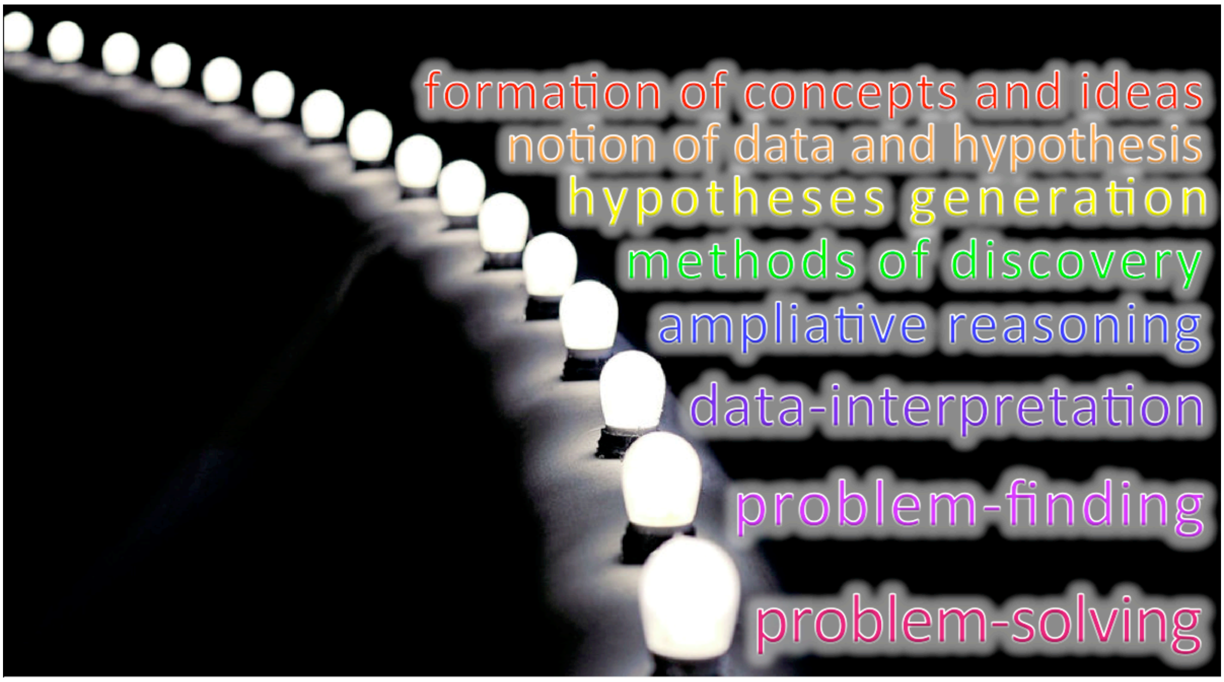
Building Theories
Hypotheses & Heuristics in Science

The construction of theories is at the core of scientific method.

Understanding the process and principles of construction is thus essential to science and how it has evolved over history.

There are various starting points for an exploration of these processes and principles.



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Program

Thursday 16 June 2016

10:00-10:15 ***Opening***

10:15-11:20 **Margaret Morrison** (University of Toronto) *Building Theories: Strategies not Blueprints*

break

11:40-12:45 **Giuseppe Longo** (ENS - Paris), *Theoretical challenges in biology: from evolution to organisms and cancer, and conversely*

Chair: Thomas Nickles

15:00-16:05 **Emiliano Ippoliti** (Sapienza University of Rome), *Heuristic Logic: a kernel*

16:05-17:10 **Donald Gillies** (UCL)**,** *Discovering Cures in Medicine*

break

17:35-18:40 **Alain Ulazia** (Universidad del Pais Vasco) *Activations of the eddy mental schema and its heuristic cooperation in the historical development of fluid dynamics*

Chair: Carlo Cellucci

Friday 17 June 2016

9:40-10:45 **Lorenzo Magnani** (University of Pavia), *How to Build New Hypotheses. Apagogé and the Optimization of the Eco-Cognitive Situatedness*

10:45-11:50 **Michela Massimi** (University of Edinburgh) *Realism, pluralism and assessing truth across scientific perspectives*

break

12:10-13:15 **Carlo Cellucci** (Sapienza University of Rome) *Theory Building as Problem Solving*

Chair: Emiliano Ippoliti

15:15-16:20 **Lindley Darden** (University of Maryland) *Finding Mechanisms: The Product Shapes the Process of Discovery*

16:20-17:25 **Fabio Sterpetti** (Sapienza University of Rome), *Scientific Progress and Understanding*

break

17:45-18:50 **Thomas Nickles** (University of Nevada–Reno), *TTT: A fast heuristic to new theories and models?*

Chair: Donald Gillies

Saturday 18 June 2016

09:40-10:45 **David Danks** (Carnegie Mellon), *Richer than reduction: Scientific discovery by intertheoretic constraints*

break

11:00-12:05 **Uskali Maki** (University of Helsinki) *Discovery by interdisciplinarity*

12:05-13:10 **Monica Ugaglia** (SNS Pisa) '*Knowing by Doing': Problem Solving and Theory of Knowledge in Aristotle.*

Chair: Fabio Sterpetti

Abstracts

Carlo **Cellucci** (Sapienza University of rome) ***Theory Building as Problem Solving***

After examining the objection that the so-called big data revolution has made theory building obsolete, the talk will discuss two views according to which there is no rational approach to theory building: the hypothetico-deductive view and the semantic view of theories. Then it will outline the analytic view of theories, illustrating it with some examples of theory building by Kepler, Newton, Darwin, Riemann, Bohr. Finally, it will examine some aspects of the view of theory building as problem solving.

David **Danks** (Carnegie Mellon University) ***Richer than reduction: Scientific discovery by intertheoretic constraints***

One heuristic for scientific discovery has been to find a new model or theory that connects with existing ones in interesting ways. In particular, reductionism—the search for models to which our current models can reduce—has often been proposed as a highly productive research strategy. In this talk, I will first argue that intertheoretic relations are far richer than the usual subjects of reduction (of different types) and autonomy. Instead, I argue that we should understand intertheoretic relations in terms of constraints. I will then show how these constraints can provide a heuristic guide for scientific discovery: by searching for models that constrain, and are constrained by, existing models, we can fruitfully expand our space of scientific hypotheses.

Lindley **Darden** (University of Maryland), ***Finding Mechanisms: The Product Shapes the Process of Discovery***

The "new mechanistic" philosophy of science advocates building mechanism schemas, which play the roles of theories in many biological sciences. Characterization of mechanisms guides the reasoning to discover them. Three levels in evolutionary theory--genes, populations, and species--exhibit integrated mechanisms at all three levels. Molecular and cellular biology are paradigm mechanistic sciences. Chromosomal mechanisms implement Mendelian laws of classical genetics. A key current task is to find mechanisms that link gene to phenotype, both for "normal" mechanisms and for disease mechanisms. Heuristic reasoning strategies and diagrammatic representations facilitate finding disease mechanisms and possible sites for therapeutic intervention.

Donald **Gillies** (University College London) ***Discovering Cures in Medicine***

The paper begins by suggesting that the discovery of a theory involves not just the formulation of a theory, but some degree of justification of the theory as well. This will be illustrated by the example of the discovery of the special theory of relativity by Einstein.

The paper then goes on to apply this approach to medicine. The discovery of a cure involves first the formulation of a theory, hypothesis, or conjecture to the effect that such and such procedure will result in the disappearance of a disease without harm to the patient. The discovery is not complete until a theory of this form is confirmed empirically. Attempts at empirical confirmation of an initial conjecture regarding a possible cure may result in a series of conjectures and refutations (or at least disconfirmations), which eventually lead to a cure different from what was first.

The final section of the paper will illustrate this general view of discovery by two case histories. The first is the discovery that penicillin cured a variety of bacterial infections. The second concerns the drug thalidomide. The disaster, which attended the introduction of thalidomide, is well known. What is not so well known is that subsequently thalidomide has proved a very effective remedy for some severe, and otherwise untreatable, medical conditions. Naturally it must be used with great caution in the light of the earlier disaster.

Emiliano **Ippoliti** (Sapienza University of Rome) ***Heuristic Logic: a kernel***

I will propose a kernel, both conceptual and formal, for a 'heuristic logic', that is a method for discovering and advancing knowledge by solving problems. After a brief *genealogy* of the logic of scientific discovery and a specification of the sense of 'method', 'logic' and 'discovery', I will argue for a heuristic logic, i.e. an open set of rules and rational procedures for constructing hypotheses during the search for a solution of a problem. I will examine the positive and the negative heuristics, the generative and the selective heuristics, the primitive heuristics (mostly analogies and inductions), and the derivate heuristics—obtained by a combination of the former. I will show how derivative heuristics presupposes a primitive form, and uses it to enhance our capacity to generate hypotheses. Drawing on recent works in this field, I will put forward a brief formal account of the most important rules of a heuristic logic.

Giuseppe **Longo** (ENS - Paris) ***Theoretical challenges in biology: from evolution to organisms and cancer, and conversely***

The fundamental principles of Darwin's theoretical construction will be recalled. The role of variability and diversity, at the core of phylogenesis, will be stressed also in ontogenesis. The historicity of all biological dynamics will allow a theoretical distinction between two observable times: the time of processes and the time of history.

The loss of the "sense of organisms" and of their historicity, jointly to the myth of the "genetic program", will allow to understand some aspects of the so far dominating cancer research. Alternative proposals, pursued today by a few biologists, are based on a *novel* interaction between evolutionary theory and theories of organisms.

Uskali **Maki** (University of Helsinki) ***Discovery by interdisciplinarity***
t.b.d.

Lorenzo **Magnani** (University of Pavia) ***How to Build New Hypotheses. Apagogé and the Optimization of the Eco-Cognitive Situatedness***

The process of building new hypotheses can be clarified by the eco-cognitive model (EC-Model) of abduction I have recently introduced. I will illustrate that, through abduction, knowledge can be enhanced, even when abduction is not considered an inference to the best explanation in the classical sense of the expression, that is an inference necessarily identified by an empirical evaluation phase, or an inductive phase, as Peirce called it. To further deepen the eco-cognitive character of abduction I will provide a simple genealogy of logic, that will be of help in stressing what I call the eco-cognitive immunization, which typifies Aristotle's syllogism and deduction. I will show that it is still Aristotle who presents a seminal perspective – in which the eco-cognitive immunization no longer holds – on the generation of new hypotheses: in this case he is instead pointing to the fundamental inferential role in reasoning of those externalities that substantiate the processof "leading away" (*apagoge*) gain a new positive perspective about the "constitutive" eco-cognitive character of abduction, just thanks to Aristotle himself. In the last part of the presentation I will describe that the optimization of the eco-cognitive situatedness is one of the main characters of the abductive inferences to new hypotheses

Michela **Massimi** (University of Edinburgh) ***Realism, pluralism and assessing truth across scientific perspectives***

In this paper, I assess recent claims in philosophy of science about scientific perspectivism being compatible with realism. I clarify the rationale for perspectival realism and the challenges it faces in striking a middle ground in between realism and epistemic pluralism. I focus on how knowledge claims can be regarded as true across different scientific perspectives, and I propose a new way of thinking about truth across scientific perspectives that in my view can deliver on the promise of realism while also being sensitive to epistemic pluralism.

Margaret **Morrison** (Toronto University) ***Building Theories: Strategies not Blueprints***

Views of theory structure in philosophy of science (semantic and syntactic) have little to say about how theories are actually constructed; instead, the task of the philosopher is typically understood as reconstruction in order to highlight the theory's essential features.

However, if one takes seriously these views about theory structure then it might seem that we should also characterize the practice of building theories in accordance with the guidelines they set out. If we look at examples of some of our most successful theories (especially in physics) we see nothing like the practices that conform to our present accounts of theory structure. Instead we have a variety of different approaches, approaches that partly depend on the phenomena we want to account for and the kind of theory we desire.

A number of strategies can be identified in high energy physics, two of which are (1) top down using symmetry principles and (2) the use of simplified models as a way of extending/correcting theories already in place. A bottom up strategy is often used in condensed matter physics, beginning with phenomenological models and gradually embedding these in a broad theoretical framework. Finally, in cases where methods and techniques cross disciplines, as in the case of population biology and statistical physics, we can see that theory construction was largely based analogical considerations such as using mathematical methods for treating systems of molecules in order to incorporate populations of genes into the theory of natural selection. Using these various examples I argue that building theories doesn't involve a blueprint for what a theory should look like, rather the architecture is developed in a piecemeal way using different strategies that fit the context and phenomena in question.

Tom **Nickles** (University of Nevada - Reno), ***TTT: A fast heuristic to new theories and models?***

Gerd Gigerenzer and co-authors David Murray and Thomas Sturm have described a scientific practice that amounts to a quick way of generating new theories that they term the tools-to-theories heuristic. Call it the TTT or T3heuristic. My presentation will place the TTT heuristic in additional historical contexts, further extend and further critique it in relation to modeling practices, human limitations, and scientific realism. I shall introduce my own ridiculously simple crowbar model of method (or of research tools), using it to defend a pragmatic conception of science. I shall raise the question whether our science must retain an element of anthropocentrism. For how long can we hope to continue the "Copernican Revolution" of modern science?

Fabio **Sterpetti** (Sapienza University of Rome), ***Scientific Progress and Understanding***

There are three main accounts of scientific progress. The epistemic account, according to which an episode in science constitutes progress when there is more knowledge at the end of the episode than at the beginning. The semantic account, according to which verisimilitude is the central concept in defining progress. The problem-solving account, according to which progress is made when a scientific development succeeds in solving a scientific problem. Each of these accounts has received several criticisms. Recently, the noetic account has been proposed by Dellsén. On this view, there is scientific progress when scientists grasp how to correctly explain more aspects of the world than before. The crucial feature of this attempt is that it relates scientific progress to the concept of understanding, instead of the concept of knowledge, in order to account for those cases in which a progress is made but it cannot be said that knowledge has increased. Indeed, knowledge requires truth, while many untrue elements are usually considered to be able to increase understanding. The paper will be devoted to point out how Dellsén's proposal does not succeed in giving a realist account of scientific progress, since the distinction between knowledge and understanding on which it rests is wanting.

Monica **Ugaglia** (SNS PIsa) '***Knowing by Doing': Problem Solving and Theory of Knowledge in Aristotle.***

Aristotle often employs mathematical examples in his works. We often look at them with the wrong expectation: we expect to find more or less stringent proofs, while for the most part Aristotle employs mere analogies. Moreover, in many cases he does not refer to mathematics as a result—a formalized system—but to mathematics as a practice.
In this perspective I will discuss some interesting geometrical examples, focusing on the status Aristotle ascribes to geometrical diagrams. The diagrams are not conceived as a result—that is, as part (the right κατασκευή) of a formalized proof—but as a work in progress. Aristotle is not interested in the final diagram—such as those accompanying proofs in Euclid's Elements—but in the construction viewed in its process of development; namely, in the figure a geometer draws, and gradually modifies, when he tries to solve a problem. The way in which the geometer makes use of the elements of his diagram, and the relation between these elements and his inner state of knowledge is the real feature the mathematical passages are intended to clarify.

Alain **Ulazia** (Universidad del Pais Vasco), ***Activations of the eddy mental schema and its heuristic cooperation in the historical development of fluid dynamics***

Eddy or vortex mental schema is a powerful heuristic instrument in scientific thinking with its properties of rotation and attraction. Descartes considered celestial vortexes to explain planetary motion, or Maxwell developed the electromagnetic theory via a model based on rotating vortexes. But historically, there were more unknown creative and detailed uses of the eddy schema which had great importance as cooperative heuristic instrument, instead of as a mere expedient analogy. I will present two episodes to underline the activation via provocative analogy of the eddy schema, multiple roles that it can play and its heuristic adaptability: firstly, the eureka visualization of an eddy by Johann Bernoulli in the genesis of fluid dynamics; and secondly, Helmholtz's vortex and Reynold's eddies to understand the dynamic and resistance of flow which produced the distinction between turbulent and laminar regimes.