Artificial Cognitive Systems

Module 4: Autonomy

Lecture 2: Biological autonomy; constitutive autonomy; behavioural autonomy; homeostasis; allostasis; self-organization & emergence; autonomic systems

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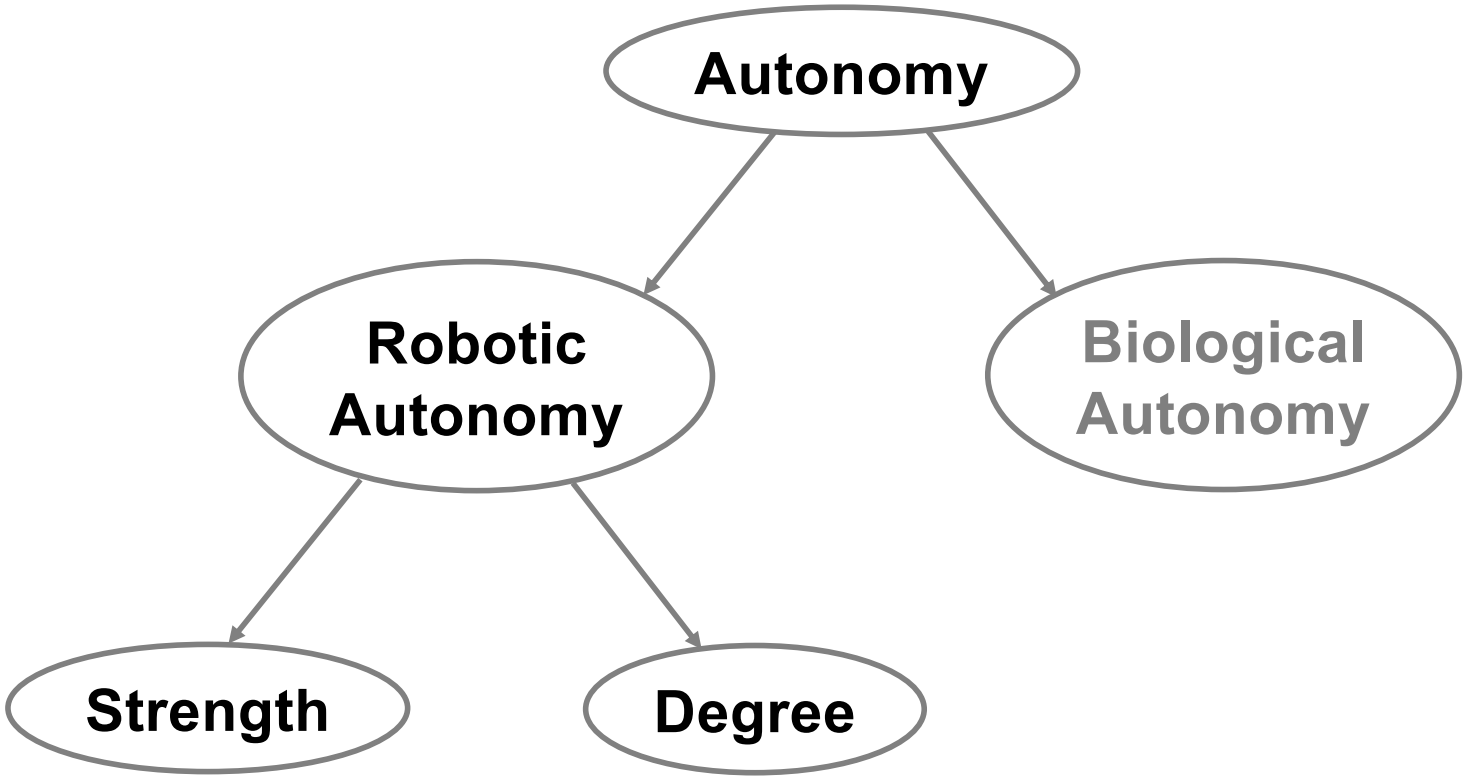
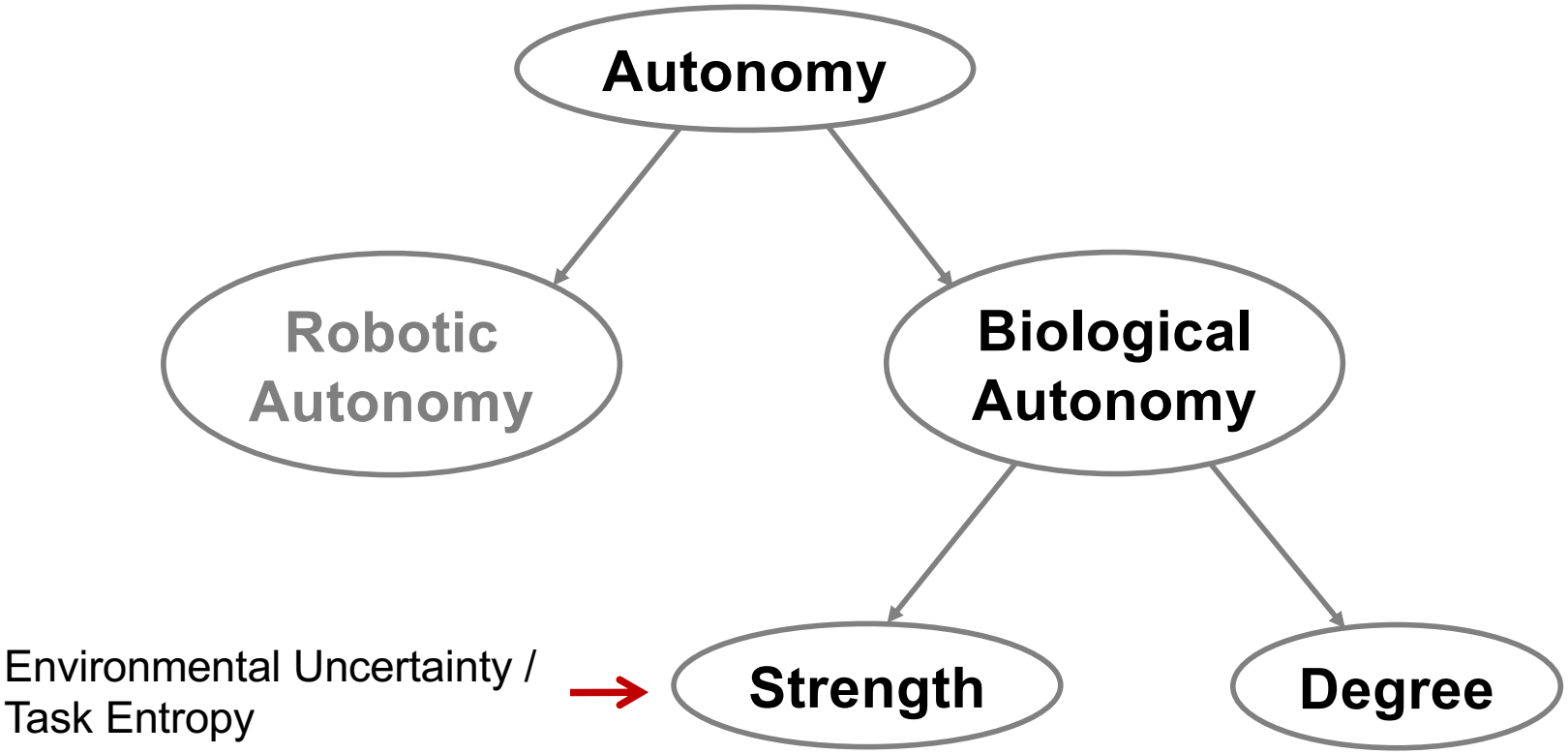
www.vernon.eu


Autonomy
Robotic Autonomy
Biological Autonomy
Strength
Degree



Environmental Uncertainty / Task Entropy →

The issue of autonomy is one of survival, in the face of **precarious** conditions

… physically and organizationally as a dynamic self-sustaining entity.

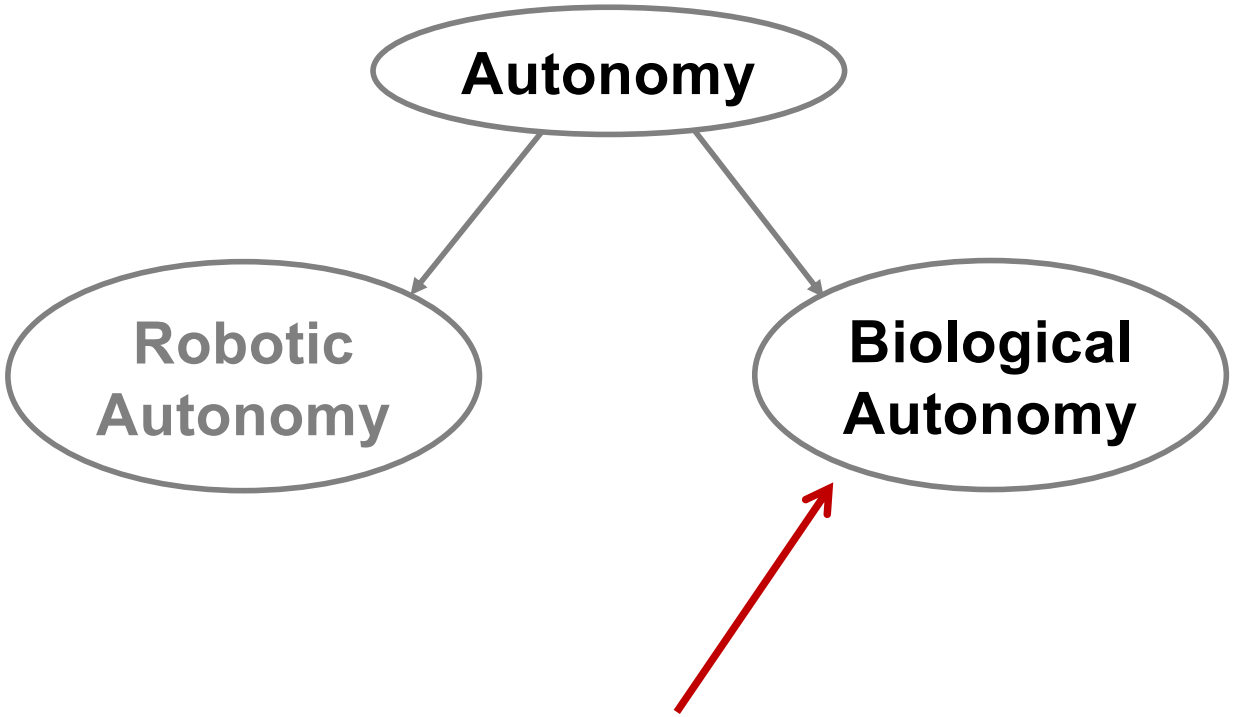
Living systems

Delicate: easily disrupted/destroyed

... avoid them & repair / heal

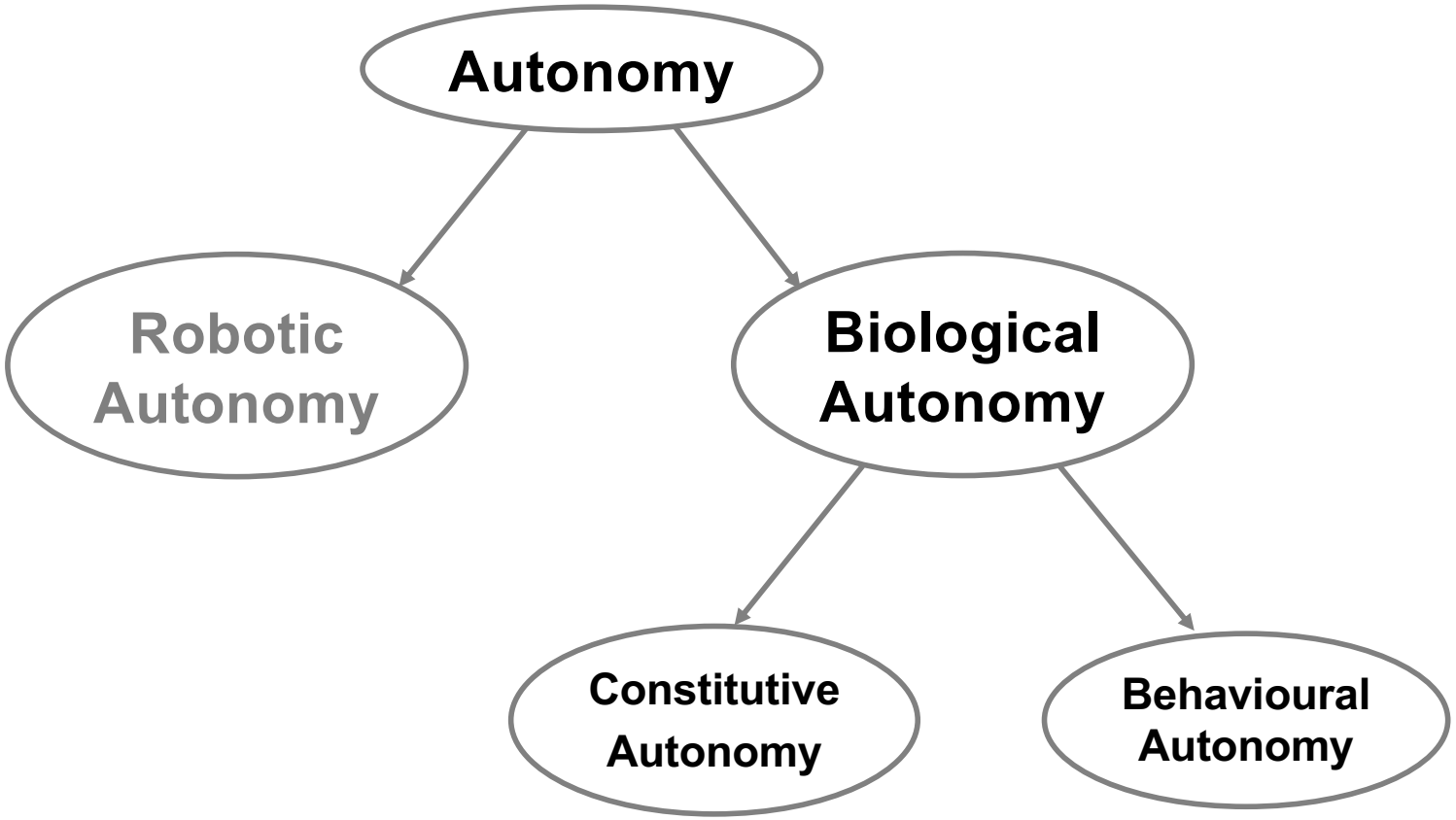
Dissipative: far-from- equilibrium processes

... need some external source of energy or matter



The self-maintaining organizational characteristic of living creatures

... compensate for dissipation, avoid disruption, and self-repair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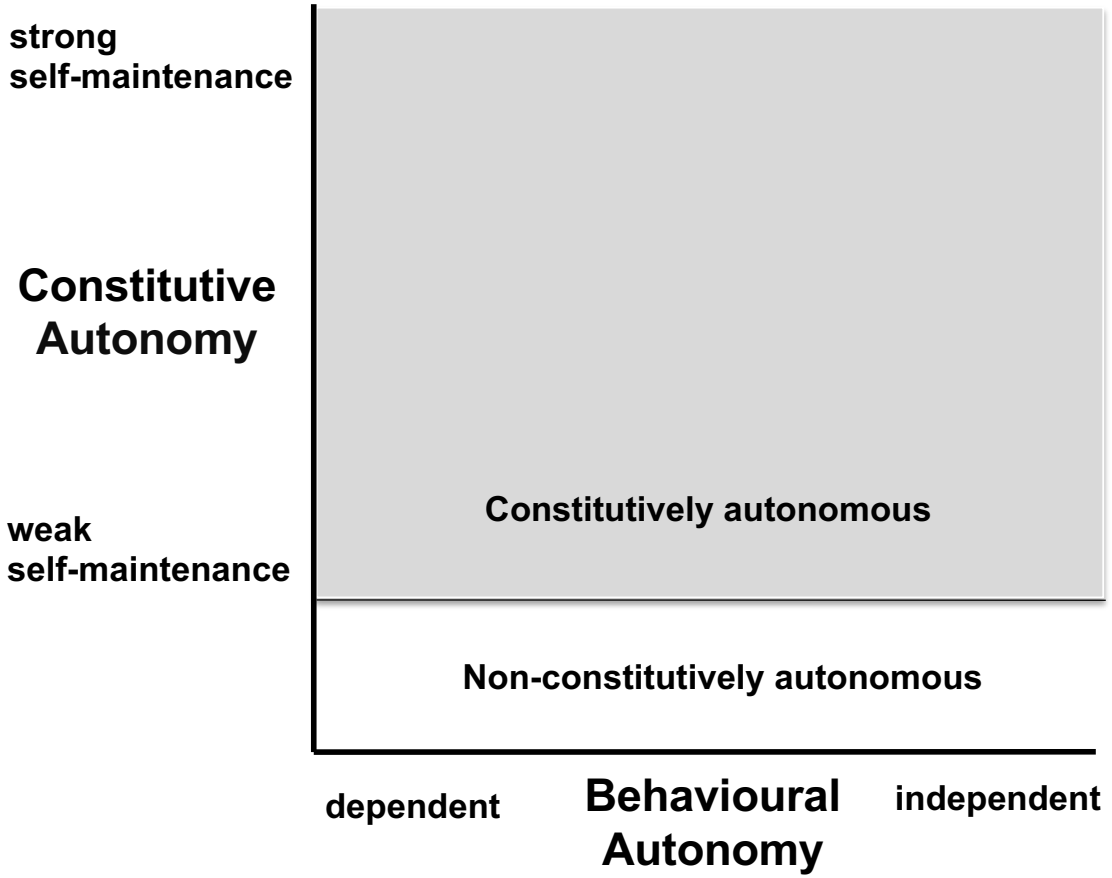
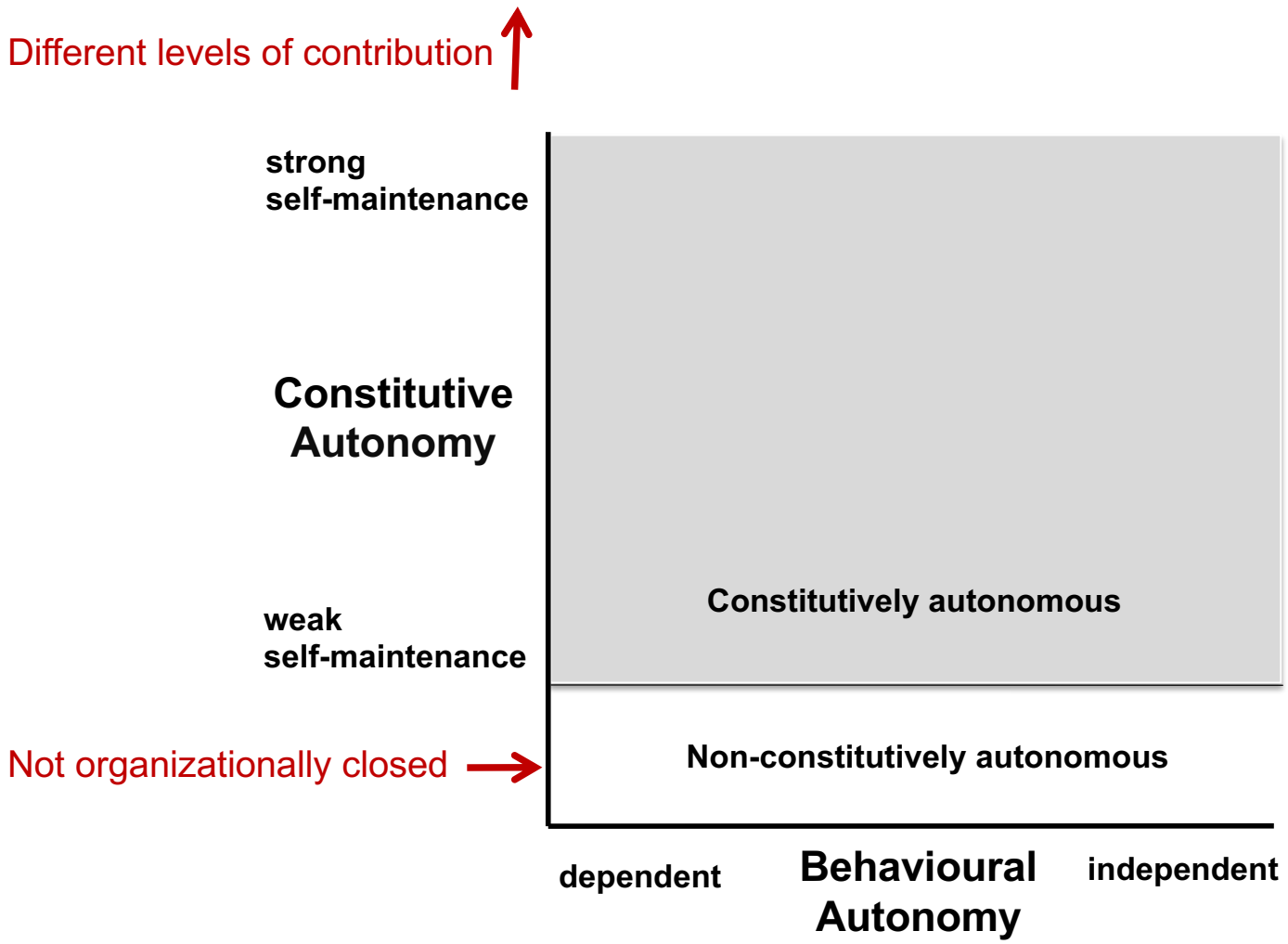
Behavioural Autonomy



T. Froese, N. Virgo, and E. Izquierdo. Autonomy: a review and a reappraisal. In F. Almeidae Costa et al. ,editors, Proceedings of the 9th European Conference on Artificial Life: Advances in Artificial Life, volume 4648, pages 455–465. Springer, 2007.



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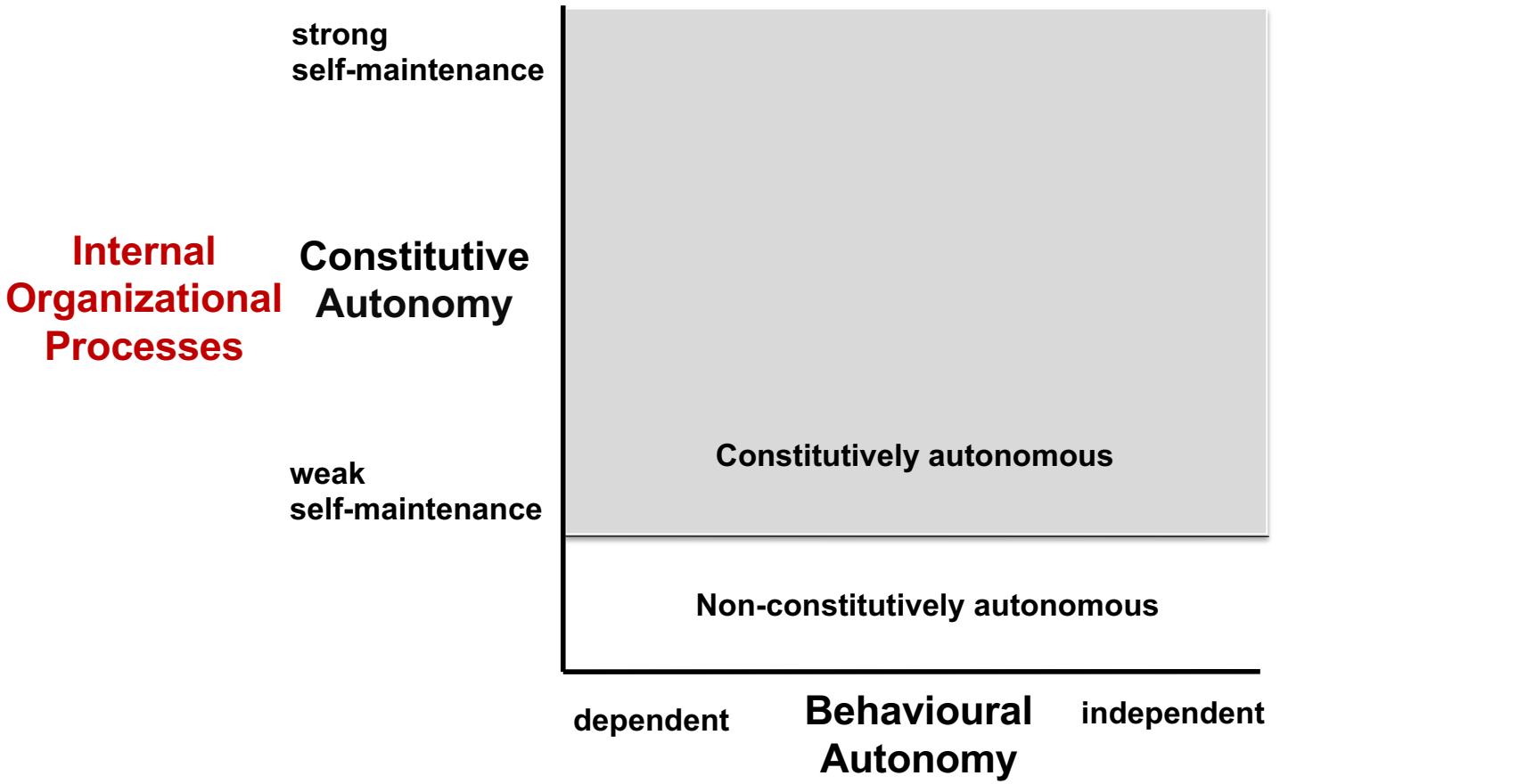
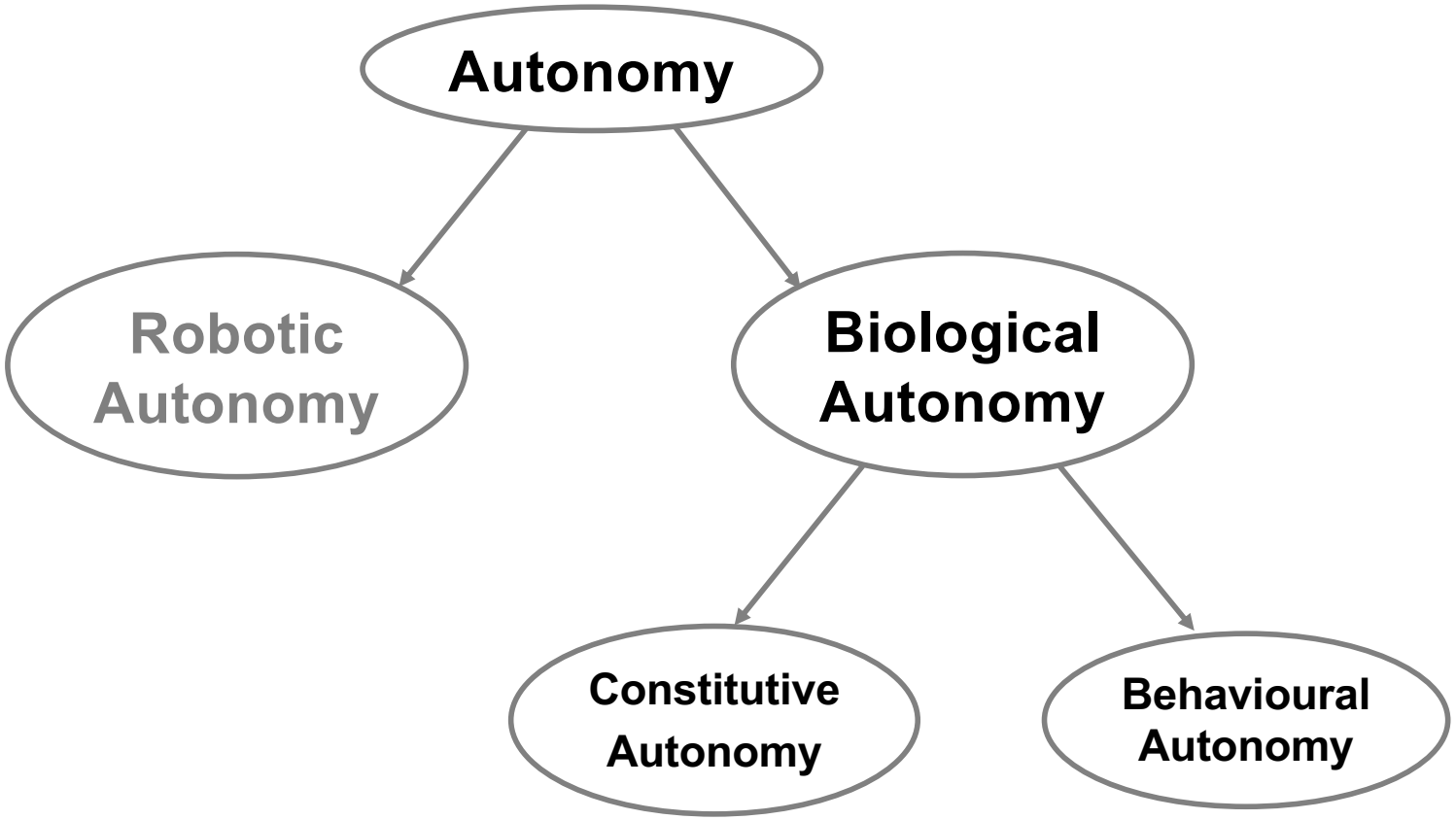


External Aspects: independent goals in precarious environment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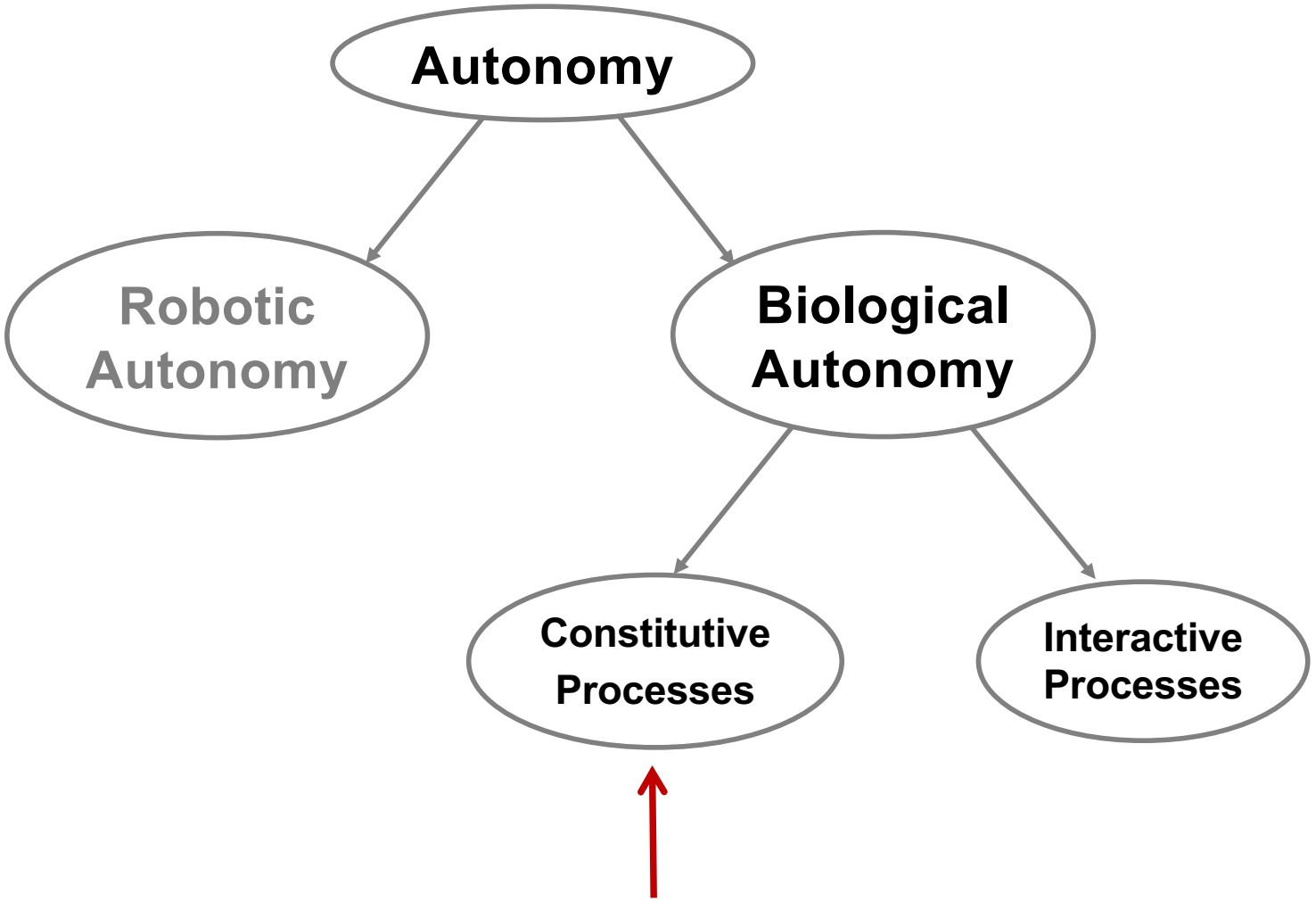
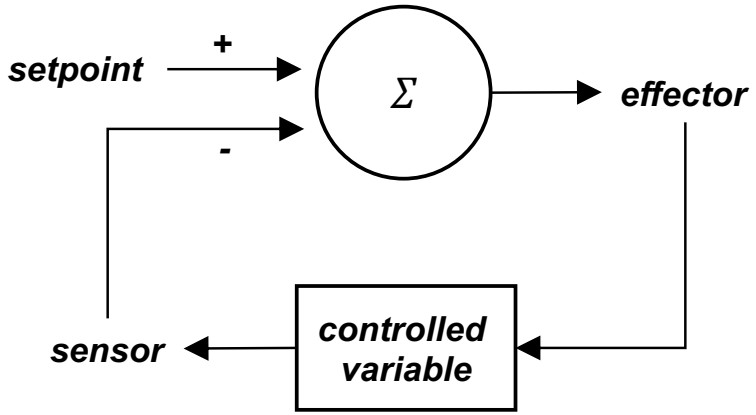


Self-construction, self-regulation, & self-repair;
faster time-scales to interaction processes

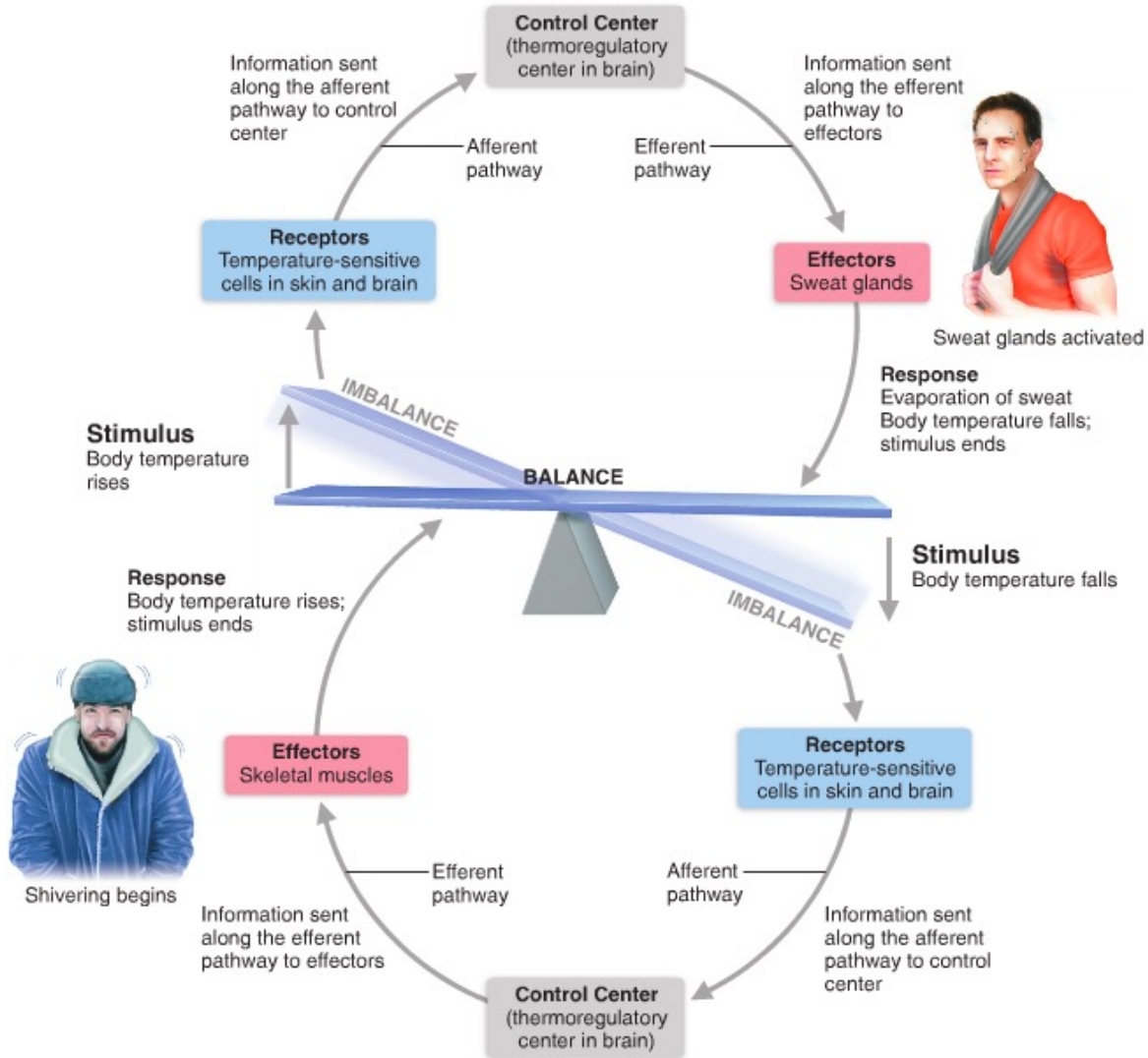
Key processes: Homeostasis & Allostasis



Homeostasis: the automatic regulation of physiological functions: essential variables (EV)

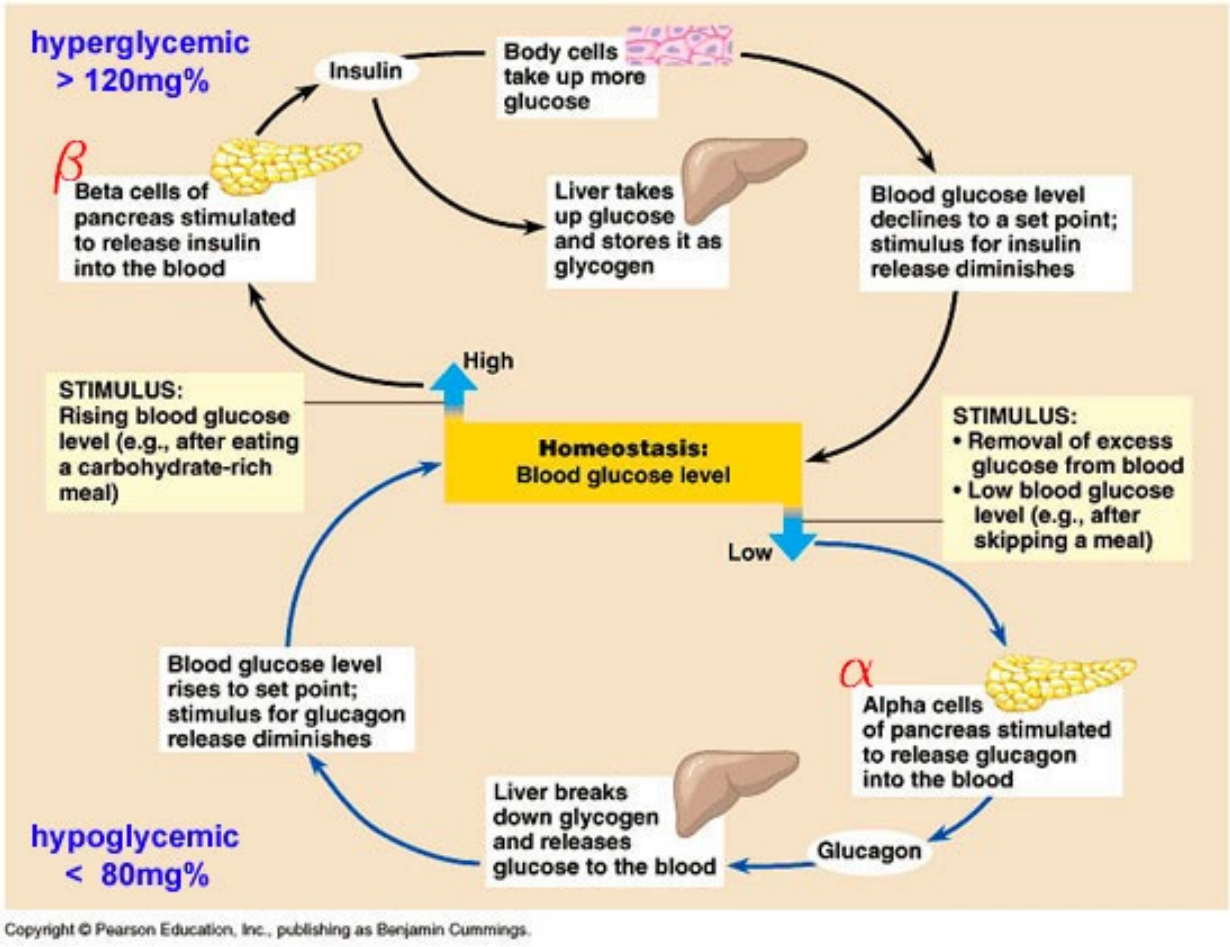
Walter Cannon in 1929: “Organization for Physiological Homeostasis”

Goal: **stability through constancy**: set point & negative feedback

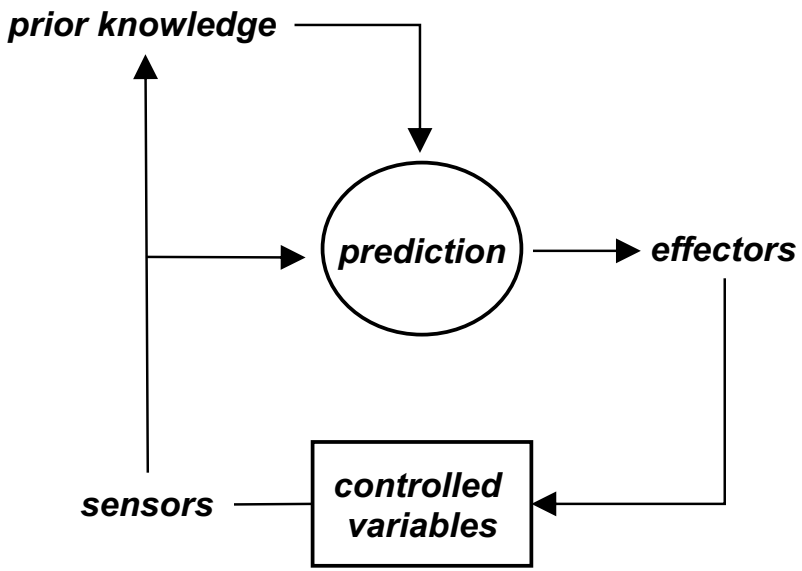


https://www.studyblue.com/notes/note/n/homeostasis/deck/6151960

Feedback Control

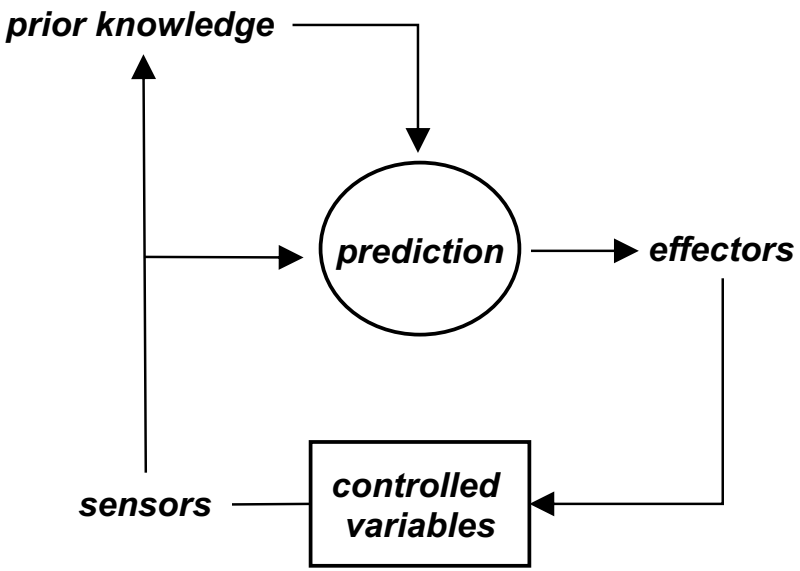


http://biochemgroup.blogspot.com/2010/07/diabetes-mellitus.html



Homeostasis: adjusting to an event

Allostasis: adjusting before an event occurs

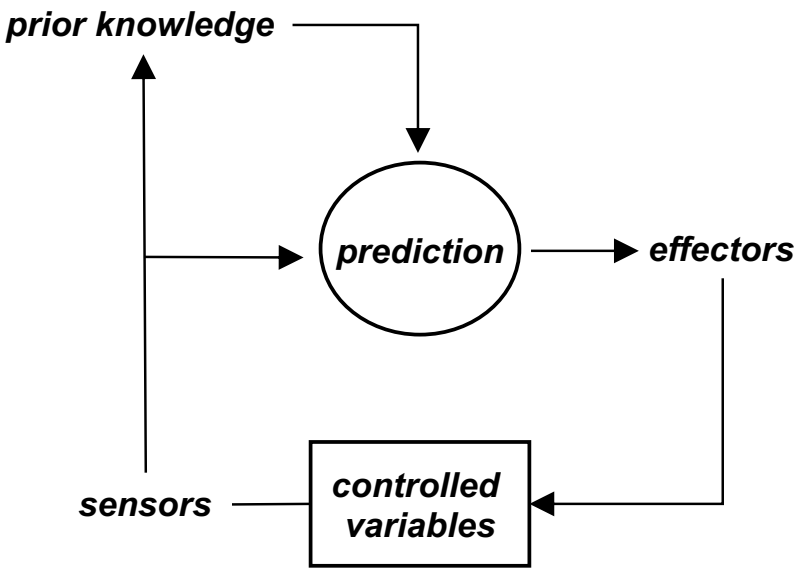


Continual preparation for what might be coming next

Anticipates events, actively prepares

Predictive self-regulation vs. reactive self-regulation

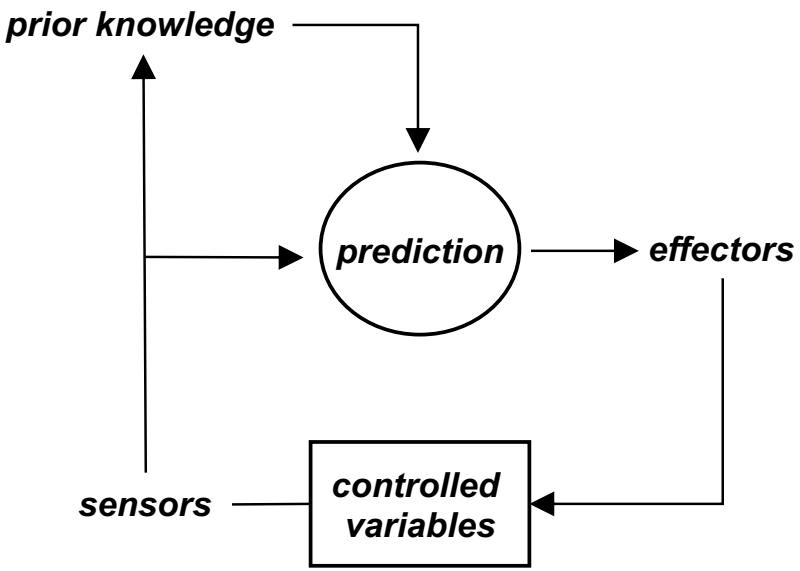
Ready themselves for multiple contingencies



Use priors to anticipate the likely demands that will be placed on the system

Pre-emptively adjust all the parameters to meet this demand

Goal: **stability through change** … change the controlled variable by predicting what value will be needed and **overriding** local feedback to meet anticipated demand



Allostatic systems adapt to change rather than resist it

Allostasis is effected at a higher level of organization, involving greater number of sub-systems acting together in a coordinated manner

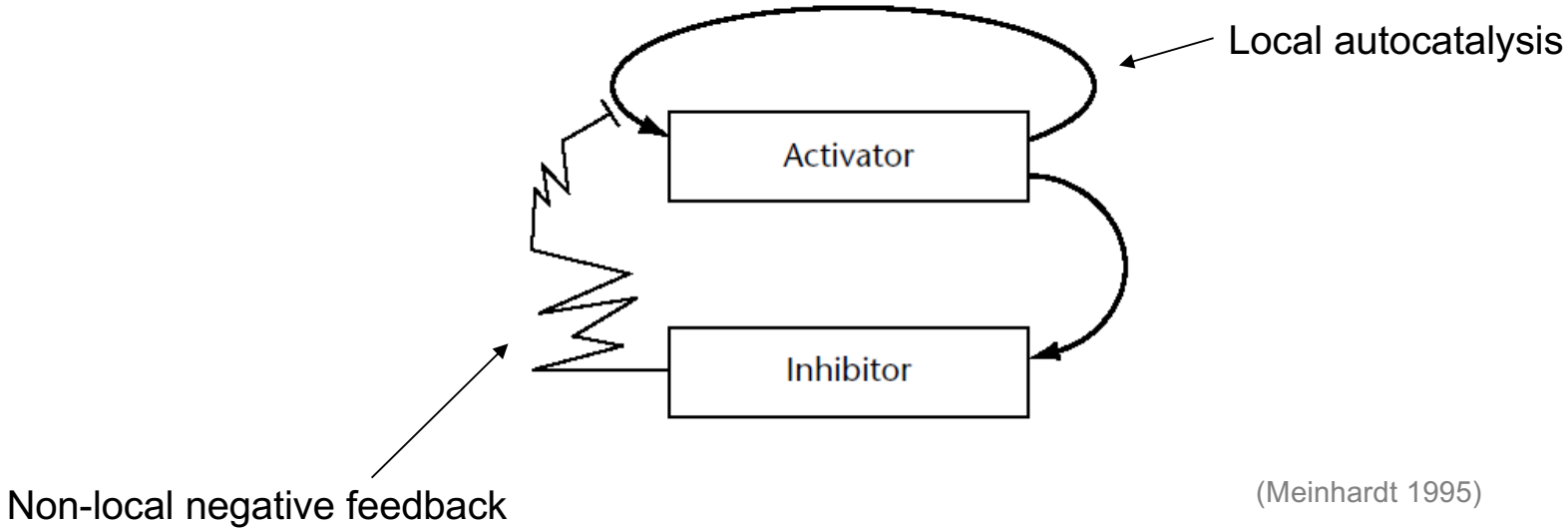
(Homeostasis operates at a simpler level of negative feedback control)

Self-organization & Emergence

Self-organization

"Pattern and structure at the global level arises solely from interactions among the lower-level components of the system ... without reference to the global pattern."

(Camazine 2006)



(Meinhardt 1995)

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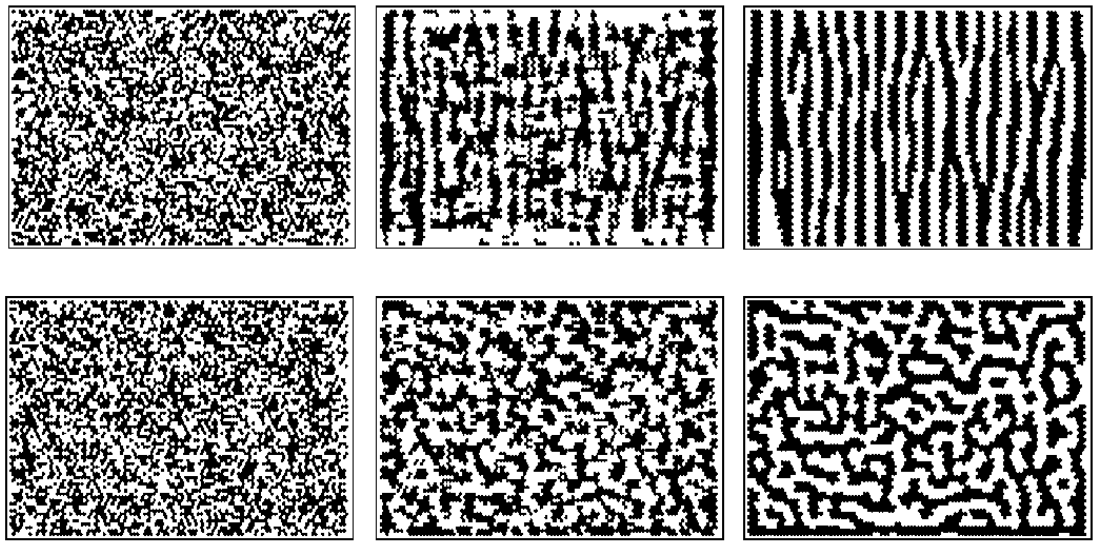


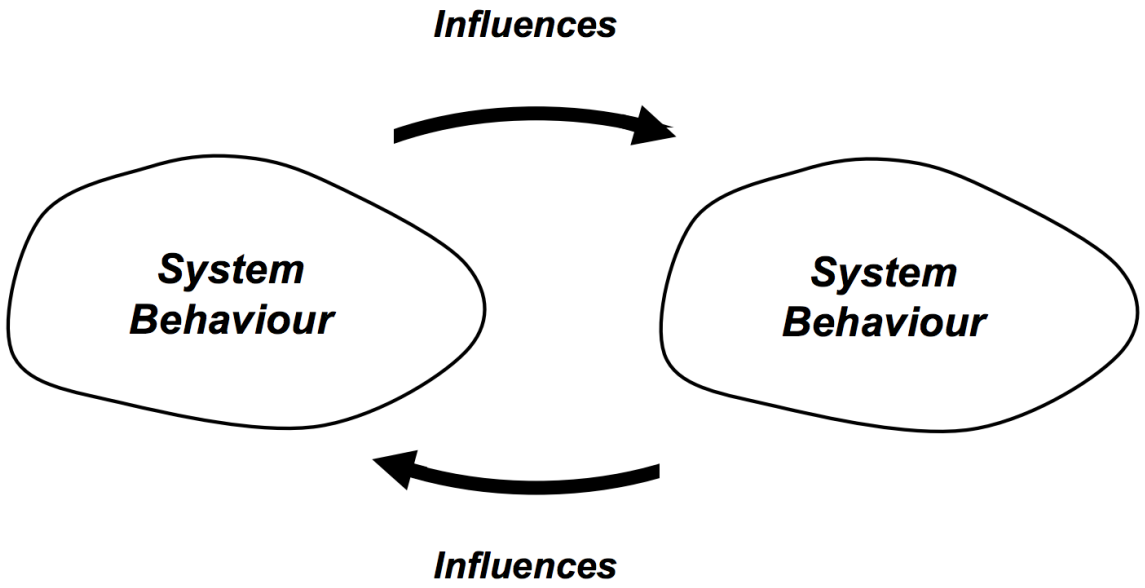
Emergence

"A process by which a system of interacting elements acquires qualitatively new pattern and structure that **cannot be understood simply as the superposition of the individual contributions**"

(Camazine 2006)

- Non-linearity in component interaction
- Mutual interaction of local and global

Continuous Reciprocal Causation (CRC)



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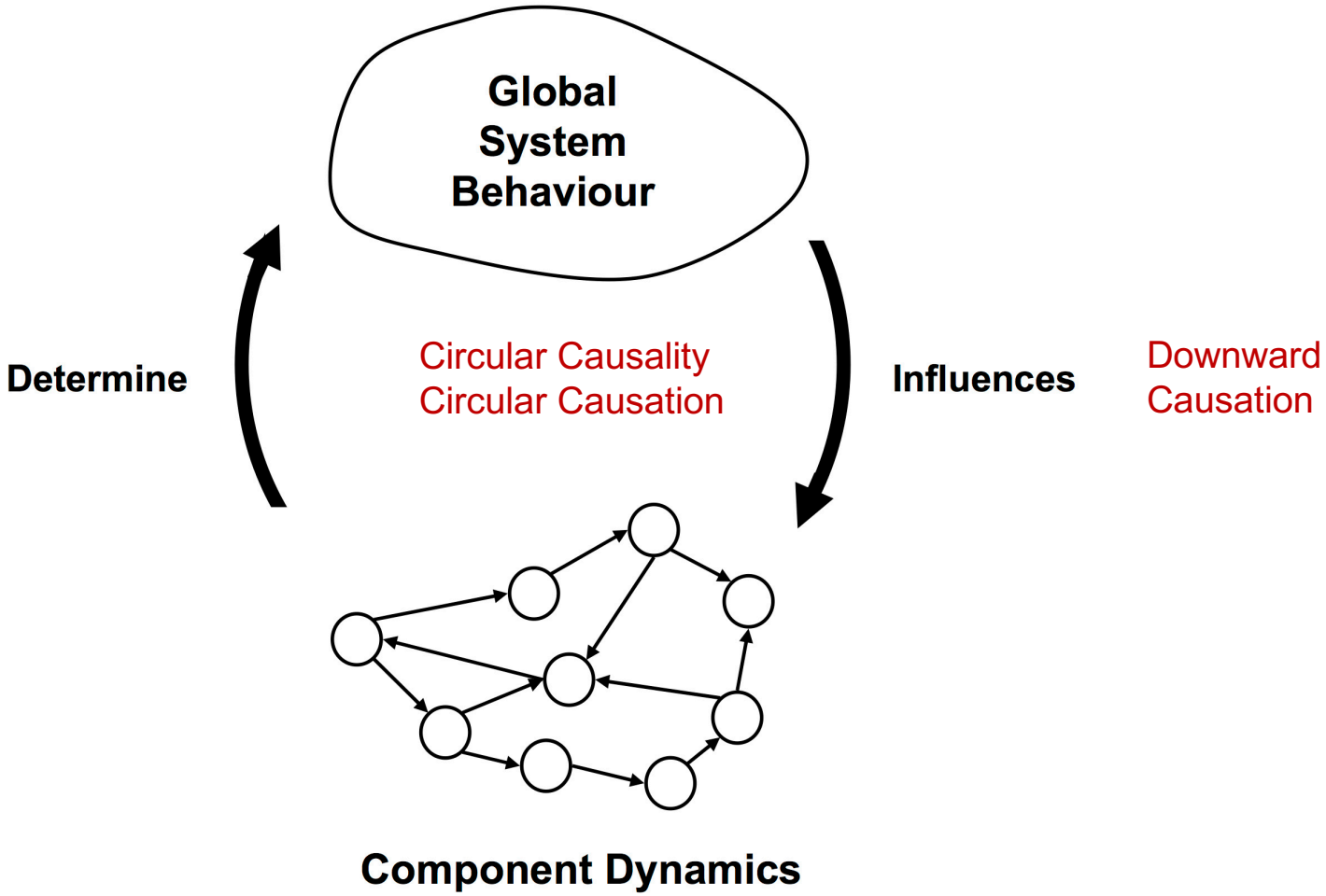
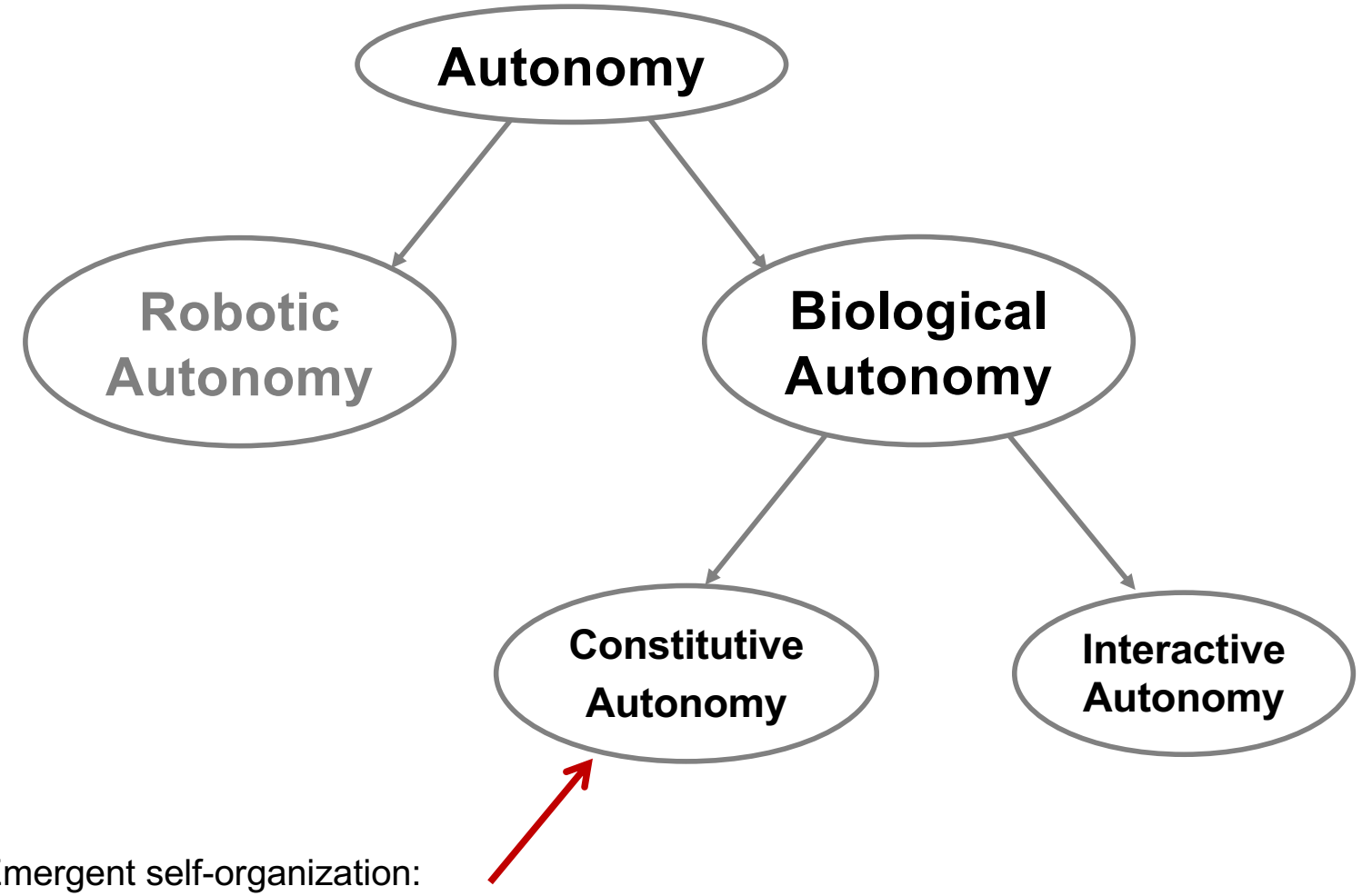


Emergent self-organization:

"the spontaneous emergence (and maintenance) of order, out of an origin that is ordered to a lesser degree"

[Boden 2008]

- Results from the intrinsic character of the system (possibly involving interaction with the environment)
- Not imposed by some external force or agent



Emergent self-organization:

Organizational closure & autopoiesis (literally self-production)

Homeostatic self-regulation applies not to some system parameter but to the organization of the system itself

Self-maintenance & Recursive Self-maintenance

Self-maintenance

Make active contributions to its own persistence

Do not contribute to the maintenance of the conditions for persistence

Autonomy: Self-organization and Emergence

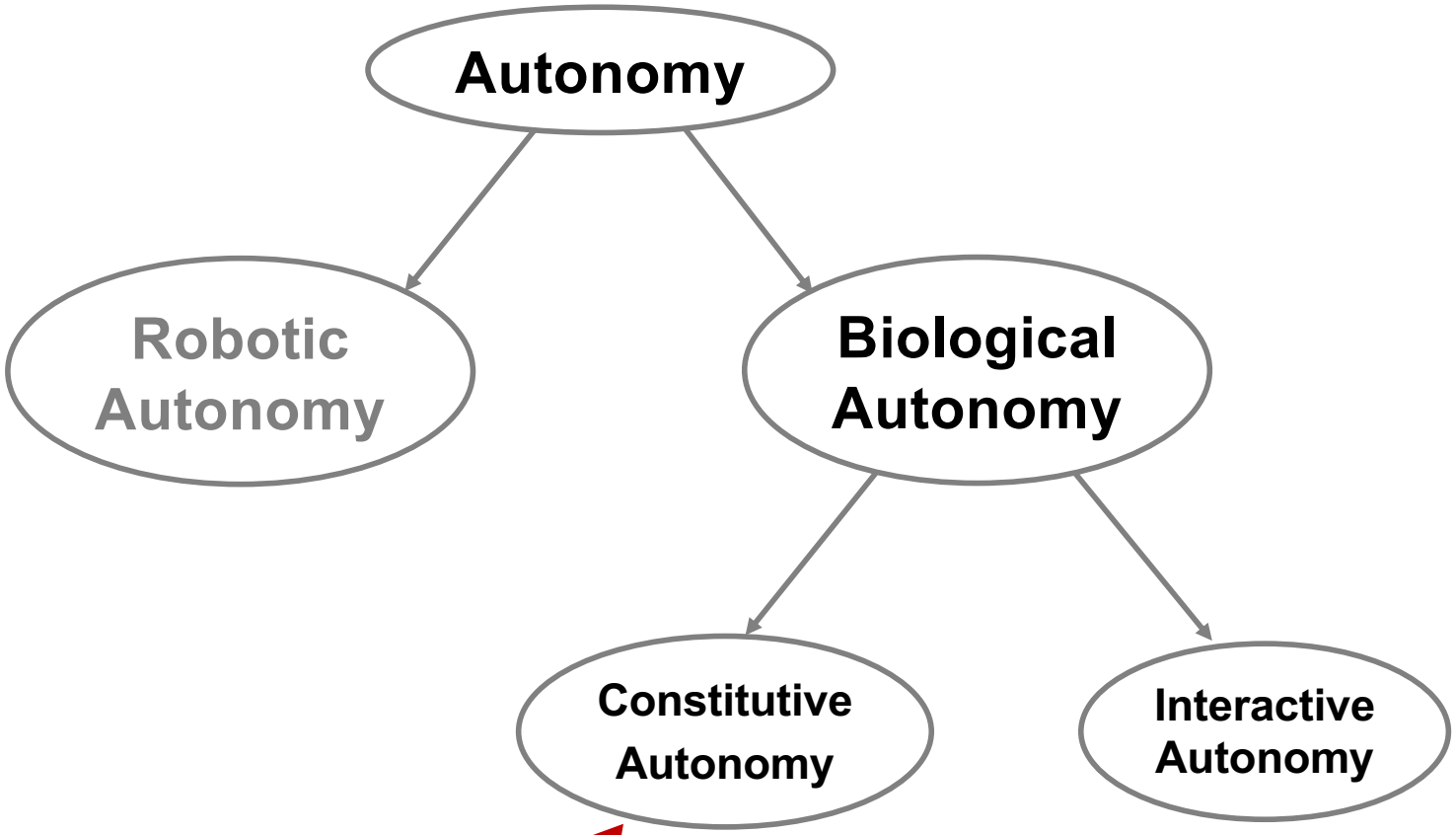
Recursive self-maintenance

Do contribute actively to the conditions for persistence

Can deploy different processes of self-maintenance depending on environmental conditions

“they shift their self-maintenant processes so as to maintain self-maintenance as the environment shifts” !!!

(Bickhard 2000)



Emergent self-organization:

Recursive self-maintenance

Take-home message:

Emergent self-organization is autonomous

and

Autonomous systems typically involve some form of emergent self-organization

Autonomic Systems

Systems that can manage themselves, given high-level objectives from administrator

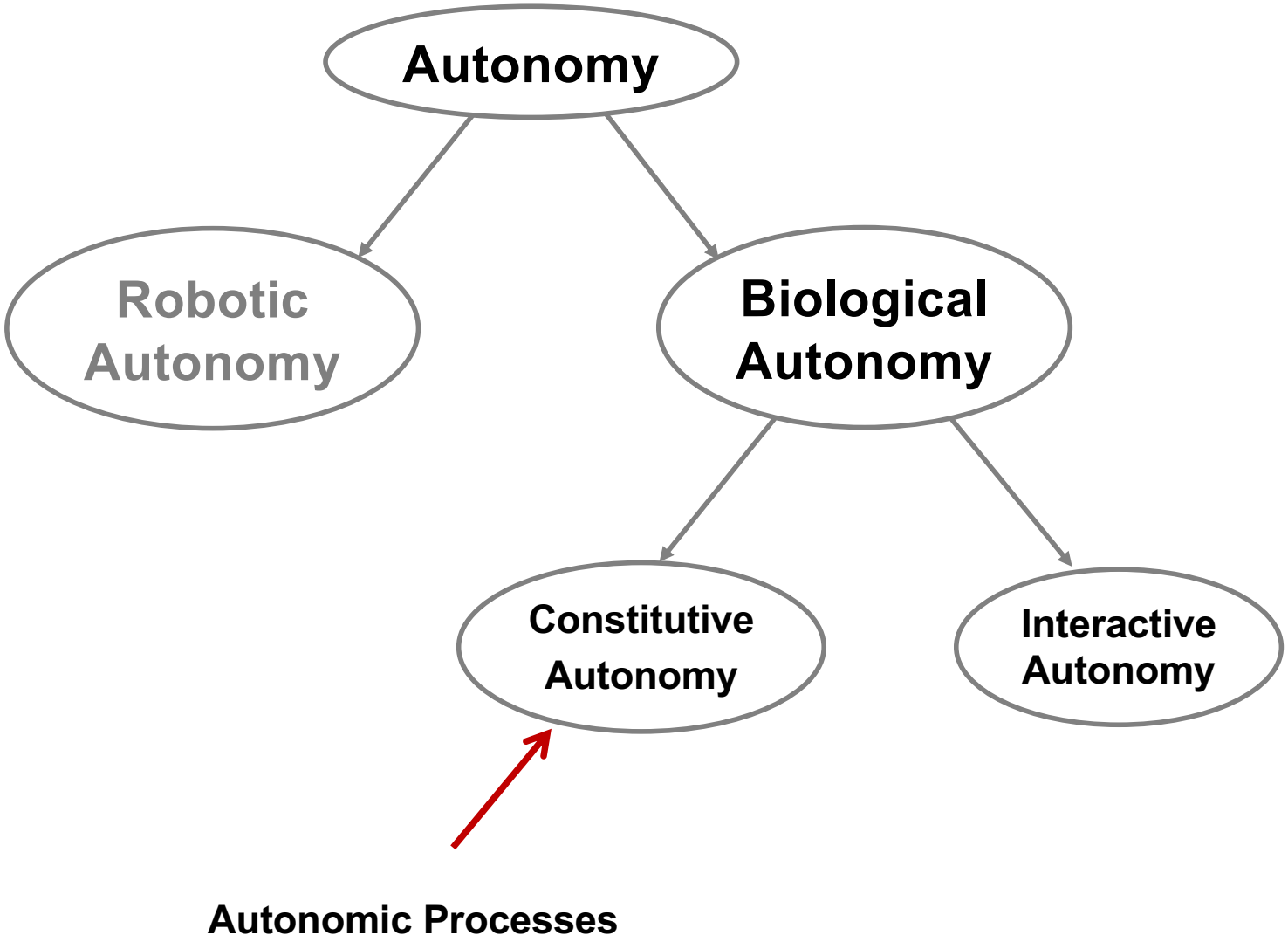
Inspired by the autonomic nervous system

> Operates automatically to regulate the body's physiological functions such as heart-beat, breathing, and digestion

Closely related to homeostasis

Self-configuring
Self-healing
Self-optimizing
Self-protecting

J. O. Kephart and D. M. Chess. The vision of autonomic computing. IEEE Computer, 36(1):41–50, 2003.


Autonomy
Robotic Autonomy
Biological Autonomy
Constitutive Autonomy
Interactive Autonomy
Autonomic Processes

Different Scales of Autonomy

Autonomy appears at different levels in hierarchies in natural systems

- Ant
- Ant colony
- An eco-system, e.g. a tidal lake, and the constituent species of flora and fauna

Degree of autonomy depends on perspective: viewed from which level of the hierarchy

Autonomy and Goals

"This is the apparent paradox of autonomy.

The system should in some sense build itself, the designer should intervene less,

but it should at the same time be more intelligently involved in setting the right processes in motion"

[Di Paolo and Iizuka 2008]

Autonomy and Goals

Autonomous systems set their own goals

- How do you get it to do something useful for others?

Adjustable, shared, sliding, and subservient autonomy

- Trade-off between autonomy and needs of other agents

Measuring Autonomy

Formal mathematical theory of autonomous systems?

Good place to start: measuring autonomy

Causal autonomy

The degree to which mutual information between the system and its environment is caused by the environment or by the system itself

[N. Bertschinger, E. Olbrich, N. Ay, and J. Jost. Autonomy: An information theoretic perspective. Biosystems, 91(2):331–345, 2008.]

Measuring Autonomy

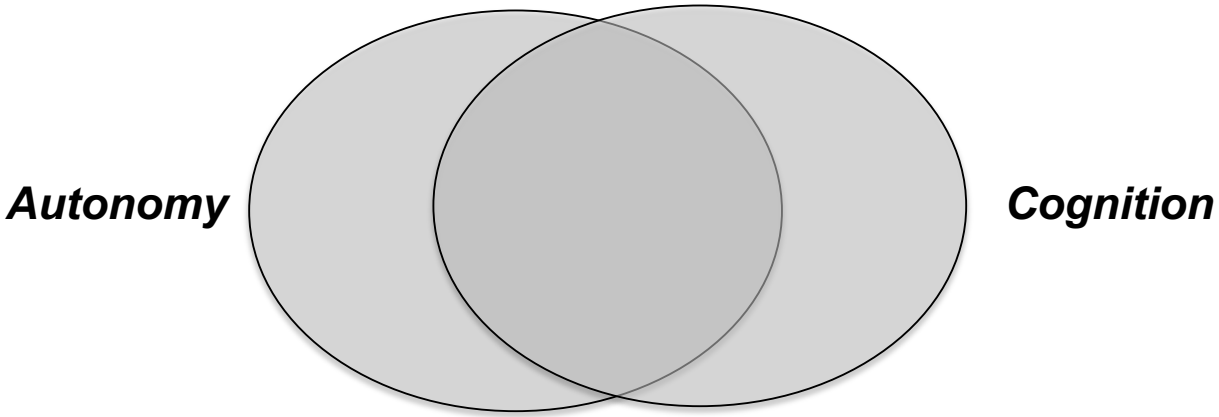
Formal mathematical theory of autonomous systems?

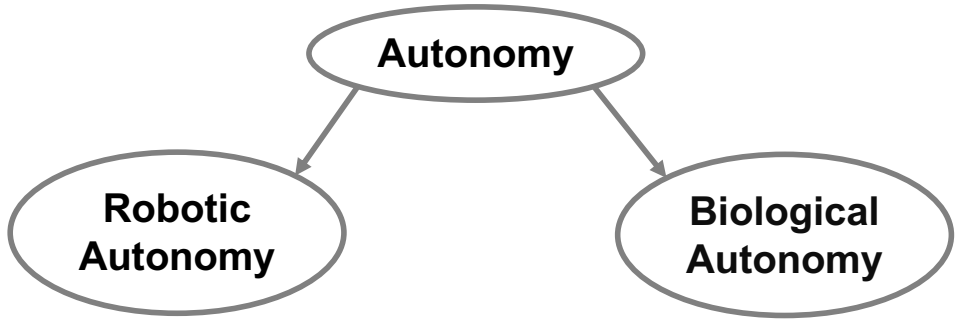
Good place to start: measuring autonomy

> G-autonomy
>
> "... prediction of ... future evolution is enhanced by considering its own past states, as compared to predictions based on past states of a set of external variables"
>
> Based on Granger Causality

[A. Seth. Measuring autonomy and emergence via Granger causality. Artificial Life, 16(2):179–196, 2010.]

Is autonomy an important characteristic of cognition?
Is cognition an important characteristic of autonomy?





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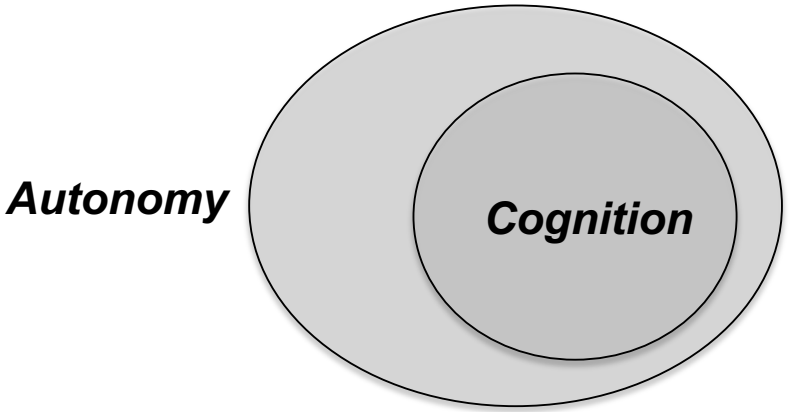
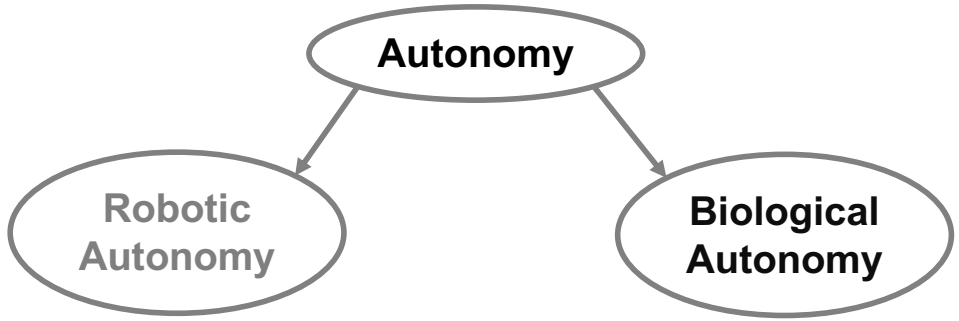


"The grounds of cognition are adaptive far-from-equilibrium autonomy — recursively self-maintenant autonomy"

[Bickhard 2000]



Adaptive autonomy	Ziemke 2008; Barandian 2004.
Adjustable autonomy	Bradshaw et al. 2004; Schillo 2002.
Agent autonomy	Hexmoor, Castelfranchi, Falcone 2003.
Basic autonomy	Ruiz-Mirazo and Moreno 2004.
Behavioural autonomy	Froese, Virgo, Izquierdo 2007.
Belief autonomy	Barber and Park 2004.
Biological autonomy	Varela 1979; Di Paolo 2004; Ziemke 2008.
Causal autonomy	Bertschinger, Olbrich, Ay, and Jost 2008.
Constitutive autonomy	Froese, Virgo, Izquierdo 2007; Froese and Ziemke 2009
Energy autonomy	Ieropoulos et al. 2012. Ziemke and Lowe 2009.
Mental autonomy	Ziemke and Lowe 2009.
Motivational autonomy	Ziemke and Lowe 2009.
Norm autonomy	Carabelea et al. 2004; Castelfranchi & Falcone 2004.
Robotic Autonomy	Ziemke 2008; Moreno, Etxeberria, Umerez 2008.
Shared autonomy	Pitzer et al. 2011.
Sliding autonomy	Sellner et al. 2006.
Social autonomy	Carabelea, Boissier, Florea 2004.
Subservient autonomy	Meystel 2000
User autonomy	Carabelea, Boissier, Florea 2004.

Reading

Vernon, D. Artificial Cognitive Systems – A Primer, MIT Press, 2014; Chapter 4.

Further Reading

D. Vernon, "Reconciling Constitutive and Behavioural Autonomy: The Challenge of Modelling Development in Enactive Cognition", Intellectica, Vol. 65, pp. 63-79, 2016.