Chapter 3
Reflections on the Operator Theory

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Abstract This review offers a short summary of the Operator Theory, or O-theory, including the notion of closure consisting of some circular processes. Based on closure, the Operator Theory distinguishes a limited number of levels in the organization of nature: fundamental particles, hadrons, atoms, molecules, and cells, cells with endosymbionts, multicellular organisms, and organisms with neural networks. The Operator Hierarchy can be viewed as a meta-evolution theory, the higher levels of which describe ordinary Darwinian evolution. Special attention is paid to objects that are produced by higher level objects in the Hierarchy but are playing a role at a lower level. For example living organisms have added complex biological molecules to the collection of lifeless molecules.

3.1 Introduction

The *O-theory* (operator theory) of Gerard Jagers op Akkerhuis is an approach that offers a uniform view of important phenomena in the universe since the Big Bang. It considers a short hierarchy of objects: (1) elementary particles, (2) hadrons, (3) atoms, (4) molecules, (5) cells, (6) endosymbiont cells, (7) multicellular organisms, and (8) organisms with brains. At each level of this hierarchy the objects create a wealth of interactions, which leads to a proliferation of evolving objects, and the formation of new kinds of objects. In this way O-theory is a (generalized) description of evolution. Also a uniform mechanism is described by which a level is transformed into the next level. Once objects of a higher level are present, the evolution of objects of the previous level continues and may even be enriched by objects that are produced by the higher level objects.

For example, at level 4 atoms form molecules by covalent binding. The resulting world of interactions is the field of chemistry, focusing not only on the molecules

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(M) but also on the reactions. Among the possible reactions there are circular ones, possibly involving catalyzers. Such circular reactions are depicted as (*):

$$(*) M_1 \rightarrow M_2 \rightarrow \ldots . \rightarrow M_n = M_1.$$

Such a circular chain of transformations may soon terminate, for example when the needed catalyzers are taken away due to environmental change. If, however, there is a protecting topological container for the process (*) and its catalyzers, then it becomes easier to maintain the circular reaction. If moreover the topological container is supported by the products of the circular reaction, then the interaction between the circular process and container is maintained. This mechanism is called a *closure*. Chemical closure brings forth a transition to the next level of complexity: the living cell.

We have in general the following.

1. The objects of a given level are being transformed, forming objects of varied complexity.
2. Some of these interactions from a circular transformation, like (*).
3. This circular reaction may be protected by a container, functioning on the basis of the given reaction and mediating the relationship between the contained processes and the world.

The combination of the circular reaction and its supported and supporting container is called an *operator*, and signifies the next level in the hierarchy. And then the story repeats.

Notice that (2) and (3) point at two different kinds of circles: one in time and one in space (albeit a 3D circle, i.e., a sphere). O-theory is an appropriate name, because the letter O indicates both kinds of circles.

Based on closures the O-theory allows the distinction of a limited number of levels in the organization in nature.

Level 1: fundamental particles.

Level 2: from elementary particles to hadron. The formation of hadrons (protons and neutrons) from elementary particles can be seen this way. In the very early universe after the Big Bang temperature is too high to have stable interactions between elementary particles. All particles interact more or less randomly and a “soup” results, consisting of elementary particles including quarks and electrons. After sufficient expansion and hence cooling down of the universe interactions between quarks are stabilized because the exchange of gluons creates a field around triplets of quarks, and these become confined into bundles called hadrons, of which protons and neutrons are examples. This is the first development.

Level 3: from hadrons to atoms. There are stable coalitions among hadrons. Actually these are only stable in the sense of (*): disappearing and appearing again. This way a nucleus of an atom is created. The nuclei are subject to change if more hadrons become part of the coalition. When the environmental temperature becomes low enough the electrons may form protecting containers. In this way the atoms are formed. While all the atom nuclei that are lower or equal in weight compared to the iron atom form in an exothermic way, all atom nuclei that are heavier require energy to be formed. For example a Zn (zinc) nucleus cannot form in the sun. Such atoms have to be formed by a supernova explosion.

Level 4: from atoms to molecules. The formation of molecules starts with the atoms that bind through covalent bonding. Such bonding typically involves the exchange of a pair of electrons in a shared electron shell. The atoms transform each other all the time, and the electron shell causes a shared container.

Level 5: From molecules to the cell. This level was already discussed: the complex pre-biological evolution starts, producing at some point the cell as a circular process contained in the cell membrane.

Level 6 plus: From here onwards levels continue to form, from the cell to multicellular organisms. The cells make coalitions and form multicellular compounds. First there was the simple unicellular organism (archaea). Then there is in parallel the formation of blue-green algae (prokaryotes) and of endosymbiont cells (like the eukaryotic cell). The endosymbiont cell is already the product of a closure and may be called level 7. Based on endosymbionts complex multicellular organisms could evolve. If in this evolution a circular event between cells takes place that at the same time produces a common container for all the cells involved, then a multicellular organism is evolved. In the O-theory the hallmark for multicellularity is the connection of cells through plasma connections.

The evolution of organisms at level 5 and above is the ordinary Darwinian evolution.

3.2 Other Aspects of the O-Theory

An important aspect of O-theory is that some objects x of a given level can often only be produced by starting at the next level, forming a higher-order object in which x plays a role, and then isolating x. For example, a complex biochemical molecule (like a vitamin) most probably will not arise in the evolution of atoms and molecules. It needs the more complex next level, the living cell, to be evolved first. But then of course it can be considered on the previous level, after isolation. Similarly an organ like a liver appears only on the level of living organisms, after which it can be taken out. I would suggest to refer to objects like mentioned x as "higher-order." They exist at level, say, n, but can be evolved only by going to level $n+1$. Another interesting higher-order object is ammonia NH_3. The energy needing transition $3H_2 + N_2 \rightarrow 2NH_3$ happens in nature in some bacteria or in an industrial process (Haber–Bosch process). Only through this process, requiring a pressure of 400 atm, seven billion people can be fed via fertilizers. Put differently: without the availability of the higher-order molecule NH_3 there would not be so many people on earth.

Jagers op Akkerhuis constructed the O-theoretic view in order to explain that the usual way of looking at complex matter (via the classical sequence: atom, molecule, organelle, cell, mammal, population, ecosystem) is unsatisfactory for several reasons. Firstly, the notion of higher-order object is missing. Secondly, the objects included in the rankings are of different kinds, such as operators (atom, molecule, and cell), higher-order objects (organelles, organs), aggregations (planet), and abstract sets (population, ecosystem). Thirdly, the ranking rules between steps are not of the same kind. For example the way molecules are formed from atoms, is different from how organs are formed in organisms.

An important lesson to be taken from O-theory is to duly emphasize that there has not been evolution at just one level, namely the Darwinian evolution at the level of the organisms, but there is also "evolution" that leads to the emergence of new kinds of operators: such as from atoms to the cell and from the cell, via the endosymbiont cells, to the multicellular organism.

As discussed in detail in the Chaps. 4 and 6, O-theory provides a uniform description of different kinds of (Darwinian) evolution. And it emphasizes that all these kinds of (Darwinian) evolution are worthwhile topics for research. The common mechanism of Darwinian evolution that is discussed in next chapters is as follows. Some of the evolved objects will not take part in the next closure and some may take part, which can be identified as a pattern of selection. This fundamental pattern in an (exponentially) evolving tree of possibilities is what can be recognized as evolution, according to Darwin, when speaking about organisms. In O-theory the explanatory power of this mechanism is used for the identification of previous level, and future level patterns of Darwinian evolution.

In summary, O-theory provides a differentiated view on evolution, by distinguishing Darwinian evolution at several levels and by classifying in a natural hierarchy all the kinds of objects that play an important role in patterns of evolution.