Causation in Complex Systems

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ISC-PIF, Paris
November 2009
1: The nature of causation

I will claim here that there are other forms of causation than those encompassed by physics and physical chemistry, and these are described quite well by Aristotle’s four types of causes. A full scientific view of the world must recognise this fact, or else it will ignore important aspects of causation in the real world, and so will give a causally incomplete view of things.

The key idea I will pursue is that as well as bottom-up causation, top-down causation takes place in these structures, due in particular to the crucial role of context in determining the outcomes of lower level causation. Because of the existence of random processes at the bottom, there is sufficient causal slack at the physical level to allow all these kinds of causation to occur without violation of physical causation.
Fifth day of creation:
M C Escher
Topics:

2: Complexity and Structure
3: Bottom-up and Top-down action
4: Five different kinds of Top-down action
5: The nature of causality
6: Predicting and intervening
True complexity, with the emergence of higher levels of order and meaning, occurs in modular hierarchical structures because this is the only viable ways of building up real complexity on the basis of the underlying physics.

A hierarchy, with many layers of structure built upon each other, represents different levels of abstraction, each built upon the other, and understandable by itself. This is the phenomenon of emergent order.

There will be a different description and vocabulary suitable at each level of the hierarchy, related to the effective entities that occur at that level.
The Hierarchy of Structure: 1

Sociology/Economics/Politics

Psychology

Botany/Zoology/Physiology

Cell biology

Biochemistry

Chemistry

Atomic Physics

Particle physics
Hierarchy

• The key to handling complexity is *hierarchical information structure and analysis*, and associated physical structuring.

• A modular *hierarchy* represents a decomposition of the problem into constituent parts, and into processes to handle those constituent parts, each requiring less data and processing, and more restricted operations, than the problem as a whole.

• The success of hierarchical structuring depends on:
  (a) implementing modules to handle lower-level processes,
  (b) integration of these modules into a higher-level structure.

Grady Booch: Object Oriented Programming
“We find separate parts that act as independent agents, each of which exhibit some fairly complex behaviour, and each of which contributes to many higher level functions. Only through the mutual co-operation of meaningful collections of these agents do we see the higher-level functionality of an organism. This is *emergent behaviour* – the behaviour of the whole is greater than the sum of its parts” (and cannot even be described in terms of the language that applies to the parts)

“Intra-component linkages are generally stronger than inter-component linkages. This fact has the effect of separating the *high-frequency dynamics* of the components – involving their internal structure – from the *low-frequency dynamics* – involving interactions amongst components” (this is why we can sensibly identify the components)
Modularity: Abstraction

**Abstraction and Labelling:** Unable to master the entirety of a complex object, we choose to ignore its inessential details, dealing instead with a generalised idealised model of the object. *An abstraction* denotes the essential characteristics of an object that distinguishes it from all other kinds of objects.

It focuses on the **outside view of the object**, and so serves to separate its essential behaviour from its implementation; it emphasises some of the system’s details or properties, while suppressing others. “Information has to be thrown away by the billion bits all the time, because all the alternatives cannot be examined”.

**Key feature:** *Compound objects can be named and treated as units by appropriate labelling.* This leads to the power of abstract symbolism and symbolic computation.
Modularity: Inheritance

- Structuring of modular units with abstraction, encapsulation with consistent interfaces, and inheritance enables the modification of modules and re-use for other purposes.

- **Inheritance** is the most important feature of a hierarchy: it allows an object class to inherit all the properties of its superclass, and to add further properties to them (it is a `is a’ hierarchy).

- For example: cells specialise to neurons.

Efficiency and usability introduce the aim of reducing the number of variables and names that are visible at the interface, as is implied by encapsulation.
Modularity: Encapsulation

**Encapsulation and Information Hiding**: consumers of services only specify what is to be done, leaving it to the object to decide how to do it; this is an aspect of decentralisation of control.

*Encapsulation* is when the internal workings are hidden from the outside, so its procedures can be treated as black-box abstractions. “No part of any complex system should depend on the internal details of any other part”.

It involves *information hiding* – hiding all the internal aspects of an object that do not contribute to its essential characteristics [corresponding to coarse-graining in physics; the accompanying loss of detailed information is the essential source of entropy].
Information Hiding:

- a physicist does not need to know the position and velocity of each molecule in a gas; overall temperature and pressure will do

- a chemist does not need to know about nuclear binding forces and quarks; nuclei and electrons can be treated as components of molecules

- a biologist does not need to know all the internal workings of a cell to understand its role in an organism

- a motor car driver does not need to know the details of how the carburetor or battery works;

- an employee does not need to know the inner working of the payroll department (who has to sign what forms); she just needs to know when the cheque is coming
Network structures

Network structures: represented as directed graphs

**Motifs**: building block patterns in complex networks


Maximal decentralisation of function, with coherence of goals

- Stafford Beer, *Brain of the firms*

Ross Ashby: *Law of Requisite Variety* stating that "variety absorbs variety", defines the minimum number of states necessary for a controller to control a system of a given number of states.
Arithmetic simplicity beneath metabolic network architecture

Authors: W. J. Riehl, P. L. Krapivsky, S. Redner, D. Segre

Abstract: Metabolic networks perform some of the most fundamental functions in living cells, including energy transduction and building block biosynthesis. Is the evolution of metabolism subject to general principles, beyond the unpredictable accumulation of multiple historical accidents? Here we search for such principles by applying to an artificial chemical universe some of the methodologies developed for the study of genome scale models of cellular metabolism. In particular, we use metabolic flux constraint-based models to exhaustively search for artificial chemistry pathways that can optimally perform an array of elementary metabolic functions.
Despite the simplicity of the model employed, we find that the ensuing pathways display a surprisingly rich set of properties, including the existence of autocatalytic cycles and hierarchical modules, the appearance of universally preferable metabolites and reactions, and a logarithmic trend of pathway length as a function of input/output molecule size. Some of these properties can be derived analytically, borrowing methods previously used in cryptography.

In addition, by mapping biochemical networks onto a simplified carbon atom reaction backbone, we find that several of the properties predicted by the artificial chemistry model hold for real metabolic networks. These findings suggest that optimality principles and arithmetic simplicity might lie beneath some aspects of biochemical complexity.
Multiple Realisation

A key feature is that higher levels will be realisable in multiple ways through the entities at the underlying lower levels:

- molecules in a gas
- electrons in a computer
- cells in a living body
- animals in an ecosystem
- people in an organisation

The higher level entity has an existence that does not depend on the specific lower level realisation (molecules in our body).
3: Bottom-up and Top-down action

**Bottom-up action** is when what happens at the higher levels is controlled by what happens at the lower levels

- micro-physics underlies macro physics, e.g. kinetic theory of gases, theory of solids (conduction, thermal capacity)
- physics underlies chemistry, e.g. nature of chemical bond
- protein folding and recognition is based on chemical bonding
- cells with their own internal function underlie all life,
- physics and chemistry underlie the functioning of the brain
- individual human behaviour underlies the functioning of society
Bottom-up causation alone:

Micro forces determine what happens at the higher levels

They are the foundation of higher level activity
Bottom-up action

Allows the building up of a certain degree of complexity:

- Can lead to quite complex patterns occurring (sandpiles, reaction diffusion equation, convection patterns, cellular automata, etc)

- Often guided by attractors in the possibility space:
  One ends up there from a large basin of attraction, irrespective of where you start in that basin

Restricted by fundamental constraints, e.g. to do with matter and energy conservation

But cannot by itself generate genuine complexity, such as a single living cell.
Top-down causation

Top-down causation is when the higher levels of the hierarchy causally effect what happens at the lower levels, in a coordinated way. This occurs by higher level features setting the context for lower level actions, the resulting constraints thereby creating new possibilities.

In physical systems, structured interactions (e.g. electrons guided by wiring between components in a computer) can lead to high level behaviour of great complexity (e.g. the internet).

In social systems, accepted social frames and associated role models can guide individual activities so that they add up to a coherent complex emergent whole (e.g. an educational system).
**Bottom-up and top-down causation:**

Additionally the higher levels control causal effects at the lower levels. *This allows inter-level feedback loops.*

**Claim:** Emergence of genuine complexity is possible only because of top-down causation.
Reliable emergent higher level behaviour

Set initial higher level state: what transpires?

The lower level dynamics lead to coherent higher same-level dynamics when the lower level dynamics acting on all the different lower level states corresponding to a single higher level state, give new lower level states corresponding to the same higher level state. Examples: gas laws; inland revenue service, payroll office.
No reliable higher level behaviour:

The lower level dynamics does not lead to coherent higher level dynamics when the lower level dynamics acting on different lower level states corresponding to a single higher level state, give new lower level states corresponding to different higher level states.

Example: chaotic systems: weather; hairdresser; president of country.
Three contexts of emergence:

1\textsuperscript{st}: Evolutionary history of the universe and the world: Once upon a time they did not exist!

2\textsuperscript{nd}: Developmental history of each living being: Once upon a time they were a single cell.

3\textsuperscript{rd}: Functional nature of each complex object: built up out of components that do not have the higher level properties.

I suggest that in each case, it is top-down causation that enables emergence of true complexity, which in turn enables more complex forms of top-down causation.
Fine tuning:

• 1. $N = \text{electrical force/gravitational force} = 10^{36}$
• 2. $E = \text{strength of nuclear binding} = 0.007$
• 3. $\Omega = \text{normalized amount of matter in universe} = 0.3$
• 4. $\Lambda = \text{normalized cosmological constant} = 0.7$
• 5. $Q = \text{inhomogeneous seeds for cosmic structures} = \frac{1}{100,000}$
• 6. $D = \text{number of spatial dimensions} = 3$

Fourteen billion years after the big bang.
4: Top-down action: five different kinds

Rather than referring just to top down causation, it is useful to distinguish five different classes of top-down causation:

1. Algorithmic top-down causation
2. Top-down causation via non-adaptive information control
3. Top-down causation via adaptive selection
4. Top-down causation via adaptive information control
5. Intelligent top-down causation (the effect of the human mind on the physical world)

The key technical concept in each case is *equivalence classes*: a large number of lower level states can underlie a single effective high level state. But the higher level state controls the lower level dynamics; the corresponding lower level states form an equivalence class, with respect to the higher level context, so the outcome is the same.
Algorithmic top-down causation occurs when high-level variables have causal power over lower level dynamics through system structuring, so that the outcome depends uniquely on the higher level structural, boundary, and initial conditions.

It occurs through determination of structure that controls micro-interactions: which components are connected together in a computer, which neurons are joined by synapses, which memory locations are in what state. The lower level variables determine the outcome in an algorithmic way from the initial and boundary conditions as a consequence of the higher level structural relations.

Examples. Algorithmic computational procedures in a digital computer determined by the wiring and the software; Bureaucratic procedures with interchangeable operatives.
**Example: Biological development**

*Reading of DNA codings*: The central process of developmental biology, whereby positional information determines which genes get switched on and which do not in each cell, so determining their developmental fate, is a top-down process from the developing organism to the cell, largely based on the existence of gradients of positional indicators (morphogens) in the body.

Without this feature organism development in a structured way would not be possible, for each cell has the same genetic material. Thus the functioning of the crucial cellular mechanism determining the type of each cell is controlled in an explicitly top-down way; it depends on the context.

But it is algorithmic in that it is mechanical, given the context.
Positional expression of genes leading to segments ...
The brain is made of interconnected neurons.

Information flows: dendrites to nucleus to axon to synapse and on to another neuron: This is an algorithmic process.
The outcome depends on the connections between neurons. These structural relations form a network, that has to be specified in addition to the properties of the neurons. Different connections will give different outputs. Personality is determined by this network structure.
In non-adaptive information control,

higher level entities influence lower level entities so as to attain specific **fixed goals** through the existence of feedback control loops

Information flows underlie their functioning

The goals determine the outcome
Feedback control systems and information

Feedback control (cybernetic systems):

Examples - the temperature of a shower
- the speed of a steam engine
- a thermostat

It is top-down action because if you disconnect the parts it won’t work. The system is connected so as to give the outcome.
The role of goals and information

The series of goals in a feedback control system are causally effective higher level entities.

They embody information about the system’s desired behaviour or responses – living systems are goal seeking (‘teleonomic’)

These goals are not the same as material states, for they are desired rather than actual states, although they will be represented by material states and systems that will make them causally effective through such representations

A complete causal description must necessarily take them into account. They exist as emergent properties of the system – they are not embodied in any component on its own.
The role of goals in dynamics

The nature of causality is different when feedback control systems are guided by goals

**Standard Physics**

(physics, equations of state, initial conditions) → (outcomes)

(initial conditions) → (outcomes)

**Feedback control systems**

(physics, physical structure, goals) → (outcomes)

(goals) → (outcomes)

- The outcome of a feedback control system is determined by the goals rather than the initial data
Homeostasis in the human body:
• Body temperature
• Blood Pressure
• Normal heart rate
• Transport across cell membranes
• Maintenance of resting potential in neurons

- *each is governed by implicit goals, embodied in the physical structure of the body:*
  ‘the human body has literally thousands of control systems in it’ [Guyton]

- *They have been built in through the adaptive process of evolution and so embody images of environment. They are constant across individuals, time, and place in specific species.*
3. Top-down causation via adaptive selection

Adaptive processes take place when many entities interact and variation takes place in the properties of these entities, followed by selection of preferred entities that are better suited to their environment or context.

Higher level environments provide niches that are either favorable or unfavorable to particular kinds of lower level entities; those variations that are better suited to the niche are preserved and the others decay away.

A selection agent or selector accepts one of the states and rejects the rest on the basis of fitness criteria guiding adaptive selection. This selected state is then the current system state that forms the starting basis for the next round of selection. A different environment will lead to a different outcome.
Adaptive Selection: generation of adapted states with new information encoded.
Top-down action by adaptive selection: evolution

*Development of DNA codings* (the particular sequence of bases in the DNA) through an evolutionary process which results in adaptation of an organism to its ecological niche.

This is a classical case of top down action from the environment to detailed biological microstructure - through the process of Darwinian adaptation based on random mutations, the environment (along with other causal factors) fixes the specific DNA coding. There is no way you could ever predict this coding on the basis of biochemistry or microphysics alone. *You can’t even ask the appropriate questions in their languages.*

This is the way new information comes into biological processes. It is unpredictable because a random element enters.
Through natural selection, top-down action from the environment codes information about appropriate responses to the environment into the detailed base sequence in the animal’s DNA.
The DNA double helix with complementary base pairs

Ecological context

Coding: CAGTCCTA...
Neural Networks Training of artificial neural nets to perform a specific task (say letter recognition) determines the interaction weights in the network.

The niche is a particular set of letters to be recognised. The fitness criterion is correct pattern recognition, and the adaptive process is the training of the neural network.

This is a form of top-down causation from the pattern to be recognized (a high-level concept, as it is defined in terms of the relation between the elements) to the low-level property of network weights.

Decision making is a property of the network rather than of any single cell.
The initial set of relatively non-specific synaptic connections are refined to produce a precise pattern of connectivity’ [Wolpert]

This kind of refinement takes place in all processes involving neural plasticity. This is adaptively guided by neurotransmitters on the basis of our primary emotions [Neural Darwinism].
Adaptive information control takes place when there is *adaptive selection of goals in a feedback control system*, thus combining both feedback control and adaptive selection.

The goals of the feedback control system are irreducible higher level variables determining the outcome, but are not fixed as in the case of non-adaptive feedback control; they can be adaptively changed in response to experience and information received, in the context of the local environment. They vary with the individual and with time.

The process is guided by fitness criteria for selection of goals.
Top-down causation via adaptive control

_Associative learning_ in animals, such as Pavlovian conditioning: - animal response to a stimulus such as a sound, which is taken as a sign of something else and causes physical reactions implemented by motor neurons.

The training is causally effective by top-down action from the brain to cells in muscles. The fitness criterion is avoidance of negative stimuli. How do you demonstrate this top-down causation? - change the conditioning, and the response is different.

It is not always predictable: hidden internal variables may change the outcome (spontaneous alternation in rats; monkey and bananas) and emergent behaviour may occur.
Intelligent top-down causation is the special case of feedback control with adaptive choice of goals, where the selection of goals involves the use of symbolic representation and manipulation to investigate the outcome of goal choices.

The key feature of this higher level of causation, is its use of language and abstract symbolism such as mathematics for reasoning as well as communication, so enabling high-level culture and technology to arise through coordination and planning.

Probably only occurs in humans (Deacon: *The symbolic species*).
**Aircraft Design:** Plans for a Jumbo Jet aircraft result in billions of atoms being deployed to create the aircraft in accordance with those plans. This is a non-trivial example: it costs a great deal of money to employ experts in aerodynamics, structures, materials, fuels, lubrication, controls, etc. to design and then to manufacture the aircraft in accordance with those plans.

The plan itself is not equivalent to any single person’s brain state: it is an abstract hierarchically structured equivalence class of representations (spoken, drawn, in computers, in brains, etc.) that together comprise the design.

It is clearly causally effective (the aircraft would not exist without it). It could not occur without language and mathematics, as well as the social systems in which it is embodied.
A timetable for an airline determines when aircraft fly in a more or less reliable way. It results in an aircraft flying on a particular path at a particular time, resulting in particular patterns of atmospheric pollution through specific molecules.

How do you demonstrate top-down causation? - change the timetable and different patterns of pollution will result.

Physics can describe the material out of which the timetable is made and the ink markings on the paper; it cannot comprehend the causal chain by which this leads to particular aircraft flying at particular times. The relevant variables (the entries in the timetable) belong to an irreducible equivalence class of abstract entities coding information that controls what happens in the real world. They operate through social convention.
The nature of goals

Conscious Goals in human activity:

• our actions are governed by hierarchically structured goals at all structural levels in society
• these may be explicit or implicit, qualitative or quantitative

• they are not physical quantities
• they can be represented in many ways, so are effectively an equivalence class of representations

• they are adaptively formed in response to experience: learning takes place in particular contexts
• the mind responds to the meaning of symbols in the relevant social context
Hierarchical structure: 2

Cosmology    Sociology
Astronomy    Psychology
Geology      Physiology
Materials    Biochemistry

Chemistry
Physics
Particle Physics

Hierarchy of causal relations

* The right hand side involves goals & conscious choices
The Effectiveness of Consciousness

Dimensions of consciousness:
- rationality and understanding
- feelings and intentions
- social systems/constructions, e.g. laws/money

• Concepts are not the same as brain states
- They can be represented in many different ways
• These are all causally efficient: they effect the nature of physical objects in the world
• These function are based in neuronal structure
The key point about causality in this context is that simultaneous multiple causality (inter-level, as well as within each level) is always in operation in complex systems.

Any attempt to characterise any partial cause as the whole (as characterised by the phrase `nothing but') is a fundamentally misleading position. Indeed this is the essence of fundamentalism: claiming a partial truth to be the whole truth.

This is important in regard to claims that any of physics, evolutionary biology, sociology, psychology, or whatever are able to give total explanations of any specific properties of the mind. Rather they each provide partial and incomplete explanations.
Causality: Bottom-up and top-down explanation

There are always multiple levels of explanation that all hold at the same time: no single explanation

- so one can have a top-down system explanation as well as a bottom-up explanation, both being simultaneously applicable

  e.g. Why aircraft fly  [Russell Ackoff]
  - the bottom up view: kinetic theory/Bernoulli’s law
  - the top down view: it was designed that way
  - the same level view: the pilot is flying it to fulfill the timetable
  - topmost: it makes a profit for the company

They are all simultaneously true and relevant!
It won’t fly unless they all apply at the same time.
Causality: Aristotle’s kinds

*The material cause:* “that out of which”,
*The efficient cause:* “the primary source of the change or rest”
*The formal cause:* “the form”, “the account of what-it-is-to-be”.
*The final cause:* “the end, that for the sake of which a thing is done”

We can adapt Aristotle’s categorisation to the hierarchical context considered here, by seeing
the **Material Cause** as the lower level (Physical) cause,
the **Efficient Cause** as the same level (Immediate) cause,
the **Formal Cause** as the immediate higher (Contextual) cause,
the **Final Cause** as the ultimate higher level cause.
Francis Crick famously said

"You, your joys and your sorrows, your memories and your ambitions, your sense of personal identity and free will, are in fact no more than the behavior of a vast assembly of nerve cells and their associated molecules".

But nerve cells and molecules are made of electrons plus protons and neutrons, which are themselves made of quarks .. so why not

"You, your joys and your sorrows, your memories and your ambitions, your sense of personal identity and free will, are in fact no more than the behavior of a vast assembly of quarks and electrons"?

And these themselves are possibly vibrations of superstrings.
So why did Crick stop at the level he chooses? Undoubtedly because that is the level he best understood and was familiar with!

• Indeed each scientist will perceive as fundamental the level they happen to work on and understand deeply in causal terms, so they usually assume that causality at that level is real. And that is reasonable, if they are all real, as I take to be the case (a table is still a table even though it is made of atoms, for example; and the atoms are also real, as are the neutrons and protons).

• Crick’s dictum either applies to all levels except the (unknown) bottommost one, or to none. If it applies to all levels, Crick’s molecules are no more real than memories and ambitions; but he assumes the molecules are real, so his position is inconsistent.

• There is no reason to privilege molecules or cells in the hierarchy of structure. If we accept molecular reality, then we should also acknowledge the memories and ambitions as real too, for that is then the only consistent position.
All Truth is shadow except the last, except the utmost; yet every Truth is true in its own kind. It is substance in its own place, though it be but shadow in another place (for it is but a reflection from an intenser substance); and the shadow is a true shadow, as the substance is a true substance.

Isaac Pennington (1653).
6: Predicting and intervening

KEY QUESTION:

What level to work at?

The most powerful interventions are at the highest levels

Multiple realisability at lower levels: will return with new plans for same intention

True security: Turning an enemy to a friend - else they may always re-arise (Al Qaeda)
1. Algorithmic top-down causation

Prediction: Calculations can in principle predict

Possibility space:
Understand attractors and basins of attraction

Affecting it: Change viability/mode of lowest levels:

e.g. cut off supplies,
    drugs,
    poison
2. Top-down causation via non-adaptive information control

Goals determine outcome

Bottom up: Can try to set system outside its viable parameter levels

Same level: Try to change the goals, if possible

Else adapt them to your purposes (coopt predictable behaviour)
3. Top-down causation via adaptive selection

Unpredictable element; prediction difficult or impossible

But can try to understand basins of attraction or convergence in possibility space

- Convergence due to limits on how things can be done: Conway Morris

  Change of context changes adaptive behaviour (alters niches)
4. Top-down causation via adaptive information control

Again unpredictable: only meta-cause constant

Can try to change environment so that adaptation goes the way you want

e.g. Pollution and rivers [People or Penguins]
5. Intelligent top-down causation (the effect of the human mind on the physical world)

Key elements: Purpose and meaning, search for understanding
- e.g. seeing distant person: scan for purpose

That is the best level to intervene

BUT understand The myth of rational behaviour

The real roots of behaviour: emotion and intuition
- these are the guides of rational behaviour:
  Determine choices of what to pay attention to
The individual mind: Each of Emotions, Rationality, Faith/Hope, Aesthetics, Ethics, and Telos are causally effective. They are modulated by the society in which we live: they cannot be understood in isolation. We have the freedom to choose how to act in this context.
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7: Conclusion

Other kinds of entities than simply physical exist, as well as other kinds of causation.

If we ignore them we will have a causally incomplete view of the universe.

In particular, top-down processes underlie the possibility of truly complex emergent phenomena such as the workings of the mind and culture.

Intervention must understand levels of causation/control, and their interactions (top down, same level, bottom up).
Social environment: - effect of society

Genetic inheritance: - effect of biology

Mind, underlying consciousness and personality

Personal Choice:
- causal effectiveness of consciousness/will

The nature-nurture issue: three main factors that contribute to the development of the mind
8: Transcendence

This multi-faceted nature of causation allows various non-physical entities to be causally efficacious in the physical world, through their effect on the human mind.

Some of these can be said to be of a transcendent nature: they are of a different order than, and independent of the nature of, the physical matter out of which we are made.

*These features are NOT emergent, they are eternal and unchanging. It is our understanding of them that is emergent and developing with time.*
1: *Mathematics Comprehension and Utilisation* is a case of top-down causation from a Platonic world of mathematical abstractions to the human mind, being realized in details of neuronal connections, and then into the real world where it is causally effective in terms of creating patterns on paper and through underlying physics, engineering, commerce, and planning in general.

Major parts of mathematics are discovered rather than invented (e.g. irrational numbers). They have an abstract rather than embodied character; the same abstract quantity can be represented in many symbolic and physical ways, and these representations form an equivalence class. They are independent of the existence and culture of human beings.

Jean-Pierre Changeux and Alain Connes: *Conversations on Mind, Matter, and Mathematics*
The basic geometrical features

\[ H = \text{hypotenuse} \]

\[ X = \text{base} \]

\[ Y = \text{height} \]

\[ H^2 = X^2 + Y^2 \]

(Pythagoras)

\[ A = \pi R^2 \]

\[ \pi = 3.1415926535897932 \ldots \]

(universal constant)

The same results will be discovered near Alpha Centauri or the Andromeda Galaxy
Mandelbrot set
2: A second example is language:

Terence Deacon has plausibly argued that any language system must obey necessary semiotic constraints on universal grammar; these too are discovered by humans rather than being created, because they are based in the underlying logic of what is possible in symbolic representation of the real world.

“Semiotic constraints delimit the outside limits of the space of possibilities in which language has evolved within our species, because they are the outside limits of any symbolic form of communication”

[Deacon: “UG and Semiotic constraints”, in Language Evolution, Ed Christiansen and Kirby]
“So perhaps the most astonishing implication of this hypothesis is that we should expect that many of the core universals expressed in human language systems will of necessity be embodied in any symbolic communication system, even one used by an alien race on some distant planet!” [Deacon].

3: Logic itself is a third example
It is universal and discovered.
- underlies all the rest (e.g. mathematics, semiotics).
- we take it for granted in all our thought and embed it in our language.
4: Physics Theories: Maxwell’s theory of electromagnetism (an abstract entity, described by Maxwell’s equations) led to the development of radio, cell phones, TV, and so on. It is shown to be true by experiments and by its technological outcomes.

Maxwell’s theory is not the same as any single person’s brain state. It can be represented in many ways and formalisms. These various representations together form an equivalence class, as they all lead to the same predicted outcomes.

The abstract theory has altered physical configurations in the real world, and hence is causally effective. It is an irreducible higher level variable (it cannot be derived by coarse-graining any lower level variables) representing the nature of physical reality. It is based in the nature of matter but is itself a product of the human mind.
5: The functional pre-requisites of a society

- A common language and associated set of understandings
- A social organisation centered around agreed social roles
- A method of sharing out and controlling available resources
- A system of production and consumption of resources
- A set of agreed norms and values to govern behaviour
- A set of sanctions for those violating these norms
- A method of training youth to be adult members of society

All societies must tackle these same set of problems and devise means of dealing with them.

There is a limited set of ways of doing so. One or other of them will be discovered by each society.
6: Ethical values and Morality

The highest level of intention [values/ethics] is causally effective: 
*this is the choice of criteria for what are acceptable goals,* 
*and so controls all lower level goal choices*
Ethics is causally effective in the physical world
9: Causal openness for higher causes is there because

1: The functioning (according to the laws of physics) of the parts of given nature is determined by context.

Higher level purposes can conscript physics to its ends by changing the operating context/altering context dependent constraints. Structure and boundary conditions crucially affect outcomes. This is an essential part of top-down and same-level action.

Example 1: a computer operated as music system or word processor.

Example 2: muscle cells being used in football or in playing music.
Causal openness for higher causes is there because

2: We do not just have invariantly functioning parts assembled in different ways and so operating in different contexts.

The nature of the parts – the way they function – is also affected by context in a top-down way. Indeed they are often adapted to their higher level function.

Example 1: Living cells (through developmental biology).

Example 2: Neutrons in an atomic nucleus.

Example 3: Humans in society
Causal openness for higher causes is there because

3: Chance (statistics associated with coarse graining, random boundary conditions) means physical outcome in biological systems is not uniquely determined by physics alone.

This provides the openness needed for Darwinian selection processes to choose outcomes that satisfy higher level goals and values.

This top-down mechanism may be far more prevalent than recognized up to now in the developmental and functional contexts as well as the evolutionary context.

**Example:** Adaptive immune system.
4: Quantum Uncertainty means the physical outcome is not uniquely determined even in principle.

This is not always negligible at the macro level, despite occurring at a micro-level.

Example: evolutionary history on earth is influenced by cosmic rays, that are emitted subject to quantum uncertainty.