Workshop on approaches to variation and stability in contemporary biology

Charles Perkins Centre, University of Sydney, 26-27 May 2015

The experimental evidence of widespread (not to say ubiquitous) variability in biological systems has induced a progressive shift in its theoretical and epistemological understanding. Far from being mere “noise”, variation is nowadays considered as a constitutive biological dimension at any level of description. Acknowledging the crucial role of variability in biological systems, however, raises the question of understanding their stability, both at the individual and evolutionary scales. This conference explores various issues related to biological variation and stability – as well as their mutual relations – as they emergene in various fields of contemporary biology.

Co-organized by Paul E. Griffiths and Arnaud Pocheville (Charles Perkins Centre, University of Sydney), in collaboration with Matteo Mossio (IHPST, CNRS & Université Paris 1).

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Invitation only. Please contact the organizers.

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Program

<u>Tuesday 26 May</u>

9h30 : Introduction (Arnaud Pocheville & Matteo Mossio)

Session 1

9h45 – 10h30 :	Jean Gayon (Paris 1 U.) *Repetitiveness and reversibility in evolution*
10h30 – 11h15 :	Maël Montévil (Paris 7 U.) *Biological variability and physico-mathematical reasoning*
11h15 – 11h30 :	coffee break
11h30 – 12h15 :	Alistair M. Senior (U. of Sydney) *Meta-analytic and Comparative Methods for Variance in Ecological and Evolutionary Systems*

12h15 – 14h15:	Lunch

Session 2

14h15 – 15h00:	Karola Stotz (Macquarie U.) *Robustness and Plasticity in Gene Expression: the interplay of stochasticity and downward informational control*
15h00 – 15h45:	Arnaud Pocheville (U. of Sydney) *Cellular Darwinism: virtues and difficulties*
15h45 – 16h00:	coffee break
16h00 – 16h45:	Mark Read (U. of Sydney): *TBA*

Wednesday 27 May

Session 3

9h30 – 10h15 :	Cliff Hooker (U. of Newcastle)
	Variations on invariance: banal remarks on the dynamics of stability – or: 'What is the problem?'
10h15 – 11h00 :	Matteo Mossio (CNRS, Paris 1 U.)
	The organisational perspective in Biology: a manifesto
11h00 – 11h15 :	coffee break
11h15 – 12h00 :	Gaelle Pontarotti (Paris 1 U.)
	On the concept of heritable variation within an organizational account of extended inheritance
12h00 – 14h00:	Lunch

Session 4

14h00 – 14h45:	Ingo Brigandt (U. of Alberta)
	Structure and function in organismal systems: plasticity, robustness, and the limits of modularity
14h45 – 15h30:	Antonine Nicoglou (Paris 1 U.)
	Regulation as a source of variations in living systems
15h30 – 15h45:	coffee break
15h45 – 16h30:	Wayne Christensen (Macquarie U.)
	The evolution of cognition as the evolution of high order control

Abstracts

Jean Gayon (U. Paris 1 – Panthéon Sorbonne): Repetitiveness and reversibility in evolution

It is a common assumption among evolutionary biologists that evolution is a 'unique and irreversible' process. My talk intends to show that this assumption is questionable: contemporary evolutionary biology offers significant examples of repetition and reversibility, both at the theoretical and at the experimental level. Correlatively, I will try to clarify the notions of 'reversibility' and 'irreversibility' commonly used in evolutionary biology.

The first part of the paper is about repetitiveness and reversibility in population genetics. The classical models of population genetics involve significant aspects of reversibility. However, one should distinguish the intuitive invariant properties taken as a starting point for the construction of models (e.g. reproduction and life cycles), and the properties that are discovered through the development of theoretical models. From this latter viewpoint, non trivial notions of invariance and reversibility occur at that level, but can raise objections.

The second part of the paper examines the question of repetitiveness and reversibility in experimental population genetics, esp. the traditional approach of population cages (Drosophila) invented in the 1930s, and the more recent experiments by Lenski and Travisano on cultures of bacteria. In both cases, population geneticists evolve towards an increasing skepticism towards the issue of reversibility. Dobzhansky's comment in 1953 seems to be still relevant : 'The elementary components of the evolutionary, the mutational and selectional steps, are both repeatable and reversible; evolution is however unrepeatable and irreversible... the microevoluationary changes [are] fully reproducible and repeatable, while the mesoevolutionary ones were repeatable only to a limited extent.' I will show that the most spectacular attempts to obtain repeatable results fail, an observation which conflates with the important aspects of invariance and reversibility postulated in the models of theoretical population genetics. I will propose some reflections about this delicate problem.

To conclude, I will return to Dollo's 'law of irreversibility' in evolution. In spite of Dollo's use of the term 'principle', this paleontologist was highly aware that irreversibility is more a matter of fact than an apriori theoretical principle, a statement that remains as plausible as it was a century ago.

Maël Montévil (Université Paris 7): Biological variability and physico-mathematical reasoning

In this presentation, we will contrast the articulation between mathematics and phenomena that is performed in physical theorizing with the situation in biology. In short, physical theorizing is grounded on stable mathematical structures, defined by theoretical symmetries and corresponding conservation principles. By contrast, it is fair to postulate that biological organizations exhibit changes of such structures over time.
This will enable us to define a strong notion of variability, which differs from quantitative variations. Variability will then play the role of a fundamental principle for biology. We will also discuss the consequences of these ideas on the form that a general theory of biological organization may have.

Alistair M. Senior (U. of Sydney) Meta-analytic and Comparative Methods for Variance in Ecological and Evolutionary Systems

Meta-analysis has become the standard and accepted method for quantitatively combining the results of multiple studies in almost all scientific fields. Such analyses usually focus on quantifying effects related to central tendency; e.g. differences in the arithmetic mean of two groups. However, also of relevance, particularly to ecology and evolution, is not only the mean of a group but also within-group variance. Considering evolution, within-population variance underlies evolution by natural selection, and indeed between-individual variance in fitness underlies adaptation. My collaborators and I recently developed a framework for the meta-analysis of variance, with focus on the application of these methods to ecological and evolutionary questions. I will begin with a brief overview of these methods and the underlying theory, before moving on to an application of our methods to questions relevant to the research themes of the Charles Perkins Centre. Specifically, the determinants of diet breadth have long been of interest to nutritionists, ecologists and evolutionary biologists. We combine our new methods for meta-analysis of variance with models of nutritional geometry to evaluate how diet affects between-individual variance in fitness. As predicted by nutritional geometry, we found that between-individual variance in fitness-related traits is higher on single-food than mixed-food diets. The effect was strong for longevity (57% higher) and reproductive traits (37%), and present but weaker for size-related traits (10%). Further, the effect became stronger as the number of available foods increased. The availability of multiple foods likely allows individuals with differing nutritional optima to customise intake, maintaining fitness over a range of environments.

Karola Stotz (Macquarie U.): Robustness and Plasticity in Gene Expression: the interplay of stochasticity and downward informational control

The robustness of cell differentiation is produced by distributed information regulated and harnessed by top-down informational control. This happens when the system as a whole influences the causal dynamic of the interaction between the parts at the lower level. Dynamic causation is a strictly an intra-level phenomenon created by the interaction between parts. However, these parts can to some degree constrain the behavior of the whole (bottom-up mediated effects), while at the same time the functionality of the parts is to some degree constrained and selected by the whole (top-down mediated effects). Both Alexei Kurakin and Jean-Jacque Kupiec have advanced related idea. Kupiec proposes a kind of internal process of natural selection that constrains the underlying stochasticity, while Kurakin explains the visual robustness of organism development as the result of a process of molecular self-organisation. Selection, or better variation and selective retention, is of course entailed by self-organisation. However, there exist a wide variety of self-organised systems, all of which are governed by different selection and information processing regimes. Neither selection of the reproductively fittest or alternatively the selection of the physically stable seems to be the kind that allows the emergence of bi-directional causality.

Arnaud Pocheville (U. of Sydney): Cellular Darwinism: virtues and difficulties

There exists a tradition in ecological modeling which consists in modeling organisms as ecosystems where populations of cells compete for resources and undergo a process of natural selection. This has been the case, in particular, for cancer, where cancerous cells have been considered as successful competitors in comparison to normal cells.
In this presentation, I will discuss the merits and difficulties of the intra-organismal ecological approach. I will in particular emphasize that if natural selection *does* always occur within the organism, it does not follow that natural selection is always explanatory as regards the developmental dynamics.

Cliff Hooker (U. of Newcastle) Variations on invariance: banal remarks on the dynamics of stability – or: what is the problem?

This talk is framed by the assumption that all questions about variability and stability are ultimately dynamical ones, within which is provided a small meditation on the most basic dynamical ideas involved. Variability is possessing non-trivial time dependence and stability is invariance over some requisite variability, that is, having only trivial time dependence. The generality of formulation is shown to permit many different kinds of dynamical variability and requisite stability (cf. economic efficiency).

However no fundamental or general issue emerges of having variability with stability in systems, living or otherwise. [There is the trivial general exclusion that no entity can be both variable and stable in the same respect.]

Any issue of variability in tension with stability then, if there is one, is at least relatively specific to a dynamical design (though it may concern an entire category of systems). I point to what I take to be the most relevant sources of tension, but leave it to others to penetrate the devilish details.

Matteo Mossio (CNRS, Paris 1 U.). The organisational perspective in Biology: a manifesto

In this paper, I outline some of the central features of the organisational perspective in Biology. According to it, what distinguishes biological systems from other natural systems is the fact that they are organised in a specific way; understanding the principle of organisation is therefore the central aim of the biological science. I describe in some details how biological organisation may be understood as a theoretical notion, and discuss how the organisational perspective addresses the issue of biological stability, and the relation with variability. In this respect, I argue that the organisational perspective constitutes an alternative to other contemporary conceptions of the nature and sources of biological stability. In particular, I draw the comparison with physical accounts, cellular Darwinism and process ontology.

Gaëlle Pontarotti (Paris 1 U.): On the concept of heritable variation within an organizational account of extended inheritance

This presentation draws the contours of an organizational account of extended inheritance and sketches its implications for the concept of heritable variation. Within an organizational framework, extended inheritance refers to the transmission of extended or outsourced functional traits across generations of composite biological systems, whose spatial boundaries are outlined by organizational criteria. It is underpinned by the reconstruction of heterogeneous elements – symbionts; niche artifacts; socially transmitted representations – that share the theoretical status of persisting organizational constraints. These persisting constraints, which should not be conflated with stable resources consumed by the systems, collectively determine extended biological organization. In other words, they conjointly canalize flows of matter and energy so as to ensure the maintenance of a set of functions (including reproduction) across generations of composite biological systems. The case of symbiotic inheritance, in which transgenerational outsourced function is well-described, will be proposed as a paradigmatic system for the sketched organizational perspective, and a series of properties that heterogeneous elements should meet – at various degrees – to be considered inherited will be outlined. In this context, it becomes possible to draw a renewed concept of heritable variation, which finally appears as heritable difference in functional patterns, and which should be considered in the context of a whole organization. Underpinned by more or less mutable genetic and non-genetic elements, heritable variation might sometimes be less stable than traditionally thought. Relying on genetic and non-genetic mechanisms, it can give some insight into the evo-devo concept of innovation.

Ingo Brigandt (U. of Alberta) Structure and function in organismal systems: plasticity, robustness, and the limits of modularity

To articulate the stability and variability of organismal systems, I lay out an ontology of structures and functions, according to which functions are bodily parts in the same way that structures are. Due to structures and functions standing in part-whole relations, my structure-function ontology can be used to articulate biological systems' change across both developmental and evolutionary time. Such a basic ontology does not tell us the boundaries of developmental processes and organismal systems, which have to be delineated based on case-specific epistemic considerations. Phenotypic plasticity and robustness are types of biological stability in the face of biological variability; and given that how such stability is achieved has also to be accounted for in an empirical fashion, I discuss some examples of plasticity and robustness. Another property of organismal systems is modularity, a notion which is not only present in philosophical visions of a mechanism (decomposition of a mechanism into separable units), but also prominent in some approaches in systems biology (which model the functioning of smaller subsystems in detail). However, I point to empirical cases of distributed robustness as well as the theoretical approach of dynamical systems theory as limits to modularity.

Antonine Nicoglou (Paris 1 U.) Regulation as a source of variations in living systems

In this presentation, I examine the issue of regulation in biology in order to clarify when regulation might be considered as a source of variations in living systems.
In biology, references to regulation have first appeared in embryology about

regeneration. In physiology, by contrast, “regulation” mainly referred to metaphors about physics and was linked, for Claude Bernard for instance (1878), to the intrinsic properties of living systems. Just before him, Auguste Comte had introduced the idea of a regulation of the “inside through the outside”(1851).

These two views – an intrinsic conception of regulation vs. regulation as an emergent property – permeate the current conception of regulation in biology. First, I argue that regulation may either appear as 1) the self-regulation ability of living systems or as 2) the observable outcome of the interaction of living organisms within their environments. Then, I examine these two views in the light of induction in development (i.e. the developmental process, which generates a new embryonic organization). Finally, I indicate which criteria should be used to determine when regulation is a source of variations in living systems.

Wayne Christensen (Macquarie U.) The evolution of cognition as the evolution of high order control

The evolution of cognition is often conceptualised in terms of the evolutionary appearance of key cognitive abilities, which are thought of as unitary traits. Most attention has been focused on advanced cognitive abilities such as imitation, theory of mind, episodic-like memory, tool use and language. As an alternative I advocate a systems approach that focuses on the evolution of sensorimotor architectures and which emphasises deep continuity in the evolution of cognition. This approach has similarities to, and connections with, evo-devo. I present a theory of the evolution of cognition based on this approach, which proposes that the evolution of cognition is fundamentally the evolution of a particular kind of architecture characterised by high order control. I outline a model of this architecture, characterise the evolutionary processes by which it is elaborated, and show how its elaboration gives rise to increasingly complex cognitive properties. I then argue that the model is consistent with key features of the evolution of metazoan neural architectures. Finally, I compare the account to two more specific proposals: the hypothesis that the evolutionary roots of cognitive control lie in the control of spatial foraging, and the hypothesis that the evolution of advanced cognitive abilities in great apes is based on extractive foraging. I argue that both these accounts can be subsumed within the high order control theory.