Causality: Physics and Philosophy

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Abstract
Nature is a complex causal network exhibiting diverse forms and species. These forms or rather systems are physically open, structurally complex and naturally adaptive. They interact with the surrounding media by operating a positive-feedback loop through which, they adapt, organize and self-organize themselves in response to the ever-changing environment. Interaction is a two-way process, by which a system extracts as well as dissipates information into the surrounding. Information transcends through the levels of hierarchy triggering a series of phenomena in nature. Every natural phenomenon thus forms a part of an infinite *(natural)* causal chain.
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Introduction

All that physics is today, and will be tomorrow, is bound to the limitations of human thought (Bhatia, 2009; Chatterjee, 2012a). A scientific thought can be a conscious attempt at understanding nature, but deep down may contain assumptions. Every physical law has some ontological foundations that limit the human thought process. The synthesis of a scientific picture of the world, of the subjects of the different branches of science, into something integral occurs through the interaction of individual sciences themselves, but it will not be fruitful without scientific philosophy (Gott, 1977). The influence of philosophy and physics is mutual. The few aspects of the interconnection between philosophy and physics that have been examined far from exhaust the multiplicity of forms in which this interconnection manifests itself (Gott, 1977). Analysis of the works of Einstein, Bohr, Born and many other outstanding physicists shows how much attention they devoted to philosophy. Max Born wrote: *"Every scientific period is in interaction with the philosophical systems of its time…"*(Gott, 1977; Born, 1956), Einstein, too, gave much attention to philosophical questions and held that,*"philosophical generalizations must be founded on scientific results. Once formed and widely accepted, however, they very often influence the further development of scientific thought by indicating one of the many possible lines of procedure"* (Gott, 1977; Einstein and Infeld, 1954).

The field of complex systems is diverse. Nature consists of complex systems (Chatterjee, 2012a; Chatterjee, 2012b; Chatterjee, 2012c; Georgiev, 2002; Georgiev, 2010; Salthe, 1993; Salthe, 2008). Degree of complexity associated with the natural processes make their study extremely challenging and profoundly interesting. Every natural phenomenon within the domain of this vast universe is connected, because they propagate with the transaction of energy and information through a two-way, positive feed-back loop. The positive feed-back loop acts as a check mechanism for the system, which continuously helps it to increase its content of organization by cycles of self-organization. Causation and inter-connectedness between events occurring in nature is presented in this paper assuming that all natural processes are governed by physical laws *(some laws are still left to be discovered but, this initial scientific assumption is based on the foundation of scientific truth, logic and determinism).*

The great theoretical physicist and Nobel Laureate, Richard P. Feynman, had envisioned this inter-connectedness of physical laws in a very elegant way (Feynman, 1964).

Causality

Causation is event generation.Whenever anything happens; we have the general tendency to ask two questions to ourselves: 'what is the cause of it?' and 'What am I to do?' The questions originate in some deep *(perhaps unconscious)* convictions. The first is that every event must have a cause, and thesecond that we can influence things by a suitably chosen action. In our practical life, the resulting two activities go hand in hand. For example, the knowledge of causesand effects improves our ability to choose actions, so that they have the results we desire (Hájíček, 2008). In the last 10 years, the threads of chaos and non-linear dynamics have spread across the scientific disciplines like a spider's intricate web. Chaos and non-linear dynamics have provided new theoretical and conceptual tools that allow us to capture, understand and link together the surprisingly complex behaviours of simple systems - the type of behaviour called *chaos* – in essentially every field of contemporary science (Hilborn, 2004).

The universality of chaos is both intriguing and puzzling.

"Does the flap of Butter fly's wings in one part of the world set-off a tornado in the other part of the world?"

The effect of divergence of the nearby trajectories on the behaviour of nonlinear systems has been expressed in an elegant metaphor known as the *butterfly effect.* This metaphor appeared in the title of talk given by E. N. Lorenz at the December 1972 meeting of the American Association for Advancement of Science *(AAAS)*in Washington, D. C.: "Predictability: Does the flap of Butterfly's Wings in Brazil set off a Tornado in Texas?" (Lorenz, 1963; Lorenz, 1991). Although Lorenz coined this expression in context of the phenomena of divergence of nearby trajectories in non-linear systems but, it has been found to have far-reaching consequences in nature pertaining to all natural systems (Lorenz, 1963).

A similar stable attractor has been recently investigated in a two-element complex self-organizing network (Chatterjee, 2012c). These attractors show the important property of sensitivity of these systems towards initial condition, and the existence of a stable equilibrium point towards which the system gradually *tend* to evolve. Even a little variation in the control parameter can render the system towards a totally new trajectory or complete chaos.

Causality and philosophy

According to Engels: *"Reciprocal action* is the first thing that we encounter when we consider matter in motion as a whole from the standpoint of modern natural science. We see a series of forms of motion, mechanical motion, heat, light, electricity, magnetism, chemical union and decomposition, transitions of states of aggregation, organic life, all of which, if *at present* we *still* make an exception of organic life, pass into one another, mutually determine one another, are in one place cause and in another effect, the sum total of the motion in all its changing forms remaining the same*"* (Engels, 1974). The mutual transformation and transition, mutual dependence and mutual connection occupy the foreground in the interior aspects of interaction. Causal connections are here more profound; they involve both the dependence of causes upon each other and the reciprocal action of effects upon causes (Hájíček, 2008).

Consider two broad classes of inferential metaphysical questions (Gelman, 2010):

1. *Forward causal inference*: What might happen if we do *X*?

2. *Reverse causal inference*: What causes *Y*?

The philosophical doctrine that, *"Everything what happens must happen by a cause because it is impossible that anything comes into being without cause"* (Hume, 1992), establishes a connection between the two above-discussed events *(X and Y).* Taking into account the infinitude of this universe and vastness of the space-time continuum, the two events *(natural processes)* although separate, are said to form a part of *some* causal chain.

Causality and Physics

Naturally occurring systems are highly complex entities. These systems disperse their free energies into their surrounding environment (Chatterjee, 2012a; Salthe, 1993; Salthe, 2008; Chaisson, 2001) by continuous processes of self-organization (Chatterjee, 2012a; Chatterjee, 2012b; Chatterjee, 2012c; Georgiev, 2002; Georgiev, 2010) or *progressive development* (Salthe, 1993; Salthe, 2008).The inherent changes that the system encounters get stored in its physical memory (Chatterjee, 2012a). The lost free energies are absorbed by other similar systems present in its immediate surrounding and thus, acting as an activation signal for another self-organizing process (Chatterjee, 2012a; Hansel and Sompolinsky, 1992), *a causally connected one* (Chatterjee, 2012a; Anilla et al., 2009).The free energy or *information,* from one process in nature can be propagated at no speed greater than light along the naturally occurring infinite causal chain.

According to Theory of Special Relativity, such events or processes occurring in nature have time-like separation. Such events are said to be *causally connected* (Goldstein, 1980; Jackson, 1986). A point to be noted here is that, the infinitude of space and the maximum achievable speed in the space-time continuum present both, a criterion for causation of all of the infinite processes *(occurring in nature)* and also the physical limitation in the process of information transduction.

"All of the laws of physics can be contained in one equation"

The beauty of the above proposition (Feynman, 1964) elegantly describes the causation of all natural processes occurring in this universe. A functional equation *(of the form y - f(x) = 0)*is a logical *black box,* that operates between a fixed state *(input to the equation),* and a variable but *finite* state *(linear, quadratic, cubic, bi-quadratic etc.)*. So, we basically have one output for one input, for a *one-to-one* function. An interesting mechanical analogy is presented here, let a systemconsist of lots of gears and cogs through whichit transmits power from one end to the other end, then for specified input, we will have a *distinct* output irrespective of the tooth profile of individual gears along the gear train. Starting from the input end, each gear transfers its rotational energy to its adjacent meshing gear, and one by one we get a *distinct* output at the receiving end. If we take into account the frictional losses at each tooth pair interface, then we end up achieving a *reduced* energy at the receiving end as the losses at each reduction stage get multiplied *(loss of information when information transcends from higher levels of hierarchy towards the lower levels).* Thus, the gear-train is an example of a *causal chain.*

Feynman even attempts to provide a mathematical justification for his proposition in the form of a mathematical equation*"the great law of nature"* (Feynman, 1964),

$$U = 0$$

"*U* is a physical quantity which we call *"unworldliness"* of the situation. And we have a formula for it" (Feynman, 1964) *(in the actual words of Feynman)*.
He further proceeds by showing how to calculate this physical quantity, "Here is how you calculate the unworldliness. You take all the known physical laws and write them in a special form. For

example, suppose you take the law of mechanics, $(\boldsymbol{F} - m\boldsymbol{a})$ - which should, of course, be zero – the "mismatch", of mechanics. Next, you take the square of this mismatch and call it U_1, which can be called the "unworldliness of mechanical effects" (Feynman, 1964).

The above equation, proposed by Feynman is beautifully simple yet, equally innovative. The equation is extremely alluring as it elegantly hides the entire complexity of the nature and brilliantly sums up the varied domains of the universe by computing the individual unworldliness. The principle of causality can be clearly traced in the mathematics of the *"great law of nature"*.

Conclusion

Throughout this paper, the physical, metaphysical and philosophical foundations of the principle of causation have been explored. The idea of the paper builds on the thoughts of the great thinkers and philosophers of the past and establishes the connection of the causation principle in modern and contemporary physics. Scientists and philosophers alike are working all over the world towards the *grand unification theory,* which promises to connect all the interacting *(forces)* domains of this vast universe. But, the beautiful idea, *"great law of nature"*, envisioned by Feynman long ago *(clarification needed, in terms of rapidly growing technology)* deserves a real applaud. Looking at the universe through Feynman's eyes enables us not only to admire the intricate beauty of the nature but also, to investigate the cause of these processes in nature.

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