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Normality, Magic, Miracle and Error: Emergence Along a Reversibility Spectrum

Kalyan S. Perumalla

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NORMALITY, MAGIC, MIRACLE AND ERROR: EMERGENCE ALONG A REVERSIBILITY SPECTRUM

Formation of a butterfly from a pupa, extraction of a live dove from a magician's empty hat, generation of new particles from high-energy particle collisions and spawning a new dream world from mind in sleep are all examples of a common, fuzzy notion called 'emergence'. Emergence is intuitively defined in a subjective manner in various contexts, yet it eludes a universally acceptable objective definition. In this paper[1] I pin the concept of emergence to the element of surprise in a phenomenon. I then propose a characterisation of emergence by first defining surprise in terms of an objective dimension called reversibility. Using this definition, I categorise the various notions of emergence into three main classes: (1) weak emergence in which the evolution from pre-emergence to post-emergence states is fully reversible and hence evokes the least amount of surprise, (2) quasi emergence in which the evolution from pre-emergence to post-emergence states holds surprise in the form of gaps in reversibility, but the gaps can be overcome via placeholders such as deterministic pseudo-randomness, and (3) strong emergence in which it is impossible to find any reversible description of evolution from pre-emergence states to post-emergence states, thereby making the element of surprise fundamental and impossible to redress. In fact, in the strong emergence case, the pre- and post-emergence states continue to co-exist despite an apparent transformation of the pre-emergence state to post-emergence state. These definitions are used to explain instances of emergence, organised along a continuous spectrum as normality, magic, miracle and error.

Introduction

Whenever we investigate and try to understand any phenomenon of interest, we attempt to go back in the timeline of that phenomenon. We try to trace back its evolution and also try to account for the composition of all the components that contributed to that phenomenon. For example, when we witness a magic show trick, our mind attempts to retrace the observed trick backward and account for all underlying steps, ingredients and their composition. If our traced-back or composed model does not correctly predict the observed evolution, we perceive the phenomenon as a surprise. When the surprise remains largely undiminished despite repeated efforts to understand it, that phenomenon stands out from other phenomena. Some of these unresolved, surprising phenomena serve our entertainment needs (like magic shows), some lead to scientific endeavours (like understanding the creation of new particles in the universe) and some others may even lead to profound philosophical pursuits (like understanding life and death). Surprise is the underlying commonality among all.

Surprise determines emergence

The element of surprise or unexpectedness is the key element behind many common instances of the phenomenon called emergence (Ronald et al., 1999; Kubí, 2003). Note that the formation of a state or product, from a *simple* composition or evolution of ingredients, seldom by itself qualifies as emergence. For instance, the saltiness of water when salt is mixed in it hardly qualifies the formation of salty water from plain water and salt as emergence. Similarly, ice melting into water is considered 'normal' and rarely noted as an emergent phenomenon.

On the other hand, when a butterfly 'emerges' from a pupa, the hidden evolution of the pupa into a butterfly generates an element of surprise. The surprise in this case is due to the strong mismatch between the pre- and post-emergent states in prominent properties such as flying ability, colour, shape, and so on. Additional illustrations of such surprise-based emergence include the election of leaders in democracy of equals (how can a 'superior person' emerge out of equals?), renormalisation groups for scale invariance in theoretical physics (Wen, 2007; Andergassen et al., 2008) (how can collective phenomena appear at new energy scales when they are not manifest in underlying microscopic models?) and generation of new particles from high-energy collision of sub-atomic particles (Close, 2004; Butterworth, 2015) (how can 'new' particles be formed in the universe?). When there is no surprise or unexpectedness in the phenomenon, it is very hard (or unconvincing to many) to label it as an emergent phenomenon – it would simply be labelled as normal, expected, ordinary, explicable, comprehended, and so on, but not as emergent.

However, the challenge with relying on surprise in defining emergence is that the element of surprise or unexpectedness is highly subjective in nature. Something that is surprising or inexplicable to one person may be an ordinary, expected or predictable phenomenon to another. Similarly, something that is inexplicable for someone at a point in time may become comprehensible and ordinary to that same person at a later point in time. In the same fashion, a phenomenon may be inexplicable for a large body of people even though it is obvious to a few. Therefore, the element of surprise by itself is difficult to serve as an unconditional determinant of emergence.

Defining the surprise behind emergence

To overcome the subjectivity of surprise, I propose a new approach that objectifies surprise. An objectification of surprise in turn makes the definition of emergence more precise as well.

The notion of surprise is defined here in terms of the 'reversibility of the description' of the phenomenon. For example, when the observed system comprises ice melting into water, a set of reversible mathematical descriptions (say, coupled partial differential equations) can describe the time evolution. When the observed system is a pupa turning into a butterfly, a set of reversible biochemical and biophysical equations could map the state, taking into account ambient environmental conditions and fill unknown aspects with reversible random variates that fit historical data. When the observed system is mirage water on hot desert sand, no description is possible that maps the hot air properties to those of perceived water because of a fundamental incompatibility between the mistaken view of real air as imagined water, which leads to mistakes like seeking the imagined mirage water to quench thirst.

In general, whether (and to what extent) the evolution can be described as a reversible process determines the nature of emergence in the system. In some cases, the evolution can be fully described as a completely reversible process, which makes the evolution 'normal'. In other cases, the description of the evolution may not be able to capture or accommodate some portions of the system, in which case a proxy model (typically, random variates) may be required to fit the observed evolution and its reversal. In the rest of the cases, no effective model of the evolution may be possible, which makes it impossible to find any reversible description.

Surprise from Irreversibility

As previously stated, the reversibility (or irreversibility) of the description of a phenomenon determines its nature of emergence. The greater the difficulty is in describing the system reversibly, the higher the strength of emergence becomes. Based on this observation, I define the concept of 'strength of emergence' as the level of difficulty in arriving at a reversible model for the evolution of the emergent phenomenon.

How it works

In an emergent phenomenon, a base state B is evolved into an emergent state E, through one or more intermediate steps. For example, in the pupa-to-butterfly transformation, B=pupa and E=butterfly, with biological transformation appearing as steps in between. In the dove-from-hat magic trick, B=empty hat and E=dove plus empty hat, with motion of magician's apparatus intervening in between. In the case of dream-from-mind, B=awake mind and E=dream world in sleep, probably evolving via some chemical, neurological or psychological steps. In particle collisions, B=pre-collision particle set and E=post-collision particle set, with very complex events such as quantum chromodynamical transformations happening in between.

Figure 1 shows a framework containing our view of the elements involved in emergence of E from B. Whatever is responsible for the evolution is termed as the agent, and the witness of the evolution is called the observer. The actual phenomenon undergoes transformation of internal states $AS_1 \ldots AS_N$, which can never be fully known but can only be observed. Let the observed intermediate states be denoted as $OS_1 \ldots OS_N$, where OS_1=B and OS_N=E. When the observer tries to understand the phenomenon, a model of the evolution is formulated, which fits (that is, 'explains') the observations in reverse order, as $MS_N \ldots MS_1$, where MS_N=E and MS_1=B, that is, the states of the model are generated backwards from the emergent state E to the base state B.

For completeness, two additional entities are identified: insider and onlooker. The insider has perfect knowledge of the actual states and their mapping to the observed states and hence does not have any element of surprise. The onlooker has no interest in determining a model for the observed states, and, therefore, does not have any scope for surprise. Because of their nature, the insider may also be called a 'wisest entity' and the onlooker may be analogously called a 'consummate ignoramus'.

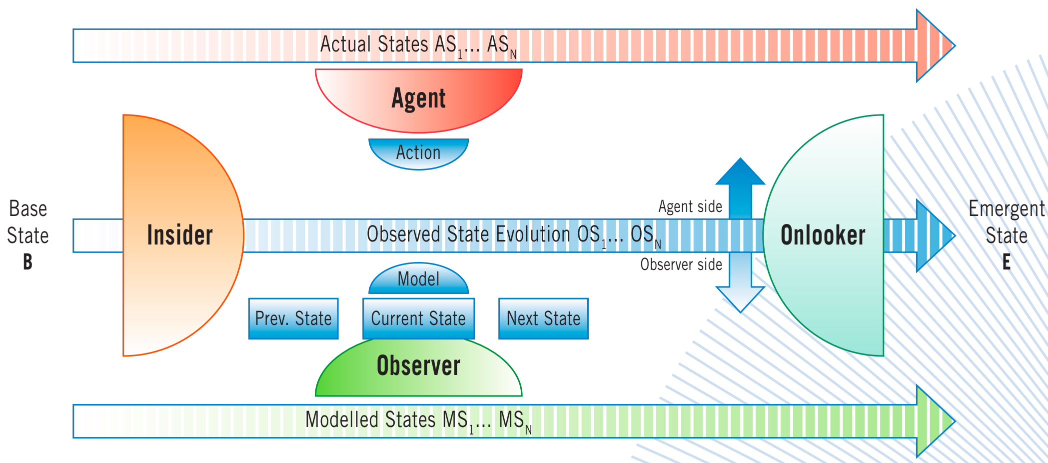

Figure 1: Emergence as an evolution of states from different viewpoints.

With the preceding definitions, surprise is defined as the existence of some state MS_m from the model that does not match the observed state OS_m. If there is no mismatch between the observed states and the modelled states, then the phenomenon is not only perfectly captured but also reversibly expressed to complete the observer's understanding. If there is at least one mismatched state, the first state at which the mismatch occurs leads to the rise of surprise: the observer's understanding is found to deviate from observation, which demands reconciliation. The level of difficulty in reconciliation equals the strength of emergence of the underlying phenomenon.

Irreversibility and strength of emergence

There are two key factors to consider: (1) whether any appropriate model to predict the states MS_i can be formulated that can fit the observed states OS_i, and (2) what the computational effort is in determining the model states MS_i. The former is more stringent than the latter because the former deals with the very existence of a model while the latter deals with the usage complexity of the model. Therefore, a phenomenon in which no model can be defined has a higher strength of emergence than a phenomenon for which a reversible model can be defined. If there are two phenomena for both of which reversible models can be defined, then the model with the larger evaluation burden or computational complexity (Sipser, 2014) between the two has a higher strength of emergence. Based on this notion of strength of emergence, three types of emergence are defined: weak, quasi and strong.

Weak, Quasi and Strong Types of Emergence

The three types of emergence by which I classify emergent phenomena are as follows.

(1) Weak emergence: this applies to a system that affords a fully reversible, objective description of the system evolution. Due to complete reversibility, there is almost no element of surprise, although the procedural aspects of reversibility may be arbitrarily complex (for example, the algorithmic sophistication with computers or intellectual machinery with logic and reasoning needed to capture the reversible evolution).

(2) Quasi emergence: this applies to a system that affords a reversible description of the system evolution by relying on placeholders such as randomness to fill the irreversible or unclear portions in the evolution in what is otherwise weak emergence.

(3) Strong emergence: this applies to a system in which the description of the phenomenon is fundamentally irreversible because of the subjectivity of characterisation inherent in the phenomenon, and hence can never have a reversible model that fits observations.

The emergence categories based on reversibility can be pinned to their element of surprise. Weak emergence is any transformation in which there is little element of surprise. Quasi emergence is any transformation in which there is some surprise, but the surprise can be temporarily overcome by an explanation that is 'good enough' acting as a placeholder, which is potentially refined later to remove all element of surprise. Strong emergence is any transformation in which no physical or logical explanation can ever be given, and hence surprise can never be overcome.

Weak emergence

Weak emergence includes all phenomena that are considered 'normal' or well understood. All inanimate-world phenomena currently modelled in physics or chemistry fall into this category. Mathematical models describing physical phenomena serve as the basis for computational expressions to trace, fit or quantitatively predict their time evolution. The modelled states are generated from the mathematical descriptions by computer-based evaluation and simulation (be they simple calculations or complex computer codes). All these descriptions essentially can be equated to computer programs. Note that the tremendous complexity of evaluating the mathematical models is not underestimated here, but it is only their ability to match many physical realities that is being considered.

It is now well established, based on construction of reversible Turing machines, that all computer programs can be reversed, either by design or by transformation (Perumalla, 2013, pp. 91–100). Some models are easier to compute than others. Some phenomena may demand very large computing capacities such as supercomputing in order to retrace their evolution and understand them. For example, global climate models are designed to capture the land and oceanic effects, among others, across many decades, in order to explain climate change at the scale of the entire earth. Notwithstanding the computational complexity, the reversible description of a phenomenon makes it, in a broad sense, belong to weak emergence where there is little or no scope left for surprise because the mapping from the base state to the emergent state is known. Because weak emergence can be expressed as computational descriptions, it is fully reversible and can be simulated to match correctly all observed states.

Quasi emergence

Apart from known physical phenomena in the category of weak emergence, there are other phenomena that touch epistemic aspects. These are phenomena in which we do not yet have comprehensive understanding, but for which a complete description is not inconceivable sometime in the future. Quasi emergence comes from two sources: (a) physical phenomena that have an unknown infusion or leakage of entropy (elaborated shortly) and (b) descriptions of the animate world processes that are difficult to define purely physically.

Entropy infusion or leakage: these are physical phenomena (such as electromechanical dynamics, chemical reactions, quantum-mechanical systems) whose descriptions are often abstracted or simplified with adjectives such as *decoherent*, *adiabatic*, *at-equilibrium*, *isolated*, *uniformly distributed*, and so on. These adjectives serve as placeholders for portions of the phenomenon that are idealised because they are difficult to be expressed in more detail. In order to generate the modelled states, these placeholders will need to be manifested as an evolution of states. The only way to manifest (or unravel) these adjectives is to use pseudo-random variates that serve as proxies for the parts of the phenomenon that were abstracted. This substitution does not necessarily imply that the abstract parts cannot be refined in fidelity sometime in the future. In either case, it becomes possible to achieve reversibility of the modelled states: if random variates are used, then reversible versions of random variates are available to serve the purpose of reversibility (Perumalla, 2013, pp. 187–206), and if the abstractions are refined and replaced, they would again be mapped to computational descriptions that can be rendered reversible by transformation (pp. 127–46).

Non-physical behavioural sources: notwithstanding advances in neurology and psychology, many phenomena based on animate behaviours are impossible to model accurately. For example, social behaviours, such as consensus formation, are notoriously difficult at high fidelity. Any emergent phenomenon that is affected by non-physical behavioural sources would need placeholders, such as scale-free distributions, as approximate models.

Due to the preceding considerations, these phenomena are relatively stronger in emergence than those in weak emergence, but can be approximated. The approximations dilute them into the category of weak emergence. Therefore, they are classified under a separate type, termed quasi emergence.

Strong emergence

While many physical phenomena are very difficult to understand, there is one class of phenomena that is harder to model than even the hardest physical phenomena. This category of phenomena is well studied in philosophy, consisting of the most confounding type of emergence wherein transformations are simultaneously real as well as unreal. In other words, in terms of the framework described in the section headed 'How it works' and the evolution illustrated in Figure 1, the base state B and emergent state E co-exist at the same time. The transformation from B to E, therefore, is only apparent, yet cannot be dismissed as unreal or asserted as real. A stark example is the emergence of dream worlds.

Two sub-types of phenomena conform to this definition of strong emergence: (a) conjunction and (b) superposition.

- Conjunction: when two or more objects are virtually combined without any tangible physical change, such a phenomenon is termed as conjunction. The simplest example is the emergence of the number 2 (two). When a banana is kept beside another banana, together they are called two bananas. However, there is no physical transformation of 'one banana and another banana' into a manifestation of a new entity called 'two bananas'. Indeed, B='one banana and another banana' co-exists with E='two bananas'. This simple illustration extends to a vast multitude of phenomena in our daily life. Any act of counting is conjunction. Any naming is conjunction. Any enumeration of series is conjunction. Conjunctions are entirely subjective processes that do not affect physical reality.

- Superposition: when a base entity B is *mistaken* for another entity E, then E is termed as emerging out of the base B. Both B and E would appear to have simultaneous existence. A common example is the emergence of a mirage in a desert in which B=hot air, E=flowing water.

Superposition is different from conjunction. In conjunction, B is physically real for every observer and E is imaginary for all observers. In superposition, B is physically real for every observer, but E appears real for some observers and is entirely non-emergent (non-existent) for others.

Conjunction is a voluntary phenomenon: one can choose to bring about the existence of E from base B, which makes the emergence an action done out of free will. In contrast, superposition is an involuntary phenomenon: the mistaken view of E over B is an action that happens inexplicably.

Past literature postulated emergence as a phenomenon of synergy in which 'the whole is greater than the sum of parts'. This synergy postulate becomes equivalent to conjunction when all parts are accounted for.

Conjunction is relatively weaker than superposition because the former can be reversed voluntarily, whereas the latter requires new knowledge from external sources to correct the error. Even after correction, superposition continues to entertain two realities simultaneously, one reality imposed by knowledge of the physical basis and another reality sustained by the observer's subjective view. Therefore, we count superposition as the strongest form of emergence owing to its utter irreversibility, inexplicability and indescribability.

The Emergence Spectrum: Normality, Magic, Miracle and Error

With the preceding background on emergence, it becomes possible to classify all worldly phenomena into four types, organised in a strictly increasing strength of emergence, that is, increasing difficulty of reversal: (i) normality, (ii) magic, (iii) miracle, and (iv) error.

- Normality: this is the set of all phenomena that can be characterised as weak emergence. Normality is computationally describable and reversible by everyone.

- Magic: this is the set of all phenomena that fundamentally belong to weak emergence. However, although the phenomena are fully reversible, the reversibility is not universally known to everyone. Hence, it is reversible by a few people, such as the magician (agent) and his/her accomplice (insider), but irreversible for everyone else (observer). Thus, it is weak emergence for the magician and accomplice, but quasi emergence for others.

- Miracle: this is the set of all phenomena containing portions that are irreversible for everyone, as far as experience is concerned, but whose irreversibility is not physically acceptable. In other words, it is quasi emergence for all at the moment, but could be demoted to weak emergence after more information is obtained sometime in the future.

- Error: this is the set of all phenomena that are based on the concept of error, which represents a mistaken view of the observations. Error is something that creates an entirely incompatible mapping from one phenomenon to another. It is fundamentally irreversible, and its irreversibility is independent of time or observer.

Each of these phenomena in the spectrum of emergence is described in greater detail next.

Normality

Normality is the set of all phenomena that everyone takes for granted without any question or feeling of surprise. The absence of surprise is due to the alignment of observations with mental models. Normality is the weakest form of emergence. In 'normal' phenomena, the modelled states always perfectly map to the observed states, with no mismatches of states. Everything that contributed to a phenomenon is either already known, and a precise traceback of its evolution is available to the observer on demand. Normal phenomena do not demand our deep intellectual attention anymore. One may still use the adjective 'emergent' for any normal phenomenon if there is some linguistic/computational effort in describing it and retracing it, but the reversal is only procedural – there is little intellectual hurdle that prevents it. Among the numerous phenomena we witness and experience every single day of our lives, the vast majority of them do not bother us with respect to their inexplicability or strangeness – they are well accepted by us as understood. All those processes, be they physical or psychological, are 'normal' because we are mentally assured of our ability to trace back, and everything 'adds up'.

Magic

The concept of 'magic' has been well known throughout the world over many centuries. Magic is that phenomenon for which an observer is unable to fill in the physical evolution between some two observed events. Conversely, the magician who is performing the magic is fully aware of the physical evolution behind the apparently magical (unexpected) events and observations from the audience's point of view. There is no disconnect between the visible states of the events, as far as the magician's understanding is concerned. How the dove emerges from the empty hat is no mystery for the magician. Thus, the nature of emergence in magic has two sides: normality from the magician's side and surprise from the audience's side. The cognitive ability or inability to fill in the intermediate physics between two events is the main differentiator between the two sides.

When the human mind is unable to fill in the gap between two notable states, it experiences a sense of shock or awe. The more this gap involves inanimate-animate interactions, the more shocking it is (for example, a dove 'emerging' out of a hat or a person's head being temporarily severed from the torso). When that gap in the mind persists for a short time it is soon forgotten without assigning any specific label to it. On the other hand, when the mind gives up, being unable to find an explanation despite furious thought, it labels it as 'magic' or 'magical'. Note that there is an explicit cooperation of the mind in this labelling. Typically, more than one person is influenced in this way in magic shows. However, other observers (society), directly or indirectly, educate everyone that although they cannot fill the gaps the magician community can do so and, hence, the audience feels reassured that there is indeed some way to fill the gaps and chooses to receive the experience as entertainment for the mind.

Miracle

When a very large fraction of observers finds a phenomenon mind-boggling for a very long time, with no way to fill the gaps in the evolution of the phenomenon, then that phenomenon gets labelled as a 'miracle'. A miraculous event satisfies the properties of quasi emergence. A miracle is essentially a surprising gap in the transition of a physical state to its previous state, unresolved by many people for an extremely long time, and viewed as an extraordinary phenomenon. In other words, no one knows how mentally to reverse the observed process, but it cannot be proven to be irreversible.

The observed process has some state X transitioning to state Y, however the known reversal of that transition does not give state X, but instead gives state Y (or some other state Z) when going back from state Y. For example, when a person who is dead (state X) apparently becomes alive (state Y) again, the mind finds that a mental reversal of that transition is incompatible with the observed phenomenon because the mental model requires the person to be alive (state Y) in the previous state also, which is mismatched with the observation that the person was dead (state X) before being alive (state Y). Therefore, this incompatibility between the cogitated reversal and the observed evolution is declared a miracle.

Often, this also leads to an attribution of that 'miracle' to the 'special agency' of an entity. The entity could be a 'divine person' or even an abstract placeholder name such as a 'divine event'. Note the contrast between magic and miracle. No one sees a magician as a 'divine' personality unless the magic is intended as a trick to fool others into thinking it is a miracle. While magic is often reproducible and repeatable, miracles are irreproducible events (otherwise, repeated occurrence of 'miraculous' events deprives them of specialty and instead creates a new normal).

Furthermore, it is the magician who declares magic as magic, intended for entertainment, whereas it is the witnesses of miracles who label them as miracles.

Miracle is quasi emergence: the phenomenon is reversible to a large extent, but portions of it have jumps for which reversal is not yet known. A placeholder is used to fill that gap in which the previous state and next state cannot be explained with any known phenomenon. This placeholder comes in many forms. One common placeholder is 'randomness' in which it is postulated that some random activity is the cause. For example, the evolution of species or the formation of stars and galaxies are all explained with randomness of interactions that increase entropy or some other objective function such as total energy in the physical system or net survivability in the species population. Another stark example is the placeholder called the 'divinity' of the agent that causes transitions such as the dead coming alive or the parting of a sea. Although some of these placeholders may remain unresolved for a long time (centuries), they nevertheless always remain susceptible to a possible demotion to weak emergence.

Error

The consummation of emergence lies in the notion commonly known as 'error'. Every instance of error is an instance of strong emergence. Physics of nature provides a shared objective world that is a common basis of existence and experience to all. Error is the difference between the shared objective world and some subjective world(s) created in imaginary planes. The physics of nature does not accommodate any concept called 'error'. Whatever happens happens – nothing more, nothing less. This means that any instance of a perceived error could never arise from the world, yet somehow appears to relate to the world. Note that the origin of error is not addressed here; it is only the nature of error that is being identified as an extreme instance of emergence.

Some prominent examples of error are movies, mirage and dream. In the case of movies, entire animated worlds are superimposed on the physics of light and colours of a flat screen, and erroneously imagined to have reality of their own separate from what is actually the physics of electronics of the screen. In a mirage, hot air is misconstrued as flowing water because of subjective semblance of their dynamics from a distance, and the imagined water is erroneously taken to be real. In a dream, a large, new imaginary world is projected and experienced inside a small physical space, and the imaginary world is erroneously taken to be real. When this concept of error is taken to its limits, it quickly leads to metaphysics in which very interesting concepts arise, leading to deeper questions about the very definition of truth or reality, and the basis of all human experiences.

Concluding Remarks

Only strong emergence is true emergence

Although I have defined multiple levels of emergence, in a strict sense, only strong emergence withstands the test of time and intellect. Hence, only strong emergence qualifies as true emergence. The other two forms of emergence – weak and quasi – are vulnerable to the onslaught of time and sharpening human intellect. Quasi emergence gets filled with more observations, and thereby more detail, over time to become weak emergence in which everything is completely modelled and well understood. Weakly emergent phenomena gradually get demoted to normality because they lose their element of surprise.

Circular logic in science

Quasi emergence pervades science in the form of circular logic. Many placeholder concepts serve their immediate scope of a given phenomenon, but, in a broader sense, all placeholder concepts depend on each other, with none actually defining anything substantial. They lead to a strange equivalence class of terms that equates the following adjectives to mean essentially the same thing (or lose meaning together): *new*, *random*, (*dis*)*orderly*, (*in*)*elegant*, (*un*)*interesting*, *first*, *spontaneous*, *abrupt*, (*un*)*expected*, (*un*)*lucky*, *coherent*, (*in*)*correct*, *simple*, *complex*, and so on. They are all words of 'high entropy' – a lot of information is implicitly packed into them without being actually defined. Circularity of logic in this case means none of the aforementioned words can be defined without relying on at least one of the other words.

Whence surprise?

If surprise is the primary basis of emergence, we might as well visit a deeper question: why are we ever surprised at all? Is not nature closed within itself and, hence, proceeds 'correctly', leaving no room for a concept of surprise? Surprise seems to arise only when we seek knowledge, because the difference between our assumptions (current understanding) and the observed reality is what leads to surprise. This in turn indicates that perhaps any surprise is fundamentally erroneous, and knowledge is correction of that surprise to normality.

Notes

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5	Ben Anderson	Emergency Futures	Futures
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No.	Author	Title	Series
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No.	Author	Title	Series
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Insights

Insights is edited by Nicholas Saul, IAS Director and Professor of German Literature and Intellectual History.

Correspondence should be directed to the Institute at enquiries.ias@durham.ac.uk.