

Pandemic Preparation, Consciousness and Complex Adaptive Systems Through the Lens of a Meta-reductive Scientific Paradigm



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Abstract The novel coronavirus SARS-CoV-2 and Covid-19 pandemic and the associated economic crisis provide an opportunity to explore an incompleteness driven novelty generating meta-construction of a Meta-Reductive Scientific Paradigm. Previous proof of formal reductive incompleteness and necessary meta-consideration in determining reductive logical consistency, permits the meta-construction of adjacent possible meta-reductive paradigms. An imagined Meta-Reductive Paradigm then allows for a search in an adjacent possible conceptual space, beyond the boundary of the Reductive Paradigm, looking for possible adaptations that might enhance the resilience of individual and community level responses to the Covid-19 pandemic and economic crisis. Unrecognized formal incompleteness of reductive scientific Logic is related to the unresolved integration of Reductive Science and Complexity Science. The lack of integration of these two broad areas of scientific interest, is in part associated with a diminished interest in formal reductive logic and its properties, particularly in the Complexity Sciences. The failure to sustain a strong link to rigorous reductive logic could indirectly relate to diminished public trust in scientific and medical information, with consequent political failure to effectively integrate scientific and medical advice in response to the Covid-19 situation. Careful meta-consideration reveals a subtle way to address formal reductive incompleteness and meta-construct an adjacent possible Meta-reductive CAS Model (MCAS) and Meta-reductive Paradigm (MRP). The strong link to logic and differentiated truth and proof in the proposed MCAS and MRP can integrate willful, intentional, brain, mind and consciousness in Nature, as well as spell-out a number of scientific and social adaptations that could improve the integration of medical and scientific information in the political management of the Covid-19 crisis, increasing the chance that humanity will be better prepared for the next pandemic or next urgent global crisis.

Keywords Pandemic · Reductive science · Complexity science · Reductive logic · Formal reductive incompleteness · Reductive paradigm · Meta-reductive paradigm · Complex adaptive system model · Mind and consciousness

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1 Introduction

An unprecedented global crisis has been caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which is the strain of coronavirus responsible for the human pandemic beginning in 2019 (Covid-19) [1].

The developing meta-construction of a Meta-Reductive Paradigm (MRP) [2, 3], responsive to demonstrated formal reductive incompleteness of formal reductive scientific Logic [4], can be used to model the Covid-19 coronavirus and its behavior in the ongoing human pandemic. An associated Meta-Reductive Complex Adaptive System Model (MCAS) could also be deployed in the task of modeling the human brain, mind and consciousness, as humanity continues with the task of dealing with and adapting to the SARS-CoV-2 Covid-19 pandemic and its economic consequences.

Incompleteness driven novelty generation is a significant meta-reductive complex causal mechanism defined in the meta-reductive scientific perspective [2, 5], as well as a significant component of the developing World-View created by the Meta-Reductive Paradigm (MRP) and Meta-Reductive Complex Adaptive System Model (MCAS) [6]. Novel adaptations and enhanced creativity of response can emerge from viewing the Covid-19 medical and economic crises through the lens of Meta-Reductive thought, which is responsive to formal incompleteness impacting reductive scientific Logic.

2 Covid-19 in Reductive and Meta-reductive Frameworks

The SARS-CoV-2 coronavirus responsible for the Covid-19 pandemic was originally limited to another animal species, probably a bat [7]. The coronavirus and bat exist together apparently without seriously harming the bat, effectively creating a consistent, ordered, interactive system. The relationship with human beings and human culture in the context of wet-markets brought the bat-virus system into close association with human beings creating a context for an inter-species jump into homo Sapiens followed by an infectious human pandemic [8].

2.1 The Reductive Framework

A reductive account of the situation concentrates attention on defining causal mechanisms and relationships, correlations, equivalence relationships and symmetry relationships [9], hoping to define and prove as best natural science can, that the likely causal origin of the present pandemic occurred in the context of a wet-market where the Covid-19 coronavirus found a local causal mechanism allowing an opportunistic chance to infect human beings [7, 8]. Ongoing reductive scientific work tries to define

other properties of the SARS-CoV-2 coronavirus [10] and epidemiological properties of the virus associated with mechanisms of individual and community infectious spread in the human population creating the Covid-19 pandemic [11]. The medical community pursues detailed monitoring and analysis of symptoms [12] and possible symptomatic treatment approaches for the infection [13], as well as possible lines of attack on the development of a vaccine and other mitigating treatments [14].

2.2 *A Meta-reductive Framework*

A meta-reductive account responds to formal reductive incompleteness [4] and its implications [6]. It incorporates the reductive model of the coronavirus-bat system and human vector as a ‘special-case’ within a more comprehensive meta-reductive assessment [2]. The fine details of the coronavirus-bat system and human vector can be modeled as an epistemological, ordered and consistent meta-reductive formal system model or equivalent system model [3]. The meta-reductive model contains within it a subset or ‘special-case’ [5], consisting of the ‘bottom-up’ reductive account. The meta-reductive model and the natural phenomenon it describes can then be examined in search of potential epistemological undecidable reductive propositions and theoretical formal reductive incompleteness correlated with ontological unresolvable natural instantiations and natural evolutionary incompleteness [3] and incompleteness driven novelty generation [2] in the complex system involving the bat-virus-human vector.

2.3 *Reductive Incompleteness in Relation to Covid-19*

In essence, does the virus system, the virus-bat system or the virus-bat-wet-market system have, fully formed, the necessary states and processes creating the causal mechanisms and relational properties required to make the jump, opportunistically infect a human being and produce a pandemic? If this is the case no undecidable reductive proposition and no reductive formal incompleteness need be involved and a ‘bottom-up’ reductive model of the situation will be sufficient. The jump to the human vector expands the range of the virus and increases the number of hosts it can infect. The emerging properties of the human infection are revealed as the novel infection and pandemic proceeds. The event can be described in a closed, resolved, consistent and complete reductive model.

Alternatively, on closer examination, the abstract model of the virus system may demonstrate properties that are conceptually equivalent to an undecidable reductive proposition and reductive formal incompleteness. For example, there could be something about the definable properties of the virus that is *undecidable*. There is structure and process present that *is true* and *proven to be true* to the given order of the virus system (in logic and in experimental confirmation) but among these

decided states and processes there is something that *is true but cannot be proven to be true*, something that is *unresolved* and *unresolvable*; in that it *is and is not* consistent with the structure and process of the virus as a closed system in isolation—there is something *undecidable* (for example: something must necessarily be left unknown—perhaps a stochastically selected well-formed strand of its genetic material or a protein expressed on the surface of the virus, with structure, position and, either, no further apparent function or a function limited to different tasks in the virus or virus-bat system; the specific genetic material or the protein have no apparent function or play a different role in the virus system, with the virus-bat-human interaction only existing as an *unresolved potential*). There may be something about the definable properties of the virus-bat system that is abstractly *undecidable* and practically *unresolvable* (for example: the virus-bat system sheds viruses from the skin of the bat when it flaps its wings, a behavior having no function but producing a mechanism for transmission in a wet-market). There may also be something about the definable properties of the virus-bat-wet-market system that is *undecidable* and *unresolvable* (the dropping viruses falling off the wings of the bat randomly fall on individual human beings working in the wet-market, creating an opportunistic mechanism for stochastic transmission to human beings with some of the randomly falling viruses surviving on or in the human host, thus selected for survival, replication and the onset of an emerging human pandemic).

The complex virus-bat-wet-market-human system may bring forth incompleteness driven novelty generating properties associated with previously non-functional viral genetic material and protein now functional and causal in the context of the human infection. Particular novel capacities are revealed as the virus infects human lung tissue, producing asymptomatic but highly infective carriers and unrecognized asymptomatic pulmonary failure. The infection involves human liver and cardiac tissue, produces changes in blood clotting mechanisms and immune system function, as well as infecting many other organs, with diverse symptomatic presentations in different age groups, sexes and complex comorbidity with other human illnesses [15]. The incompleteness driven novelty generating outcomes of the SARS-CoV-2 coronavirus human infection and Covid-19 pandemic includes the complex interaction and relationship the virus and pandemic have with the state of human readiness and preparedness to contain the virus through individual case interventions and community level, social and physical distancing, isolation and quarantine [11, 13]. Further novelty generation involves successful or tragic outcomes associated with medical systems, nursing homes, intensive care units and the availability and supply lines for personal protective gear and respirators, as local medical facilities and hospitals deal with a flattened viral curve or an unmitigated surge of viral infections, leading to large numbers of deaths when the medical system is overwhelmed. Vulnerability or resilience is revealed, involving the behavior of individual human beings, communities, local governments, national governments, particular political agendas and the interaction with other institutions, such as the CDC and the WHO [5]. Individuals and communities in scientific, medical and political contexts reveal their readiness to participate in creating an integrated, coordinated response, or, sadly, fail to integrate a coordinated response, with collapse into chaotic and disastrous outcomes, with

more viral victims and deaths associated with the spreading pandemic. The undecidable statement or unresolvable instantiation regarding the originally non-functional viral DNA and protein now becomes a decidable statement with clear mechanism, function and outcomes in the virus-bat-wet-market-human system. The unresolvable natural instantiation of the original viral DNA and protein become a resolvable natural evolutionary statement in the context of the complex virus-bat-wet-market-human system.

An ‘*is and is not*’ structure or process such as an entity, state or process, composition, interaction or relationship, that is, *true* to, and *consistent* with, the sequence of natural evolution of a self-organized *order* (under scientific investigation in a semi-isolated system) can have an abstract *undecidable* property and a correlated naturally instantiated *unresolvable* property or function. The undecidable, unresolvable or unknown ‘is and is not’ structure or process exhibits a potential or realized property or function that is, in the abstract or in the correlated natural instantiation, *false*, *contradictory* or *inconsistent* with the *logic* of the preceding *order* and process of natural evolution. To protect the abstract logic and avoid contradiction in describing the natural instantiation, it must be left undecided and unresolved. The abstractly *undecidable* can become *decidable* in an evolving context in which the correlated naturally *unresolvable* becomes a *resolvable* natural instantiation involving an entity, state or process, property or function, that is *true* and *consistent* with an *emerging*, naturally evolved semi-isolated system or self-organized *order*. Scientific narrative and natural evolution reveal themselves to be, necessarily, open, undecided and undecidable, unresolved and unresolvable, consistent and para-consistent, thus requiring imperative meta-consideration in determining consistency. Scientific narrative and models of correlated natural evolution must incorporate formal logical undecidable propositions, which are predicted to correlate with natural unresolvable instantiations accompanied by inevitable incompleteness in a meta-reductive model and narrative.

Further examples of epistemological, abstract, undecidable reductive proposition and formal reductive incompleteness associated with correlated natural ontological, realized, unresolvable instantiations and natural evolutionary incompleteness could be pursued in every corner and through every layer of viral-human interaction and relationship. The undecidable pattern of incompleteness may or may not repeat in relation to the cell, the organ, the individual human being, the human family and any complex cultural human context impacted by the invading and transformative virus-host interaction.

Scientific exploration could reveal that natural, incompleteness driven exploration of the adjacent possible, can lead to emerging, self-organized, patterns of novelty generation. Novelty generation in natural settings may have a neutral influence on the survival of any particular living species. However, as in the case of the Covid-19 pandemic, novelty generation at the level of the SARS-CoV-2 coronavirus can increase vulnerability and have disastrous consequence for the infected human species. Fortunately, novelty generation at the level of complex organization involving human mind and consciousness, has the potential to induce greater resilience and creative adaptation, in the individual, the local community or the entire social system of the human host.

3 Meta-reductive Life Cones and Self-similarity

An abstract epistemological *meta-reductive four-dimensional life cone* can model a single SARS-CoV-2 coronavirus as it instantiates its meta-reductive *ontological complex cycle of existence*. The ontological cycle of existence can be described and modeled by a meta-reductive epistemological *complex natural history* [2, 3]. The life cone, a cycle of existence and a complex natural history are *self-similar correlated* ontological and epistemological structures formulated in the meta-reductive perspective.

3.1 Self-similarity and Meta-reductive Models

A meta-reductive life cone with a correlated ontological complex cycle of existence and epistemological complex natural history reveals a further pattern of self-similarity in theory and in natural evolution. The existence of a Covid-19 coronavirus can be described by dividing its existence into three inter-related meta-reductive system components.

Semi-isolated Material Existence. The first component subsystem describes the physical and material existence of a SARS-CoV-2 coronavirus, limited to the entity, its states and processes, its composition and interactions, contained within a subsystem involving the spherical shell, the enclosed genetic material and the exposed surface proteins.

Semi-isolated Potential Dynamic Existence. The second component subsystem describes the potential dynamic existence of a SARS-CoV-2 coronavirus. This component description captures the sum and potential range of dynamic composition, interaction and relationship. There are two potential dynamic descriptions. The first models the virus in its system of origin involving the cycle of existence in the coronavirus-bat ecosystem. The second models the transition, emergence, self-organization and evolution of the coronavirus-human ecosystem involving the Covid-19 pandemic. The two dynamic descriptions of the coronavirus are synthesized into a detailed account describing the sum of all potential or possible dynamic states and processes, entities, compositions, interactions and relationships within which the SARS-CoV-2 coronavirus does or could participate.

Semi-isolated Realized Material Dynamic Existence. The third component subsystem captures specific moments in state and process involving the immediate location and behavior of a SARS-CoV-2 coronavirus in the virus-bat system or the virus-human system. The epidemiological pursuit of a single case presentation of Covid-19 in the context of public health detection, single case management, orders for self-isolation and quarantine, as well as medical management of the evolving symptoms of an individual case of coronavirus infection; these all fall into the third description. Community level public health orders recommending intentional deconstruction of connectivity with social and physical distancing, masks, handwashing

and surface sterilizing, as well as public health models of specific moments and daily reports of the pandemic state and process, describing specific individual case reports and tracking specific patterns of community spread and lab testing; all fall under the third component description.

3.2 A General Pattern of Evolutionary Self-similarity

A significant meta-reductive pattern of theoretical and instantiated Fractal evolutionary, self-similarity, iteration and scaling, is revealed by the threefold SARS-CoV-2 coronavirus description. The same three component subsystems can be employed to describe a micro-scale quantum particle/wave system, the mid-scale complexity of the human brain/mind system, and the macro-scale structure and process of the entire material/dynamic existence of the whole Universe.

Micro-scale Complexity. The micro-scale quantum particle/wave system involves complementarity with a *particle* description (*material existence*), a *wave* description (*potential dynamic existence*), and the sum of all specific individual experimental demonstrations of a particle/wave, including non-local superposition in wave state and process, local ‘collapsed’ particle state and process; ultimately creating a model mapping the sum of all possible experimentally demonstrated state and process of a *particle/wave* (*realized material and dynamic existence*).

Mid-scale Complexity. The mid-scale complexity of the human brain/mind system, involves complementarity with a *brain* description (*material existence*: localized possible brain states and processes), a *mind* description (*potential dynamic existence*: extended possible mind states and processes in relation to self, other living beings, the World and the Universe), and the sum of all specific individual theoretical or experimental demonstrations of consciousness, including localized realized brain states and processes as well as extended realized mind states in relation to self, other living beings, the World and the Universe (*realized material dynamic existence*).

Macro-scale Complexity. The macro-scale structure and process of the entire material/dynamic existence of the whole Universe as a system involves complementarity with a *physical* description (*material existence*: a localized possible Universe of states and processes), a *flow* description (*potential dynamic existence*: an extended description of a possible Universe of states and processes in relation to an observing, meta-considering conscious self, other living beings, the World and the Universe itself and possibly an unknowable greater system beyond the Universe), and the sum of all specific individual theoretical or experimental demonstrations of the Universe, involving localized realized states and processes of the Universe or extended realized states and processes of the Universe, in relation to an observing, meta-considering conscious self, other living beings, the World and the whole Universe conforming to itself (*realized material dynamic existence*).

3.3 The Implication of Generalized Self-similarity

The reductive scientific account of consciousness in the Universe, excludes mind and consciousness as mere epiphenomena of more fundamental physical or quantum realities [15] or dismisses mind and consciousness as superfluous unnecessary concepts [16]. The meta-reductive account, driven by reductive incompleteness and novelty generation, preserves mind and consciousness and brings brain, mind and consciousness into Nature as significant differentiated self-similar phenomena [2, 3].

A self-similar meta-reductive account of the SARS-CoV-2 coronavirus and the Covid-19 human pandemic treats the ‘bottom-up’ reductive account as a ‘special-case’. The meta-reductive account then expands the model of the SARS-CoV-2 coronavirus and the Covid-19 human epidemic to include a scientific search for meta-reductive abstract and realized incompleteness and incompleteness driven novelty generation. A meta-reductive formulation can create an interactive mapping of the life-cone of human consciousness, mind and brain in a co-evolving relation to the SARS-CoV-2 coronavirus and Covid-19 human pandemic. A detailed meta-reductive account reveals a self-similar systemic evolutionary pattern present in the sequence of change, self-organization, emergence and hierarchical organization of complexity associated with the composition, the interaction and the relationship the SARS-CoV-2 coronavirus has with the adaptive, novelty generating creative potential of the human being.

Willful, intentional, mindful human consciousness can very much participate in modifying the trajectory, flattening the pandemic curve as well as exploring complex alternative ways to address the pandemic and the associated economic crisis. Human consciousness, in a Meta-Reductive integration of Reductive and Complexity Science, could strongly adhere to adapted, rigorous, iterated reductive logic, responsive to reductive incompleteness and aware of incompleteness driven novelty generation. This refocusing of human scientific attention, with mind and consciousness fully integrated in Nature and rigorous logic and differentiated truth and proof invigorated at the core of scientific thought, could then actively and adaptively, try to make choices that creatively enhance the resilience of the human being and avoid individuals or communities transiting onto a trajectory of vulnerability and potential death.

4 Adapting Kinds of Reductive ‘Unfinished Description’

The Meta-Reductive Paradigm initially explored in relation to unrecognized formal reductive incompleteness [4] addresses a number of further identified patterns of ‘unfinished description’ theoretically associated with the Reductive Paradigm [2].

4.1 Micro-scale Evolution Transformed into Multi-scale Co-evolution

The meta-reductive framework first transforms the ‘unfinished’ singular reductive ‘bottom-up’ micro-scale upward interpretation of evolution, into a multi-scale interpretation of co-evolution.

The ‘bottom-up’, micro-scale first, reductive account of the SARS-CoV-2 coronavirus describes the entity, its parts, states and processes, its composition and internal interactions as well as its potential for external relationships leading to the Covid-19 human pandemic. The reductive account tends to focus scientific attention on the virus in isolation and only then on the impact it has in the arena of the human pandemic. The reductive account becomes a ‘special-case’ in the meta-reductive account.

The meta-reductive account highlights multi-scale co-evolution. This brings into focus a micro-scale, mid-scale and macro-scale description of co-evolving entities, self-organization of entities on multiple scales, developing interactions and emerging patterns of systemic relationship occurring on multiple scales of organization. From the beginning in a meta-reductive account, the states, processes, entities, composition, interactions and relationships of SARS-CoV-2 coronavirus interacting with adaptive human beings is highlighted, in relation to the evolving Covid-19 pandemic. In the meta-reductive frame, individual human consciousness (prepared or unprepared), human patterns of multi-scale social interaction (wet-markets or applied social and physical distancing), the state and recognition of scientific knowledge (ignored, unfunded, abandoned, recognized, incorporated) and the effective orientation of human political institutions and actors (accepting, collaborative, inclusive of public health, medical and scientific expertise, with altruistic motives in relation to potential human vulnerability and adaptive resilience; *or*, dismissive, combative, excluding of public health, medical and scientific expertise, with self-absorbed or self-interested motives in relation to potential human vulnerability and adaptive resilience).

4.2 Unidirectional Evolution Transformed into Multi-directional Co-evolution

This second adaptation allows the metaphoric, ‘unfinished’ unidirectional ‘bottom-up’ reductive interpretation to be treated as a ‘special-case’. The reductive perspective is adapted and transformed into a meta-reductive account by including the reductive account within an incompleteness driven, novel, metaphoric, multi-directional causal interpretation of co-evolution.

In the meta-reductive perspective, ‘simple’ non-local and local causal mechanisms are integrated with ‘complex’ incompleteness driven novelty generating causal mechanisms [2]. ‘Simple’ and ‘complex’ causal mechanisms and relationships are explored in extended meta-reductive semi-isolated systems, which include

the ‘special-case’ of the reductive semi-isolated system embedded in an extended meta-reductive sphere involving the local proximate ecosystem and the distant but relational environment. An individual case interpretation would place SARS-CoV-2 coronaviruses, or the viruses and an adaptive human being in an extended meta-reductive semi-isolated system. Alternatively, a community level interpretation would place selected populations of human beings presently impacted by the Covid-19 pandemic in an extended meta-reductive semi-isolated system. Causal mechanisms and relationships can then be explored.

The selected phenomenon of interest in an individual or community level interpretation involving virus and human interactions and relationships, is represented by a threefold description modeling the viral and human *material existence*, the *potential dynamic existence* and the *realized material dynamic existence*. An integrated reductive and meta-reductive model could represent the complexity of the situation as a meta-reductive complex physical system (MCPS) or meta-reductive complex adaptive system (MCAS) [17]. In a semi-isolated system, a reductive or complexity account would focus on the selected phenomenon of interest, analyzed in relation to defined entities, causal states and processes, composition, interaction and hierarchical organization. In an extended meta-reductive semi-isolated system, the reductive and complexity description is encompassed in a meta-reductive account of the greater systemic complexity involving the causal relationships the MCPS or MCAS has within an extended sphere of a local, proximate ecosystem and an extended interactive and relational environment. The meta-reductive frame creates a further matrix of causal relationships defined in the context of multi-directional causal accounting responsive to multi-scale co-evolution [2]. The meta-reductive framework thus encompasses ‘bottom-up’ reductive accounting and the complexity-based interpretation of CPS’s and CAS’s, as an integrated ‘special-case’ within the meta-reductive framework.

The extended meta-reductive account then explores possible causal mechanisms and relationships in an extended meta-reductive semi-isolated system. The extended system holds the SARS-CoV-2 coronavirus and an adaptive human being, or a population of human beings facing the Covid-19 pandemic, in a complex systemic, social and environmental context. A self-similar multi-level, analysis of the situation can involve an examination of viral and human *material existence*, the *potential dynamic existence* and the *realized material dynamic existence* of the coronavirus and the pandemic in relation to adaptive human bodies, brains, minds, consciousness and human communities. Within the co-evolving, realized material dynamic existence of viral-human interactions and relationships, there would be a description of causal public health, medical, scientific research and communication, as well as, causal collaborative or partisan political exchanges, which prepared individuals and communities or left individuals and communities tragically unprepared. Human individuals and communities are made more resilient or made profoundly more vulnerable, depending upon very complex interactive relationships that involve particular individual people, communities, jurisdictions, nations and international institutions attempting to deal with the Covid-19 pandemic [2]. The hierarchical, compositional,

interactive and relational complexity of the situation is made apparent by the meta-reductive method of causal accounting. The responsibility and failure to take responsibility and the adaptive or maladaptive response of particular individuals, communities, jurisdictions, nations and international institutions, are an inherent part of a meta-reductive account [5].

4.3 Reductive Logic Transformed into Iterated Meta-reductive Logic

An ‘unfinished’ description is created by the failure of ‘bottom-up’ reductive Logic to predict formal reductive incompleteness in the Reductive Paradigm. The recognition of undecidable reductive propositions and formal reductive incompleteness, multi-scale co-evolution and the need for multi-directional causal accounting, leads to a transformation of ‘bottom-up’ reductive Logic.

Reductive ‘bottom-up’ Logic is adapted by encompassing it as a ‘special-case’ in an iterated, paraconsistent form of reductive Logic [2, 18], capable of handling undecidable reductive propositions and reductive incompleteness, as well as handling multi-scale co-evolution and multi-directional causal accounting. Multiple iterative implementations of reductive Logic are then required in relation to the matrix of meta-reductive causal accounting.

The meta-reductive perspective and method of causal accounting recommends the SARS-CoV-2 coronavirus and the Covid-19 human pandemic be analyzed by applying multiple iterative implementations of reductive Logic within a detailed exploration of the complex hierarchically organized system in which the virus and human pandemic co-evolve.

4.4 Symmetry and Self-similarity Deployed in the Analysis of Causal Relations

Finally, the reductive reliance on Symmetry and Group theory in mathematically defining causal mechanisms and relationships in natural systems [9] is transformed in the meta-reductive system, into an integrated meta-reductive model of causal relationships employing Symmetry and Group theory, as well as Self-similarity and Fractals, deployed in the task of modeling naturally co-evolving systems [2]. Symmetry becomes a ‘special-case’ within a more comprehensive exploration of causal relation involving symmetry and self-similarity.

The reductive sciences employ a semi-isolated system in order to create predictable and reproducible contexts for experimental exploration of probable causal interactions and relationships and the definition of causal mechanisms. Synthesis of

symmetry and self-similarity in scientific accounting of causal mechanisms and relationships requires the implementation of an enhanced and extended semi-isolated system, which can model extended relationships within a local system as well as an associated ecosystem and environment. The usual reductive semi-isolated system becomes a 'special-case' within the extended meta-reductive semi-isolated system capable of exploring symmetry relations as well as self-similar relationships. Self-similarity is a special form of scale dependent symmetry. The meta-reductive application of symmetry and self-similarity leads to recategorization of causal mechanisms in natural systems.

The reductive sciences recognize local and non-local causal mechanisms. These are contained as a 'special-case' within the extended meta-reductive categorization of causal mechanisms. The meta-reductive account of causal mechanism includes a primary *incompleteness driven, novelty generating causal mechanism* and other secondary incompleteness driven causal mechanisms and relationships. Examples of *secondary* complex systemic incompleteness driven causal mechanisms that can combine at the *edge of incompleteness* with *incompleteness driven novelty generation*, include, for example: phase change; non-linear or chaotic process; stochastic system evolution; Lamarckian system evolution; as well as bidirectional intersection in multi-scale, multi-directional co-evolution, which leads to the development of systemic duality or self-similar complementarity previously mentioned in this article (examples: 1) complementarity defined by particle/wave and the sum of locations; (2) complementarity defined by SARS-CoV-2 coronavirus/Covid-19 human pandemic and specific interactions and relations in complex systems; (3) complementarity defined by brain/mind and moment-to-moment experiential consciousness; (4) complementarity abstractly defined as, the *material existence/the potential dynamic existence* and the *realized material dynamic existence*). The meta-reductive assumption of multi-scale, multi-directional, co-evolution leads to differentiation of simple conservative (reductive) emergence and/or more complex forms of novel or radical emergence (meta-reductive), which are consistent with multi-scale, multi-directional co-evolution and meta-reductive causal accounting.

In the meta-reductive framework, causal relationships could be experimentally evaluated through exploration of semi-isolated systems of presumed cause and presumed effect assisted by a synthesis of the applied mathematics involving both symmetry and self-similarity. The process of causal analysis in reductive thought demands analysis of correlation, equivalence relationships and symmetry relationships. In meta-reductive thought, causal analysis requires the further exploration of scaled correlation, scaled patterns of equivalence and a search for scaled, self-similarity.

The meta-reductive perspective would recommend the SARS-CoV-2 coronavirus and the Covid-19 human pandemic be examined in greater detail as a complex hierarchically organized natural system in which the causal mechanisms and relationships are derived from both the reductive and meta-reductive paradigms. The applied mathematical accounting entails both symmetry and self-similarity. The iteration of

reductive Logic in the meta-reductive frame can then explore the matrix of meta-reductive causal description in relation to multi-scale, multi-directional, co-evolution [2].

5 Meta-reductive Thought During the Covid-19 Pandemic

The jump of the SARS-CoV-2 coronavirus into human beings having no specific immunity and the ensuing catastrophic Covid-19 human pandemic provides a tragic vehicle for spelling-out the importance of Natural Science responding to a number of shortcomings and challenges to its continued progress.

Reductive Natural Science, the ‘bottom-up’ Logic of reductive science and the Reductive Scientific Paradigm have enabled almost 4 centuries of vastly successful scientific and applied mathematical discovery. There are, however, limits to the application of ‘bottom-up’ reductive Logic and the semi-isolated reductive scientific experimental method. The favored ‘bottom-up’ Logic of Reductive Natural Science is susceptible to undecidable reductive propositions and formal reductive incompleteness. Addressing this unrecognized property of reductive Logic could lead to a resurgent interest in the relationship shared by Logic and Natural Science. How truth must be separated from proof in the scientific context becomes an important theoretical and experimental question. The necessity of meta-consideration when determining reductive logical consistency provides a further impetus to explore how human consciousness can be fully integrated in a scientific model of Nature.

The present political climate in which the Covid-19 pandemic evolves includes a decay into irrationality and a resurgence of emotionally based, sometimes grossly illogical argumentation with blatantly false interpretations of reality. The handling of the Covid-19 pandemic frequently reveals inaccurate translation of public health advice, as well as medical and scientific information. In this context it can only be a good thing for there to be an increased interest, in Logic, truth, proof, consistency, the nature of unfinished scientific and mathematical description, as well as the implications of formal incompleteness in scientific and mathematical domains.

The scientific investigation of the SARS-CoV-2 coronavirus and the Covid-19 human pandemic will most certainly proceed in conformity with the structure and method of Reductive Natural Science and the Reductive Paradigm. However, there are many problems associated with Covid-19 pandemic that may be better addressed through the further development of a meta-reductive perspective. The important issues directly reflect upon how human beings see themselves in Nature and indirectly influence how we might choose to collectively address an evolving pandemic threatening our existence and way of life on Earth.

First, the meta-reductive account offers a way to bring Reductive Natural Science into consilience with the Complexity Sciences. The integration of reductive and complexity thinking offers a way to transform a reductive Complex Adaptive System Model (CAS), challenged by the unresolved contradictions and paradoxes of consciousness and mind; into a Meta-Reductive Complex Adaptive System Model

(MCAS) that can include brain, mind and consciousness in Nature [6]. An MCAS can introduce a resolved and decided acceptance of willful, intentional, mindful human agency within Nature and create a model of complex adaptation unfettered by contradiction and self-referencing paradox.

The meta-reductive inclusion of human conscious agency and a renewed interest in truth, proof and consistency in natural science, in medicine, as well as in the political arena and wider human culture, are critical to the future hope and efforts of humanity in the face of the Covid-19 pandemic and economic crisis. A Meta-Reductive Paradigm could also offer novel means to model complex features and properties of other co-evolving global crises including climate change.

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