Lorentz Center Workshop (in cooperation with the **NIAS**)

Report

Symmetry as a Modern Scientific Concept:
Historical and Philosophical Perspectives

Dates: Tuesday, 11 March to Friday, 14 March 2008
Organizers: Giora Hon (Haifa, NIAS fellow 07/08), James W. McAllister (Leiden), and Vincent Icke (Leiden)

Goals and Themes
The modern concept of symmetry has proved remarkably fruitful in science. It plays a role in delineating fundamental epistemic and ontological principles. The aim of this interdisciplinary Lorentz Center workshop was to review conceptions of symmetry and to investigate their possible underlying links by addressing the following themes:

- Day 1: Order vs. disorder
- Day 2: The epistemological status of symmetry principles in physics
- Day 3: Symmetry and symmetry breaking in morphogenesis
- Day 4: Overarching perspectives: D'Arcy Thompson and Hermann Weyl

The workshop was conceived within the program of collaboration between the Lorentz Center, Leiden University, and the Netherlands Institute for Advanced Study in the Humanities and Social Sciences (NIAS), Wassenaar, to foster interdisciplinary research involving diverse scientific and academic disciplines. In this workshop collaboration took place between historians and philosophers of science, physicists, biologists, and mathematicians, as well as aestheticians and historians of art.

Realization
We were successful in attracting prominent scholars from diverse domains who have been pursuing different conceptions of symmetry. The talks were appropriately designed and achieved the stated aims. The discussions following the talks were constructive and lively, and extended in the spirit of the Lorentz Center into the plentiful coffee, lunch, and tea breaks. The goal of fostering interaction between natural scientists on the one hand and philosophers, historians, and scholars in the humanities on the other hand was largely achieved. Of the speakers at the workshop, 6 are based in the Netherlands, 5 in the United States, 2 in Israel, 1 in Canada, 1 in Italy, and 1 in Germany. The workshop attracted 33 registered participants.

There were two outreach elements. The first was a lecture by Professor Giora Hon, one of the organizers of the workshop, "Symmetry—The Power of a Modern Scientific Concept", in *This Week's Discoveries*, an open lunchtime colloquium at the Faculty of Mathematics and Natural Sciences. The second was an illustrated public lecture by Professor Jan van de Craats, "Symmetry in Mathematics and in Art". This lecture was held at the Kamerlingh Onnesgebouw in the centre of Leiden and was followed by discussion with the audience. The workshop dinner took place after the public talk in a modest restaurant to the enjoyment of all the participants.

The idea that each day should be dedicated to one theme, to be addressed from different perspectives, proved most productive. For example, on Day 3 the relation between symmetry breaking and morphogenesis was discussed by a cosmologist in the context of structure formation in the early universe, by an evolutionary biologist in the context of bilateral asymmetries in organisms, and by a philosopher of physics in the context of wave-function collapse in quantum mechanics. Looking back, the organizers feel that the focus of the discussion could have been sharpened even further by starting each day with a programmatic introduction to remind participants of the research questions posed in the workshop description, or by scheduling a round table discussion at the end of the day. The organizers will keep these suggestions in mind for future similar events. Nonetheless, both the interdisciplinary nature of the discussion and its concrete focus were more than sufficient to regard the workshop as a success.

One of the contributors to the workshop wrote to us upon arriving back home: "Thank you and congratulations on the symmetry workshop. It was well conceived and very well executed, an extraordinary experience for me. I appreciated the opportunity to interact with such a diverse group of symmetricians, and I enjoyed the hospitality of the Lorentz Center, the city of Leiden, and yourselves." Another contributor commented in writing: "I thank you once again for organizing such a successful and enjoyable workshop at the Lorentz Center, where I was pleased to be able to meet you and exchange ideas about symmetry."

The workshop organizers are very grateful to the Lorentz Center team that supported this workshop, especially Dr. Martje Kruk-de Bruin, Dr. Henriette Jensenius, and Ms. Yolande van der Deijl. The organizers received support and advice also from Professor Wim van Saarloos, Director of the Lorentz Center, and Professor Wim Blockmans, Rector of the NIAS as well as Drs. Jos Hooghuis, Head of Research Planning and Support. Lastly, we are grateful to all the financial sponsors of the Lorentz Center and the NIAS that made it possible to organize this workshop.

All talks are one hour: 40 minutes talk and 20 minutes discussion.
All talks take place in Room 201 of the Lorentz Center.

Tuesday, 11 March – Day 1: Order versus disorder

09:00 – 09:45	Registration
09:45 – 10:00	Introduction Lorentz Center by Martje Kruk

Morning session

10:00 – 11:00	**James McAllister**: *From patterns in empirical data to symmetries in the world*
11:00 – 11:30	Coffee break (Common Room)
11:30 – 12:30	**Ruth Lorand**: *Symmetry and aesthetic order*
12:30 – 14:00	**Lunch break (Gorlaeus)** **This Week's Discoveries:** lecture by Giora Hon

Afternoon session

14:00 – 15:00	**Albert van der Schoot**: *The birth of symmetry from the spirit of proportion*
15:00 – 15:30	Coffee break
15:30 – 16:30	**Jos Uffink**: *Taking algebra too seriously. On the illusion of irreversible behavior in statistical dynamics*
17:00 – 18:30	Wine and Cheese party (Common Room)

Wednesday, 12 March – Day 2: The epistemological status of symmetry principles in physics

Morning session

10:00 – 11:00	**Elena Castellani**: *Curie's principle and invariance principles*
11:00 – 11:30	Coffee break
11:30 – 12:30	**Renate Loll**: *Emergence of symmetry from Planck scale physics*
12:30 – 13:45	**Lunch break**

Afternoon session

13:45 – 14:45	**Peter Kosso**: *The empirical status of symmetries in physics*
16:00	Transportation to Leiden
17:00 – 18:30	**Public talk – Jan van de Craats**: *Symmetry in mathematics and in art* (Kamerlingh Onnes building)
19:00	Workshop dinner (downtown Leiden)

Thursday, 13 March – Day 3:
Symmetry and symmetry breaking in morphogenesis

Morning session

10:00 – 11:00	**Richard Healey**: *Perfect symmetries*
11:00 – 11:30	Coffee break
11:30 – 12:30	**Ana Achúcarro**: *Symmetry breaking in the early universe and cosmic defects*
12:30 – 13:45	**Lunch break**

Afternoon session

13:45 – 14:45	**Richard Palmer**: *Symmetry-breaking in development and evolution – Sometimes genes are superfluous*
14:45 – 15:15	Coffee break
15:15 – 16:15	**Chuang Liu**: *Quantum measurement as spontaneous symmetry breaking*

Friday, 14 March – Day 4:
Overarching perspectives: D'Arcy Thompson and Hermann Weyl

Morning session

10:00 – 11:00	**Giora Hon**: *Hermann Weyl's Symmetry* (1952) --*The over-arching concept of symmetry*
11:00 – 11:30	Coffee break
11:30 – 12:30	**Erhard Scholz**: *Symmetry between beauty and truth: Hermann Weyl's contributions to group structures in 20th- century mathematical sciences*
12:30 – 13:45	**Lunch break**

Afternoon session

13:45 – 14:45	**George McGhee**: *Beyond Thompsonian transformations: A symmetry of existent versus nonexistent biological form*
14:45 – 15:15	Coffee break
15:15 – 16:15	**Thomas Ryckman**: *Hermann Weyl: The a priori in physics and "constructive cognition"*
16:15	**Workshop close**

Symmetry as a Modern Scientific Concept
Historical and Philosophical Perspectives
from 11 Mar 2008 through 14 Mar 2008

Background and Motivation

The modern scientific definition of symmetry is that of invariance under transformations. The concept of symmetry has proved remarkably fruitful in recent physical science. Symmetry provides a guide to ontology: the indiscernibility of elementary particles is a form of symmetry. It plays a role in delineating fundamental physical principles: every conservation law is associated with an invariance under a specific transformation. It constitutes a framework for modelling causal processes, by suggesting that effects must possess the symmetries of their causes. It serves as a heuristic principle in theory formulation: symmetry considerations suggest which physical situations must be treated as distinct and which as the same. The attendant notion of symmetry breaking has demonstrated a similar fruitfulness and range of applicability.

Recently, symmetry has come to play important roles in biological science too. The symmetries of plant morphology are regarded as a leading principle in ontogenesis. The bilateral symmetries of animals, and their assessment by potential mates, have been revealed as an important factor in sexual selection.

But foundational questions about the status of symmetry principles in science remain. Do symmetry principles convey empirical information about the world, or are they in some sense trivially true? Are symmetry considerations merely methodologically sound procedures, or do they correspond to the structure of the world? Can the validity of symmetry principles be established a priori by logical means, or must it be learned by experience?

Symmetry also plays important roles in domains other than the sciences. In architecture, for example, symmetry is associated with order, balance, and seemliness. Symmetry principles are similarly prominent in other art forms, though perfect symmetries are frequently regarded in visual art as aesthetically sterile.

The aim of this interdisciplinary Lorentz Center workshop is to review conceptions of symmetry from four different perspectives. The following themes are intended to facilitate interactions across disciplines:

- Order vs. Disorder
- The Epistemological Status of Symmetry Principles in Physics
- Symmetry and Symmetry Breaking in Morphogenesis
- Overarching Perspectives: D'Arcy Thompson and Hermann Weyl

Workshop Themes

Session 1: Tuesday 11 March 2008

Order vs. Disorder

The opening day is devoted to exploring the general concepts of order and disorder to shed light on the tension between symmetry and asymmetry. On one reading, symmetry is understood as corresponding to a highly ordered state, which requires effort to achieve and maintain, whereas departures from symmetry are understood to correspond to disorder and lack of structure. The concepts of entropy and of the thermodynamic arrow of time encapsulate the idea that isolated systems in nature tend to decay from order to disorder, a conception to which Paul Ehrenfest, a physicist in Leiden, made a signal contribution. On a reading inspired by algorithmic information theory, by contrast, symmetrical states of affairs correspond with low information, whereas increasingly disordered or random outcomes have higher information content. This juxtaposition of perspectives yields some apparently paradoxical conclusions: for example, many physicists would hold that the discovery of a symmetry in phenomena shows nature to be highly structured, whereas one might conclude that such a discovery shows nature to be simpler and less richly structured than if the symmetry failed to hold. The same ambivalence pertains to the role of symmetry in aesthetic discourse: beauty is associated with symmetry in classical theories of art, but many modern onlookers would associate perfect symmetries with lifelessness and lack of aesthetic value. What do these conceptual relations tell us about the relations of order and symmetry?

Session 2: Wednesday 12 March 2008

The Epistemological Status of Symmetry Principles in Physics

Symmetry principles number among the fundamental methodological principles of physics. Physicists often use them as premises in arguments aiming to show that some quantity is conserved, that one state of affairs is observationally or metaphysically indistinguishable from another, or more generally that a certain state of affairs is physically necessary. Symmetry principles appear to arise in a variety of ways, however. Curie's principle appears to derive from metaphysical considerations concerning the relation of cause and effect. Other symmetry principles are posited on the grounds of high-level considerations, such as transformations and their resultant expression in conservation laws (Noether's theorem). Yet other symmetry principles are induced from experimental data, such as the approximate symmetries that hold among elementary particles. What different sorts of symmetry principles can be discerned? Can these principles be established by a priori means, or are they

based on empirical data? Correspondingly, are these symmetry principles trivially valid or do they convey information about the structure of the world?

Session 3: Thursday 13 March 2008

Symmetry and Symmetry Breaking in Morphogenesis

The concepts of symmetry and symmetry breaking play an important role in accounts of morphogenesis in at least two widely differing contexts: cosmogenesis in cosmology and ontogeny in developmental biology. In both contexts, a symmetrical early state results in an asymmetrical and thus more highly differentiated later state. What is the conceptual basis for treating structure formation as an outcome of symmetry breaking? Can any systematic principles relating symmetry breaking to the evolution of structure be established for these two domains? Is it possible to quantify the degree of symmetry breaking, or construct a measure of how far the outcome lies from the initial symmetry?

Session 4: Friday 14 March 2008

Overarching Perspectives: D'Arcy Thompson and Hermann Weyl

In the final session we revisit two classic texts of the twentieth century: D'Arcy Thompson, *On Growth and Form* (1917) and Hermann Weyl, *Symmetry* (1952). Both Thompson and Weyl present mathematical theories of transformations and invariances that are intended as overarching organizing principles in their different domains. In pursuing this goal the two authors offer historical accounts of the concepts at stake. However, while Weyl's work has remained central to and acknowledged in theoretical physics and science in general, Thompson's approach largely fell out of fashion in the "modern synthesis" of evolutionary theory, regaining importance only with the rise of evo-devo. What general conclusions can be drawn within a historical framework about the role of theories of transformations, invariances, and symmetries in different branches of science?

[Back]