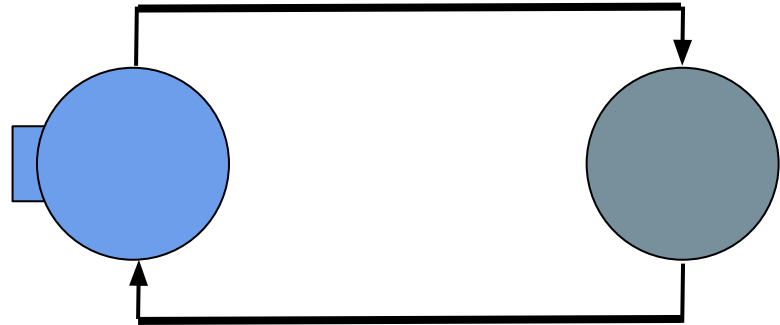
What is the relationship between morphogenesis and perception?

Morphogenesis

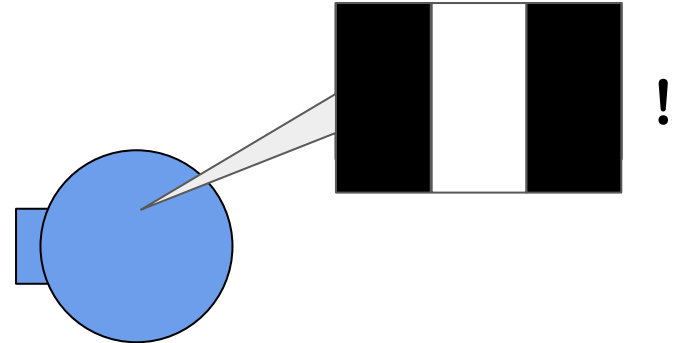
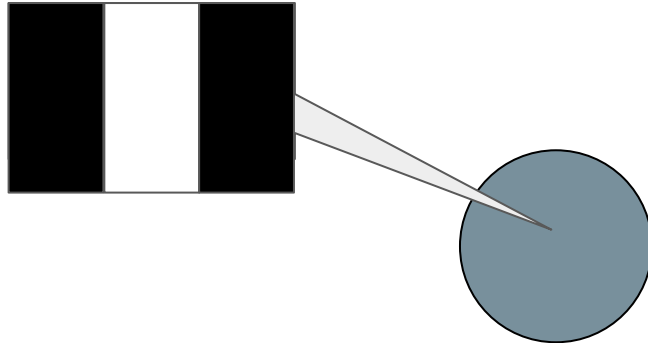
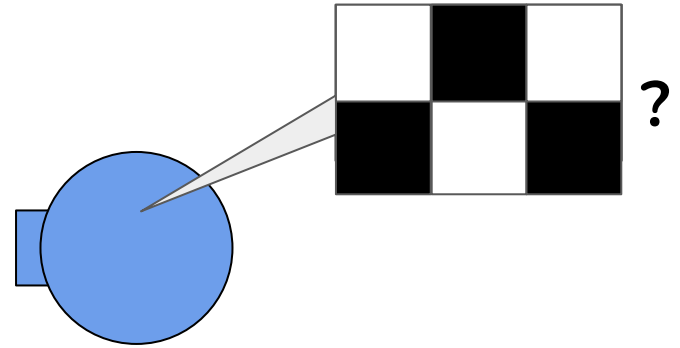
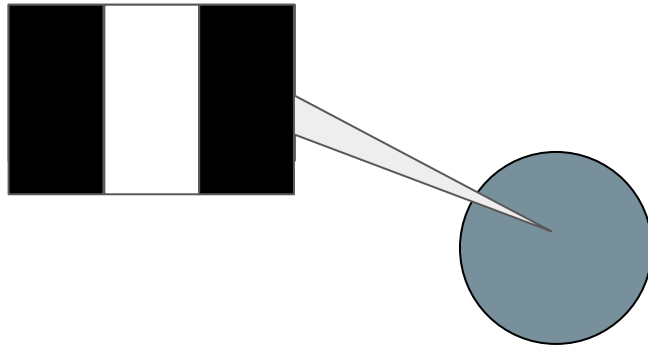


Perception

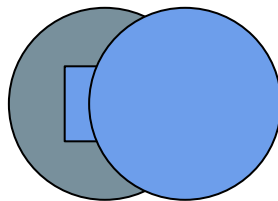
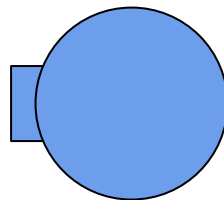
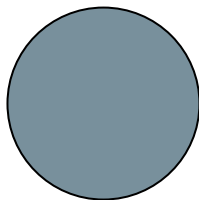
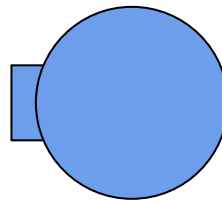
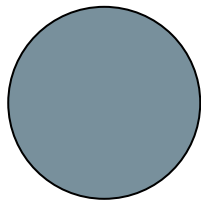
Link between spatially-restricted shapes
and attentional mechanisms.



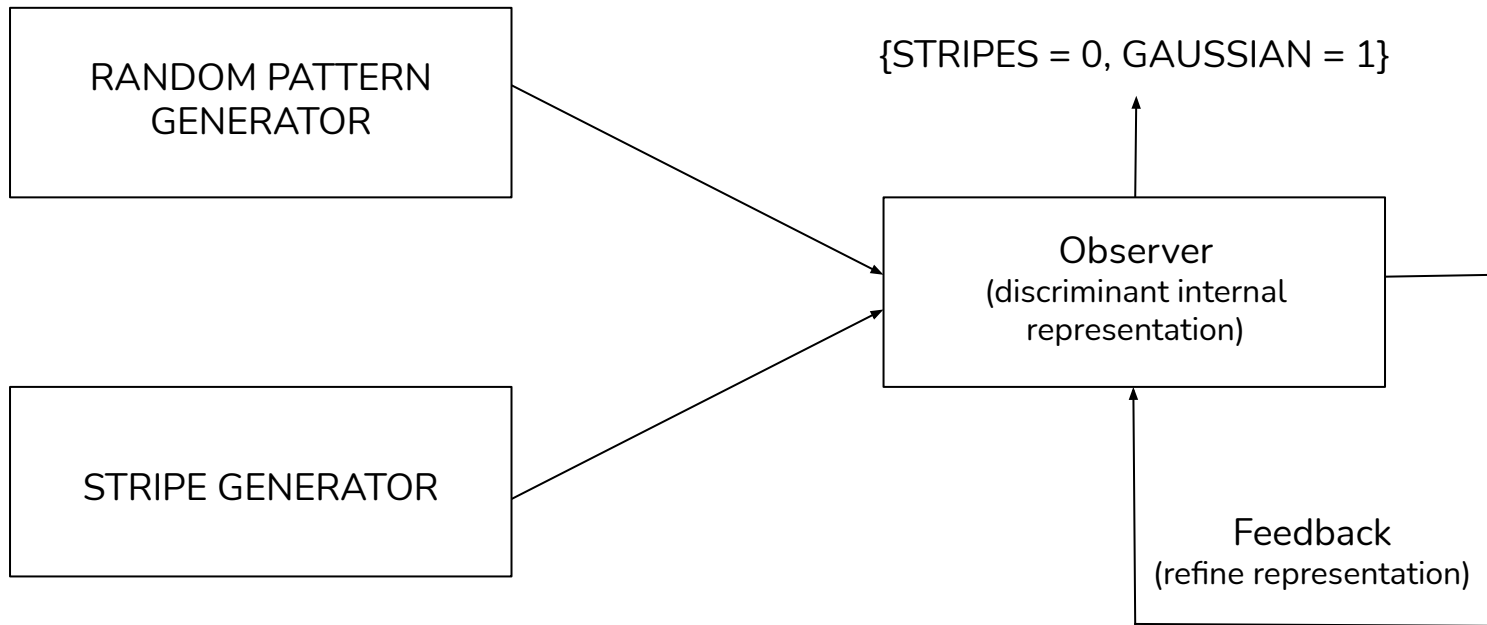
Pattern recognition between emitter (pattern generator) and observer (pattern recognizer)



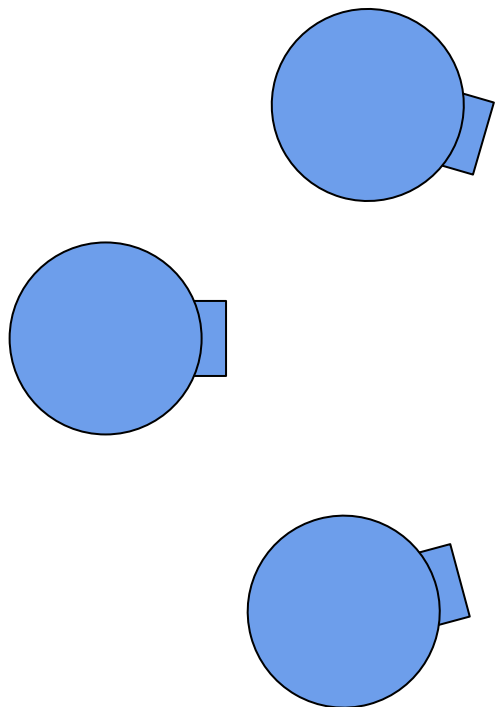
Adversarial Agent-based Model



Adversarial Agent-based Model

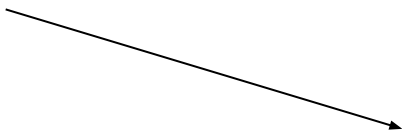
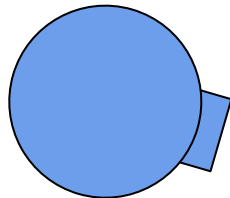


Viewpoint Networks

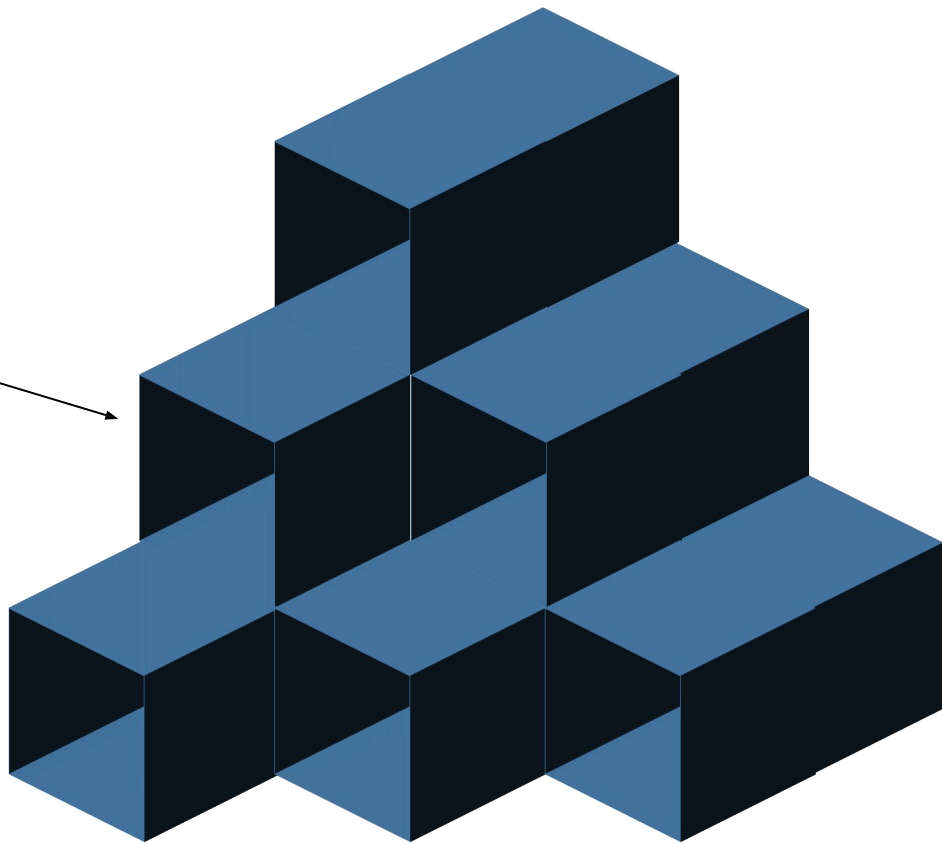


Isometric Projection (equivalent right-left angular orientation)

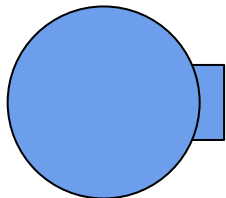
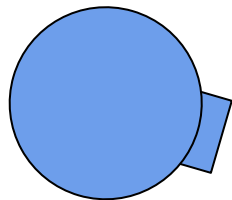
Viewpoint Networks



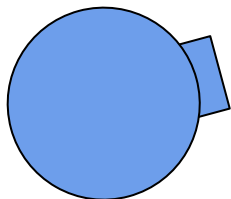
An agent A take a vantage point V on a projected geometric object that forms a graph G .



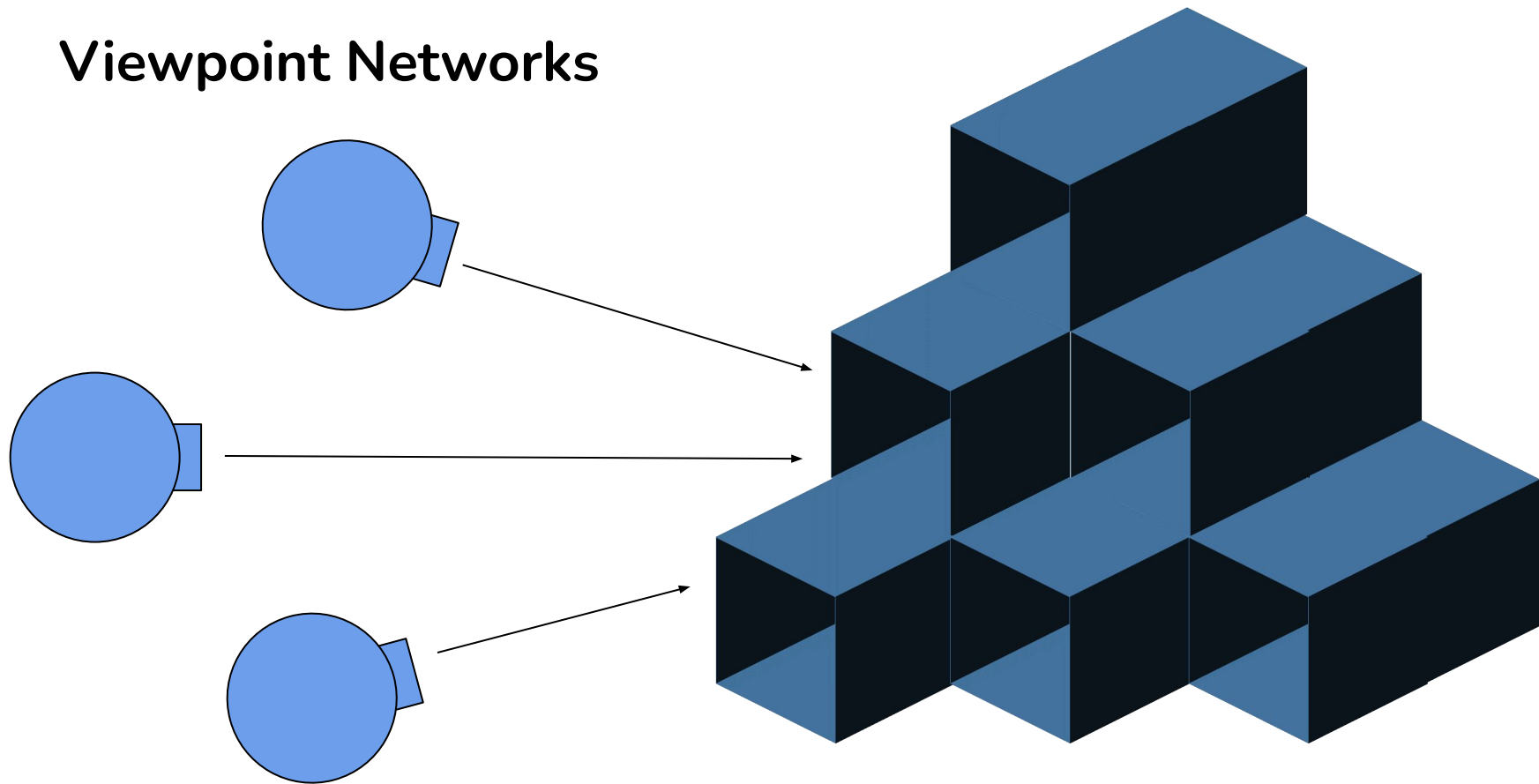
Viewpoint Networks



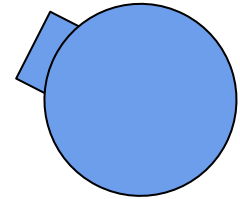
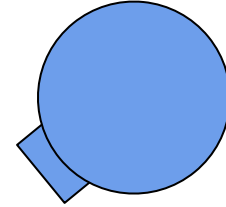
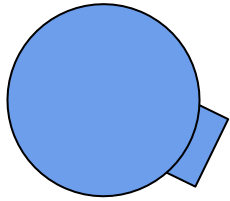
For population A, each A_n takes a particular viewpoint, resulting in a heterogeneous set of perspectives.



Viewpoint Networks

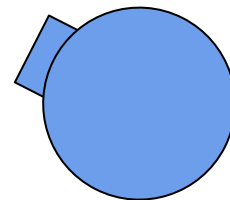
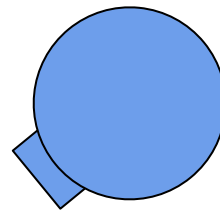
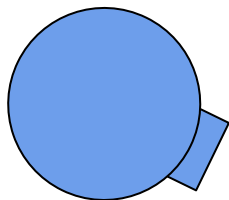


Viewpoint Networks

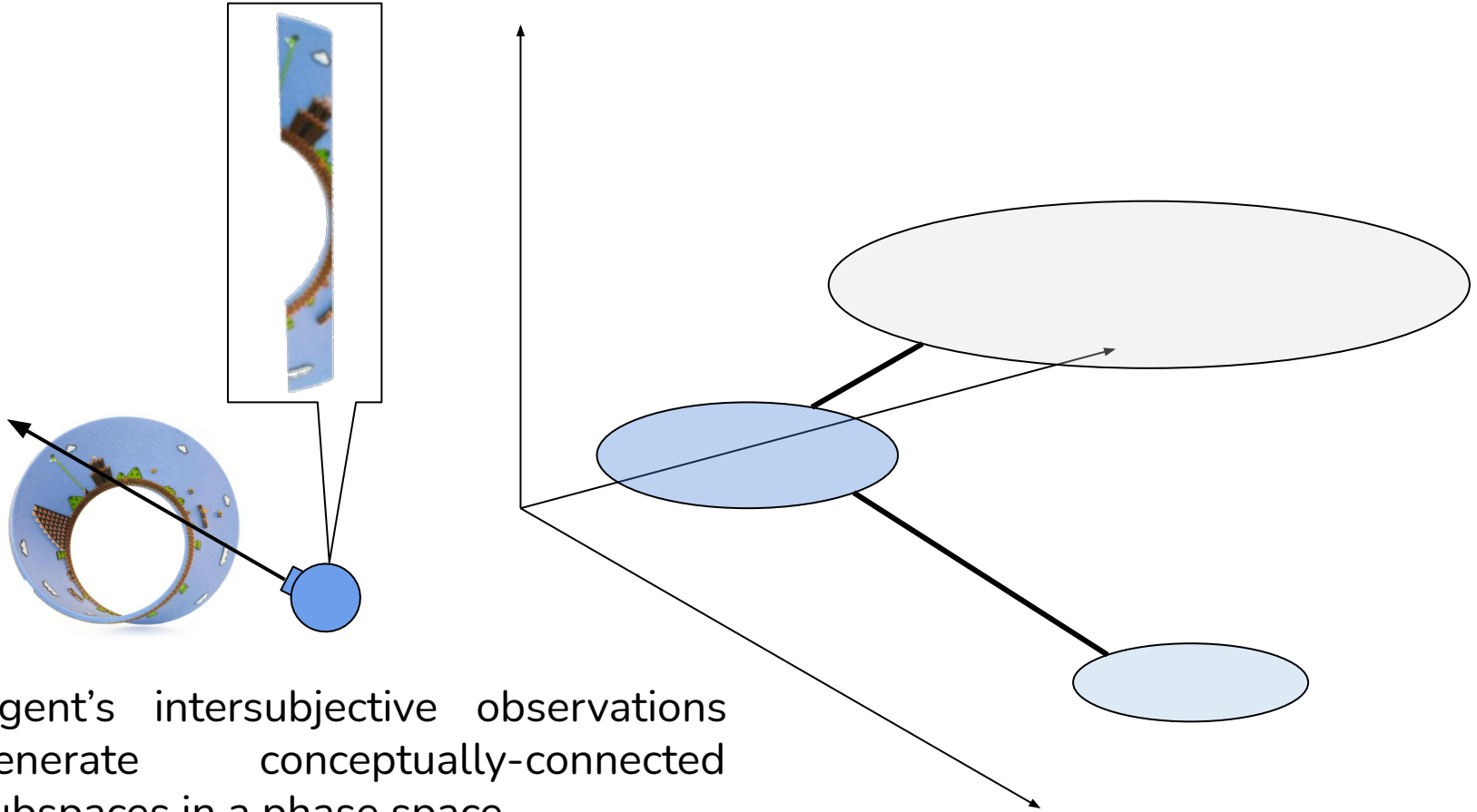


Super Mario Moebius Strip
COURTESY: 8 bit Nirvana

Viewpoint Networks



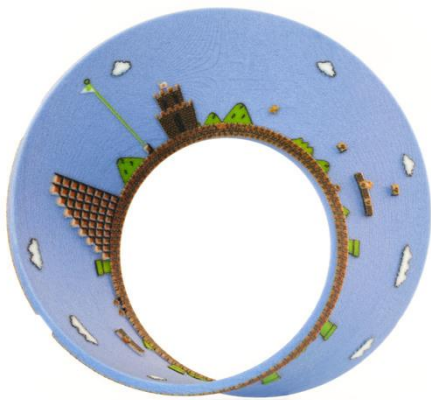
Can we approximate a global state sensitive to locally-specific features (context)?



Agent's intersubjective observations
generate conceptually-connected
subspaces in a phase space.

Viewpoint Networks

Geometries such as isometric cubes (right) and constant positive curvatures (lower left) provide networks with dimensional cues that approximate motion and structural information over time.

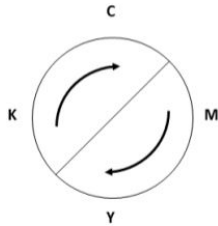


Each observer has a unique perspective on the world, comparison of different perspectives allow for differential forms of learning and superadditive information.

Future Directions

Viewpoint Networks allow for merger between physical, perceptual, and cultural relativism (relative motion to alternate ideologies).

Epistemology of clusters (natural groups), **plenitude** (all possible natural types).



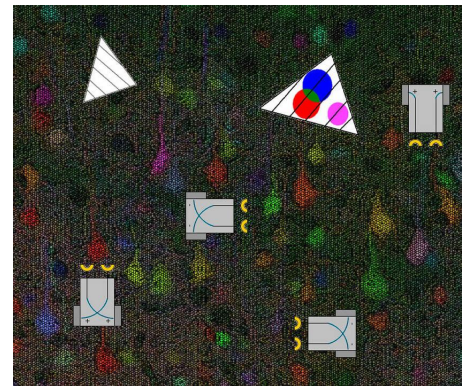
Contextual Geometric Structures: represent cultural world for a particular set of natural features (e.g. components of color spectrum).

Thanks For Your Attention!

Saturday Morning Neuro Sim Meetings

3pm UTC, meet.jit.si/SMN-Room

Then on YouTube!



Meta-brain Models

(open-source, hybrid agent-based models to layered brains!)

<https://github.com/OREL-group/Meta-brain-Models>