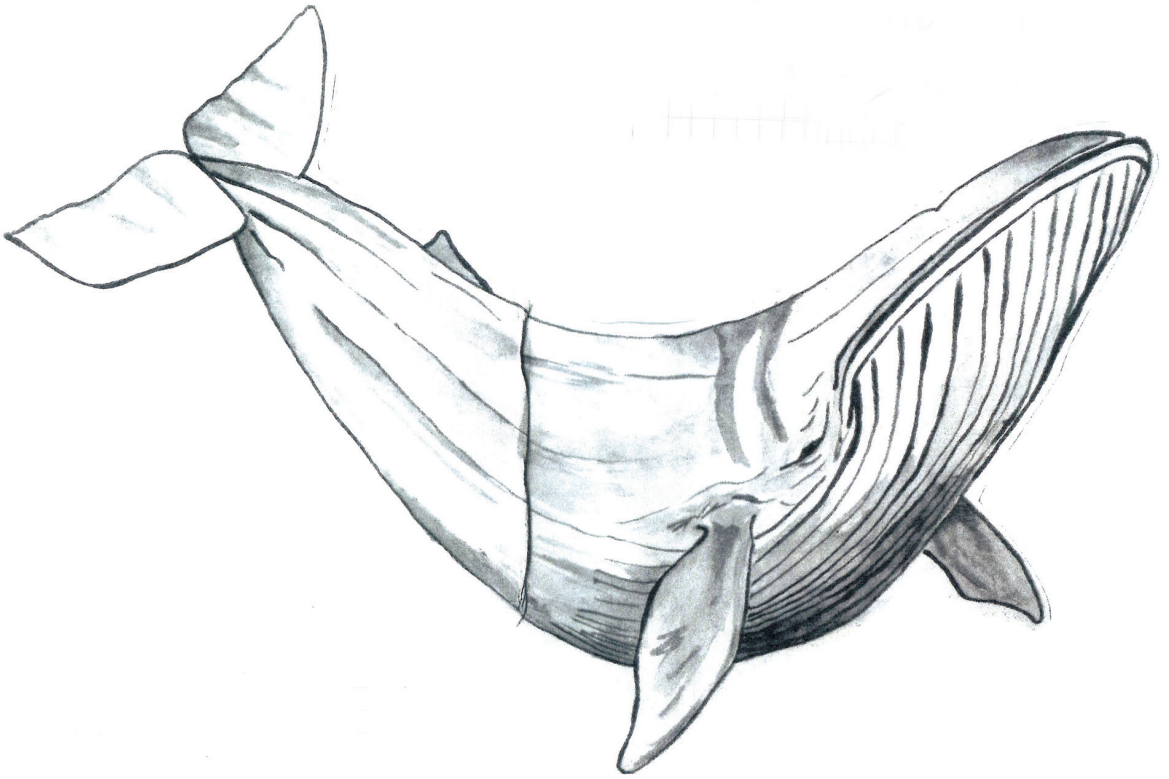


OF MOLECULES, FORM AND LIFE

From Van Helmont to Maturana

A journey through theories while looking down the microscope

Daniela Brill



ONE FUNDAMENTAL PRINCIPLE
OR
THE FUNDAMENTAL PRINCIPLE:
OUT OF TWO MICROSCOPIC CELLS
EMERGE MILLIONS AND BILLIONS
OF CELLS
AND IN THE OCEAN THE BLUE
WHALE DANCES

ernesto cardenal

Everything is scrambled, at first. Then, centrioles position themselves on the sides, one at each pole. Spindles form out of microtubules and create bridges that connect the two poles. Some of the microtubules attach themselves to the chromosomes in the middle and the chromosomes travel to the center. They move slowly, and stop when they find themselves at the equator of the cell thereby creating a line. Division proceeds, the sister chromatids are separated, all of them at the same time. The chromatids travel to the poles, pulled by the microtubules. The final stage begins, the cell is ready to divide, a nuclear envelope forms around each set of chromosomes, two new nuclei form, two new cells appear.

– Studying single-cell division in yeast (*Saccharomyces cerevisiae*) : author's field note 20th September 2016

Johann Baptiste Van Helmont (1579-1644) advanced the theory, that a living organism, such as a mouse, could spontaneously generate inside of a vessel, if all necessary conditions were met. He wrote his *Ortus Medicinae* in 1667 to describe to the world his view of science. He proposed a 'recipe' which, if followed carefully, should prove that mice spontaneously generated out of wheat, sweaty clothes, darkness, time, and some other crucial ingredients. These mice would be 'parentless', they would not have developed from the conjoining of two parent-cells, but would be able to mate and create new mice, which would have exactly the same anatomy as a mouse born of two parents. According to Bruno Latour¹ the discussion about spontaneous generation 'ended' 200 years later, in the Académie des Sciences in Paris, when two scientists, Félix Pouchet and Louis Pasteur, tried to demonstrate with their own experiments what each of them thought to be true. Pouchet believed to have confirmed the theory of spontaneous generation, while Pasteur was making evident that Pouchet's experiments did not prove the possibility of spontaneous generation. In fact, Pasteur was convinced that microscopic *animacula* were floating in the air that surrounded Pouchet's experiments, and that these germs were the ones 'creating' new life inside Pouchet's test tubes.

There are all kinds of theories concerning the force that make a cell divide, an organism grow, a species evolve. Johann Friedrich Blumenbach for example proposed his *Bildungstrieb*² (formative drive) as a

force common to all developing organisms operating on them until they reached their final form. It also should prove that new species can emerge out of already existing organisms. This concept had also effected the discussions between preformationists and epigenesists: the former proposed that the organism was already formed in miniature size inside the egg or seed, and that it just had to unfold until it reached its normal size. The latter were convinced that the embryo developed from loose materials that organised themselves until they reached their final form. This side was taken by Caspar Friedrich Wolff, who can be seen as one of the fathers of embryology. He made a simple experiment to demonstrate that preformation was a wrong concept: he showed that the growth of a plant did not depend on a preformed plant in the seed and that it can regenerate from its roots, after its leaves and parts of stem had been removed. Rather its growth depended on layers of cells organising themselves again and again thereby building the body of the plant. Inside of the cells of the plant is the information necessary to grow a new stem, new branches, new leaves, new flowers. Scientists like Wolff or Hans Driesch developed theories of forces that they believed were responsible for the growth of organisms. These forces are described as *vis essentialis* by Wolff and as *entelechy* by Driesch. The tree in Wolff's experiments regenerates itself, *it creates itself*. It is a question of *self-generation* or *self-organisation*. In her text about Kant's concept of self-organisation³, Alicia Juarrero Roqué also uses a tree as an example to explain this theory:

The tree develops itself 'by means of a material which ... is its own product'; thus the preservation of one part depends on the preservation and production of other parts. A tree's leaves, for example, not only are produced by but also maintain the tree (...) only organisms exhibit finality, and they do in virtue of their self-organizing capability.⁴

And Driesch writes, 'Living bodies are not simple geometrical forms, not, like crystals, merely a typical arrangement of surfaces in space, to be reduced theoretically, perhaps, to an arrangement of molecules.'⁵

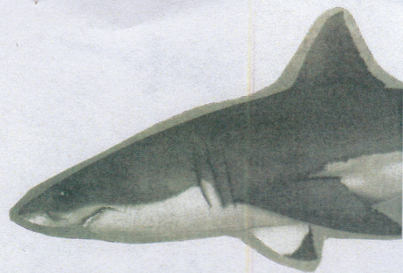
1) Bruno Latour, Pasteur und Pouchet: *Die Heterogenese der Wissenschaftsgeschichte* (Frankfurt, Suhrkamp, 1994).

2) Johann Friedrich Blumenbach: *Über den Bildungstrieb (Nisus formativus) und Seinen Einfluss auf die Generation und Reproduktion* (Göttingen: Göttingisches Magazin der Wissenschaften und Litteratur, 1780).

3) Alicia Juarrero Roqué: Self Organization: Kant's concept of teleology and modern Chemistry, in: *Review of Metaphysics*, 39, 1985.

4) *Ibid.*, p. 105.

5) Hans Driesch: *Science and Philosophy of the organism* (London: A. & C. Black, 1929) p. 19.



~~an~~ atom is
nothing but

empty space and fields
of energy

but it looks for another atom.
For example the love in one atom of
hydrogen:

The union between the positive proton
and the negative electron

The cosmos could have started
with only two
particles

of opposite negative charges.

ernesto
cardenal

The simplest life forms are unicellular, take up what they need and divide seemingly immortal. Take in what they need, to release what they don't need to divide and to die. And behind this system there is an 'energy' that drives them. An energy that separates them from non-living things, or from dead organisms: the difference between an *aggregate* and an *organism*. The purpose of existing as a unity, as a living being, life is unknown to us except in association with bodies: we only know living bodies and call them organisms. In simple terms one could say that atoms that create the aggregate, like a snowflake or crystal, organise themselves but show no finality. They do not organise themselves with the intension of their own existence, they do so following physical forces.

It is the final object of all biology to tell us what it ultimately means to say that a body is 'living', and in what sorts of relation body and life stand one to the other.⁶

At the beginning of biological evolution, in the stage between molecules and cells there was something that was 'injected' from outside, or that came from the inside of the atoms/molecules that changed their function and finality, and created life. The process of life arising from chemical elements is called 'abiogenesis', and it states that life came out of a chemical soup, in which the perfect conditions were given for life to begin. In 1911 Stéphane Leduc, based on Lamarck's theory that life 'should stem out from physical and chemical principles only'⁷ made some experiments to prove that life did spontaneously arise out of non-living molecules. 'Living things are made of the same chemical elements as minerals; a living being is the arena of the same physical forces as those which affect the inorganic world.'⁸ He stated that the fundamental part of a living being is its form. Furthermore he found out how to mix specific elements to create forms, that looked exactly like living organisms, divide just like living cells, but in which life itself was missing.

Very beautiful growths may be obtained by sowing calcium chloride in a solution of potassium carbonate, with the addition of 2 percent of a saturated solution of tribasic potassium phosphate. This will give capsules with figured belts, vertical lines at regular intervals, or transverse stripes composed of projecting dots such as may be seen in many sea-urchins.⁹

Pouchet's idea of spontaneous generation reappeared:

The question of spontaneous generation exists, and it's not in the power of anyone to suppress it. It is

stupefying that Pasteur's experiments could extinguish it so completely for more than thirty years.¹⁰

After the rise of the first cell out of the chemical soup, this first cell had to divide. The mystery of how life emerged from a soup of chemical elements is striking, however, the mystery of the first cell that decided to divide and create an organised and elaborated living being is even much more striking:

As Freeman Dyson puts it, 'one evil day, a cell resembling a primitive bacterium happened to find itself one jump ahead of its neighbors in efficiency. That cell separated itself from the community and refused to share. Its offspring became the first species. With its superior efficiency, it continued to prosper and to evolve separately.' The rest, as they say, is history.¹¹

Listen 'A living point...No, I'm wrong. Nothing at first, then a living point... Another living point attaches itself to this one, and then another. And from these successive conjoining a single living unity results, for I am certainly a unity. Of that I have no doubt...' (As he was saying this he was feeling himself all over). 'But how does this unity create itself? (...) All right, philosopher, I can grasp an aggregate, a tissue of small sensitive beings, but an animal... A totality, a unified system, on its own, with an awareness of its own unity? That I don't understand. I don't understand at all...'¹²

One may be a first-rate organic chemist even when looking upon the atoms as small billiard balls, and one may make brilliant discoveries about the behavior of animals even when regarding them in the most anthropomorphic manner – granted that one is a good observer; but it can hardly be admitted that our chemist would do much to advance the theory of matter, or our biologist to solve the problem of the relations between body and mind. It is only by the aid of philosophy, [...] that natural sciences are able to acquire any significance for what might be called the science of nature in the most simple form.¹³

Hans Driesch arguments that it is only philosophy that will answer the 'highest questions which man's spirit of inquiry suggests'¹⁴, he calls it 'philosophy of nature'. A system to study the phenomena of life, or *nature* ('what is given to us in space'¹⁵) through analysis and experimentation to find the laws that apply on it. After experimentation with sea-urchins and exact description of his discoveries, he concludes that pure analysis is not enough to get to the bottom of the life phenomena. There is a limit if one only works with description. It's not only about the mechanics in nature¹⁶:

There must be something deeper to be discovered: we only have been to the surface of the phenomena, we now want to get to the very bottom of them. Why then occurs all that folding, and bending, and histogenesis, and all the other processes we have described? There must be something that drives them out, so to say.¹⁷

These words and the image of a cell dividing under the lens of the microscope makes me wonder if only the first one of the living *unity* was spontaneously created out of the molecules found in the *soup*, and only because the perfect conditions were reached. Humberto Maturana and Francisco Varela introduce the term ‘autopoiesis’ in 1963.

A living being is for them a unity that constitutes itself completely and is autonomous. What has to happen for a being with these characteristics to arise? Each molecule that arises participates in the creation of the following molecules, and this is autopoiesis, self-creation.

An autopoietic system is organized (defined as a unity) as a network of processes of production (transformation and destruction) of components that produces the components that:

1. Through their interactions and transformations continuously regenerate and realise the network of processes (relations) that produced them; and
2. Constitute it (the machine) as a concrete unity in the space in which they (the components) exist by specifying the topological domain of its realisation as such a network.¹⁸

Varela and Maturana state that this process does not occur by chance, it occurs because of the perfect conditions that are given for it to arise. On the other hand, Ilya Prigogine, tries to find the point of connection between natural science and history of man, (separated by Newton, in Prigogine’s opinion),

between science and philosophy. He breaks with a scientific world view being built on top of the idea that everything is stable and in constant equilibrium. For him, we living beings come from two paradigms, on the one side Parmenides’s paradigm, *the being is not movable, it is perfect and whole*. On the other side Heraclitus’s paradigm, *everything is in permanent movement and fluctuation*. Non-equilibrium is, for Prigogine, a source of organisation and of order. For him it is crucial to think that not everything is stable and unmovable to be able to solve nature’s big questions and one of them being the presence of life. He questions the models of the universe and introduces the principle of *order through fluctuation*, which is already present in the important role probability plays in Darwin’s work where evolution is a result of fluctuation. For Prigogine it is important to start making the transformation from science as a geometry, to science as narration. There is a theological background, following Leibniz’s idea that *God made everything the best way possible*.

So we are brothers and sisters of all living beings, but also of all non-living ones. Recently I read the book *Out of Chaos* written by Louis J. Halle, who states that the living and the non-living are just categories in which our mind separates all beings. We don’t consider the crystal of a snowflake that is floating in the air to be alive, he said, but we consider the diatom to be alive, the beautiful cell of siliceous shells that carry amazing extraordinarily delicate drawings and that is floating on the sea. Nevertheless the molecules that form the diatom are not more alive than the ones forming the snowflake.¹⁹

* Images and zine by Daniela Brill.

6) Ibid., p. 16.

7) Raphaël Clément: *Stéphane Leduc and the vital exception in the Life Sciences* (Marseille: Institut de Biologie du Développement, 2015), p. 2.

8) Stéphane Leduc: *Mechanism of life* (London: William Heinemann, 1911), see introduction.

9) Evelyn Fox Keller: *Self Organization, Self Assembly, and the Inherent Activity of Matter* (Boston: The Hans Rausing Lecture, 2009) p. 16.

10) Raphaël Clément, quoting Leduc: *Stéphane Leduc and the vital exception in the Life Sciences* (Marseille: Institut de Biologie du Développement de Marseille, 2015) p. 7.

11) Evelyn Fox Keller: *Self Organization, Self Assembly, and the Inherent Activity of Matter* (Boston: The Hans Rausing Lecture, 2009) p. 25.

12) Denis Diderot: *Rameau’s nephew and D’Alambert’s Dream* (London: Penguin classics, 1976) Act 1, Scene 1.

13) Hans Driesch: *Science and Philosophy of the organism* (London: A. & C. Black, 1929) p. 4.

14) Ibid.

15) Ibid., p. 5.

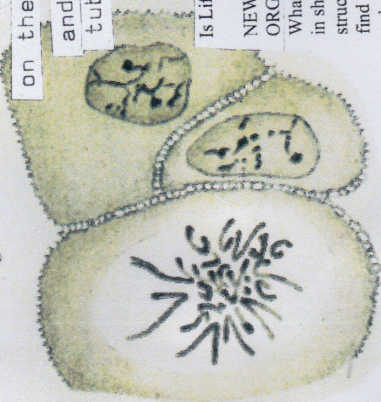
16) See Gustav Kirchhoff: *Treatise on the Theory of Light Rays*, 1882 (Singapore: World Scientific, 2016).

17) Hans Driesch: *Science and Philosophy of the organism* (London: A. & C. Black, 1929) p. 50.

18) Dr. Randall Whitaker: *A tutorial in Autopoiesis, quoting Varela*, (<http://www.enolagaia.com/Tutorial1.html>, 1979).

19) Ernesto Cardenal: *Este mundo y otro* (Madrid: Trotta, 2011).

Fig. 71.



Everything is scrambled, at first. Then, centrioles position themselves on the sides, one on each pole. Spindles form out of micro tubules and create bridges that connect the two poles. Some of the micro-tubules attach themselves to the chromosomes in the middle, the chromosomes travel to the center.

They move slowly, and stop when they

find the middle
creating a line on the
equator of the cell.

Is Life Based on the Laws of Physics?

NEW LAWS TO BE EXPECTED IN THE ORGANISM

What I wish to make clear in this last chapter is, in short, that from all we have learnt about the structure of living matter, we must be prepared to find it working in a manner that cannot be reduced to the ordinary laws of physics. If a man never contradicts himself, the reason must be that he virtually never says anything at all.

Division proceeds,

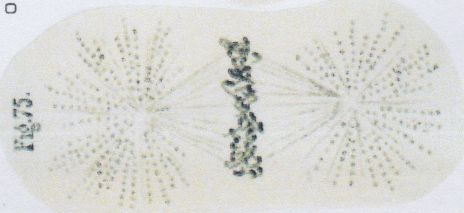
each chromosome is torn apart in two equal pieces all of them at the same time. The half-chromosomes travel to the poles

pulled by the micro tubules. The final stage begins, the cell is ready

to divide itself, nuclear membrane forms around each identical set

of chromosomes, two new nuclei form, two new cells appear

Fig. 72.



The arrangements

of the atoms in the most vital parts of an organism and the interplay of these arrangements differ in a fundamental way from all those arrangements of atoms which physicists and chemists have hitherto made the object of their experimental and theoretical research.

For it is in relation to the statistical point of view that the structure of the vital parts of living organisms differs so entirely from that of any piece of matter that we physicists and chemists have ever handled physically in our laboratories or mentally at our writing desks.

For, naturally, not only the body of an adult individual of any higher species, but every single cell composing it contains a 'cosmical' number of single atoms of every kind.

Indeed, in my view, it lies outside the range of natural science and very probably of human understanding altogether.

MAGIC

This nucleus, in the ordinary 'resting state' of the cell, usually appears as a network of chromatin, distributed over the cell. But in the vitally important processes of cell division (mitosis and meiosis, see below) it is seen to consist of a set of particles, usually fibre-shaped or rod-like, called the chromosomes, which number 8 or 12 or, in man, 48.

It is these chromosomes, or probably only an axial skeleton fibre of what we actually see under the microscope as the chromosome, that contain in some kind of code-script the entire pattern of the individual's future development and of its functioning in the mature state. Every complete set of chromosomes contains the full code.

How can we, from the point of view of statistical physics, reconcile the facts that the gene structure seems to involve only a comparatively small number of atoms (of the order of 1,000 and possibly much less), and that value nevertheless it displays a most regular and lawful activity - with a durability or permanence that borders upon the miraculous?

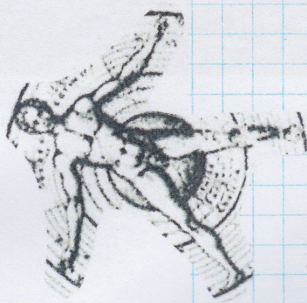
Since we know the power this tiny central office has in the isolated cell, do they not resemble stations of local government dispersed through the body, communicating with each other with great ease, thanks to the code that is common to all of them? Well, this is a fantastic description, perhaps less becoming a scientist than a poet. However, it needs no poetical imagination but only clear and sober scientific reflection to recognize that we are here obviously faced with events whose regular and lawful unfolding is guided by a 'mechanism' entirely different from the 'probability mechanism' of physics.

Fig. 72.



Fig. 73.



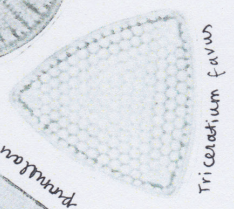
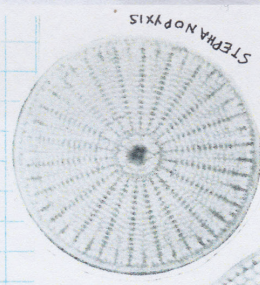
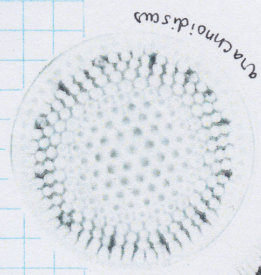
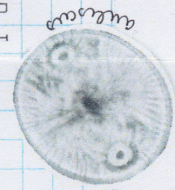
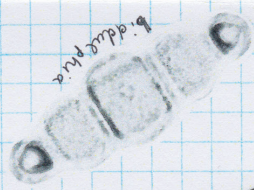


"WE ARE ANIMALS THAT ARE CHEMICAL ELEMENTS
THAT ARE ATOMS THAT ARE A CLOUD OF PROBABILITIES.
IT IS A MYSTERY THAT CHANCE CAN CAUSE ORDER. E.C.

"A living point...No, I'm wrong. Nothing at first, then a living point... Another living point

attaches itself to this one, and then another- and from this successive conjoining a single living unity results, for I'm certainly a unity. Of that I have no doubt... (As he was saying this he was feeling himself all over) But how does this unity create ITSELF? (...) All right philosopher, I can grasp an aggregate, a tissue of small sensitive beings, but an animal... A totality, a unified system, on its own, with an awareness of its own unity? That I don't understand. I don't understand at all"

Denis Diderot, BA
D'Alembert's Dream



The universe is uniform. There are only about a hundred elements (hundred types of atoms) in the whole universe, and out of them we are built. And so is life. From All cells have a similar composition. From the unicellular diatom to the big blue whale (and in the middle the human beings) all living beings are built from the same amino-acids. In total twenty of them. And from one single cell all living beings emerged.
Ernesto Cardenal

TriCeladum favus

Tricardium

Staphylinus

Staphylinus

STAPHYLINUS