Editorial

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Complexity Ingredients Required For Entrepreneurial Success

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Abstract: This "comment" begins with a summary of the various complexity concepts (ingredients) that relate to the creation and development of effective startup companies. No single complexity concept is sufficient to create an effective entrepreneurial startup, but a random mix of organizational components and behaviors is also ineffective. As the competitive environments of entrepreneurial firms change, they also need to continually change their mix of complexity ingredients to remain competitive. In moving from biology to *digital business*, the most dominant evolutionary difference for companies is the *much higher speed* at which complexity dynamics – emergence, self-organization, and the creation of new order – occur. In a dynamic business ecosystem, firms will quickly disappear that don't recognize digital-business effects and adapt to the high speed of coevolution amongst competitors.

Keywords: complexity ingredients

1 Introduction

The difference between good and bad chefs is that the former create foods (pasta, paella, curry, chicken pie, tomato soup, or cake) that taste better. Good tasting foods all contain a complex mixture of ingredients that cause good taste as the emergent outcome. No single ingredient makes a food taste appropriate or good. The amount of each ingredient is important and for a cake, how long it is baked is also crucial. Some chefs know how to create a mixture of ingredients that end up as a good-tasting cake, while many others do not.

Likewise, there are also complexity ingredients that lead to creative and well-performing, startup entrepreneurial companies. No single ingredient – or component – is sufficient, but a random mix of organizational components and

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behaviors is also ineffective. As the competitive environments of entrepreneurial firms change, they also need to continually change their mix in complexity ingredients to remain competitive, as has long been observed in biological species and organizations as they try to survive in their changing environmental context (Casti 1994; Bak 1996; Brown and Eisenhardt 1997; Anderson 1999; Dooley and Van de Ven 1999; Gell-Mann 2002; Benbya and McKelvey 2006; Maguire et al. 2006; McKelvey 2013).

Finally it's important to recognize the effects of our modern digital world – i.e. advent of the "*Digital Age*" and "*digital business*" (Tapscott 1996; Coupey 2004; Corallo, Passiante, and Prencipe 2007; Malecki and Moriset 2007; Strader 2010; Herdon, Várallyai, and Péntek 2012; Laudon and Laudon 2013; Mcquivey 2013; Schmidt, and Cohen 2013; Westerman, Bonnet, and McAfee 2014; Tapscott 2015) on complexity dynamics. It took ~130 million years for dinosaurs to evolve from their beginning to when they were exterminated. It took only a few years beyond 2007 for Apple's *iPhone* to change the world's communication and information transfer. In moving from biology to digital business, the most dominant difference for companies is the *much higher speed* at which complexity dynamics, emergence, self-organization, and the creation of new order occur. In a coevolving business ecosystem, firms that don't recognize digital-business effects and adapt to the high speed of coevolution amongst competitors will quickly disappear.

I begin with a short review of basic complexity theory and concepts. Then I use Table 1 to offer a quick summary of the various complexity ingredients entrepreneurs have to cope with that are embedded in the various complexity theories that relate to the creation and development of effective startup companies. Next I offer more detailed definitions and examples of the various complexity ingredients defined in Table 1. A Conclusion follows.

2 Basic Complexity Theory

2.1 Adaptive Tension: Phase 1: The European School

Early European complexity science – Phase 1 – emphasizes imposed tension, critical values, and emergent phase transitions, which Prigogine labeled "*dissipative structures*" because they emerge so as to dissipate the imposed tension. Is based on the works of Prigogine (1955, 1962); Prigogine and Stengers (1984); Haken (1983); and Mainzer (1994), among many others. It begins with the Bénard (1901) process – an energy differential is set up between warmer and cooler surfaces of a container (measured as temperature, ΔT). In between

Table 1: Complexity dynamics starting from tensions resulting from new knowledge.

	Basic complexity ingredients	Entrepreneurial complexity-ingredient examples
1	***Tension*** (force causing adaptation)	New knowledge giving rise to environment challenges, changes in the market, organizational discontinuities (Bettis and Hitt 1995).
2	***1st critical value*** (edge of order)	Organizational re-designs based on changing knowledge (i.e. mission changes, strategic changes, operational changes, including structural changes, technological changes, changing the attitudes and behaviors of personnel). (Bradford and Burke 2005).
3	***Dissipative structures*** (phase transitions)	Organizations redesigned as a result of new knowledge so as to dissipate the tensions between Supply and Demand (Barnard 1938) or Self-renewal (Nonaka 1988).
4	***2nd critical value*** (edge of chaos)	Too many new changes based on responses to imposed tensions instigated at the same time send firms over the edge of chaos (Beinhocker 1997).
5	***Region of Emergence*** (melting zone)	Emergent strategies based on new knowledge (Mintzberg and Waters 1985).
6	***Heterogeneous agents***	Innovation in the form of heterogeneous new knowledge gained by agents that makes them heterogeneous (Chesbrough 2003).
8	***Self-organization***	New knowledge-driven tensions causing self-organization in organizations (Thompson 1967); self organizing project teams emerging as a result of new/changing knowledge (Takeuchi and Nonaka 1986).
9	***Tiny initiating events*** (butterfly events)	Strategy as Weeds – small ideas based on new knowledge grow into large organizations (Mintzberg and McHugh 1985).
10	***Connections; connectivities***	*Organizational networks* (Dodds, Watts, and Sabel 2003); alliance networks (Gay and Dousset 2005); *company networks* (Souma et al. 2006); degrees of connectivity (Santiago and Benito 2008); *investment networks* (Song, Jiang, and Zhou 2009) indicate connectivities across various groups and boundaries within firms (many others mentioned earlier).
11	***Motives to connect***	Knowledge-based managerial intentionalities in strategy making (Oliver and Roos 2000).
12	***Motives to survive and grow*** (learn, change, adapt, etc.)	Learning and application of new knowledge in organizations (Argyris and Schön 1978; Senge 1990).
13	***Bottom-up emergence***	*See below*
	a. *Emergent ideas*	Strategy revolution stemming from knowledge (Hamel 1998).
	b. *Emergent networks*	Building from new knowledge via cluster formation (Feldman and Francis 2004) and alliance networks (Gay and Dousset 2005).
	c. *Emergent groups*	Self-managed teams resulting from tensions to learn about, develop, and/or apply new knowledge (Barry and Stewart 1997).

(*continued*)

Table 1: (*continued*)

	Basic complexity ingredients	Entrepreneurial complexity-ingredient examples
	d. *Emergent hierarchies*	New organizational forms based on tensions from foregoing new-knowledge applications for managing in hypercompetitive environments (Illinitch, D'Aveni, and Lewin 1996).
14	***Upward AND downward influence***	Organization design stemming from new knowledge tensions (Galbraith 1982).
15	***Haken's enslaving principle***	Organization culture as a complex system (Frank and Fahrbach 1999).
16	***Coevolution***	New-knowledge-based dynamics of organizations as adaptive and evolving systems (Morel and Ramanujam 1999) give rise to different kinds of knowledge that then fosters co-evolutionary pockets and new knowledge-based strategies for rugged landscapes (McKelvey 1999) and co-evolution between organization and environment stemming from interacting new-knowledge developments (von Krogh, Roos, and Slocum 1994).
17	***Equivalents to the sandpile's slope***	Increasing returns (Arthur 1994).
18	***Self-organized criticality***	Emergent innovation (Oster 2009).
19	***Multi-level scale-free phenomena***	Information systems (Benbya and McKelvey 2006); scale-free business networks (Souma et al. 2006); scale-free networks (Barabási and Bonabeau 2003).
20	***Fractals***	Ontological dimension of knowledge (Nonaka and Takeuchi (1995)
21	***Rank/frequency distributions and Power-law phenomena***	PL distributions of productivity of innovation (Jones 2005), Many kinds of power-law networks exist (some of them are cited in the text).

the 1st and 2nd critical values (R_{c1}, R_{c2}), a region is created where the system undergoes a dramatic shift in the nature of fluid flow, i.e. a phase transition. For example, increasing the heat under water molecules in a container exposed to colder air above leads to geometric patterns of hotter and colder water – a chef's "rolling boil" emerges; new order appears. The critical values define the "*melting zone*" (Kauffman 1993), within which new structures spontaneously emerge; Prigogine (1955) labeled these *dissipative structures* because they are pockets of order – governed by the 1st Law of Thermodynamics – that dissipate the imposed energy toward randomness and entropy according to the 2nd Law (Swenson 1989). When a tension rises between Supply and Demand – i.e. customers want a product that is not sufficiently available – startup entrepreneurial firms are created, i.e. they emerge as dissipative structures aiming to increase the nature, quality, and supply of the product customers appear to be wanting.

2.2 Bottom-Up Emergence: Phase 2: The American School

Bottom-up emergence emphasizes agents'[1] self-organization absent outside influence. Its advocates consist largely of scholars associated with the Santa Fe Institute (Holland 1988; Lewin 1992; Arthur 1994; Cowan, Pines, and Meltzer 1994; Gell-Mann 2002). While Phase 1 focuses mostly on dramatic phase transitions at R_{c1} – the *edge of* order, Phase 2 complexity scientists focus mostly on avoiding R_{c2} – the "*edge of chaos*" (Lewin 1992; Pascale, Milleman, and Gioja 1999; Lawler 2013; Ramalingam 2013; Kandjani et al. 2014; Lichtenstein 2014; Tsai 2014; Burgelman 2015). Focusing on living systems (Gell-Mann 2002), Phase 2 emphasizes the spontaneous co-evolution of agents in a complex adaptive system. Agents restructure themselves continuously, leading to new forms of emergent order consisting of patterns of evolved agent attributes and hierarchical structures displaying both upward and downward causal influences. The signature elements within the melting zone are self-organization, emergence and nonlinearity. Kauffman's "*spontaneous order creation*" begins when three elements are present: (1) heterogeneous agents; (2) connections among them; and (3) motives to connect – such as mating, improved fitness, performance, learning, reducing imposed tensions, etc. (Kauffman 1993). Remove any one element and nothing happens. According to Mainzer (1994), complexity dynamics among agents results in emergent new order. Holland (2002) describes emergent new order as consisting of *multiple level hierarchies*, *bottom-up and top-down causal effects*, and *nonlinearities*. Nonlinearity often stems from scalability and often shows power-law distributions (see below).

2.3 Self-Organized Criticality and Adaptive Viability

In his now classic book, *How Nature Works*, Bak (1996) explained self-organized criticality by looking at how sandpiles build up: falling grains of sand are allowed to slowly accumulate to form a pile. Eventually the sandpile becomes high enough and its slope steep enough to trigger sand slides of

1 "Agents" may be atoms, cells, organs, people, groups, departments, organizations, industries, economies, cultures, societies, government entities, and so on.

varying numbers of grains here and there down the slope. These restore stability to the slope. The steepness of the slope depends on two elements: (1) *gravity* and (2) the sharp *irregular* shape of the individual sand grains. Take away gravity and there is no force causing the grains to slide down past each other – call the influence of this force the *tension* effect. Take away the irregular shape of the individual grains, on the other hand, and they become frictionless, unable to resist the downward force exerted by gravity – somewhat like smooth M&M peanuts; they then scatter, unable to cohere enough to build up a pile. Call the influence of friction the *connectivity* effect. Bak observed that sand-grain movements varied from the frequent but barely perceptible movement of a few isolated grains to the rare but gigantic avalanches in which thousands of sand grains move in unison. The size and frequency of sand-grain avalanches are power-law (PL) distributed (Bak, Tang, and Wiesenfeld 1987) (defined in the next section below).

The nonlinear tensions and connectivities that lead to extreme outcomes (the largest avalanches) are key elements of complexity science. Bak labeled the results of the nonlinear interplay of tension and connectivity "*self-organized criticality*" (SOC) – when the force of gravity encounters the friction-induced resistance of irregularly shaped grains of sand, these will move so as to maintain the sandpile's slope in a precarious state of equilibrium. The rate and volume of sand moving at any given instant is (1) nonlinear, (2) unpredictable, and (3) occasionally results in extreme events. In addition to the normally-distributed phenomena characterizing much of physical, social, and organization science – and described by Gaussian statistics (data points assumed to be *i.i.d.*, i.e. independent and identically distributed) – many researchers, however, have discovered an ever-increasing number of phenomena – from physical to biological to social – that are best described by attributes 1–3 above. These attributes are associated with random "*tiny initiating events*" (what Holland termed "small 'inexpensive' inputs" or "lever-point phenomena" (2002, 29).

Needless to say, effective surviving and growing entrepreneurial companies are also subject to SOC; they have to respond to tensions such as poor sales, departing employees who have essential skills, emerging competitors, changes in customer preferences, supply-chain problems, insufficient income, costs higher than profits, accounting failures or irregularities, loss of financial supporters, changes in imposed government regulations, ecosystem dynamics, and so on. Like sand grains sliding now and then to maintain a sandpile's slope (based on gravity and connectivity effects), entrepreneurial firms have to resolve the foregoing tensions so as to maintain survival. If the foregoing tensions are somewhat separated in time an entrepreneurial firm (hopefully) can respond to each tension and maintain its survival by self-organizing so as to reduce the tension. Ideally the firm responds to the foregoing tensions quickly and effectively enough so that its profit margins stay at the level necessary to pay employees, buy supplies, cover other costs, and make enough profits to keep its shareholders or other financial investors satisfied. But, if too many tensions occur at the same time and a firm tries to fix too many different, conflicting, or opposing tensions at the same time, chaos results; i.e. (1) too many changes are required at the same time; (2) fixing one tension makes another one worse; (3) fixing tensions costs money and the firm has no extra funds to spend; or (4) can't effectively respond to any of them. If its SOC fails, an entrepreneurial firm has little chance of survival.

2.4 Fractals and Power Laws

SOC among firms comprising an industry usually result in what are called "*rank/frequency distributions*" of outcomes that are power-law (PL) distributed. Entrepreneurial firms that are actually in many different industries are also PL distributed, as recently shown by Crawford et al. (2015). PLs typically result when firms show well-performing SOC.

Consider the cauliflower. Cut off a "floret;" cut a smaller floret from the first floret; then an even smaller one; and then even another, and so on. Despite increasingly small size, each lower-level component performs the same function and has the same design as the floret above and below it in size. The cause of repetitive formation is the same at each level and hence is explained by a "*scale-free*" theory. This feature defines it as "*fractal*." Fractals are frequently shown to result from mathematical formulas – as in Mandelbrot's "*Fractal Geometry*" (1983). However, fractal structures also originate from adaptive processes – like the cauliflower – in biological, social, and financial economic contexts. In fractal structures the same adaptation dynamics appear at multiple levels. McKelvey, Lichtenstein, and Andriani (2010)) cite nineteen studies showing adaptation-based predator/prey fractal dynamics. Zanini (2008) argues that the same effects hold for merger and acquisition activities in business niches.

A well-formed Pareto rank/frequency distribution plotted using double-log scales appears as a PL distribution – an inverse sloping straight line. PLs often take the form of rank/frequency expressions such as $F \sim N^{\beta}$, where F is frequency, N is rank (the variable) and β, the exponent, is constant. In a typical "exponential" function, e.g., $p(y) \sim e^{(ax)}$, the exponent is the variable and e is constant. The now famous PL "signature" dates back to the early twentieth century (Auerbach 1913;

Zipf 1929, 1949). Andriani and McKelvey (2007, 2009) list ~140 kinds of PLs in physical, biological, social, and organizational phenomena, all of which are good indicators of fractal geometry. Others find that manufacturing firms in the U.S. show a fractal structure (Stanley et al. 1996; Stanley, Amaral, and Plerou 2000; Axtell 2001). See also PL findings by Newman (2005); Chou and Keene (2009); McKelvey et al. (2013), and all those in McKelvey (2013). McKelvey and Salmador Sanchez (2011) list another 60 or so specifically in financial economics. Park, Morel, and Madhavan (2009) find empirically that M&A actions over the past 100 years or so show a rank/frequency power-law distribution.

The econophysicist Barabási (2002) connects scalability, fractal structure, and PL findings to social networks. He shows how networks in the physical, biological and social worlds, are fractally structured such that there is a rank/frequency effect – an underlying Pareto distribution showing many sparsely connected nodes at one end and one very well connected node at the other. A wide variety of social and business networks have been found to have fractal and PL structures (e.g. Barabási and Bonabeau 2003; De Vany 2003; Dodds, Watts, and Sabel 2003; Watts 2003; Battiston and Catanzaro 2004; Gay and Dousset 2005; Powell et al. 2005; Souma et al. 2006; Chmiel et al. 2007; Saito, Watanabe, and Iwamura 2007; Song, Jiang, and Zhou 2009; Hu, Qi, and Wang 2013; Nobi et al. 2013; Zhai, Yan, and Zhang 2013; Mizuno, Souma, and Watanabe 2014; there are many others).

Since PLs mostly appear to be the result of SOC, they often if not always, signify active SOC processes at work. Thus, Ishikawa (2006) shows PLs in adaptive and changing industries (as opposed to static ones). Podobnik et al. (2006) show PLs in the stock markets of transition economies. As compared to the machinery and chemical industries, Zanini (2008) shows the software industry to be much more PL distributed and Iansiti and Levien (2004) show that the software industry is the most resilient across the 2002 dot.com bust. Why? Because computer software is the most rapidly changing existing industry because of its continuous frequent changes in software product designs – as opposed to the relatively unchanging products of the machinery and chemical industries.

3 Summary Table

In Table 1, I summarize the key complexity concepts – i.e. ingredients – that if working effectively, will lead to the emergent organizational behaviors and components that lead to some startup entrepreneurial companies adapting to their competitive context, and then surviving and growing. After the Table, I expand the complexity-ingredient definitions, with examples added.

4 Definitions of the Various Complexity Ingredients and Dynamics

4.1 Phase 1: The European School

Tension (force requiring adaptation): Like high heat on a stove that causes a rolling boil or steam in a kettle (a *phase transition*), tension in complexity science is an imposed external or internal force of some kind that causes new order of some kind – a phase transition. In Prigogine's view (1955, 1962), tension was imposed from outside a system. But an additional view is that some agents respond to self-imposed tension. Steve Jobs was famous (or infamous) for self-imposed tension (but also for forcing it onto others). Needless to say, these two sources of tension may combine forces or work at odds to each other. And, of course, there are tensions by CEOs and other managers within firms.

→ *For entrepreneurs, tensions occur if: Supply doesn't meet Demand; a competitor has put a better product on market; all Departments are ordered to cut costs by 10%; a startup firm needs increased financial support; the CEO calls for 25% new products every 5 years or at least one new product per year; wants more efficiency; higher profits; faster new technology development, etc.*

1st critical value (edge of order): Phase transitions typically occur after a tipping point is passed. This is called the "*1st critical value*" in thermodynamics. I call it the "*edge of order*," – where existing order is abandoned and replaced by new order of some kind.

→ *For entrepreneurs, the 1st critical value is reached if or when a tension (such as any like those mentioned just above) reaches a point where it can't be ignored, could put the company out of business, severely damage it, or give it a compelling competitive advantage.*

Dissipative structures: Nobel Laureate Prigogine referred to new order emerging after the 1st critical value is passed as "*dissipative structures*" – i.e., whatever order emerges after the phase transition occurs simply to reduce the imposed tension – it *dissipates* the tension.

→ *Most obviously, entrepreneurs dissipate the tension between Supply and Demand by creating new companies that produce needed new, better, or cheaper products. Any of the internal company or organizational changes typically involve intra-company structural or process changes that play the role of dissipative structures because they have been created to dissipate tension imposed by the CEO, or other managers, or by entities in the company's external environment.*

4.2 Phase 2: The American School

2nd critical value: Researchers at the Santa Fe Institute (where the American School began) began by focusing on change occurring just before what they called the "*edge of chaos*." This edge occurs because of two different problems: (1) when there too many different kinds of tension imposed on an agent or system at the same time such that it can't responded effectively to any of them or (2) if there so much of one kind of tension imposed on an agent or system that it becomes dysfunctional.

→ *Ideally, an entrepreneur's startup firm's tensions (some of which are mentioned above) do not occur all at once. Nowadays, an ineffective website design, incompetent accounting, lack of financial resources, supply-chain problems, a very effective new competitor, or a change in government regulations are new tensions – often occurring at the same time – that can create the chaos that puts an entrepreneur out of business. Or sometimes a single tension – such as insufficient financial support or a competitor's new product (e.g. consider the effect of Apple's new iPhone on Nokia) – results in chaos and consequent ineffective response.*

Region of Emergence: The region of emergence lies between the edges of order (1st critical value) and chaos (2nd critical value). Kauffman (1993) calls it the "*melting zone*" – existing order melts away, disappears, and is replaced by new order. Systems are more adaptive if the Region is larger than smaller. This occurs when the edge of order occurs with less imposed tension and the agents or system can tolerate higher levels of tension or can respond effectively to more than one at the same time. Systems benefit by creating as wide a Region as possible.

→ *An entrepreneur benefits if she/he hires employees who don't want to just follow orders and who want to talk to customers and technical support staff to discover new ideas, or are more capable of coping with the chaos of several existing tensions. An entrepreneur also benefits if she/he creates an organizational culture and managerial behaviors that allow employees to deviate from just following orders, or find ways to cope with chaos more effectively. Given an appropriate organizational culture, employees can make effective responses to multiple tensions without getting freaked out or going chaotic. Sometimes it is effective to hire employees who like working for/with bosses that behave like Apple's Steve Jobs.*

Agents: These may be entities of all kinds, mental processes, bacteria, ants, animals, concepts and ideas, people, groups, departments, organizations, economies, societies, and so on. They are agents because they show some level of ability to respond to forces, change, and self-organize.

→ *Employees, groups, networks, ideas in an entrepreneur's firm and its competitors may be agents.*

Heterogeneous agents: Agents may be clones of each other, or forced to become more like each other – this is what Granovetter (1973) calls the "*strong-tie*" effect [agents connect and talk to each other frequently (e.g. once a week) – this can develop trust and efficiency, but also produce agents who think alike]. Granovetter's "*weak-tie*" effect occurs when agents meet less frequently (e.g. once a year); they may change and learning new things in between meetings and so when they do meet they learn new things from each other – weak-tie connections are more likely to produce innovation, novelty, and entrepreneurship. If all the agents connecting in a system are clones of each other, they learn nothing new by connecting. Hence, for self-organization and new order to occur, the agents need to be "heterogeneous" – i.e. different from each other in various ways.

→ *The more an entrepreneur hires people who are at least somewhat different from other employees, the more likely new product and managerial behaviors will emerge from employees interacting with each other. Company problems are more likely to be identified sooner and new ideas created. Maybe they will start saying something like: "Every time I talk with someone about a problem we often come up with new ideas."*

Self-organization: "Self" organization is defined to occur only when agents themselves become motivated to change – there is no "*global controller*" as Holland (1988) put it – they don't need to be told to start changing; they just do it. The minimum ingredients for self-organized new order to emerge are tension, connectivities among agents, and agents' motivations to adapt to the imposed tension.

→ *When change occurs that is not instigated by an entrepreneurial CEO (Holland's "global controller"), it is evidence that self-organization is occurring among lower-level employees because of tensions imposing on them. The entrepreneur might say: "I see new ideas, behaviors, groups, and networks are popping up all over the place." OR: "No matter when or where I go, it always seems the same. I don't see any Google- or Apple-type folks here."*

Tiny initiating events (butterfly events): There are many (tens, hundreds, thousands) of seemingly meaningless incidents or changes in any given firm over the course of a year. Most are just random events. But, some repeat and start growing/repeating, thereby becoming the beginnings of networked behavior, agreements, groups, and so on. In the latter instances, the initially seemingly random events become what Holland calls "*tiny initiating events*" that grow into significant changes, whether positive or negative from a firm's perspective – i.e. they could be ideas that ramp up into new products or products that come with higher costs or customer dislikes. Because of a famous presentation by Lorenz (1972), they are sometimes called "*butterfly events*." Such events are the beginnings of self-organized new order creation.

→ *Though most new ideas in an entrepreneurial firm are probably useless, skills are needed for employees and managers to decide which are the few really useful ideas that need to be nurtured instead of being stomped on. And, once a new idea starts growing, managers need to be sure that it will lead to a good outcome, not an expensive failure. If employees have weird, even amazing, new ideas in the parking lot but never bring them to work, this kind of organizational culture needs to be fixed.*

Connections; connectivities: Creativity is often a mixing of existing ideas that give rise to a new idea. If heterogeneous agents don't connect and interact, novelty is much less likely to occur. Absent connectivities, novelty, and innovation, new entrepreneurial ventures are much less likely. But, again, remember Granovetter's strong- and weak-tie effects: interacting frequently with the same people creates trust and efficiency but not novelty; infrequent interactions are what bring on innovation, novelty, and novel entrepreneurship.

→ *Entrepreneurs need to do whatever it takes to create opportunities and motives for employees to connect and form networks. It may seem more productive to keep employees focused and isolated so they get their work done, but this can lead to the minimization of the kinds of interactions that give rise to new ideas that can rescue a failing startup firm.*

Motives to connect: Connectivities are essential, yes, but absent agents' motivations to interact connectivities don't appear. What are the best motives for agent interactions? See next:

Motives to survive and grow (learn, change, adapt, etc.): Ants are motivated to search for food, leave pheromone trails, bring food back to the colony, eat, reproduce, adapt to changing environmental conditions, and avoid predators, etc., or the colony doesn't survive. Dogs like to eat, chase things, reproduce, and can be trained to sleep all day or attack. People have all kinds of motivations, but they can enter a firm or be trained or incentivized to become passive-dependent, loners, and maintain the status quo OR they can be motivated to learn, change, interact, motivate others, innovate, and adapt to and survive changing competitive environments. Some people are strongly self-motivated but managers and/or fellow employees may lead or stimulate them in either direction (i.e. toward passive dependence or innovation and change).

→ *Does a would-be entrepreneurial firm show mostly passive-dependence – employees sitting around with arms across their chests; following orders? Or, does it show employees who are always trading ideas and talking about how to keep their toughest customer happy and about how to do things better? They don't wait to be told what to do; when the need arises, they respond as necessary.*

Bottom-up emergence: Some people in a firm inevitably know that bottom-up emergence has occurred. But there are lots of emergent behaviors and structures that managers don't know about. In a classic Harvard case, a bunch of Sicilian cousins had totally changed a company's product line because of changing technology and customer preferences – all totally unknown to management! It happens! True, newly emergent ideas and intellectual capital (IC) may be intangible and based on tacit knowledge, but even so, emergent developments in IC are there to be found. Emergent networks, groups, and hierarchies are more tangible and hence are more easily observable or discovered kinds of emergence. Implicit in the foregoing is to what extent a firm tolerates, punishes – or rewards – people generating emergent ideas, behaviors, and structures. They may be treated as deviations from approved behavior or treated as developments at least worthy of further study and potentially worthy of value and further stimulation.

Emergent ideas? *Emergent networks*? *Emergent groups*? *Emergent hierarchies*?

→ *An entrepreneur needs to study her/his firm to discover how many (if any) new ideas, networks, and groups, emerged over the past year via bottom-up emergence? New product ideas? New projects? New projects funded or ramped up to market?*

Upward AND downward influence: Of course, all firms show top-down influence from the CEO down through the management hierarchy. Firms show much more variance in whether or not vibrant bottom-up influence exists. Some firms show one or more layers of middle management that act as blocks to either kinds of influence. In 2012 I met a new top manager at GM who said his main objective was to try and get rid of a "frozen" layer of middle management at GM that blocked both: (1) new ideas from going down from top management to lower-level employees; and (2) new ideas originating among lower-level employees going up to top management.

→ *Entrepreneurs need to have regular meetings where they actually listen to their employees! Do employees only listen to what their bosses have to say? No one does anything until the CEO gives her/his stamp of approval.*

Irregular oscillation of top-down vs. bottom-up influence: While we are all advocates of significant bottom-up influence via emergent behaviors and structures, we are also well aware that the "*no global controller*" reality (Holland 1988) that characterizes ant and bee colonies surely doesn't apply to most firms. They all have CEOs who are paid to be in charge; and most CEOs and lower-level managers take this very seriously – some to the point of being control freaks (e.g. Bob Nardelli, who "controlled" *The Home Depot* into decline and became the 1-year CEO of bankrupt Chrysler Inc.). There are times when either, or, or both, top-down and bottom-up influence streams are required; see for example Thomas, Kaminska, and McKelvey Thomas, Kaminska-Labbé, and McKelvey 2005, Thomas, Kaminska, and McKelvey 2012). It could be that bottom-up emergence is beneficial much of the time but every now and then the CEO has to "jerk the chain" toward a significant re-organization to get back into a competitive position. Frequently this is coupled with a new CEO appointment – one of the most dramatic and effective being the hiring of Lou Gerstner from outside to rescue IBM; which he did! But of course, this is the ultimate and most dramatic example; many other chain-jerks are much less dramatic and not so all-enveloping, but none the less equally essential.

→ *Entrepreneurial firms benefit from both top-down and bottom-up influence streams. They could alternate or both could be operating at the same time, i.e., oscillating rapidly from one to the other? Many new entrepreneurial firms eventually require the replacement of the startup entrepreneur with a "professional" manager who has more accounting experience, specifically, and prior experience in resolving more of the other kinds of tensions mentioned above. Some managers create meetings where both influence streams are discussed, evaluated and implemented at the same time.*

Enslaving principle: Haken (1983) wrote about what drives the actual characteristics of a phase transition after the edge of order is crossed. As a system composed of some number of agents starts tipping across the edge of order into the *Region of Emergence*, which or how many agents actually determine the nature of the emergent new order? Suppose you are the key person at Microsoft who has authority to work with 100 engineers at Nokia to quickly come up with a digital-phone design to compete effectively with the iPhone or Android. OK, just imagine this.... Following Haken's logic, then, you see that – despite the apparent dominant motive to connect with Microsoft so as to create a mobile phone that could save Nokia from fading into oblivion is the dominant imposed tension – many of the 100 engineers have become more or less enslaved by other more personal or more immediate tensions: searching for a new job, finding a better school for their kids, buying a new car, trying to leverage some other new project to get a promotion, getting ready for the annual ski trip as winter approaches, on and on. Hence, many engineers slowly become enslaved by various other tensions. Consequently, Haken notes that as a phase transition develops, there are usually only a few highly-networked individuals who actually determine the nature of the new order. This could be good or bad.

→ *Presuming that an entrepreneur has effectively created a Region of Emergence in his or her firm – and consequently processes are in place for various tensions to be dealt with – the key question is: For any given tension, will all or most of the relevant employees be involved in creating a solution to negate the tension, or will an already existing (strong) network amongst a few employees define which employees actually resolve the tension. The entrepreneur could see a lot of new order (new, emergent dissipative structures) in her/his firm, but they always appear to be created by a small subset of employees acting at the last minute; most employees that should be involved seem too distracted by other issues to pay close attention to the tension at hand.*

Coevolution: Changes in one entity force responsive adaptive changes in a 2nd entity (Kauffman 1993). Changes in the 2nd entity then force the 1st entity to make further changes; and then the 2nd entity makes even more changes; the 1st entity responds to these; on and on. Positive feedback may result. This is one way we see butterfly events scaling up into noticeable emergent new order.

→ *An entrepreneur could have coevolutionary dynamics going on in his/her firm; A change in one part of a product leads to a change in another part, which then leads to further change in the part showing the initial change; these changes could affect marketing, production, supply chains, and so on. Finally, it could happen that an entirely new product appears. For example, think of all of the coevolving changes in computer, cell-phone, battery, and touch-screen technologies, computer programming, cell towers, the Internet, and the development of apps that led to current smart-phone products.*

Nonlinearities: Any kind of a positive-feedback process produces nonlinear outcomes. Any butterfly event that ramps into a significant new product is a nonlinear outcome. But positive feedback processes are only one kind of what are called "*scale-free*" causes (Gladwell 2000; Mandelbrot and Hudson 2004; Newman 2005; Baum and McKelvey 2006; Andriani and McKelvey 2009; Crawford et al. 2015). Academics have various motives for wanting/needing to assume linear dynamics and "*normal*" distributions, but the organizational and managerial worlds are full of nonlinear distributions. Studying the causes and consequences of nonlinear dynamics has become the 3rd phase of complexity science.

→ *It is well known that complexity dynamics usually lead to nonlinear outcomes. For further description see: Bak (1996); Mandelbrot (1997); Mantegna and Stanley (2000); Barabási (2005); Anderson (2006); Chatterjee and Chakrabarti (2006). Though some 90% of entrepreneurial startups fail (Griffith 2014), those that remain appear as rank/frequency distributions that are nonlinear and skew (power-law) distributed (Crawford et al. 2015).*

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