Sketch for a Theory of Evolution based on Coding

Joachim De Beule
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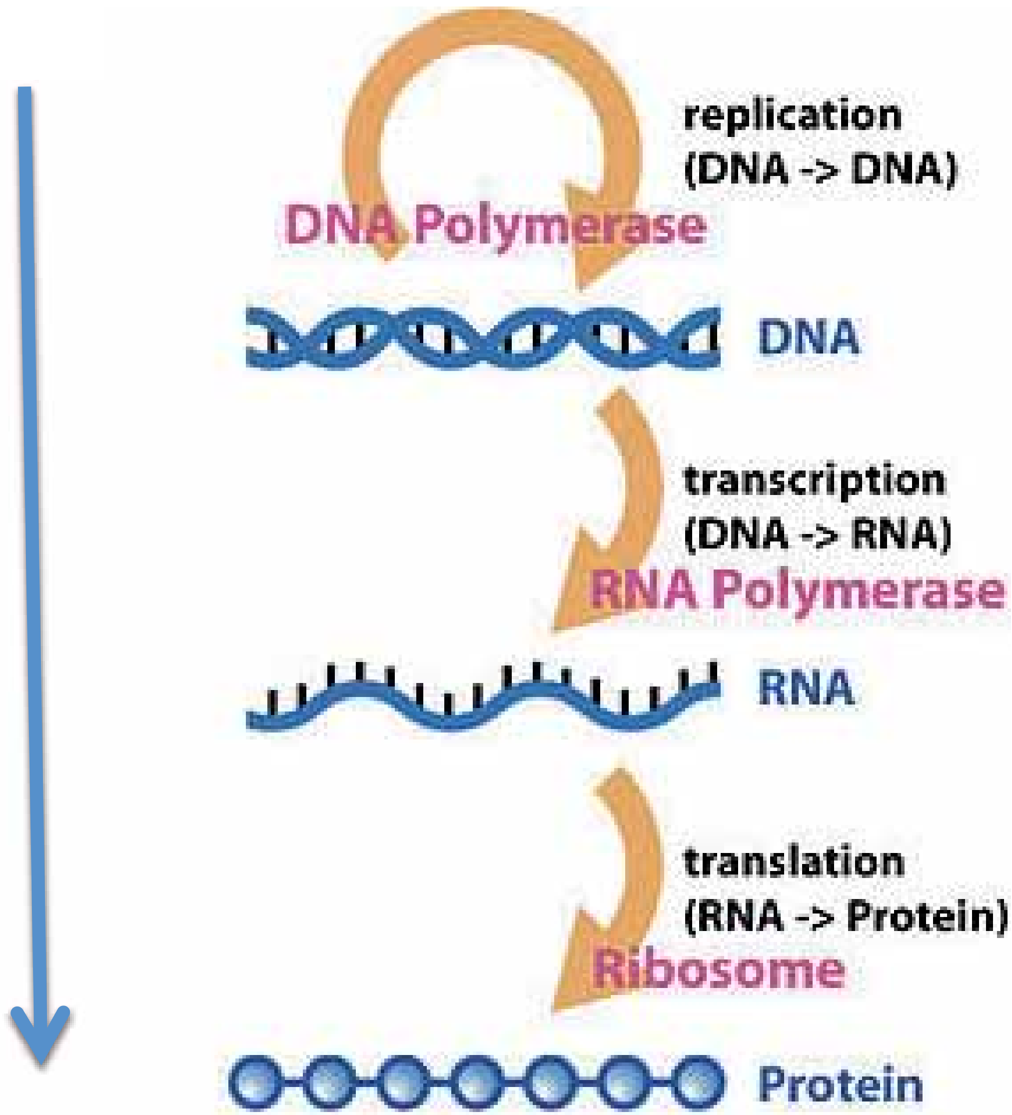
Overview

Part I: Basic terms and concepts

Part II: Application to Macroevolution

The Mechanisms of Life: Copying and Coding

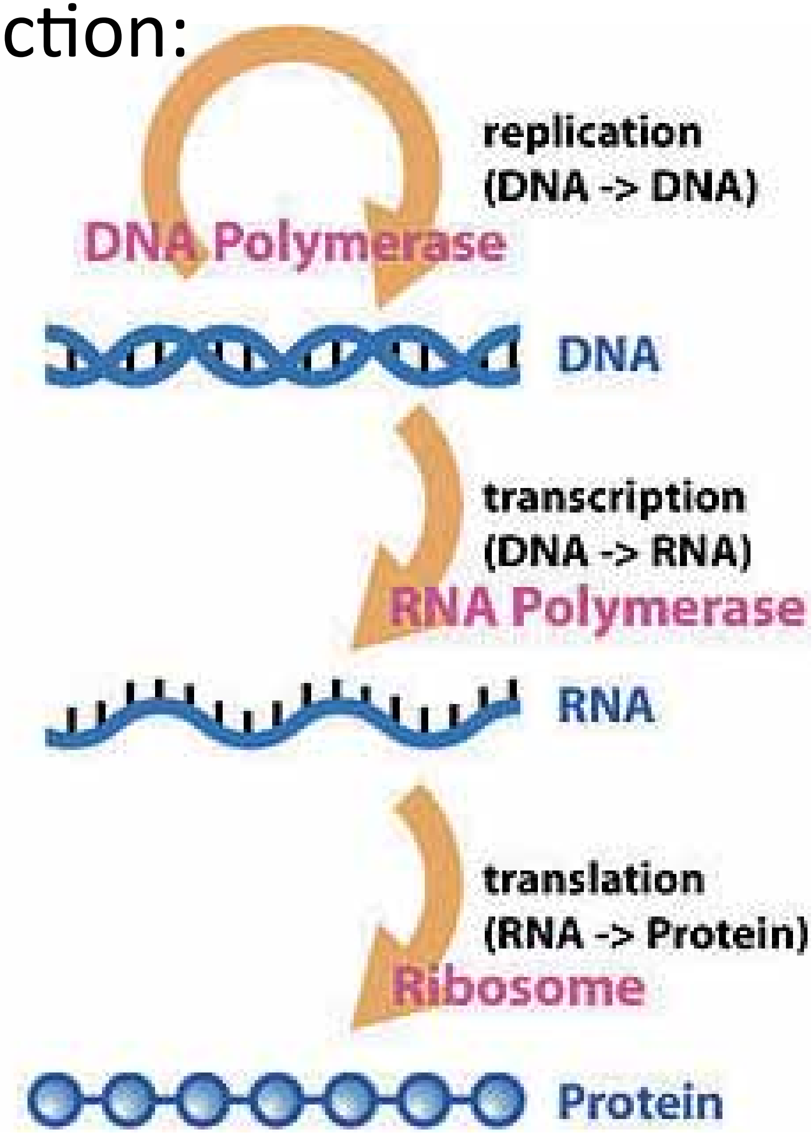
Information
(Central Dogma)



The Mechanisms of Life: Copying and Coding

The logic of evolution by natural selection:

- Replication (copying)
- Variation (mutation)
- Selection (limited resources)



The Mechanisms of Life: Copying and Coding

The logic of evolution by natural selection:

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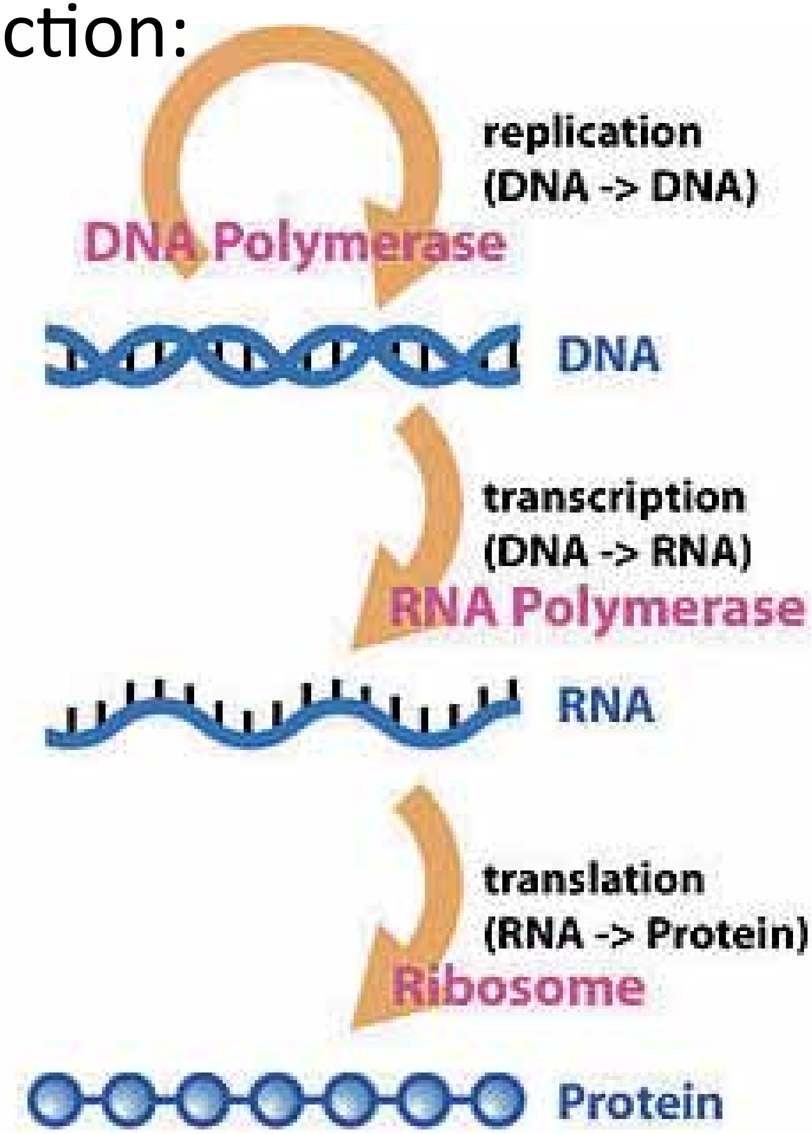
My Claim:
Replication always
Involves coding!



Reprinted with corrections from *The Bell System Technical Journal*,
Vol. 27, pp. 379–423, 623–656, July, October, 1948.

A Mathematical Theory of Communication

By C. E. SHANNON

INTRODUCTION

THE recent development of various methods of modulation such as PCM and PPM which exchange bandwidth for signal-to-noise ratio has intensified the interest in a general theory of communication. A basis for such a theory is contained in the important papers of Nyquist[1] and Hartley[2] on this subject. In the present paper we will extend the theory to include a number of new factors, in particular the effect of noise in the channel, and the savings possible due to the statistical structure of the original message and due to the nature of the final destination of the information.

The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point. Frequently the messages have *meaning*; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem. The significant aspect is that the actual message is one *selected from a set* of possible messages. The system must be designed to operate for each possible selection, not just the one which will actually be chosen since this is unknown at the time of design.

Replication always involves coding!

12	21	33
121	312	323
31	21	13
23	42	22
12	21	33

3, 15 or 33 numbers?

Implication for Evolutionary Theory

Replication as instantaneous copying leads to a gene centered and *impoverished* theory of evolution

$$G \xrightarrow{1_G^*} G \xrightarrow{1_G^*} G \xrightarrow{1_G^*} G \xrightarrow{1_G^*} \ldots$$

Replication as a process that involves coding leads to a much *richer* picture of evolution (Nature *and* nurture, phylogeny *and* ontogeny, competition *and* coordination, …)

$$G \xrightarrow{\gamma} P \xrightarrow{\phi} G \xrightarrow{\gamma} P \xrightarrow{\phi} G \xrightarrow{\gamma} \ldots$$

$$\gamma\phi = 1_G^* \quad \text{when} \quad \gamma \simeq \phi^{-1}$$

Implication for Evolutionary Theory

Replication as instantaneous copying leads to a gene centered and impoverished theory of evolution

1^* 1^* 1^* 1^*

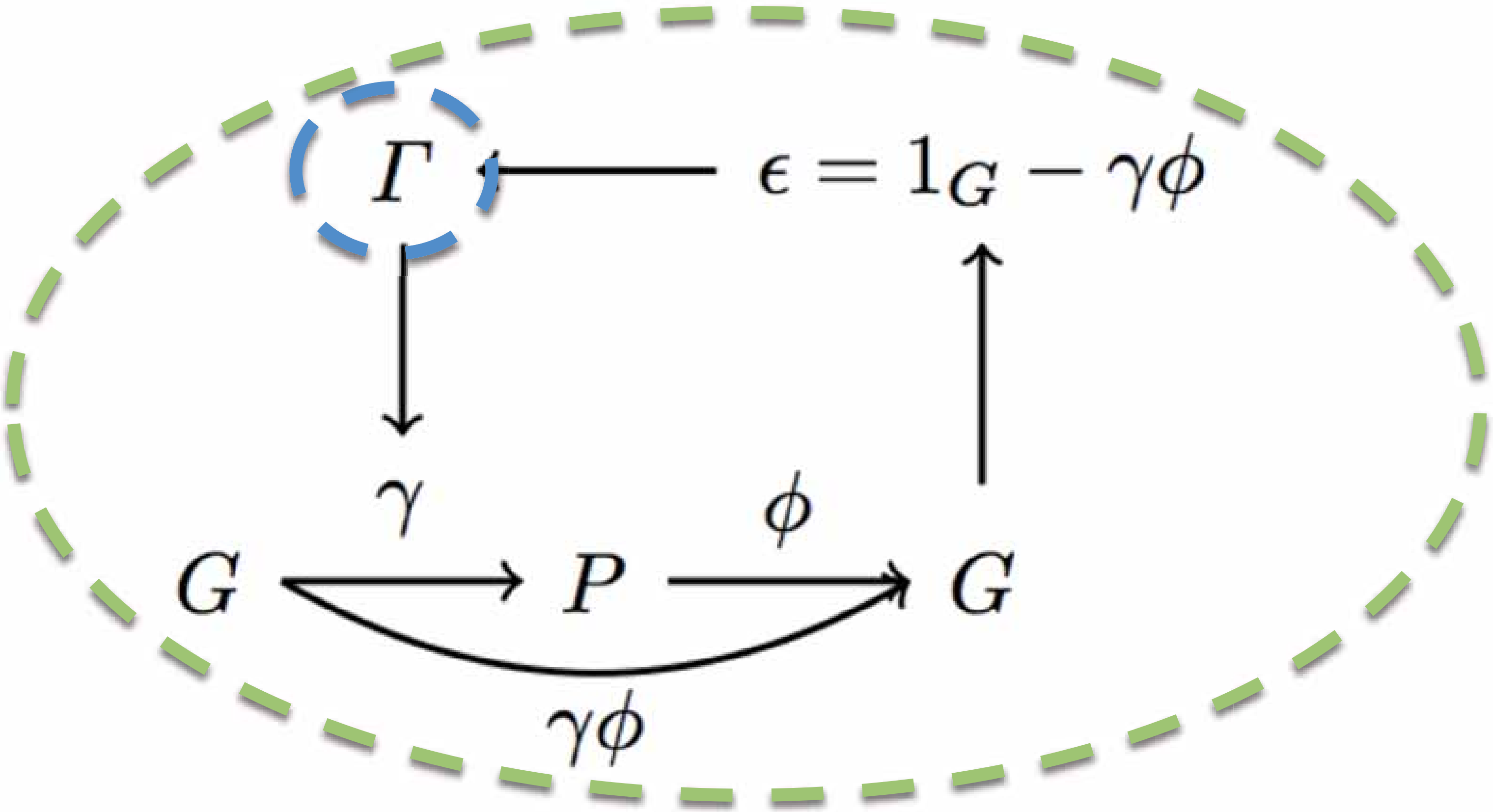
Replicat … to a
much ri … ure,
phyloge … nation,
…)

The mapping from genotype to phenotype, or the degree to which replication is achieved, now becomes something that can (*has to*) evolve and *be regulated*!

$$\gamma\phi = 1^*_G \quad \text{when} \quad \gamma \simeq \phi^{-1}$$

Error-controlled Regulation

Code makers and Closure



The coding map γ is regulated or realized by a *code maker* Γ. The target of regulation is replication, meaning that if the regulatory activity of the code maker is good, then replication is achieved, and the composite map $\gamma\phi$ approaches the identity map 1_G. This is indicated by the equality between the error of regulation ϵ and the expression $1_G - \gamma\phi$.

Biological Information and Variety

12	21	33
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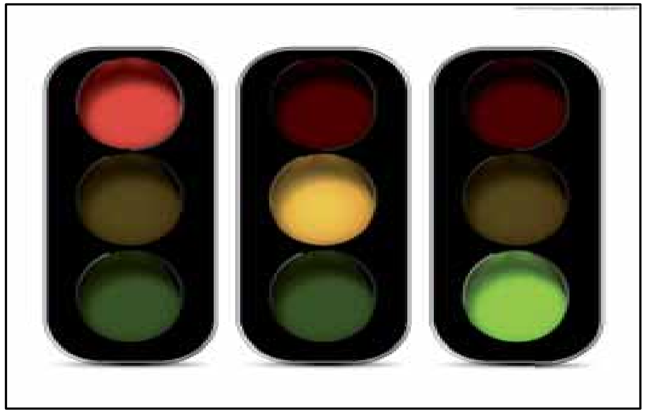
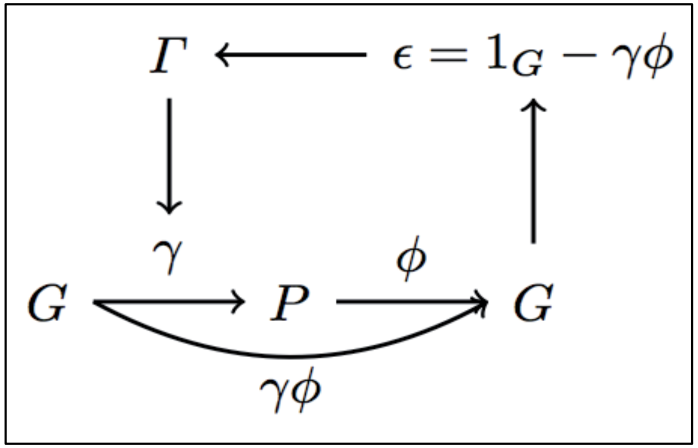


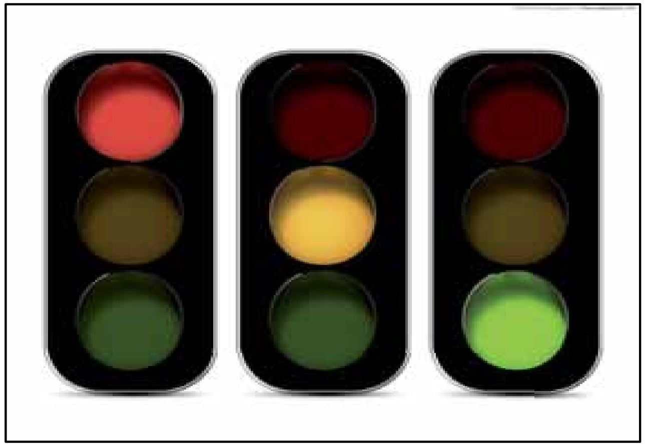
"a system's variety is not an intrinsic property of the system: the observer and his powers of discrimination may have to be specified if the variety is to be well defined". ,

(Ashby, 1956, **7/6**)

Closure and the Relativity of *Meaning*
“variety that makes a difference”

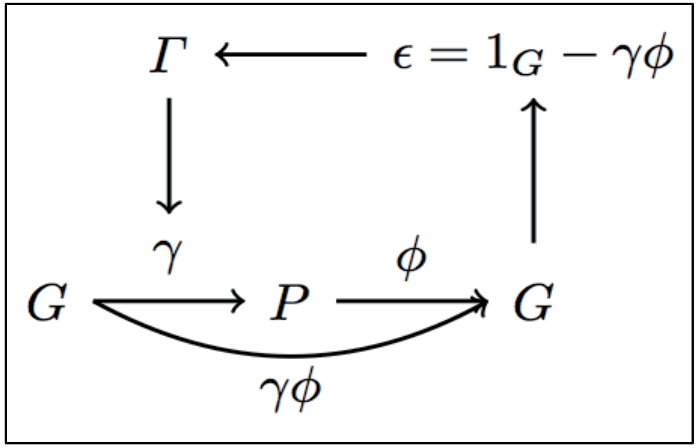
(MacKay, Bateson)





The Good Regulator Theorem

(Conant & Ashby, 1970)



"Every good regulator must contain an (inverse) model of what is being regulated"

$$\gamma\phi = 1^*_G \quad \text{when} \quad \gamma \simeq \phi^{-1}$$

Requisite Variety and Shannon's 10th Theorem

"The variety of disturbances regulated by a system cannot exceed that system's variety"

"The regulatory capacity of a system equals that system's capacity as a communication channel"

"The amount of noise that can be corrected by a correction channel is limited by the amount of information that can be carried by that channel"

Beyond Phylogenetics

"Evolution should favor code makers that realize larger quantities of variety"

"Evolution should favor code makers with increased Intrinsic or natural capacity as a communication channel"

"Evolution should favor code makers with increased Semantic Capacity"? (Dittrich)

Beyond Phylogenetics

“Evolution should favor code makers that realize larger quantities of variety”

“Evolut … *eased*
Intrinsic or … *channel”*

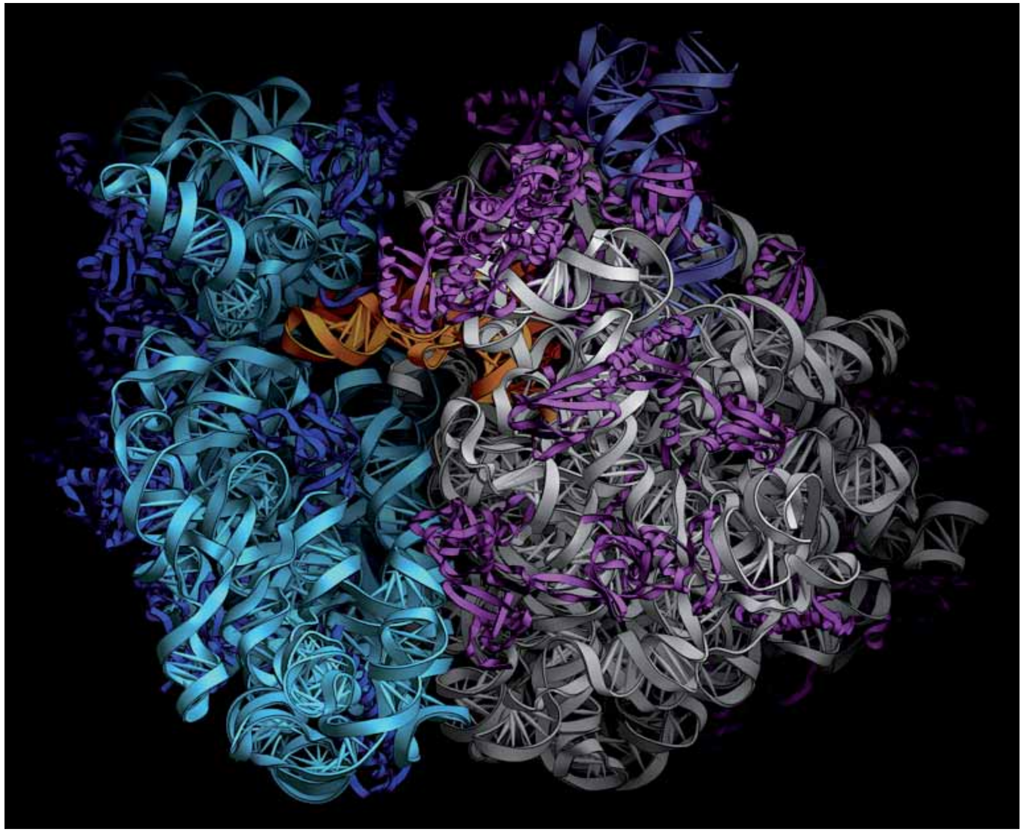
How?

“Evolution should favor code makers with increased Semantic Capacity”? (Dittrich)

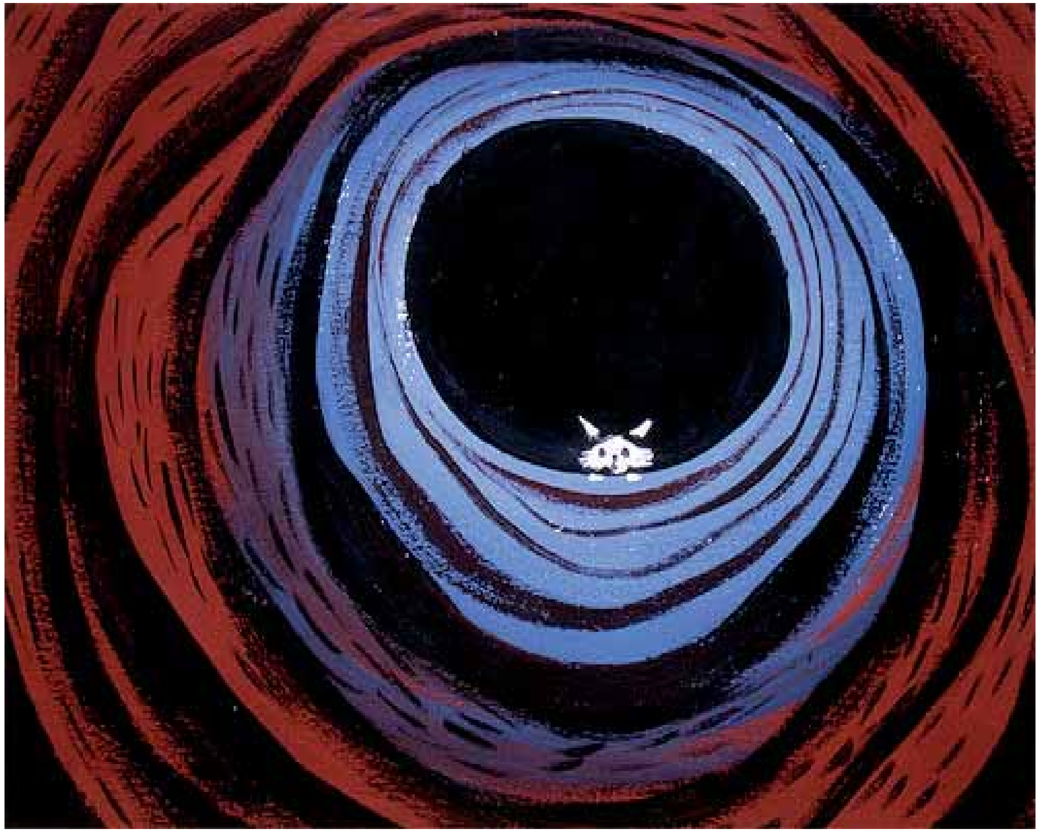
Supplementation and Tools

(Ashby, Clarck, …)

Supplementation and Tools



The ribosome is a
molecular tool



A rabbit's burrow
Is a tool

Specialization and Constraints

Extension

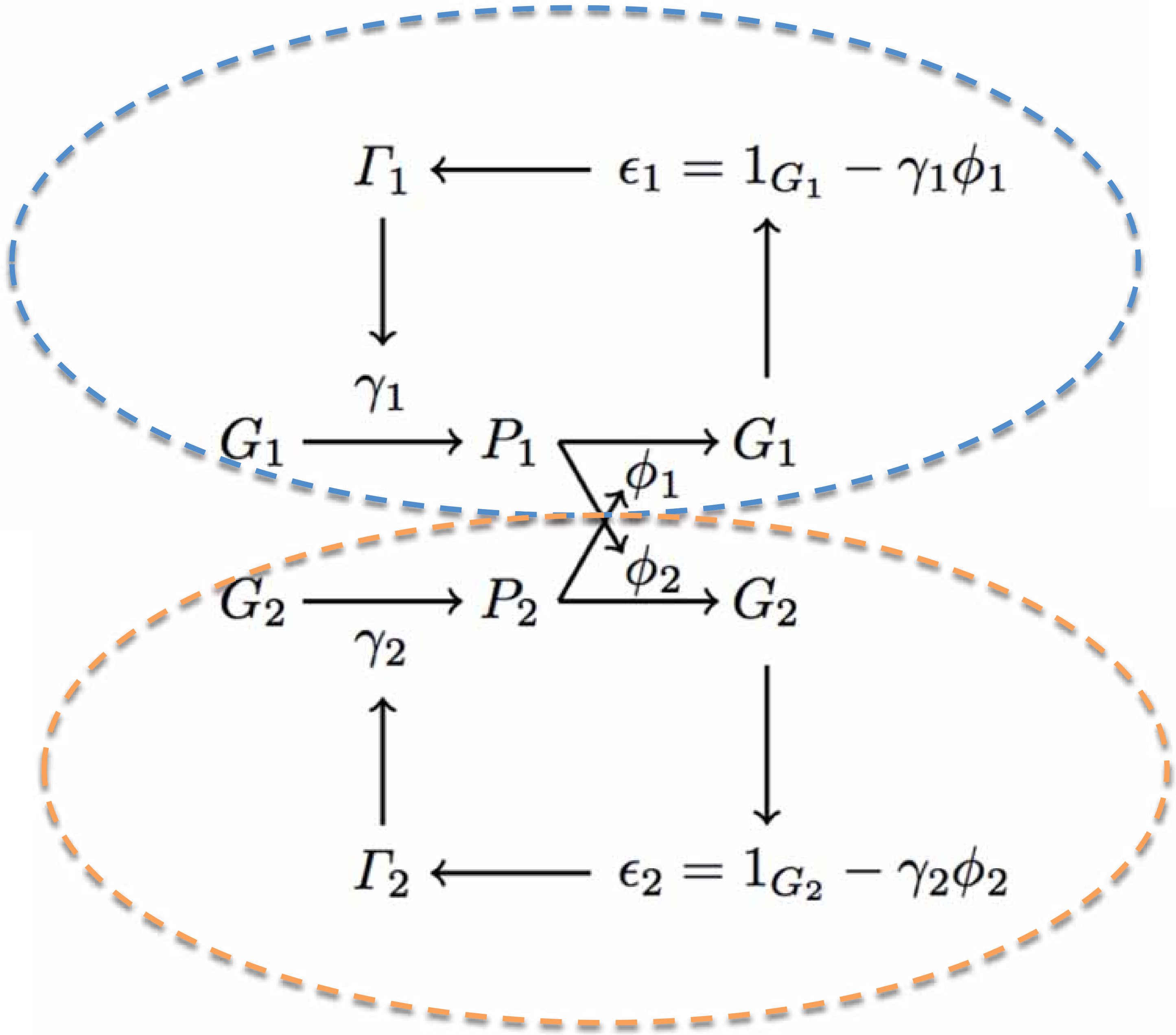
(Clarck, Chalmers, 2006)

Inside The New Human: The Near Future Of Embeddable, Implantable Technology

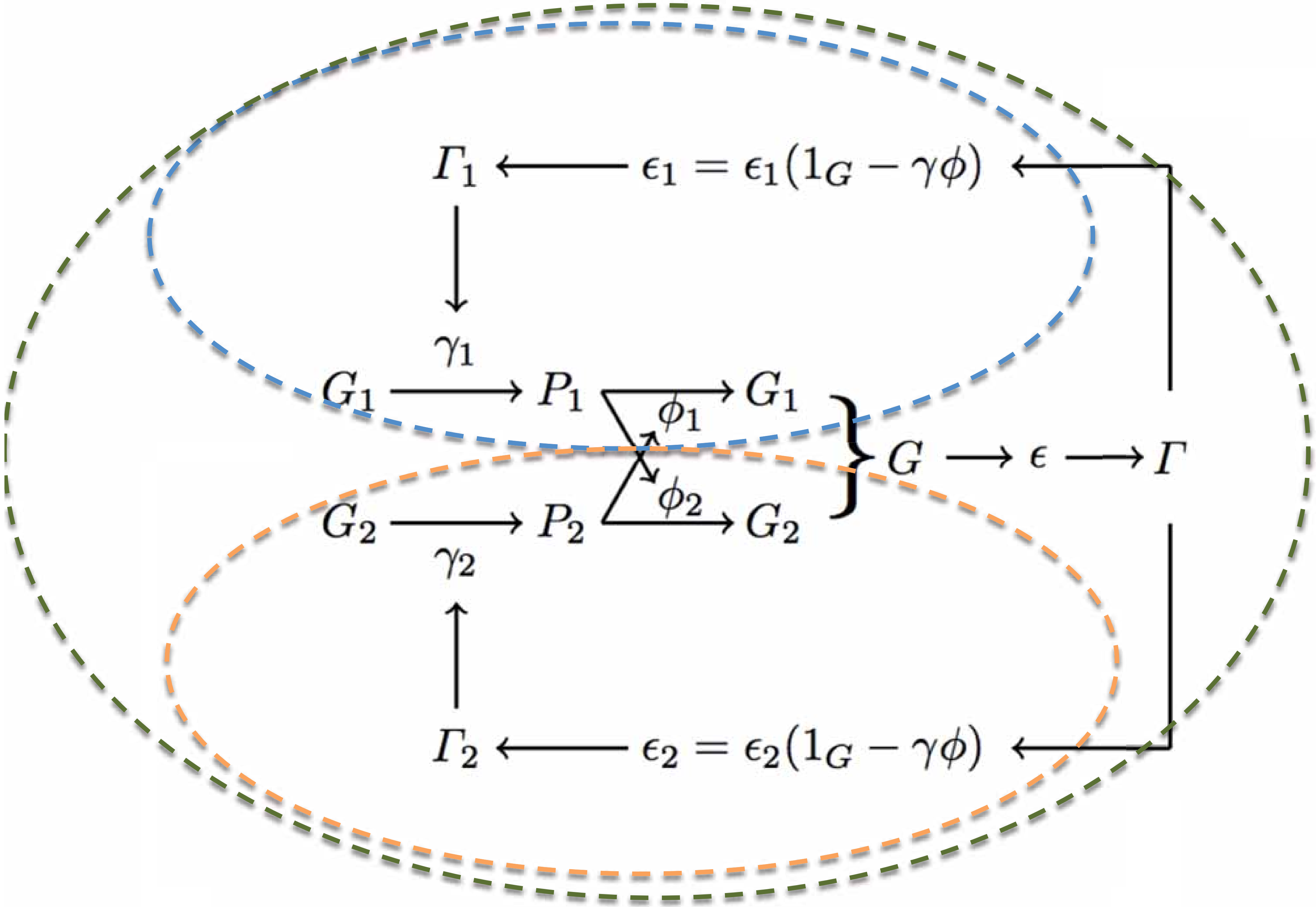
The line separating human from machine got a bit fuzzier last month, when Google finalized two patents for smart contact lenses designed to alert people with diabetes to potentially dangerous dips in blood sugar levels. Around the same time, scientists at the University of Louisville helped three people with complete lower limb paralysis move their legs and feet by stimulating electronic devices they'd embedded in their spinal cords. And earlier this year, doctors implanted a chip in the brain of a man with complete paralysis that allowed him to move objects with his mind with the help of a prosthesis.

http://www.worldsciencefestival.com/2014/05/inside-new-human-near-future-embeddable-implantable-technology/

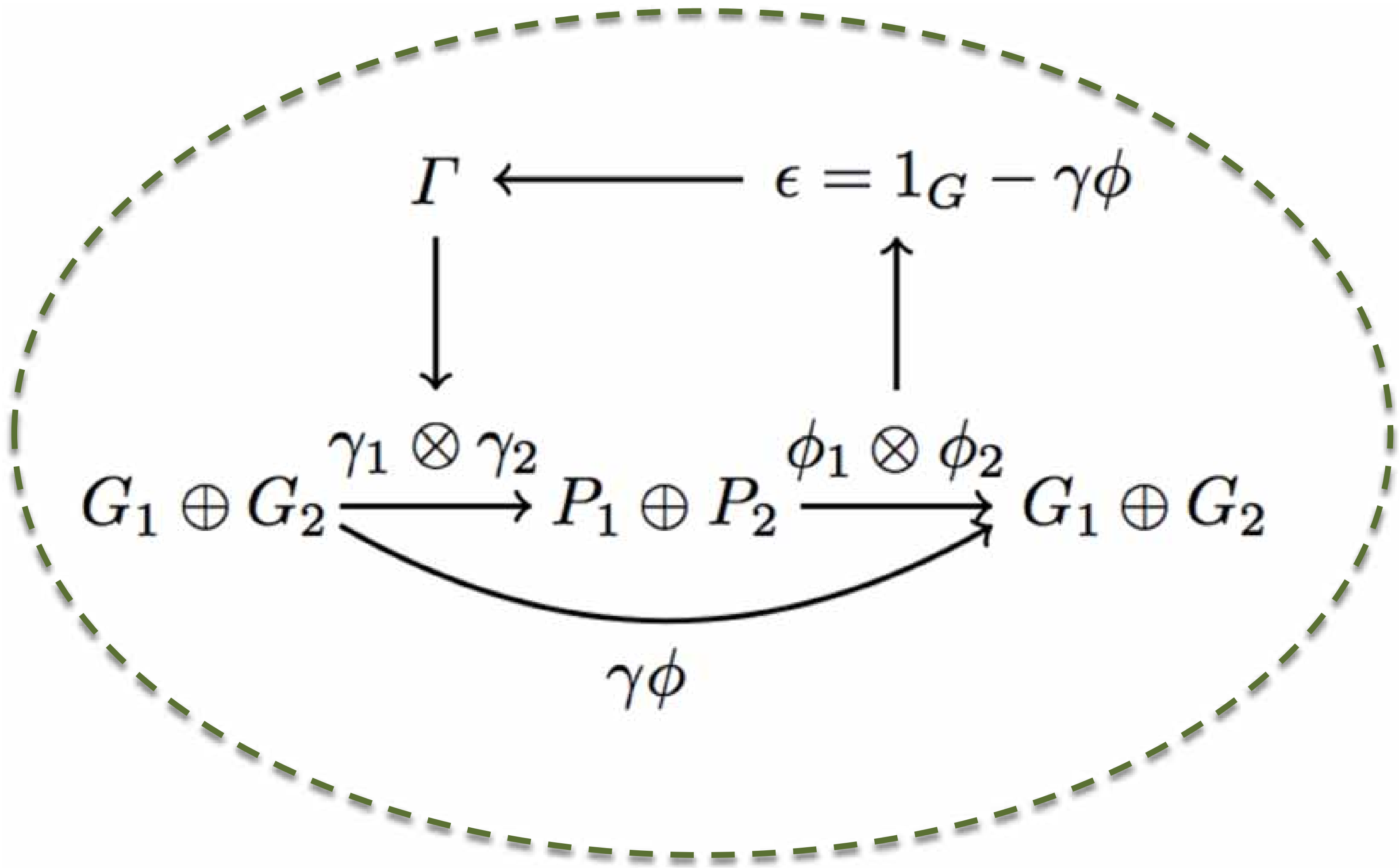
Symbiosis and Conventionalization



Symbiosis and Conventionalization



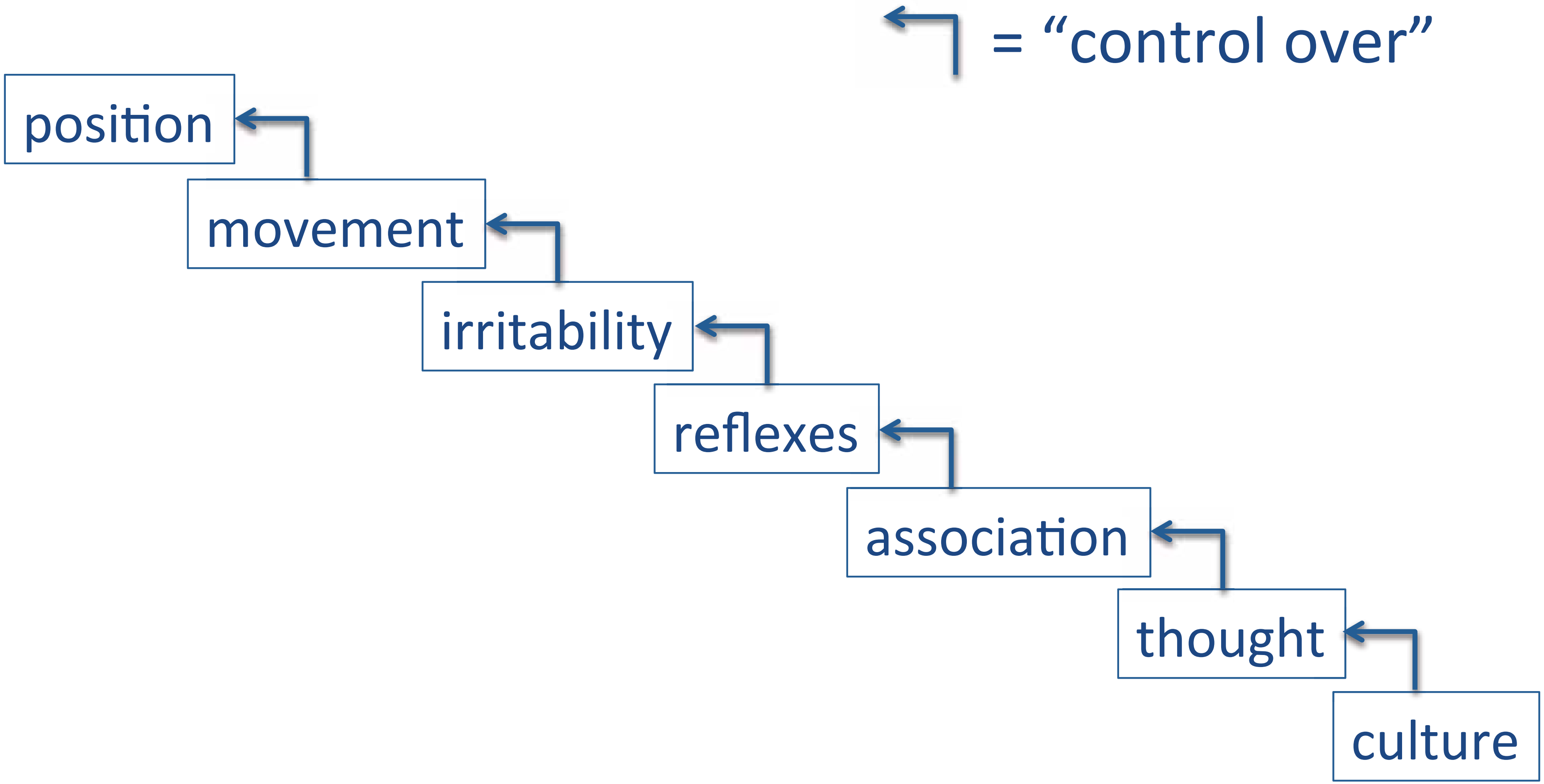
Symbiosis and Conventionalization



Meta-system Transitions

Turchin (1977)

[t]he metasystem transition creates a higher level of organization, the metalevel in relation to the level of organization of the subsystems being integrated.



Meta-system Transitions

Turchin (1977)

[t]he metasystem transition creates a higher level of organization, the metalevel in relation to the level of organization of the subsystems being integrated.

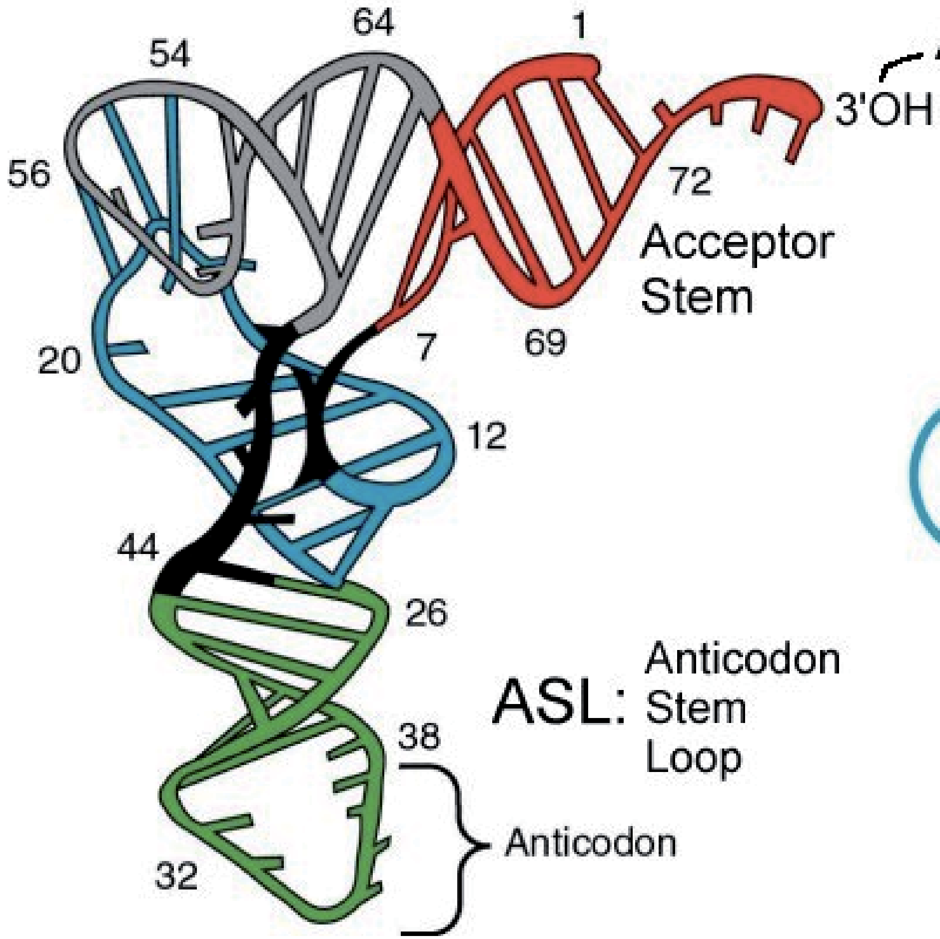
At each level, *novel code-makers* arise, imposing *novel distinctions* (variety of signs and meanings) upon the world at a higher level of organization

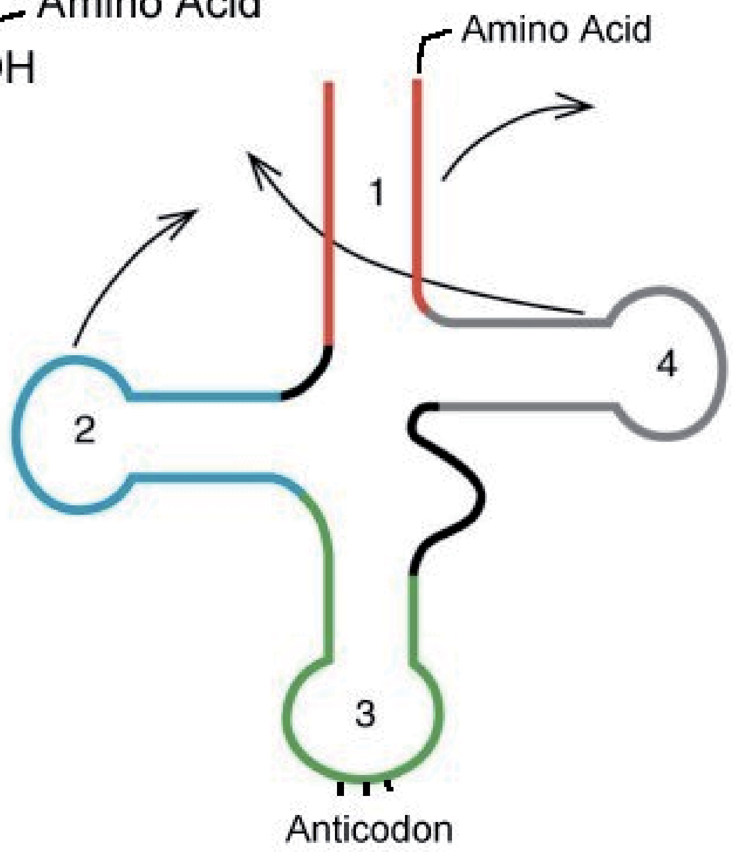
Part II

"[p]roperly speaking, to define a particular science is the same as introducing its basic concepts, for all that remains to be added is that a description of the world by means of this system of concepts is, in fact, the particular, concrete science." Turchin (1977)

- Replication and evolution + relation to copying and coding
- Communication, information, variety, signs, meaning, and arbitrariness
- Code makers, regulation, closure and essential variables
- Requisite variety, supplementation, tools, specialization, constraints
- Extension, coordination, conventionalization, symbiosis and meta-system transitions

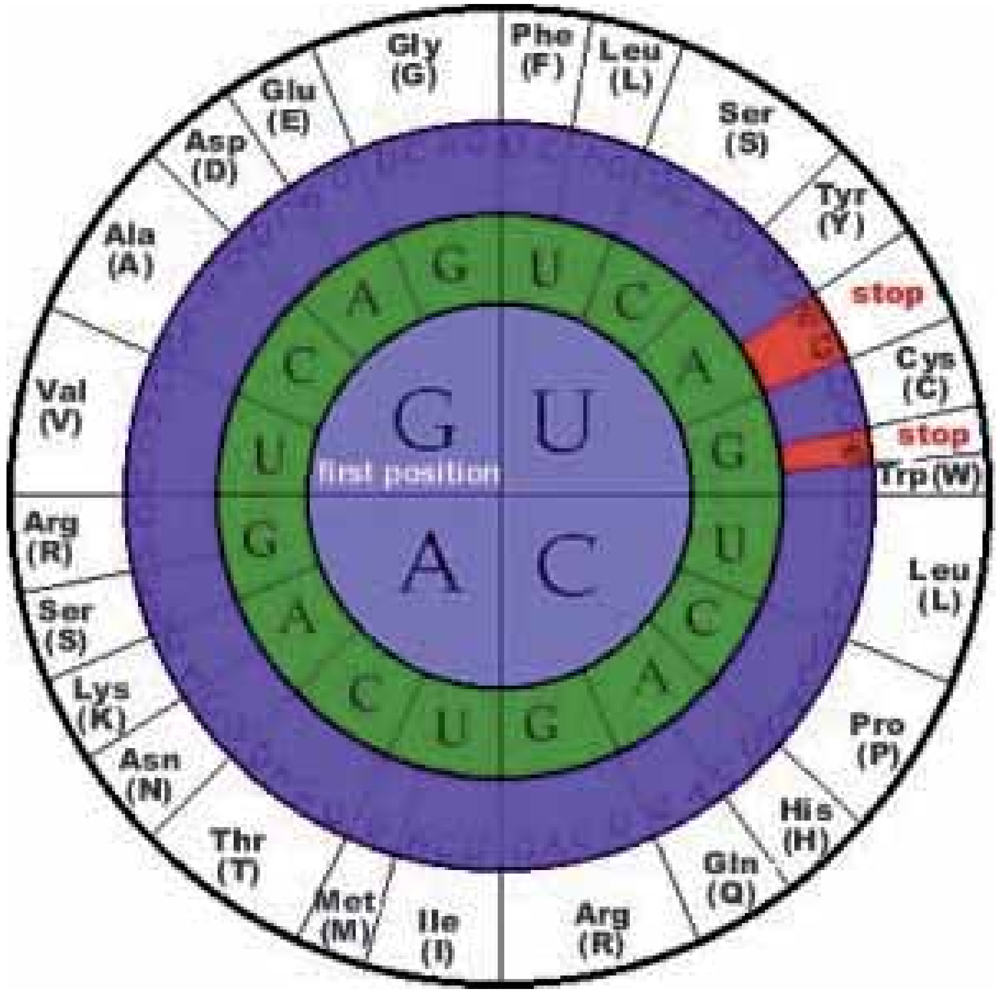
The Origin of Life Itself





tRNA molecules are primitive code-makers (the sets of signs *G* and meanings *P* are *singletons*)

Conventionalization and the first meta-system transition



A semi-synthetic organism with an expanded genetic alphabet

Denis A. Malyshev, Kirandeep Dhami, Thomas Lavergne, Tingjian Chen, Nan Dai, Jeremy M. Foster, Ivan R. Corrêa & Floyd E. Romesberg

Affiliations | Contributions | Corresponding author

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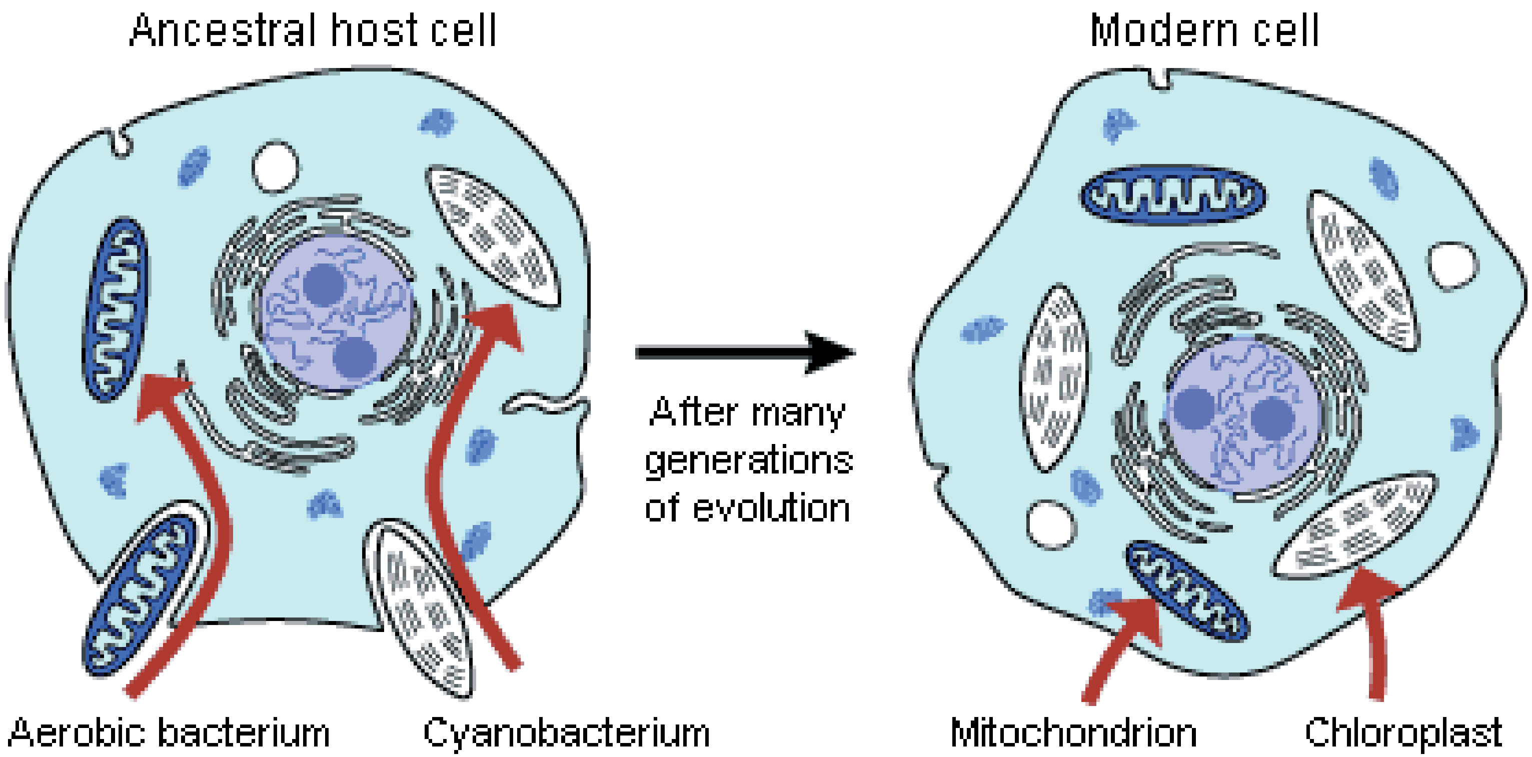
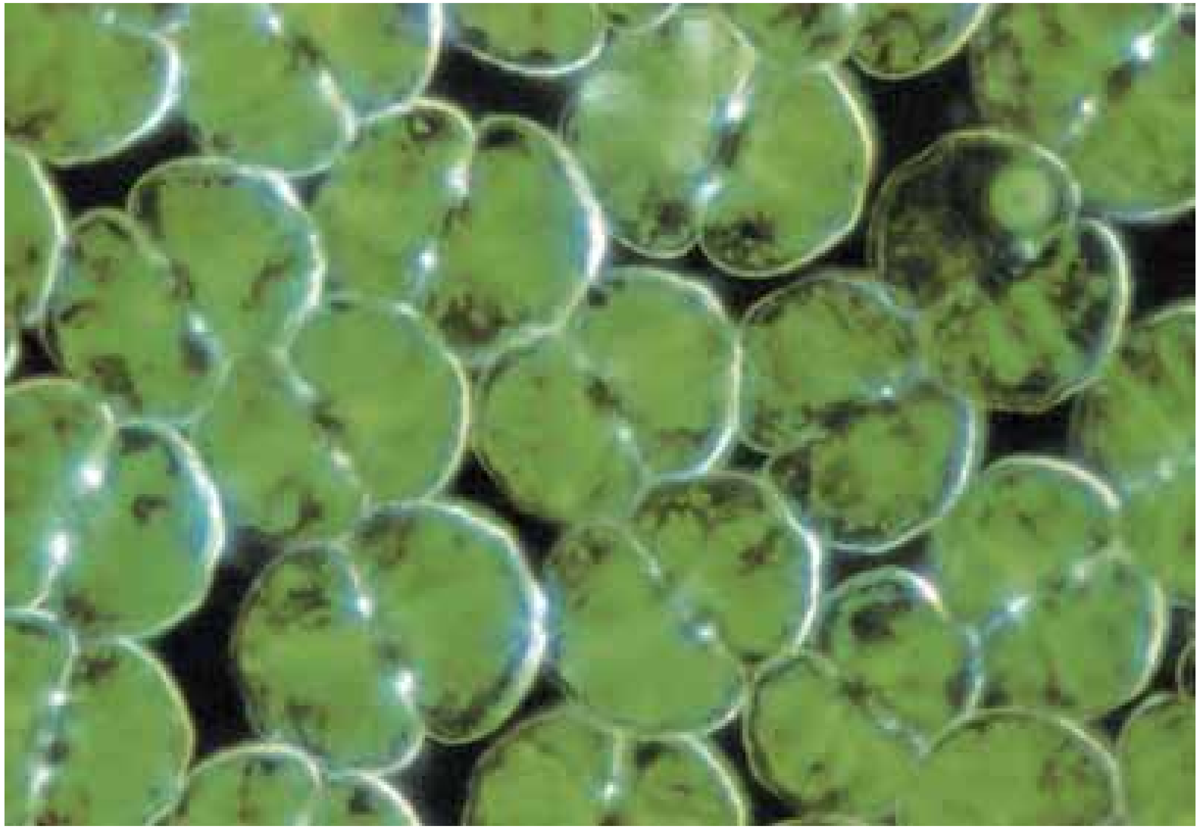
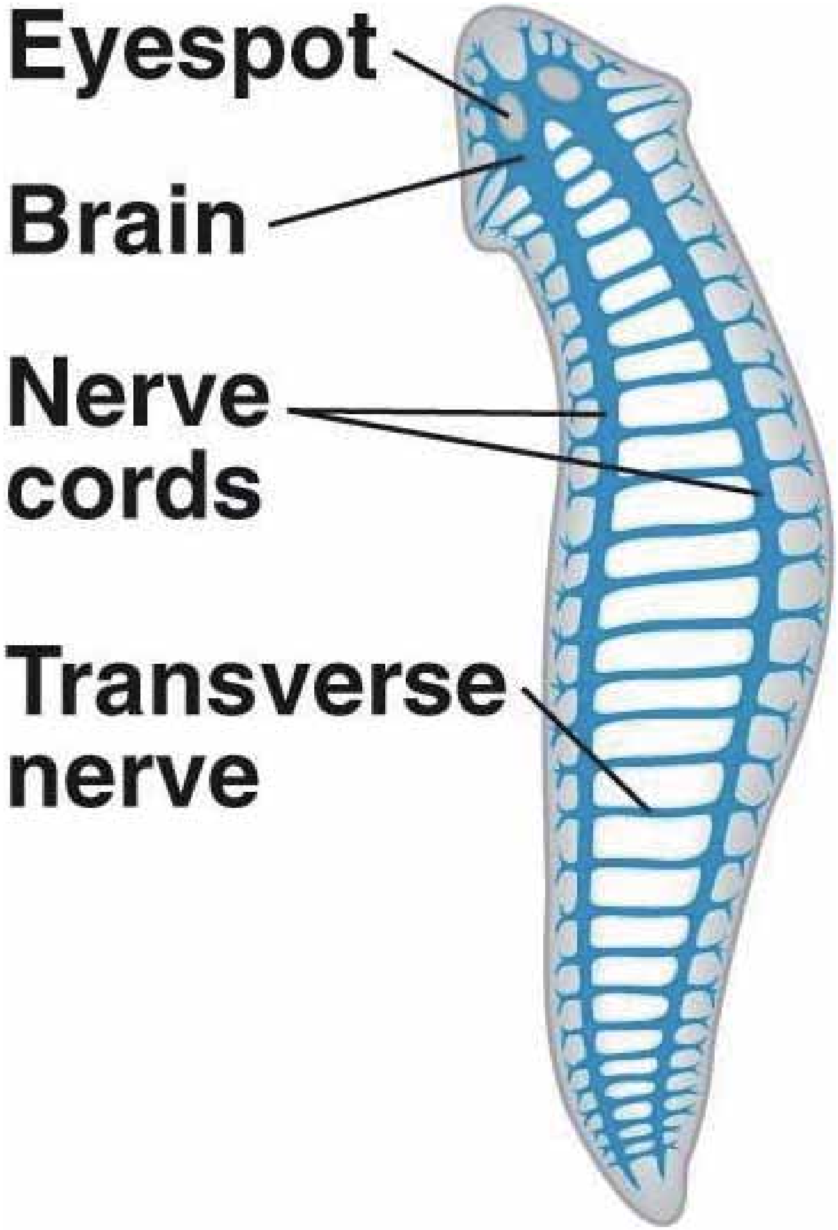
Endosymbiosis



Multicelled Organisms

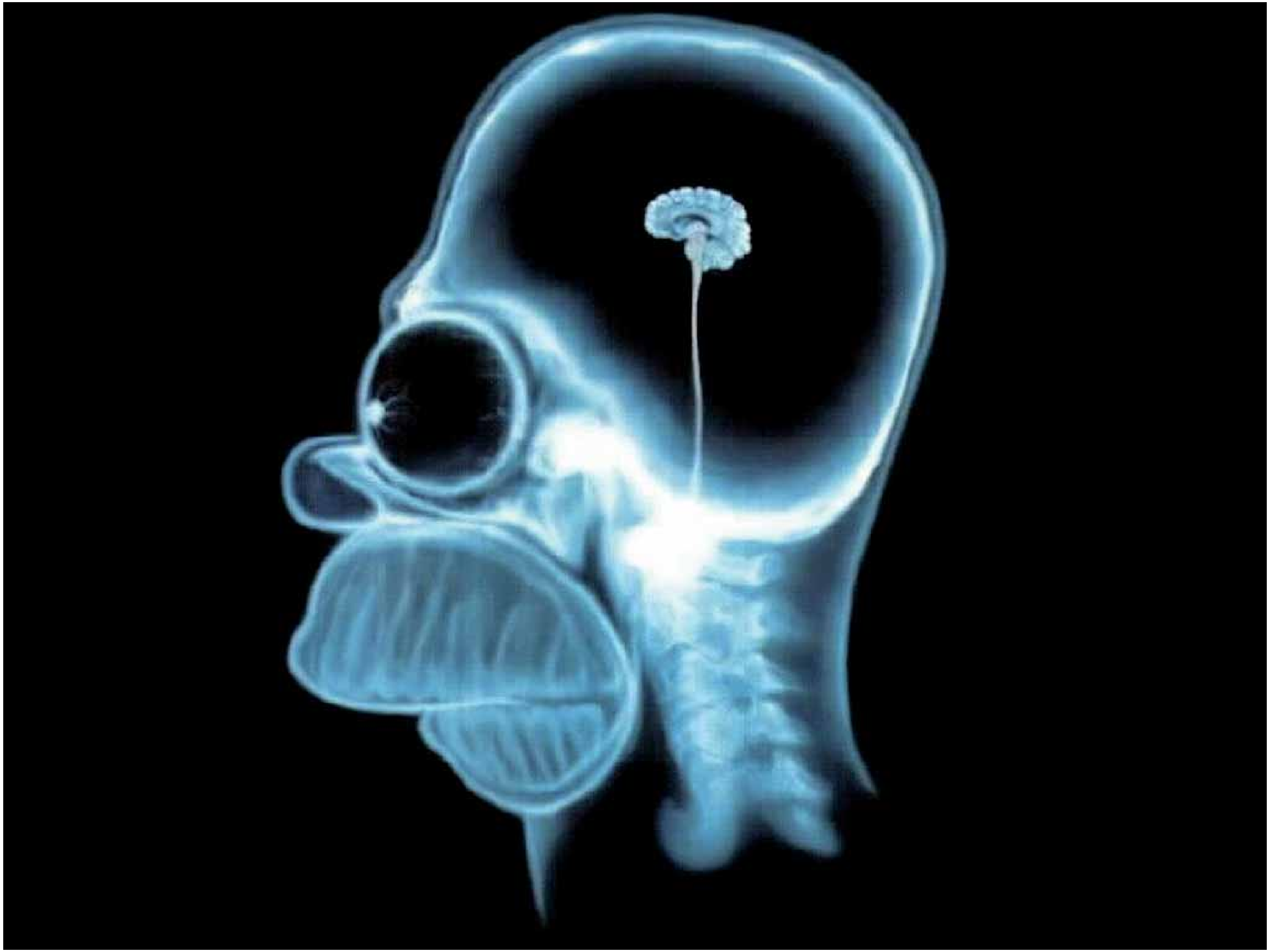


Specialization and Neural Codes

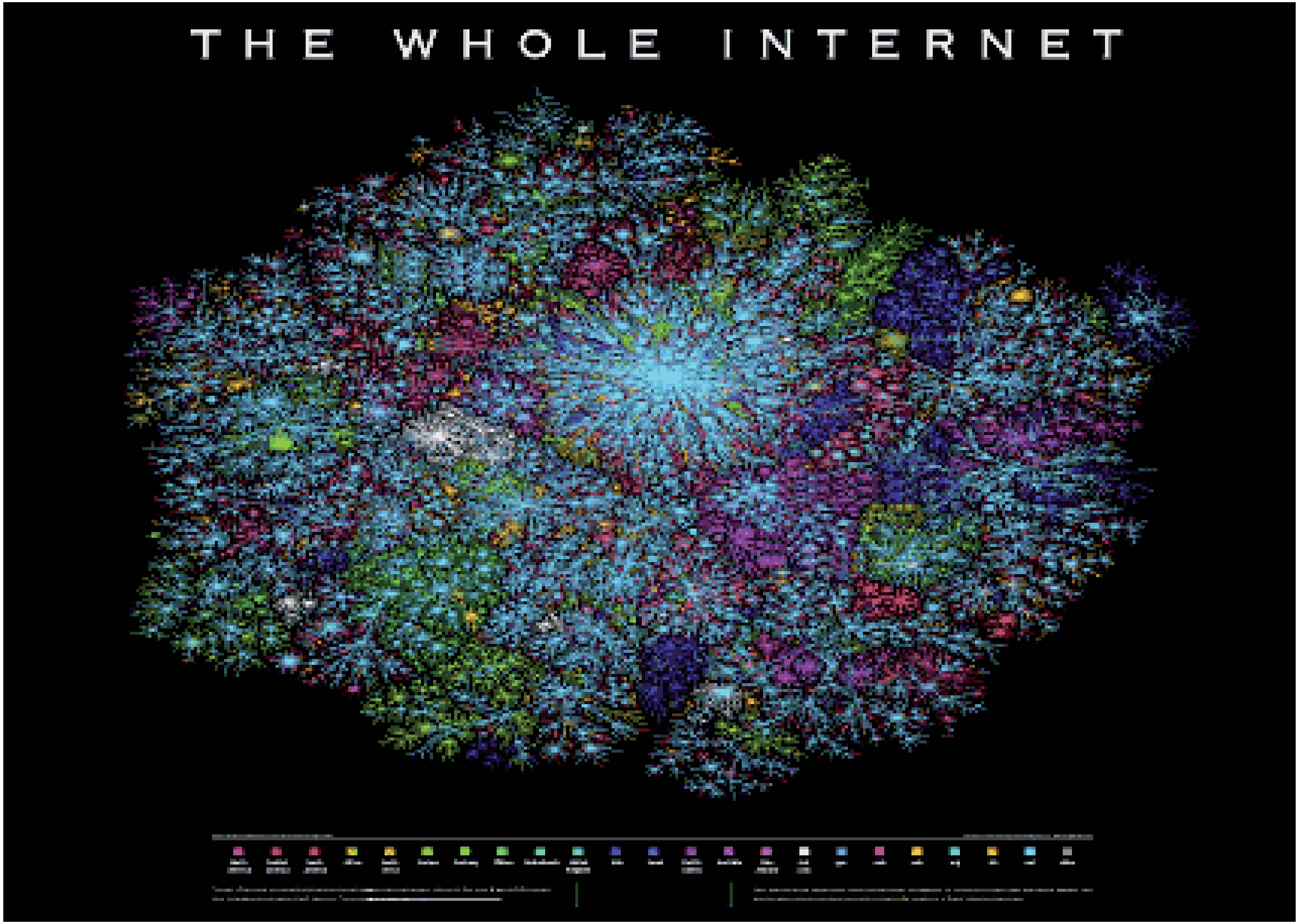


Plathelminthes (Flat worm)

The brain’s second modeling system



Language and Culture



Final Remarks

- Replication *always involves coding*
- Evolution is the result of the interplay between replication, variation and *interaction*
- Malthusian interaction leads to *natural selection*
- Extension oriented interaction leads to conventionalization, novel codes, and novel code-makers during meta-system transitions

More? See my contribution to our special issue!

One of the reasons why Darwin's theory of evolution by natural selection had such profound impact is that, for the first time in history, it explained how we got here, in a mechanistic fashion, essentially setting humanity on a par with any other life form on earth. Evolutionary biology is not the only field that has offered such an explanation however. The theory of dynamical systems offers the mechanisms of emergence and self-organisation (Kauffman, 1993), and evolutionary cybernetics offers the theory of metasystem transitions (Turchin, 1977). In code biology, these different perspectives all naturally fit together. Moreover, by placing humanity in an even broader evolutionary perspective, it further frees biology from any remaining anthropomorphic preconceptions and ideological debates. Specifically, it settles the issues that evolution is not by genes alone, and that culture, our primary characteristic, is essentially a social construct that must be developed with coordination in mind rather than competition.

Thanks!