Jay R. Lynch
Derek T. Williamson
Editors

Natural Selection

Biological Processes, Theory and Role in Evolution

SCIENCE, EVOLUTION AND CREATIONISM

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NATURAL SELECTION

BIOLOGICAL PROCESSES, THEORY AND ROLE IN EVOLUTION

JAY R. LYNCH

AND

DEREK T. WILLIAMSON

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NATURAL SELECTION

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PREFACE

In evolution, natural selection is the gradual, non-random, process by which biological traits become either more or less common in a population as a function of differential reproduction of their bearers. In this book, the authors present current research in the biological processes, theory and role in evolution of natural selection. Topics include evolutionary transitions in mathematical modeling complexity using evolutionary systemic modeling; natural selection applications for algorithmic computation; allozymes, and DNA and natural selection in the mollusk population.

Chapter 1 - Everything evolves but the patterns are displayed at the *evolutionary timescale*, which are not intuitively evident or visible; whereas visible changes are at the *dynamic timescale* but they are evidently unique, idiosyncratic and not suggestive of evolutionary processes. This scenario was even sharper before the emergence of theory of evolution in biology as an *ontological essence* was attached strongly to Man's existence. However, the Darwinian natural selection is pivotal in successfully unearthing the common descent among all species; proves the growth of simplicity into complexity; can explain the trait of altruism; all of which are through the natural selection criterion of being callous, purposeless, unintelligent, and without foresight. Owing to evolutionary thinking in biology, it has become feasible to recognize the evolution of everything but it remains a challenge to devise a *generalized theory of evolution* transparent across all disciplines. This chapter has the aim of meeting the challenge by recognizing the existence of the above timescales and using a modified concept of feedback loops of systems science/cybernetics. The outcome is *evolutionary systemics*, which is a *generalized theory of evolution* applicable to every human endeavor. The applications include philosophy and science as a whole, all driven by evolutionary transitions.

Chapter 2 - Artificial Intelligence (AI) is in symbiotic relationships with computer systems and includes neural networks, expert systems and agents. Each area of AI is complexity in the sense of having hierarchy and interconnectivity but these are overlooked giving a monolithic or unique sense. Therefore, knowledge gained from one area is not transferrable to new areas. Also, some AI applications involve solving complex over-redundant equations using optimisation techniques, implying architectural dissimilarity with natural intelligence. These problems expose major flaws in current thinking stemming largely from overlooking hierarchy and interconnectivity as a part of possible *missing links* in science and their AI paradigms. This chapter invokes possible solutions as a vision suggesting: (i) integrating *evolutionary thinking* with *systemic thinking* expediting the introduction of hierarchy and interconnectivity into AI complexity; (ii) *a new calculus of number sequences,* allowing a mirror image of complexity in the world of integer numbers to possibly removing over-redundancy of the equations and making usage of *bondage* between objects; and (iii) *morality* to discourage the way reductive science, oblivious to morality, facilitated uncontrolled exploitation of natural resources. The vision would contribute to target investments on AI-products towards their potential returns by reusing existing capabilities.

Chapter 3 - The increase in oxygen concentration in the Earth's atmosphere represented an important selective pressure for living organisms and contributed to set up the pace of evolutionary changes in physiological and metabolic systems. Despite the evolution of molecular mechanisms to use oxygen for efficient energy production represented a relevant evolutionary innovation, the reduction-oxidation (or redox) reactions associated with its use have been responsible for the production of free radicals and, more in general, of reactive species (RS). These products of oxygen metabolism may have damaging effects on organism, in essence, due to oxidation of essential cellular components. Consequently, animals have evolved mechanisms to avoid or minimize the production of RS of oxidative metabolism as well as of antioxidant defense systems needed to limit the pro-oxidant activity of RS. The result was a high diversity in molecular and structural antioxidant defenses as well as in redox signaling pathways perfectly integrated in the cellular metabolic machinery. However, the antioxidant machinery is not 100% efficient in mopping RS up, especially when there is a strong imbalance between production of RS and antioxidant response. The consequence of such an imbalance is the generation of oxidative damage to biomolecules. This kind of biochemical stress of cells has been called oxidative stress, which may be defined as the rate at which oxidative damage is generated. Recent studies on animal species suggest that oxidative stress could also represent a universal constraint of life-history evolution, and a modulator of phenotypic development. Oxidative stress could therefore have worked as a relevant selective pressure, and that is why animal taxa have evolved a myriad of mechanisms to regulate and adjust the redox balance. This high diversity in antioxidant mechanisms also suggests that organisms have a great deal of flexibility in how they deal with RS challenges across time, conditions, and tissue types, as well as that different organisms may have evolved different strategies for dealing with similar oxidative challenges. In this chapter, the authors review the high diversity of molecular and structural defenses against RS evolved by animals. In particular, it is their goal to describe physiological mechanisms underlying the production of RS and the biochemical regulation of defense mechanisms, to extend the traditional concept of antioxidant to other structural and functional factors affecting the 'whole' organism, and to review the state of the art about the link between oxidative stress and longevity. It is proposed that evolution of long-lived animals tends to decrease the rate of generation of endogenous damage and to increase the molecular resistance to the oxidative damage in long-lived species.

Chapter 4 - Mathematical complexity is often regarded as an abstract world and sterile due to its formidable status but this reflects the grip of an ontological mindset. This complexity seems beyond the reach of evolutionary processes, where it sounds counterintuitive to explain it by *evolutionary thinking*. This chapter shows that there is nothing unique about mathematics, as it evolves like any other complexity. The modeling approach used is *evolutionary systemics*, which is the integration of *systemic thinking* (the architecture) with evolutionary thinking (the architect). Evolutionary systemics is driven by a set of *axioms*, in which natural selection drives evolutionary transitions through four types of feedback loops from a lower loop to higher ones. The outcome is a modeling capability, which uses historic accounts as evidence. Thus, evidence gathered from historic accounts identifies evolutionary transitions and the approach copes with the roles of *cognitive mathematics of individuals*, *communal mathematical thinking*, and *institutional mathematics*.

The chapter offers an insight into mathematical practices and holds that evolutionary transitions in mathematics are in tandem with other human endeavors. It can be highlighted that, during evolutionary transitions, the past knowledge may become obsolete without being unselected. As mathematics is pluralist by its nature and increasing in complexity, feedforward loops are indispensible for proactively reshaping mathematical practices with the evolving culture. The following strategies are identified. (i) Philosopher's aspirations are in asking stimulating questions but they produce mutually exclusive doctrines, which are contentious and devoid of significant practical benefits. (ii) Practitioners' aspirations are fruitful in axiomatization to overhaul existing knowledge riddled with conflicts to self-evident information but these are few and far in-between. (iii) This chapter promotes goal-orientation by applying evolutionary systemics through identifying missing links in mathematics, proposing a model to resolve their impacts, outlining the elements of a vision to identify its equivalent cladistics and to manage expectations on mathematics. A new calculus is presented to support the thinking behind goal-orientation in the sequence of natural numbers primed from the building block of "1" by the virtue of new operators.

Chapter 5 - Since the emergence of computational mathematical modeling in the 1950s, its developments have been suffering from fragmentary visions, if any. Still there is no insight into, or foresight of, modeling complexity as a whole. This chapter formulates a vision for modeling complexity using evolutionary systemics, which integrates evolutionary and systemic thinking. It recognizes cognitive model thinking of the individuals assisted by their instincts; communal model thinking due to cohesion of individual mindsets; and institutional modeling practices capable of evolutionary transitions. The following transitions are identified: (i) primitive modeling, prevailed until the 17th century; (ii) prototype modeling until 1950, which started afresh by unselecting its past primitive modeling practices; and (iii) computational modeling since 1950, which largely reinvented past capabilities under the computational environments. Over the years since 1950, modeling complexity has seemingly been growing organically but whilst this signifies healthy growth, it underlines potential problems. The practice-data is used to analyze this complexity by applying evolutionary systemics. This helps referencing a vision of modeling complexity to the full evolutionary contexts and identifying relevant issues. In this way, the paper shows that modeling complexity is infested with increasing complexity and increasing dynamism. The emerging complex systems suffer from a new kind of entropy retarding growth. The chapter also studies the structure of complexity exploring the feasibility of deriving a cladistics for modeling complexity. This is a radical departure from conventional thinking, as new investments on model developments can avoid bottlenecks. The gained insight invokes the need for rethinking and making a research case for the formation of the science of modeling .

Chapter 6 - Natural selection is one of the cornerstones of modern biology and one of the great intellectual revolutions of human history. The term was first introduced by Charles Darwin who put forth a coherent theory of evolution and amassed a great body of evidence in support of this theory. In the last few decades, the continuing advance of modern technology has brought about something novel. Evolution is now producing practical benefits in a very different field, and this time, the creators can claim that their explanation fits the facts perfectly. This field is computer science, and the benefits come from a programming strategy which incorporates the notion of natural selection within algorithmic computation, and builds the so called evolutionary algorithms. The main goal of this survey is to summarize the previous research on two of the most important evolutionary algorithm techniques, which are Genetic Algorithms (GAs) and Differential Evolution (DE). Both algorithms are population-based, which means that a population of candidate solutions is optimized through the inspiration of biological motivations. GAs are efficient search methods based on principles of natural selection and population genetics. DE took a serious attempt to replace the classical crossover and mutation operators of genetic algorithms. The authors focus on these algorithms to guide us through a review of many of the most important innovations that they have provoked to science. In this chapter, different variations of operations used by these algorithms such as fitness function, mutation, selection and crossover are discussed. The authors try to identify some of the problems of these methods that have not been studied systematically yet. They also describe the parallel potential of the evolutionary algorithms by focusing on the higher computational costs that big populations causes for some hard problems. As astonishing and counterintuitive as it may seem to some, evolutionary algorithms have proven to be an enormously powerful and successful problem-solving strategy, dramatically demonstrating the power of evolutionary principles.

Chapter 7 - Mollusks are a group in which some interesting examples have been described over the years concerning effects of natural selection over populations. A classical example is the observed clines of *Lap* alleles and salinity gradients in mussels. With the introduction of DNA techniques in the field of population genetics, it has been proposed that comparing the amount of geographic variation in allele frequencies for protein and DNA polymorphisms is a powerful method for detecting the effects of natural selection. Once more, mollusks are important models in these studies. These issues will be reviewed in this chapter and the importance of the molecular markers (allozymes and DNA) for studies on natural selection discussed in the light of the results obtained from mollusks which includes the Brazilian cockle *Anomalocardia brasiliana*, the brown mussel *Perna perna* and the blue mussel *Mytilus edulis*.

Chapter 8 - Soil microbes are important component of the terrestrial ecosystems that play the critical role in decomposition of organic substances and mineralization of nutrients. Since soil microbes influence the nutrition of plants in the nitrogen-limited areas there has been an increased interest on using soil microbes as an important indicator of soil quality.

It is also widely recognized that changes in soil microbial biomass and community composition can influence decomposition of organic matter and nitrogen cycling in soil. Grasslands constitute about one thirds of the earth´s area and are regarded as one of the most productive ecosystems on earth.

Since management measures are often taken in order to optimize the productivity of this system, enhanced knowledge about the functional differences of the soil microbes under various management activities is relevant for proper management of these systems. This chapter attempts to review studies on the structural and functional differences of soil microbial communities in various grassland ecosystems. This chapter also presented data on the differential responses of soil microbial functions such as decomposition rate and nitrogen mineralization rate to litter inputs in order to reveal the characteristic differences of the semi-natural and improved grasslands with special references to grasslands of Shiriyazaki in the northern Honshu island, Japan.

Chapter 9 - Darwin's well-known idea of evolution by natural selection was complemented during the last 100 years: evolutionary changes depend on adaptive evolution (mutation + natural selection), but chance and historical contingency also contribute to evolution. The effects of chance are usually due to founder events, bottlenecks and genetic drift. Historical contingency can become important if certain genetic changes of adaptive value in the past constrain or promote evolutionary outcomes. The importance of genetic adaptation, chance and history on evolutionary change can be empirically tested by the robust laboratory experiments using haploids and asexual microalgae. The experiment followed the idea of "replaying life's tape" by means of the simultaneous propagation of 10 independent isolates of each strain which were grown under increasing nutrient concentration and temperature (resembling global change) during c. 100 generations. Evolutionary changes in fitness (acclimated maximal growth rate), photosynthetic capacity and morphology (size and form) were analyzed in species from continental freshwater-bodies, coastal and oceanic habitats (using two strains per species). Adaptation by new mutations that resulted in the enhancement of growth rate arose during propagation of derived cultures under the new environmental conditions was the main component of evolution of fitness. Mutations were selected, displacing the wild-type ancestral genotypes. However, chance was the pacemaker of evolution of photosynthetic capacity. In contrast, changes in morphology and size were due to the contribution of history and chance.

CONTENTS

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Chapter 1

LEARNING FROM NATURAL SELECTION IN BIOLOGY: REINVENTING EXISTING SCIENCE TO GENERALIZE THEORY OF EVOLUTION – EVOLUTIONARY SYSTEMICS

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ABSTRACT

Everything evolves but the patterns are displayed at the *evolutionary timescale*, which are not intuitively evident or visible; whereas visible changes are at the *dynamic timescale* but they are evidently unique, idiosyncratic and not suggestive of evolutionary processes. This scenario was even sharper before the emergence of theory of evolution in biology as an *ontological essence* was attached strongly to Man's existence. However, the Darwinian natural selection is pivotal in successfully unearthing the common descent among all species; proves the growth of simplicity into complexity; can explain the trait of altruism; all of which are through the natural selection criterion of being callous, purposeless, unintelligent, and without foresight. Owing to evolutionary thinking in biology, it has become feasible to recognize the evolution of everything but it remains a challenge to devise a *generalized theory of evolution* transparent across all disciplines. This paper has the aim of meeting the challenge by recognizing the existence of the above timescales and using a modified concept of feedback loops of systems science/cybernetics. The outcome is *evolutionary systemics*, which is a *generalized theory of evolution* applicable to every human endeavor. The applications include philosophy and science as a whole, all driven by evolutionary transitions.

Keywords: natural selection, generalized theory of evolution, evolutionary-systemics, entropy, hierarchy, interconnectivity, fixed ontology, self-organization, feedback loops: d-loop, ℓ-loop, e-loop

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1. INTRODUCTION

1.1. Statement of the Problem

"Evolution in, fixed ontology out" is the message of this paper, each reflecting a different worldview or mindset in relation to existence. Evolutionary thinking, driven by *natural selection*, explains existence through selections from small and random variations, but this worldview seems counterintuitive. The *fixed ontological mindset* regards organisms and the natural world as fixed creations and imposes permanency, a deceptively self-evident and rather intuitive idea. Fixed ontology was overturned by evolutionary thinking in the second half of the 19th century, when biology was unshackled and evolutionary thinking emerged as the only scientific basis to explain the existence of organisms. Fixed ontology has become irrelevant forever within biology. In spite of claims of evolutionary processes outside biology, evolutionary thinking has failed to reach its full potential. This paper builds on the rigor of evolutionary biology and presents a generalized model of evolution applicable to science, culture and complexity.

Evolution processes are better differentiated on the time dimension, as follows. (i) *Dynamic timescale*: time starts at an origin, processes are triggered on continuous or discrete time intervals of fractions of a second to hours, days and so on, the process ends. (ii) *Long timescale*: this is normally large compared with dynamic timescale, during which adaptation may take place. (iii) *Evolutionary timescale*: changes take place in many generations at the genotypic level. There is also a fictitious ontological timescale, in which time is regarded as eternal and ontological substances attached to entities are regarded as fixed throughout with primacy over their *accidental* properties. Evolutionary timescale ought to be parts-and-parcels of the wider science and its importance is underpinned by resorting to the following strategy: if evolutionary thinking is not explicit in any particular human endeavor, it is in the grip of ontology, even if inadvertent. Fixed ontology unduly retards the wider sciences and is irreparable. Thus, this paper aims to undo its grip.

1.2. Evolutionary Systemics in a Nutshell

Scientific enquiries are focused largely on explaining the complexity of life, where the role of theory of evolution is pivotal. The enquiries through evolution started from the physical world (phenotypic resolution) ever since the 17th century; consolidated in the 1920s by the emergence of neo-Darwinism; and came to its culmination in 1953 when it penetrated the chemical world (genotypic resolution). Thus, by drawing on from many disciplines, theory of evolution inadvertently opened the way to holistic thinking independent of systems science, where the latter emerged since 1950. Holism is now one of the tenets of science.

The existence of three timescales for any *evolvable entity*, as stated in Section 1.1, is the statement of the obvious. Evolutionary scientists deal explicitly with the evolutionary timescale with a focus on both phenotypic and genotypic behaviors and tacitly with other timescales but without any formalized approach.

Scientists observe widely the three loops of positive feedback, negative feedback and feedforward but only at the dynamic timescale and as such, if system scientists have a tacit perception of the long and evolutionary timescales, this is tacit but not explicit.

Table 1. Proposed Timescale Subdivisions of Feedback Loops

Loops	Drivers at		
	Dynamic Timescale	Long Timescale	Evolutionary Timescale
Zero⁺ Feedback See Box 1.2	d-loop: Randomness	ℓ-loop: Obscure	e-loop: Spontaneity
	Zero$^+$ Feedback Loop gives rises to simplexes, which then grow.		
Positive Feedback (Boxes 1.3-1.4)	d-loop: Performance	ℓ-loop: Adaptation	e-loop: Natural Selection
	$Positive\ Feedback\ Complexes = d\_loop + \ell\_loop + e\_loop$		
Negative Feedback (Boxes 1.4-1.5)	d-loop: Internally-consistent performance	ℓ-loop: 'Discretion'	e-loop: Natural selection of rules for internal consistency
	$Negative\ Feedback\ Complexes = d\_loop + \ell\_loop + e\_loop$		
Feedforward See Box 1.6	d-loop: Goal-driven for external consistency	ℓ-loop: Mission for external consistency	e-loop: Natural selection of rules for external consistency
	$Feedforward\ Complexes = d\_loop + \ell\_loop + e\_loop$		

Note 1: Positive feedback has three integral components of d-loop (real dynamic state of the system), ℓ-loop (manipulation of the phase), or e-loop (changes to hereditary codes)
Note 2: The same is said about negative feedback or feedforward loops.
Note 3: In discussing a loop, the focus is on all three types of d-loop, ℓ-loop e-loop.
Note 4: These loops operate pluralistically and emerge (or are pump-primed) one after another through evolutionary transitions due to inherent entropy normally in the above order.
Note 5: The emergence of the next evolutionary transition is not deterministic but a potential driven by natural selection. Sound entities may be pump-primed but not selected.

This paper integrates theory of evolution with systems science and therefore it is expedient to institute the roles of these feedback loops at each of these timescales. As shown in Table 1, the following sub-loops are proposed: *d-loop* at the dynamic scale, *ℓ-loop*, at the long timescale, and *e-loop* at the evolutionary timescale. This synthesis goes a long way towards a generalized theory of evolution making every discipline transparent. Although there are generalized Darwinian theories of evolution, they are problem-specific and not transparent to one another. This paper takes a critical view of science and presents an original approach to synthesize existing scientific knowledge to develop a new generalized theory of evolution. It fully embraces neo-Darwinism without getting involved with its ongoing scientific debates. The 'leitmotif' of this paper is: building blocks and rules. It builds on Khatibi (2011). The building blocks are not fixed but vary in each discipline. However, the arrangement of building blocks is not arbitrary but they are 'fashioned' by the concept of feedback loops, where each loop has three manifestations corresponding to each timescale. The feedback loops comprise: zero$^+$ feedback, positive feedback, negative feedback and feedforward loops, where zero$^+$ is proposed by Khatibi (2011). The systems science account of these loops makes up the basis for the generalization of theory of evolution.

Box 1.1 – Axioms on System

The term 'system' immediately and unequivocally means:

(i) A set of inputs; a set of building block modules; a set of outputs;

(ii) Workable connection from inputs through building blocks toward the outputs;

(iii) Flow of material and information from inputs towards the outputs and depending on the evolutionary stage of the system the flow of information from the output or even the environment to or toward the inputs;

(iv) System encompasses: feedback loops, hierarchy, institutionalization, various timescales, pluralism and working together holistically.

Box 1.2 – Axioms on Zero$^+$ Feedback Loop

- **Tailback**: zero$^+$ feedback is the tailback of *evolvable entities* to uncertain origins;
- **Connectivity**: no connection between building blocks, no output for a given input, no dynamic timescale, no evolutionary timescale and no system but a potential;
- **Spontaneity**: motion or motivation exists to hone abundantly existing potential building blocks by shaping and reshaping in the environment; in the natural environment, the honing is spontaneous as they freely float or available but in man's world, there are a host of activities including having a hunch;
- **Emergent property**: At one instance, the potential materialises through self-organisation for the production of an entity by a particular intertwining of building blocks with rules triggering an emergent properties in the natural environment or through man's activities, e.g. design or trial-and-error;
- **Priming prototype (3 if-s)**: (i) if the entity has an emergent property; (ii) if the emergent property creates a selective advantage; and (iii) if the selective advantage primes a selection, the entity should be called a *prototype*;
- The prototype may emerge at one or many locations, at one or many times;
- **Emergence of purpose**: The *prototype* at the instant of emergence; triggers the purpose for survival through uncontrolled reproduction, characteristic of one-way flow of information of connecting inputs to building blocks to outputs;
- **Critical mass**: if the prototype proliferates in the environment, then it can form a critical mass to be transformed into an *evolvable entity*;
- **Triggering selection**: the zero$^+$ feedback stage is completed by reaching a critical mass, from which time the evolvable entity kicks off the next stage;
- **EvSyM** characterises this period by the term the Zero$^+$ Feedback. "Zero" signifies that during this long period, there was no viable connection; "+" signifies that a new feature has emerged from the 'no-existence' of the past; Feedback signifies that the prototype connected to its past;
- Other terms are equally valid: *open loop, spontaneous potential system with zero-flow of information*.

The classical science of feedback loops is confined to d-loops and this is why it is unwittingly ontological; whereas ℓ-loops and e-loops are all that define the horizon of theory of evolution.

This makes the culture rife for doubt on the law of natural selection, e.g. Karl Popper, who was even ambiguous on the law of natural selection. In between systems science and theory of evolution there is a gap, but bridged by Table 1, their integration. This is the integration of building blocks with rules or the architect with the architecture, to be referred as *evolutionary systemics* or *evolutionary systemic modeling* (EvSyM).

Box 1.3 – Axioms on Positive Feedback Loops

Routemap: survival, proliferation, diversification, adaptation, co-evolution, flow of information in one direction and instigation of entropy;

Positive feedback d-loop

- Inputs are connected to building blocks in the direction from the inputs towards the outputs and the whole arrangement produces outputs from given inputs;
- The interactions between the building blocks instigate internal entropy and between evolvable entities instigate external entropy;
- The survival is ensured by uncontrolled reproduction under entropy;
- In EvSyM, the positive Feedback refers to, *open loop*, closed system with 1-way information flow; closed systems becomes rather vague;

Positive feedback ℓ-loop

- Different configurations of the building blocks gives rise to different traits and this is at the core of adaptation, which may be attributed to the behaviours at the long (adaptive) timescale for the individuals of the *evolvable entities*;
- As there is no one way of reproductions, variations are inevitable in the long-run stemming from mutation but in man's world, there can be many reasons for variations contributing to *diversity*;

Positive feedback e-loop

- The e-loop is the connectivity of the building blocks as the architecture or blueprint for reproduction, including the know-how on the building blocks;
- The e-loop is simple but over many generations, natural selection transforms simplicity to complexity by selections dictated by selection pressures.

Box 1.4 – Axioms on Transition to Negative Feedback

- As no system is perfect, the connections between the building blocks are one source for potential inconsistencies and waste of some of the inputs;
- Often, the higher the dynamism, the greater is inconsistencies. This triggers a selective advantage for the emergence of a system to reduce entropy;
- A positive feedback complex is unable to cope with its inherent entropy unless it operates at a slow dynamic rate. An additional subsystem is needed to modulate both inputs and the working of the modules to maintain the output at the required level and maintain the integrity of the system. Entropy triggers the selective advantage for the emergence of such a subsystem;
- If such a subsystem fails to emerge, entropy undermines the system's efficacy;
- Due to entropy, evolvable entities dwindle, reach critical masses and perish;
- Critical masses may show resilience and revive through cyclic fluctuations.

Box 1.5 – Axioms on Negative Feedback Loops

Negative feedback loops emerge to maintain homeostatic conditions.

- The emergence of negative feedback is not automatic but is triggered by entropy, selected by natural selection and is operated by a small subsystems;
- This subsystem comprises: transmitters, a fact engine, actuators;
- The positive feedback complexes are reinvented to flexibly accommodate the supervision by negative feedback subsystems;
- Targets are essential for creating consistencies within the internal systems;
- Two-way flow of Information is essential;
- Traditionally, these subsystems are referred to as regulating subsystems, *closed loop* and open system with two-way flow of information but EvSyM distinguishes three negative feedback sub-loops:

Negative feedback d-loop: This is the reactive fact engine and works ubiquitously

Negative feedback ℓ-loop: This provides adaptive provisions against stagnation to snap out by "*discretionary*" powers overriding set targets or by resetting them;

Negative feedback e-loop: This is the routemap of resetting fact engines;

The role of natural selection: Negative feedback is a product of natural selection in the first place but the set targets are subject to natural selection in the long runs.

Box 1.6 – Axioms on Feedforward Loops

Feedforward loops emerge to maintain external consistency with the environment

- The emergence of feedforward is not automatic but is triggered by external entropy and selected by natural selection;
- The systems are reinvented to flexibly accommodate goal-seeking capabilities;
- Goals are essential for creating consistencies within the external environments
- Free-flow of Information is essential;
- Traditionally, these subsystems are referred to as goal-seeking systems, *closed loop* and open system with free information flow but EvSyM distinguishes three feedforward loops:

Feedforward d-loop: This is the proactive fact engine focused on the environment;

Feedforward ℓ-loop: This adaptive provision periodically articulates the goals;

Feedforward e-loop: This is the routemap of resetting vision/mission;

The role of natural selection: Feedforward is a product of natural selection in the first place but the goals are subject to natural selection in the long runs.

For a lay scientist the stimulus of "feedback/feedforward loops" would bring immediately physical systems to focus, i.e. *d-loops*. By the same token, the focus of same lay scientist on hearing "adaptation" or "hereditary codes" would be theory of evolution or natural selection, i.e. *ℓ-loops and e-loops*. It would hardly cross anyone's mind that science is ignorant on the integrity of these three sub-loops. Evolutionary systemics unearths this integrity – "so near, and yet so far."

This paper offers EvSyM as the transformation of the state-of-the-art on science into building blocks; it then reworks and reassembles them. The rules for reassembling are original and reworking of some of the building blocks involve originality but the rest is the state-of-the-art in science.