Journal of Systemics, Cybernetics and Informatics (2022) 20(5), 1-16
https://doi.org/10.54808/JSCI.20.05.1

Scientific Milieu, Multi-disciplinary Science and Creativeness

Maurício Vieira Kritz[1]

[1]*Faculty of Biology, Medicine, and Health, University of Manchester, Manchester, M13 9PT, United Kingdom*
National Laboratory for Scientific Computing, Petrópolis, RJ, 25651-75, Brazil
Graduate Program in Knowledge Diffusion, CAPES, Brazil

[1]*Mauricio.kritz@manchester.ac.uk*, *kritz@lncc.br*

Abstract[1]

Western science has always been intrinsically a social enterprise. How the population of scientists organises itself to produce knowledge, though, has changed enormously during the last 150 years. Generally, these changes occurred instinctively and spontaneously, being rarely, if at all, planned beforehand or investigated a posteriori. The result of this process is that the actual organisation of the scientific society is being considered far from optimal to face the gigantic and complex challenges lying ahead. In inquiry domains aiming to understand problems of organised complexity it is even inadequate, although it is often difficult to state why and to identify where inadequacies lie. Grounding on organisations, a generalisation of the system concept, on the in-formation concept induced by them and on the ground-breaking achievements of the science of generic systems in the last century, I tentatively sketch a description of the scientific milieu and its social arrangements that allows for questioning about agonistic, antagonistic, and synergistic situations and patterns of interaction, collaboration, and knowledge-creation.

Keywords: *Scientific Milieu, Scientific Enterprise, Innovation, Creativeness, Multi-disciplinary Science, Organised Complexity*

1. Introduction

Modern western science is a collection of scientific fields of inquiry which achievements form the kernel of Humanity's knowledge about natural and artificial phenomena. The arguments herein take for granted that the great achievement of Scientific Revolution, as a socio-cultural event, was the binding of pure thought to observation, of philosophy to nature. The intellectual discipline stemming from this revolution of course came to be named Natural

[1] Peer-editor: J. Karam Filho, National Laboratory for Scientific Computing

Philosophy. This move required reasoning to be intertwined with observation, passive or actively gathered through experimentation, and observation to be reproducible (Hanson, 1958). A less conspicuous, but not less important, achievement is the transformation of scientific activities and knowledge production into a curiosity-driven *social* enterprise (Vieira Kritz, Issues of Multidisciplinary Sciences, 2007), centred around concerns and inquiries in given domains of interest. This later achievement allowed for extending the reach of scientific inquiries to phenomena with characteristic times longer than the human lifespan. The collection of all scientists undertaking the scientific adventure is the scientific milieu.

This move towards collective investigation occurred slowly, grounded on individuals exchanging ideas by communicating two at a time, through letters, printed documents, and face-to-face encounters. Nonetheless, in the last 170 years, there were non-trivial qualitative, quantitative, and contextual changes in the social organisations participating in the scientific enterprise, bringing into stage actors like “labs”, evaluation boards, national directives, associations, funding agencies and so on. These social changes occurred spontaneously along the centuries, without any introspection, planning or self-criticism. Often, they were only slightly inspired by necessities intrinsic to the scientific activities and quests that were leading to discoveries and the creation of inquiry-specific knowledge. Instead, they were in principle moulded by humankind cultural-social-economic background in subtle ways. This sloppy, un-steered evolution of the scientific milieu was made possible by a lack of self-contemplation and was largely induced by important changes in the kind of problems humankind needs to address. It resulted in a present-day scenario where scientific activities are driven mainly by factors strange to scientific values, methods, and paradigms. A scenario that is being baldly and boldly considered dark and confusing, ultimately promoting a wave of obscurantism (Lima-de-Faria, 2020).

Waves of obscurantism in the sciences are not new nor rare. They seem to occur when we depart from the directives of scientific scepticism and stick to ideas that bring us nowhere, even confuse us, refusing to look around for alternatives or new paradigms and perspectives. For the actual ones, though, other factors come into play. Since late XVIII century, problems addressed by scientists have drifted from problems of simplicity to problems of (organised) complexity (Weaver, 1948), of which many demand multi-disciplinary brain-force to be addressed. Concomitantly, but not consequently, the way scientists organise themselves to produce knowledge has changed dramatically. Lately, a deluge of spurious information and distracting interruptions, produced by scientific and non-scientific actors, by technology, intrusive behaviour, cultural trends, and philosophical tints (Reis, Guerra, & Braga, 2006) (Pyenson, 2020), only make things worse. It produces noise and obscures our vision of what nature is telling us about our subjects of concern and defocus our attention from what indeed matters.

This work looks forward to promoting an introspection of the scientific milieu about better ways of organising itself and be ready for the ever-greater complexity of subjects. It starts with an essay to obtain a better picture of what currently goes-on in and around the scientific process and its milieu, and of how the scientific milieu changed in the course of time. I sketch a picture of the scientific milieu in a unified framework, using concepts of system sciences, mainly J. G. Miller (Miller, Living Systems, 1978), modelling (Rosen, 1991), and the organisation/in-formation paradigm (Vieira Kritz, 2017). Individuals, their channels of interaction and their associations will be pictured by constructs grounded on the organisation/in-formation formalism, while function and behaviour will be identified and analysed following Miller's ideas. Arguments herein are essentially non-quantitative (Katzner, 1983) and illustrative outside the domains above.

This sketch is based on observations gathered from my life-long working experience as a scientist with collaborators in Brazil, Europe, and US, in small groups and in networks. It is a humble, partial, and biased account. By no means it addresses all relevant aspects of scientific achievements, chiefly those arisen after the digital revolution, demanded by multidisciplinary subjects, or that are originated after the 2020 lockdown. This presentation is meant as a hypothesis and an initial step for boosting an in-depth investigation about the peculiarities and singularities identifiable in all facets of the scientific process. It should allow us to address questions like "how our training and work-habits affect our brain potentialities?", "is the commonly found master-slave organisation of collective work efficient?", "what do we need to do to maximise creativity of scientific groups and networks?".

I start by highlighting historical events and scientific terms/facts to the best of my abilities and perception (apologies to historians and philosophers of science) in a time-line perspective[2], as a chronicle (Rosen, 1991), with no intended chronological or historical commitment. This picture will support the description of the social organisation and scientific interactions while doing science, as well as the identification of changes along time in our ways of producing scientists and scientific knowledge, as I perceive it. This description aims to throw light in the scientific activity as a Human endeavour (Vieira Kritz, Issues of Multidisciplinary Sciences, 2007) and its evolution over time, providing a basis for thinking about possible future directions. I present in the sequel the essentials of the two intellectual frameworks that will be used and then sketch the scientific milieu discussing its evolution and

[2] M. Vieira Kritz, Modelling as a Process, manuscript, Sep 2022, submitted to *Computational and Applied Mathematics*, Springer-Nature.

some of its creativity bottlenecks. I conclude emphasising the importance of getting the sharpest self-retract of the scientific milieu possible to adapt and be ready to face present and future challenges.

2. Science Begins…

The Scientific Revolution gave birth to modern science. It is generally accepted that the historical socio-cultural events that made it happen took place during approximately 140 years, from N. Copernicus times (1543) up to the publication of I. Newton's Principia (1687). They do not provide the whole picture, though. We need to also inspect events before and after this period, as well as other facts and achievements surrounding our inquiries about nature, to get a better picture of how science came to be. I do sketch here a hypothetical chronicle without any chronological compromise or historical rigour to using a formal timeline (**Figure 1**) to unveil possible enchainments (Rosen, 1991). An amazingly rich, in-depth, and marvellously organised account of events, organisations, institutions, and enterprises

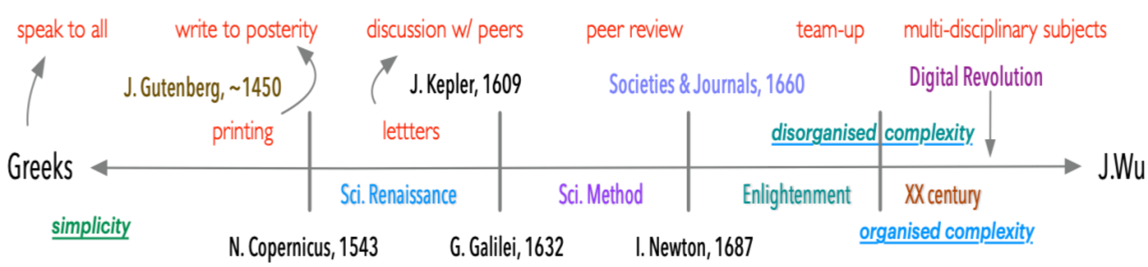


Figure 1: Chronicle 1 – Historical Events Relevant to the Development of Western Science

surrounding scientific revolution and the sciences is available in (Pyenson & Sheets-Pyenson, Servantes of Nature: A hystory of scientific instittions, enterprises and sensibilities, 1999). The chronicle, though, contains non-historical information as well.

Loosely speaking, the following events prepared the backcloth for the occurrence of Scientific Revolution. In ancient times, knowledge was restricted to temples and other closed communities, where knowledge was produced, taught, and preserved. Greek philosophers changed that discussing ideas and teaching in open spaces for anyone interested in learning. During the Middle Ages, Arabs diligently developed a lot of crafting skills that were later crucial in creating scientific observation apparatuses, that allowed for regular observation and extending human sensorial capabilities (Braga, Guerra, & Reis, 2003). They were also instrumental in developing mathematical and computational skills, widening our ways of reasoning, and in starting scientific team work (in observatories). Printing (J. Gutenberg, 1450) allowed for collective memory and more permanent dissemination of ideas, while availability of paper and user-friendly writing gadgets speeded-up intellectual exchanges by facilitating person-to-person communication through letter-exchanging. The cultural push Renaissance had in the Scientific Revolution is largely acknowledged. However, the importance of achievements in logics and mathematics as well as the role of abstract representations of observations (models) have not been properly acknowledged to this moment; possibly because models appeared exclusively as equations in the subjects of physical sciences.

Modern science is characterised by some key actions tying philosophical thinking to nature contemplation: questioning, observing, modelling, making hypothesis and predictions, analysing models, hypothesis, and their consequences, deducting through logic or forecast, elaborating interpretations for what has been found and so on (Hanson, 1958). Furthermore, any scientific inquiry-explanation domain has an underlying logical system (da Costa, 1997). Along these characteristics, there is the requirement of observation replicability, what naturally led to a cycle of actions that gradually refine our ideas and understanding. Some key elements, like questioning-observing or deducting-foreseeing, cannot be easily disentangled, nor arranged in any precedence relation. These entangled elements can be aggregated by means of three landmarks — observation, modelling, and theory construction — resulting in a cycle OMT (**Figure 2**) that enhances knowledge.

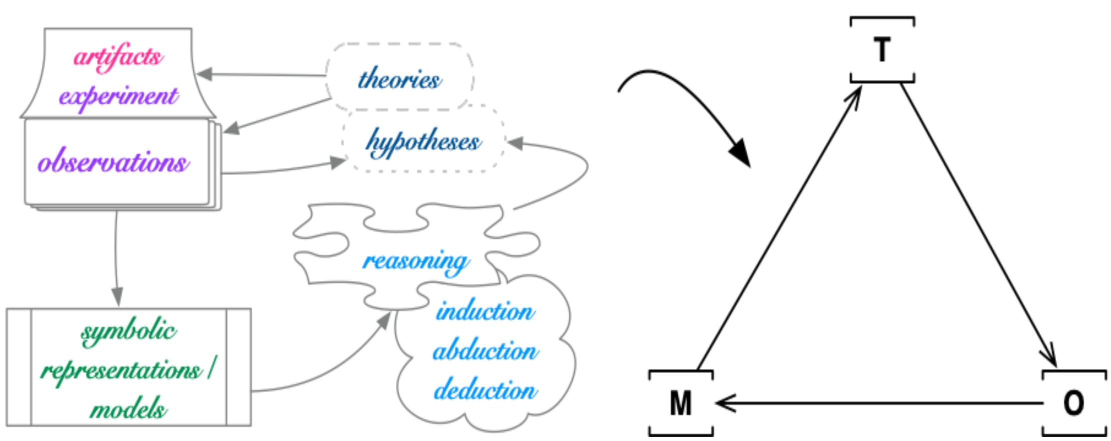


Figure 2: Nature-thought Interaction Cycle

This short account faithfully describes how Weaver's problems of simplicity and disorganised complexity have been successfully treated for about 300 years mainly, but not exclusively, within the domain of physical sciences. It highlights the core steps in everyday physicists' work that remain valid until today, despite the quanta crisis (Gamow, 1966 (1985, reprint)). Physicists think ahead plenty of imagination and check their thoughts through intelligently planned observations. Not even the introduction of uncertainty, non-determinism, and model-plurality due to the study of quantum phenomena and other last century achievements has changed this tradition appreciably (Pyenson, Three Bells: Thoughts at the End of Postmodernity, 2020). An important feature of these phenomena and the way they are handled is the strong assumption that all interactions among components are alike and that interactions can be completely described through changes in the components' attributes and by means of equations, when conservative, or inequations, otherwise.

3. Science Goes-on

Another important consequence of the scientific method concealed in the OMT cycle is that observation and reasoning change due to new knowledge. In the last decades of 19th century scientists started to be interested in problems beyond the borders of physical sciences, e.g., ecological, and environmental problems. This means that scientists were moving from problems of simplicity into problems of (organised) complexity. Generally, this kind of problem demand multi-disciplinary efforts to be profitably addressed. These are phenomena where displacement and movement are not central to their understanding. An immediate example is living entities. A biological event, e.g., becoming hungry, doesn't depend whether the subject is stationary on Earth's surface or flying at ultrasonic velocities but do depend whether it is relaxing calmly by the sea or fully stressed running for its life on a prairie. Biological events depend on arrangements, internal interactions, and mutual relations (Harold, 2005). Biological relevant events relate to "architecture", availability, and energy flow rather than position and the underlying energy distribution due to motion. Biological "architecture" comes from connections, interactions, and relative positions, that is, from organisation.

Biological entities are the simplest subjects in Weaver's complementary class of *organised complexity* problems, which is not to be equated with subjects of complex systems science or self-organisation (Schweitzer, 1997). Both lay between movement and organisation. The science of complex systems results from the intellectual inertia that keeps us using movement to address organisation through self-organisation and pattern formation. Though a bit unfocused, these disciplines are not at crisis. Their stunning achievements relative to complex systems invariably state that organisation is not incompatible with movement and laws of physics (Vieira Kritz, From Systems to Organisations, 2017), fortunately. They form a boundary layer between Weaver's class of organised complexity problems and the other two.

During the 20th century there were several developments related to all sciences and the scientific process that profoundly changed or are about to change the interplay between thought and nature as depicted in **Figure 1**. Probably in a not far distant future we will have the necessary historical perspective to reckon these events as another scientific revolution (Vieira Kritz, Revisiting The Systemic Golden Years From A Contemporary Organisations' Perspective, 2020). A snapshot follows.

Systems Science (Klir, 2001 (1991)) was born in the first half of last century, short after the quantum earthquake took physics. It brought along a distinctive change in perspective that considers interactions to have the same importance as phenomenon components and adopts a holistic approach to everything. Systems science hosted *cybernetics* (Ashby, 1956), (Wiener, 1961) with the concours of Shannon-Brillouin *information* concept, born around the middle of the century, but is still insufficient to face many problems of organised complexity, all biological, ecological, and environmental phenomena included (Vieira Kritz, Revisiting The Systemic Golden Years From A Contemporary Organisations' Perspective, 2020), (Wu, 2006).

The last century saw, if not the birth, the blossoming of many non-numerical mathematical disciplines. It is rather naive to consider nowadays mathematics as a science of numbers. Many fields came from a deep and extensive enquiry about the foundations of mathematics and foundations of science at large, including the sciences of the artificial (Simon, 1996). We learned that there is a plurality of ways of reasoning and representing, as well as various concepts of things, proximity, and form. Not forgetting the odd idea of connectivity stemming from graph and network theories, as well as games and decision theories.

The advent of computers, generically seen as 'number crunching machines', curiously gave birth to yet another collection of non-numeric mathematical disciplines: automata theory, theory of programming, temporal logics, computation theory, formal systems and grammar theories, programming languages, and so on. Different computer architectures bounce middleware back into programming paradigms that deeply affect our ways to represent phenomena as computational models (computer programs) instead of as mathematical

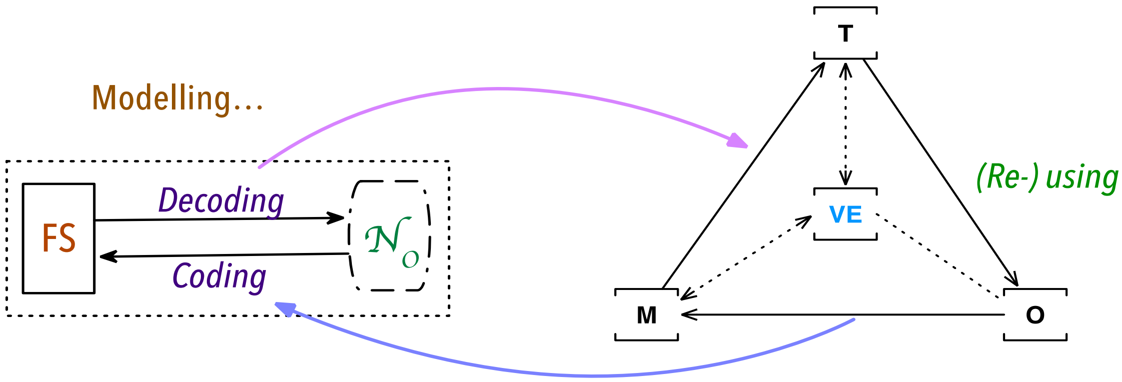


Figure 3: Nature-thought Interaction with Virtual Experiments – Many Cycles

objects and, by extension, our ways of thinking. Finally, computer programs are amazingly plastic emulators allowing us to perform virtual experiments not just about nature but also about our ways of reasoning. And here is where their major contribution to science lies. It is difficult to express in simple form the overwhelming possibilities this trait opens to human creativity. Just to give a hint, the cycle in **Figure 2** becomes the one in **Figure 3**.

Note that the new cycle can be traversed in far more ways than the first one, that it requires constant modelling and refer to all mathematical disciplines and programming paradigms just referred. Amazingly, this plurality is not without unity since many of these new scientific disciplines interconnect (Kalman, Falb, & Arbib, 1969), (Mac Lane, 1986), (Arnol'd, 2000).

4. Scientific Community and its Milieu

Since shortly after the scientific revolution, the development of scientific disciplines has been a social enterprise centred around problems and inquiries in definite domains of inquiry. As an enterprise, scientific investigation transforms ***Unknown*** into known things and knowledge. Hence, by definition, it lacks an important referential present in all other human endeavours. Namely, the raw material that is transformed into a product by any other enterprise. Therefore, the iteration cycle of **Figure 2** can only start out of the blue, from pure thought and imagination. Observations surely inspire us but nothing new can arise exclusively from observations. Hence, it is very important to obtain a better and more objective picture of how science is done to be able to improve its doing.

Scientific *community* is the population of all scientists on Earth. Scientific *milieu* is this community plus all organisations, institutions, and non-scientists with whom scientists need to interact to produce humankind's scientific knowledge. The following account is based on my own working experience as a scientist with collaborations in Brazil, Europe and US, person to person, and in networks. It is humble, partial, and biased, providing a rather limited picture. Moreover, due to my training, it is not a historical account either. Its aim is to support and illustrate the arguments in the sequel. A more complete and accurate description of this subject can be found in (Pyenson & Sheets-Pyenson, Servantes of Nature: A hystory of scientific institutions, enterprises and sensibilities, 1999), that should be taken as referential. I haven't though checked every statement below against it.

The phenomenon object of this essay and depicted in the sequel is the social behaviour of the scientific community, its various *organisations* at several levels of complexity, and the interactions of these organisational units, human beings included, between themselves and with the rest of the human society. This is clearly an utter-complex subject. Its description and clarification require knowledge from various disciplines to be accomplished to any satisfactory level. I present below a first sketch towards this quest. This trial is to be sharpened and improved in the future, possibly in different directions guided by several objectives, improving the scientific milieu itself for one. But, first, some intellectual ingredients.

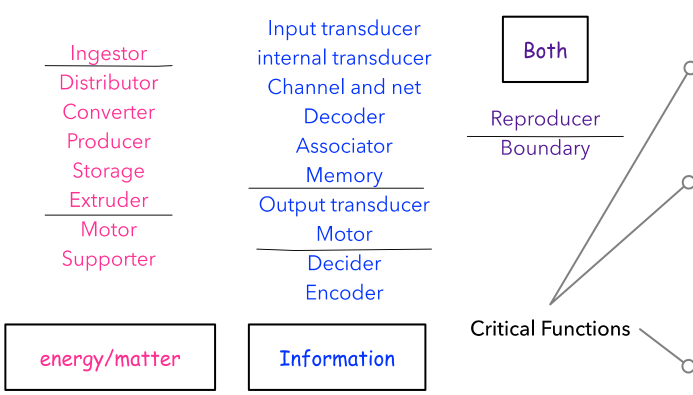
4.1 Organizations and Living Organizations

The following concepts shall be useful to describe and understand the scientific milieu: organisations, in-formation, and living-systems characteristic functions. For the hard work and more information see (Vieira Kritz, From Systems to Organisations, 2017) for the first two and (Miller, Living Systems, 1978) for the last one.

Definition 1 – An *organisation* is either:
1. an atom, a black-box we do not *want* to open or inspect.
2. a set of *organisations*.
3. a group of *organisations* put somehow in relation to one another.
4. nothing else.

Clearly, sets are organisations as much as systems, that are sets of interrelated things (Klir, 2001 (1991)). Organisations generalise systems in two aspects. The definition above straightforwardly shelters the phrase "systems made of systems". It also accommodates collective (m – n) connections and bindings by a proper choice of the "relation" in item (3). Furthermore, the recursive character of the definition regains hierarchy. Organisations are trees (hierarchical arrangements) whose forks are relations and whose leaves are relations or atoms. These assertions hint at their mathematical model that when formalised results in a space **Γ** of organisations (whole-part graphs). Additionally, the ensuing mathematical model for “concrete” organisations (synexions), i.e., organisations that have been instantiated in a physical space, associates organisations with dynamics and provides for representing all admissible behaviour of organisations in any given configuration. Synexions are ideally tailored for describing molecules (Peacocke, 1983), molecular aggregates, organelles, cells, tissues, and live processes. Houses, human beings, and human brains may all be seen as organisations in the above sense. Eventually their purpose affect how objects are seen as organisations. Any object, component, or process may be seen as one out of various organisations.

The main form of interaction between organisations is the exchange of signals that are interpreted into in-formation by the synexions that receive them. In-formation requires time to be defined, is not quantitative, and its definition allows to recast the usual Shannon-Brillouin measure. It is based in three processes: perception, imprint-recall, and interpretation. It also uses two concepts: signal and (signal) imprint. The simplest description of this definition lays outside the scope of this text. Its traits relevant to the present discussion are as follows. Any organisation can be a signal and any signal, an organisation. Imprints are representations of signals in the memory of the organisation that perceives it. An imprint become information when and if it is interpreted by its host. A signal may become information for one host but not another.



Organisation Entities

Entity	Number of scientists	Subjects of inquiry
Individuals	1	1/a few
Collaborators	2 - 5	1
Group	5 - 8	1
Team	9-13	1/a few
Lab	13-20	a few
Department	15-50	many
Faculty/Institute	40-150	many/several
University	> 150	several
Nation	?	several

Figure 4: J.G. Miller Living Functions

In a gigantic and profound work to characterise living systems, J.G. Miller considered any assemblage of human beings as living and identified the 20 ‘systems’ depicted in the left of **Figure 4** in all of them — from cells to cities and nations. He didn’t seem to have addressed ecosystems and landscapes, since their boundaries are not directly assessable. Some Miller systems process matter and energy, some process information, while two process both.

What Miller discovered is indeed a collection of critical functions that any living entity must perform. This means that, whenever living entities are depicted as organisations, there must exist sub-organisations of theirs that perform these 20 functions. To them, I shall add still another function — *enquirer* — that is responsible for sustaining our learning processes and lust. The most relevant functions to the present discussion besides the *enquirer* are those responsible for processing information, including the *boundary* marker that identifies the self or, in scientific milieu terms, our peers. For the sake of simplicity, I shall name the collection of these functions, as well as the (sub) organisation that performs them, the (organisational) *brain,* taking off the italics whenever referring to a human brain. It is quite clear that the *enquirer* function may be a human characteristic and exist only in organisations having human beings as sub-organisations.

4.2 Scientific Milieu

Taking for granted that any living entity or living-related component can be represented as synexions, the above framework is ideal to represent the scientific community, its changes along time, and the interaction between their components, as well as its environment and context.

During the scientific revolution and the centuries immediately following it, the scientific community organised itself as a collection of single individuals sharing ideas, materials, and stimuli every now and then; first through letters or personal contacts, then in meetings that eventually became regular with the appearance of scientific societies. Besides meetings, the journals of scientific societies greatly contributed to speed-up sharing of ideas. Scientists appeared rather spontaneously out of self-training, what certainly moulded their abilities to think and create, as well as their independence of thought. This can be depicted as a time-varying graph $g_t = \{N_t, A_t\}$ where nodes represent scientists and arcs their exchange of ideas. A node enters the graph every time a scientist is formed, staying there until s-he dies or forever if s-he publishes. Yet, they can remain forever disguised and enriched if they train other scientists. Arcs represent scientific interactions between scientists, that result in the production of scientific knowledge. Clearly, A_t is more prone to vary than N_t. If $n \in N_t$ is a publication, we may consider that an arc (n, n') can only exist if $n' \in N_{t'}$ for $t' > t$ and $(n, n') \in A_{t'}$. The representation possibilities run quickly to infinity and the good ones depend on the inquiries being explicitly posed.

A few remarks apply at this point, though. In the beginning, most nodes of g_t were isolated within g_t, linking just to its future versions. Dialogues and multilogues are cycles in g_t and discussions are cycles that persist for a while. Brainstorms are regular, complete, or otherwise unstructured sub-graphs of g_t, depending on how the discussions are moderated. Creativeness, however, remains constrained to individual brains to the best of our knowledge, that are indeed embodied organisations or synexions (Vieira Kritz, From Systems to Organisations, 2017), (Vieira Kritz, De la modélisation à la créativité mathématique, 2020).

After the beginning of the 20th century, the scientific milieu changed drastically starting with the mass production of researchers in the USA, which required a standardisation of the training process analogously to any other production line. The quickly enlarged scientific community essayed spontaneously to organise itself in a series of different modes, some within already existing institutes like universities, research institutes, observatories, and hospitals. Concomitantly, factors and influences external to the scientific community started to "have a word" in the scientific labour, first due to the intrusion of scientific interests into everyday human affairs and later due to the necessity of justifying investments in science when it became more and more widespread and expensive.

Figure 5 displays a collection of entities that can be found in the scientific milieu today, hints at their subliminal motivations and exemplifies a possible hierarchy

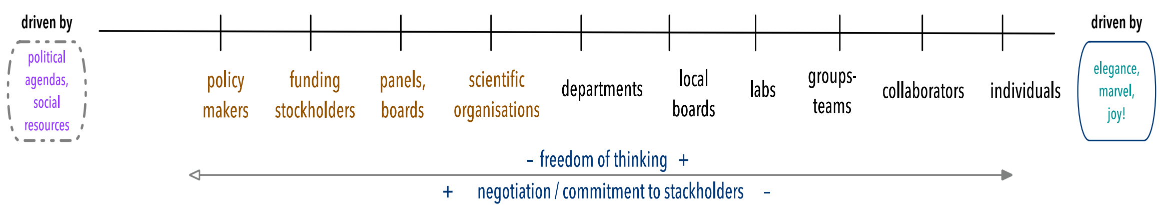


Figure 5: Chronicle 2 – Scientific Milieu Actors and Motivations

based on the complexity measure defined in **Γ**, that accounts for components, connections, and hierarchy. The possibilities of hierarchy exemplified on the left are indicative and aim to displace thinking habits. Any of them may have concrete organisations, tailored to optimise different goals: execution, information flow etc.
Each organisation in the above chronicle, from individuals to policy making boards or committees, present all Miller functions and we must identify which sub-organisations of theirs perform which Miller function to get deeper into describing the scientific milieu, at least for the relevant functions. For reasons that are both social

and psychological, generally there is presently no easily identifiable *brain* beyond small collaborating groups. Even in small groups it can be difficult to identify them. When a board or panel has a leader or dean, or someone who speaks for the group, we may consider the leader or dean brain as the *brain* of the board or panel. But is this correct? Did this person really participate and direct the enquiry so closely, that his answers reflect the board's opinion or conclusions? Of course, an enlarged *brain* is not necessary in a department or institution since their members do not all engage the same study at the same time. But is certainly desirable for evaluation boards at any level if we want to enlarge our scientific understanding and stimulate innovation, creativity, and "thinking out-of-the-box". Funding and promoting boldly and wisely, without focusing on immediate returns, is paramount to this quest. As it is for enacting innovative resolutions in scientific organisations, societies, and institutions.

5. Sensibility, Brains, Creativeness

Creativeness and sensibility are immaterial and elusive entities. It is difficult to acquaint for them (Vieira Kritz, De la modélisation à la créativité mathématique, 2020). However, not only they are connected to each other but to our bodies and emotions as well. Science is not just reason. It is time to fully acknowledge the fact that the human intellect has a body, and they constantly interact, mutually affecting each other's performance. Innovation is closer to matter. If we innovate exchanging organisation α for organisation β, innovation may be valuated by considering the complexity of the minimum necessary transformations in $\mathbf{\Gamma}$ to take α into β. To decide if an innovation is creative, though, we resource to aesthetic values and pleasure and many brain processes, especially synaptic plasticity, are regulated by the limbic system and, per extension, by our emotions. This can only be found in embodied organisations or synexions (Vieira Kritz, From Systems to Organisations, 2017), where frequency (vibrations) and other dynamical aspects of organisations allow for handling the bio-chemical aspects associated with emotions and pleasure.

The organisations in **Figure 5**, except individuals, cannot be said to be embodied in any easy manner. Two or three persons may be tuned emotionally and be said to 'feel' each other, acting accordingly. In this case, they may be represented as one synexion. The consequences of this remark to the creation of *brains* in larger groups of human beings will be the subject of future work. Nevertheless, it is very clear even from this initial stand that inducing integrative work and emergent-creativity in groups of scientists require dealing with emotions, or emotional intelligence.

6. Conclusions

The above intentionally recounts existing knowledge from a different perspective. It tells about what things are but prepares the ground to discuss how things could or should be, by emphasising that all elements intervening in this phenomenon are or can be seen as embodied organisations as much as our brains are, no matter how they are described. This common description allows for comparing things more widely and deeply than previously. It is pointless, for instance, to make calls for multi-disciplinary projects or articles when the evaluating boards are disciplinary or, having representatives of various disciplines, do not really evaluate the object of their decision together as, or approaching, a *brain*.

Certainly, we can decorate the chronicle of **Figure 1** with information about cultural trends and sociological behaviour to help inspect their influence on evaluators and decision-makers. Notwithstanding, how can we turn evaluation boards into a multi-disciplinary team with one heart and *brain*? What board organisation, group etiquette, feelings, and collective reasoning would rend scattered backgrounds and opinions into something unique? I shall use the Jain parable of 'the eight blind wise men inquiring about an elephant' (Wikipedia Community, 2022) to clarify my argument.

In the parable, the wise men work individually competing to describe in the best possible form what is being studied and are about to enter a dispute about who is right. Suppose now that they can talk to each other, they have multi-disciplinary backgrounds, and they absolutely trust the willingness integrity, capacity, and honesty of the other seven. This is no dream as they are the main traits of character required from scientists (Mayr, 1997). Blind people know with great precision where sounds come from, how far they are, and have a good estimate of their availability. How can they develop a *modus operandi* and protocols for acting and communicating together to be able to integrate their observations, their curiosity, and knowledge into one global geometric opinion about the elephant, even if imprecise?

This is the motivation of this study. The challenges facing humankind, from understanding the Amazon landscape and its interactions with Earth climate to understanding the role of viruses in Earth's biota and all life-processes (Rohwer & Barott, 2013) and its eventual destabilisation into endemics or pandemics, are greater and more complex than elephants while the whole scientific community is, comparatively, far smaller than 8 wise men.

We need to solve this puzzle, or we risk not surviving.

7. Acknowledgments:

This paper is a revised and slightly improved version of (Vieira Kritz, Scientific Milieu, Multi-Disciplinary Science and Creativity, 2022), presented at the 26th World Multi-Conference on Systemics and Informatics (WMSCI). I wish to thank the organisers and the audience for their friendly reception to my ideas and to myself. I would also like to thank my collaborators, *à la fois*, peer editors and reviewers Drs. Jean-Marc Schwartz (FBMH/University of Manchester) and José Karam Fº (LNCC/MCTI) for their precious time allocated to read, comment, and help me improving this text.

The line of reasoning that led to this article and the previous work cited above started in 2017, when I needed to explain what I do as a researcher to the support personnel of the Faculty of Biology, Medicine and Health, University of Manchester, so they could better advise me during an application for medium-term funds. My heartfelt thanks for their patience. Finally, I would like to express my deepest gratitude to Dr. Lewis Pyenson, Emeritus Professor of History, Western Michigan University, for kindly addressing my flaws and introducing me to a world of wonder — our own world, seen through the eyes of an utterly creative historian. Any remaining flaws in the text are, nevertheless, mine.

References

Arnol'd, V. I. (2000). Polymathematics: is mathematics a single science or a set of arts? In Arnol'd, V. I., Atiyah, M., Lax P. & Masur, B., editors, *Mathematics Frontiers and Perspectives,* pages 403–416. Providence (RI): American Mathematical Society.

Ashby, W. R. (1956). *An Introduction to Cybernetics.* London, United Kingdom: Chapman & Hall.

Braga, M., Guerra, A. & Reis, J. C. (2003). *Breve História da Ciência Moderna, vol 1: Convergência de saberes (Idade Média).* Rio de Janeiro: Jorge Zahar Editor.

da Costa, N. C. A. (1997). *O Conhecimento Científico*. São Paulo, SP: Discurso Editorial.

Gamow, G. (1985/1966). *Thirty Years that Shook Physics: The Story of Quantum Theory*. N. York, NY: Dover Publications Inc., reprint edition.

Hanson, N. R. (1958). *Patterns of Discovery: An Inquiry into the Conceptual Foundations of Science.* Cambridge, UK: Cambridge University Press.

Harold, F. M. (2005). Molecules into cells: Specifying spatial architecture. *Microbiol. Mol. Biol. Rev.*, 69 (4):544–564.

Kalman, R. E., Falb, P. L. & Arbib, M. A. (1969). *Topics in Mathematical System Theory.* New York, NY: McGraw-Hill Book Co., Inc.

Katzner, D. W. (1983). *Analysis without Measurement.* Cambridge, UK: Cambridge University Press.

Klir, G. J. (2001/1991) *Facets of Systems Science.* New York, NY: Plenum Press, 2nd edition.

Lima-de-Faria, A. (2020). *Science and Art are Based on the Same Principles and Values.* Artena (Rome), Italy: Artena Anarchist Press.

Mac Lane, S. (1986). *Mathematics Form and Function*. New York, NY: Springer-Verlag.

Mayr, E. (1997). *This is Biology: The Science of the Living World*. Cambridge, MA: Belknap Press/Havard University Press, 1997.

Miller, J. G. (1978) *Living Systems*, N. York, NY: McGraw-Hill Book Co., Inc.
Peacocke, A. R. (1983). *An Introduction to the Physical Chemistry of Biological Organization*. Oxford: Clarendon Press.
Pyenson, L. (2020). *Three Bells: Thoughts at the End of Postmodernity*. Kalamazoo, MI: Fair Oaks Editions.
Pyenson, L. & Sheets-Pyenson S. (1999). *Servants and Interpreters of Nature: A History of Scientific Institutions, Enterprises and Sensibilities*. London, UK: Fourth State/HarperCollins Publishers.
Reis, J. C., Guerra, A. & Braga, M. (2006). Ciência e arte: relações improváveis? *História, Ciências, Saúde-Manguinhos*, 13 (suppl), 71–87.
Rohwer, F. & Barott, K. (2013). Viral information. *Biol. Philos.*, 28:283–297.
Rosen, R. (1991). *Life Itself: A Comprehensive Inquiry into the Nature, Origin, and Fabrication of Life*. Complexity in Ecological Systems Series. New York, NY: Columbia University Press.
Schweitzer, F., editor (1997). *Self-Organization of Complex Structures: From Individual to Collective Dynamics*, Boca Raton: CRC Press, Taylor and Francis Group, LLC.
Simon, H. A. (1996). *The Sciences of the Artificial.* Cambridge, MA: The MIT Press, 3rd edition.
Vieira Kritz, M. (2007). Issues of multidisciplinary sciences. *Technical Report 24/2007*, Petrópolis: LNCC/MCTI. Available from: https://www.researchgate.net/profile/Mauricio Kritz.
Vieira Kritz, M. (2017). From Systems to Organisations. *Systems*, 5 (1): 23.
Vieira Kritz, M. (2020). De la modélisation à la créativité mathématique. In Beziau, J.-Y. & Schulthess, D., editors, *L'Imagination. Actes du 37e Congrès de l'ASPLF (Rio de Janeiro, 26-31 mars 2018)*, vol. 1 of Academia Brasileira de Filosofia, pages 267–289, London: ASPLF / College Publications.
Vieira Kritz, M. (2020). Revisiting the systemic golden years from a contemporary organisations' perspective. In de Barros, J. A. and D. Krause, editors, *A True Polymath: A Tribute to Francisco Antonio Doria*, vol. 2 of Academia Brasileira de Filosofia series, chapter 21, London: College Publications, pages 379–398.
Vieira Kritz, M. (2022) Scientific milieu, multi-disciplinary science and creativity. In N. Callaos, J. Horne, B. Sánches, and M. Savoie, editors, *Proceedings of the 26th World Multi-Conference on Systemics, Cybernetics and Informatics (WMSCI 2022), volume III*, pages 58–63, Winter Garden, FL, USA: IIIS – International Institute of Informatics and Systemics.
Weaver, W. (1948). Science and complexity. *American Scientist*, 36, 536–544.
Wiener, N, (1961). *Cybernetics, or control and communication in the animal and the machine*. Cambridge, MA, USA: MIT Press, 2nd edition, 1961.
Wikipedia Community (2022). Retrieved 2022, from Blind men and an elephant: https://en.wikipedia.org/wiki/Blind_men_and_an_elephant
Wu, J. (2006). Landscape ecology, cross-disciplinarity, and sustainability science. *Landscape Ecology*, 21:1–4.