

# Long term stability and the meaning of life.

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## *Abstract*

*A new definition of life is given, which is sufficient to construct practical experiments to understand the origin of life. Stable mechanisms throughout evolution are discussed and their importance on human society are highlighted in the conclusion.*

## 0.Introduction.

The topic proposed by FQXI is:

*How can mindless mathematical laws give rise to aims and intention?*

To begin with, we have to make sense of the meaning of the words in the question. An answer to this can be given in two main ways. By how the mathematics, that describe physics laws, can yield complex systems such that they can self organize somehow and yield/emerge complex systems that can have some kind of cognition. The other approach is how these same mathematical laws were used by life in such a way that it could be build by circumstances toward some kind of cognition. Both are useful, and well explored, but I give a proposal more related to the letter where the domain of life becomes more fuzzy.

The definition of “Intention” is something quite complicated and follows very difficult trains of thought to be defined, if it is linked to the philosophical concept of intentionality[24]. The popular meaning overlaps with aim and purpose. So, to tell meanings apart, I will define here from its etymological origin, “intendere” (latin), “purpose”, from which I define intention as the tendency to achieve a state of a system. Taking inspiration from the same source[24], I define “aim” it as taking a measurement.

Note that there is no presence of a mind in “aim” and “intention” using these definitions. That’s a problem because there is suggestion of a mind with “aims” and “intention”. Such thing cannot be achieved without a massive chemical simulation of the human brain. So, some kind of link must be built in order to somehow link the abyss between the latter and molecules.

A way to explore this can be as analysing how mathematical laws and patterns are used by life, across many scales of complexity in a similar fashion, in such a way that it could build itself toward some kind of cognition. In order to

access this topic, we have to look for the widest possible points of view. Given the small space allowed for discussion, I've chosen 4 points situations. The origin of life. An example of a widespread pattern in the formation of body morphology of animals. The long term stability of life in the planet. And the use of mathematics by humans beings to change their own intentions and aims, by changing their culture, and the way they perceive the contact between nature and the abstract ideas.

# 1.The Origin of Life

All life is immersed in control systems. This is needed in order to compensate for changes in the environment as well as to regulate substances within the organism. For example, there is the cell membrane, which has as its most basic function the maintenance of the difference in concentration of pH between outside and inside and “trivial” function of selecting what goes in and out. Yet, the main theories regarding the origin of life regard these controls either as emerging patterns, disconnected from a primordial molecular origin, or at most in background to other conditions that yielded the necessary compounds for life, such as composition of the atmosphere and primitive geology.

Here, I argue that the for controls case is fundamental. That life is all about control and stability, adapted to a random environment and that it tries to stay as close as possible to a predictable pattern equilibrium, even if it shows a non trivial behaviour. [8] Nevertheless, considering the fact that no type of life exists without such controls, we can say that life is directly related to a type of set of complex systems of control.[6,7],

It is given now a practical definition for life, which immediately incorporates the definition of aim, intentions as well as the use use of mathematics and which can result in an experimental path to conduct experiments that might lead to artificial life “from scratch”: It is the propagation of a chemical clock that varies between at least two determined operators, acting on a system, and also modified by the system. By such simple operations, the mathematical operations of sum, subtraction, (and a set of differential equations, if simulation is required) and the mathematical relation of scale of magnitude (inequality relation), simple chemicals can literally become alive. Outside the range of these parameters, the whole system will enter in a saturated or deficient state and the chemical reactions will cease. One control will act as an activator and other as an inhibitor. This situation is similar to what a thermostat does: bellow a certain temperature, it will send a signal to the compressor turn on, above a temperature, it will send a signal to turn down the machine.

Staying on these ranges is the purpose of life. It is a more important property than staying alive, as it will be seen later. These operators will make the system fluctuates with stability. This is where it becomes necessary to define the concept of aim of life, which to measure its own states. All these chemical reactions consumes energy, so there will be a also belong to the purpose to reach chemicals which are required to sustain the reaction, that is, to eat. Observe that not all environments are stable, so another part of the purpose of life is to reach regions where conditions are not favorable, and thus the system is pushed to explore parameters that tends to to stay out of its range of stability: this is what leads to ever increasing complexity, on average.

This approach also tries to solve the apparent contradictions of theories concerning the origin of life, that is, what came up first, metabolism, reproduction or information? The answer given here is neither and all of them, since the most basic operator is both a metabolic component and something which carries information. There is no geometric

boundary between, at least in the beginning, between life and non-life, the former is just a flux of reactions. Precision is not required to the continuity of life. It is just an advancing wave of varying states in some equilibrium.

This definition considerably simplifies a mechanism to link the quite random distribution of substances in the primitive Earth. Any other that does not go beyond considering superficial elements thought to be synthesized during that time or trying to link elements or common structures found in all life, are probably doomed to not give clear answers. The latter approach, alone, leads to circular thoughts and makes the idea of the origin of life an impossible case, since, at one hand there are chemical reactions which are so complicated, but on the other hand, despite that that merely produces the most simply compounds present in what is now considered life, like RNA; on the other hand, RNA is considered to be self reproducing entities (even so, they are auxiliated by enzymes, to speed up reactions) which is itself a huge gap, since there is no easy way, or any way in the foreseeable future, to bridge the evolutionary pathway between such compounds while simultaneously keeping non life to spontaneously constitute self reproducing segments. Another confusing attempt was to focus on the thermodynamical aspect of life, and putting much weight in a framework of dissipative structures and non equilibrium phenomena [1,2,3], that does not produce any clue to how an evolutionary pressure could work and be can be reproduced in laboratory, not even not noticing that the a life was already there. Life is about regularity seeking to avoid non linearity.

In light of this definition, artificial life has already first related in 1828, by Lechner[4]. These are merely called chemical oscillators or chemical clocks are the simplest life known. A nice description of these systems is given in [5].

## 1.1 An Operational View

So, we can say that the life is composed at least by a very primitive network of chemical clocks, which a triple  $(O^1, O^2, P)$ , let it denote it A. This is the simplest case since there is no absolute parameter other than concentration,  $O^1$  so needs another operator to measure itself in terms of proportion, and also  $O^2$  requires the same function to establish the same function. If that didn't happen, it would be just a reaction spreading and decaying in the solving media. Thus, the definition yields the equivalent of self awareness, at chemical level, in order to differentiate from non life.

Evolution happens at the beginning not by isolating entities. They all collaborate, predate, fuse, or parasite, since there is no clear overlapping between entities. Suppose an entity called A life, crosses with B by being carried by a water current. A is composed by  $A = P \rightarrow (O^1, O^2, P)$ , O being operators,  $P_n$  being input or output chemical, and B by  $B = P \rightarrow (O^3, O^4, P)$ . When they interact, the following systems could result, for example say  $A = P \rightarrow (O^3 O^1, O^1, P)$  or  $B = P \rightarrow (O^1, O^3 O^1, P)$ . It's not clear if this is parasitism, cooperation or fusion. B can also use its product as its food  $P^1 \rightarrow (O^3, O^4, P^2)$ . If the food becomes the exclusive chemical input for B, it might be considered become a fusion with the first life, so  $(P \rightarrow (O^1, O^2, (P^1 \rightarrow (O^3, O^4)), P^2)) \rightarrow (P \rightarrow (O^1, O^2, O^3, O^4, P^2))$ . It's also possible that the reverse happens:  $(P \rightarrow (O^1, O^2, O^3, O^4, P^2)) \rightarrow ((O^1, O^2, (P^1 \rightarrow (O^2, O^3)), P^2) \rightarrow A+B$ . Also, it is not possible to say whether or not there was fusion or cooperation. The possibilities grow exponentially and this provides a natural background based, on chemical clocks, for network theories of life to evolve from scratch.

## 1.2 Examples

BZ oscillator is a type of chemical clock. The most famous example is the one which uses as operators  $HBrO_2$  which works activator operator as an  $Z = Ce(IV)$ , which works as an inhibitor operator. The food is  $CH_2(COOH)_2$  and

$\text{BrO}_3^-$  and excretion is  $\text{HOBr}$  or  $\text{BrCH}(\text{COOH})_2$ . There are many substitutes for it: “The only irreplaceable initial reagent is the oxidant bromate. Ce and Mn ions can be used as the catalysts as well as complex ions of Fe, Ru, Co, Cu, Cr, Ag, Ni, and Os; each usually with two or more different ligands. A plethora of various reductants give rise to oscillations” [26] as long as oxidant bromate is kept. Slowly, the system runs out food and the reaction ceases.

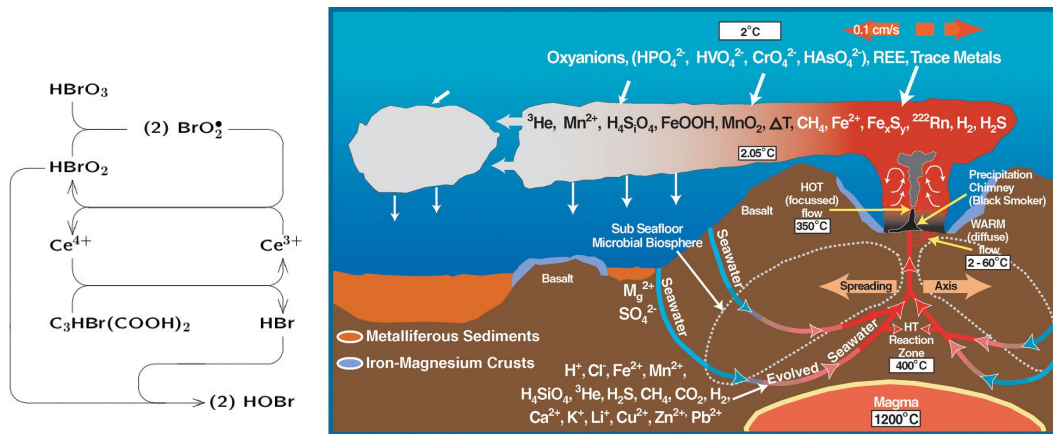


Figure1: On the right, it is shown a scheme representing a possible mechanism of Bz reaction. Released in CC 3.0 license, scholarpedia. On the left, a diagram of the hydrothermal circulation in a mid-oceanic ridge (MOR) system. U.S. federal government work, public domain

In the additional notes, a rich example is presented, the classical Briggs–Rauscher reaction, where the controllers are iodate and hypoiodous, where the food is  $\text{CH}_2(\text{COOH})_2$ , malacoid acid, and oxygen. Note that in order for life to emerge, within a BZ set up, it would be required a reaction involving boron, which stabilizes ribose and do not let long carbon chains to accumulate. So far, I couldn't locate any paper that resolves this problem, but I believe it is possible, given the similarity, in many cases, between the carbon, which is present in many chemical clocks, and boron nitride.

## 1.4 Starting up life as we know it

In the primitive ocean, large masses of water, in different states, carried a similar reaction, though with organic matter as input. As it was noticed, there is the danger of running out of equilibrium, so some operators tended to be superseded, or controlled other, more stable ones. The addition of a membrane kept all these units close.

The idea is that the primitive ocean was replete of this mechanisms, where it got its energy by several sources. I suppose that there were cycles in many places, such as near underwater volcanoes, near the surface of the sea( fueled by substances synthesized by UV-light) or by meteor crashes. The possibilities are numerous. But, most likely, evolution began on the limits between these environments, where chemical clocks were on the threshold of survival. The reason is that the circulation within each of these environments tended to be non chaotic, but in the boundary, the difference in speed and density of the solutions, caused the Reynolds number to be high.

In such view, more complex networks of chemical clocks could compensate for the difference in media, with the tendency to stabilize those that keep stable under turbulence. Lipid membranes could work as a way to keep substances attached so that, the important substances could be kept in place when going through such zones. So,

keep going with these reasoning, RNA molecules would be an advantage to these systems, when membranes, as way to kick start these reaction. RNA, specially a long chain of adenosine nucleotide, so that it could serve to attach energetic chains, since phosphoric acid holds a lot of energy (this molecule is similar to the energetic molecule ATP). These RNA attached frequently attached certain amino acids to increase the energy density even more. These longer and longer chains, could, eventually, appear types that could achieve reproduction, very imperfect. As time went, RNA was reproduced with precision and some secondary function among RNA began, like acetyl-CoA (which is similar to ATP and A nucleotide), which metabolizes lipids. Eventually, for the sake of stability (RNA is very unstable), and thus exactness of reproduction, a more stable structure appeared appeared, the DNA. At this stage, the existence of a geometrically undefined chemical clock was counterproductive, deadly, it was incorporated to the set of attached structures of the self replicating lipid membrane.

Note the similarity with the virus, where it is active, that is alive, only when within certain places. The Alkaline type of thermal vents is a colder type and it tend to accumulate in the most superficial layers a large concentration of amino acids. This follows the approximately the Obcell theory[15], except that there was a evolutionary pressure to enter more niches, within hydrothermal vents, where more substances could enhance the chances ways of survival due the abundance of nucleotides[28]. This view incorporates Iron–sulfur world hypothesis sulfur hypothesis incorporates natural catalyzers, of ions of Ni or Fe, present in the catalytic sites of important proteins common to all live. It would be a primitive remain of the earliest stages of life Given its porous nature as well the evolutionary path from less, the obcell could travel attached from displaced porous places, that feel from vents and carried to others. It would infiltrate the structure and continue its spread.

## **2.The eight immortals of the animal kingdom**

Life can incorporate mathematics within more complex organisms. The formation of basic patterns of bilaterians, organisms where left and right sides are mirrors, it is formed by breaking the symmetry of a sphere. The embryo stars developing when a certain point marks a pole from where everything will develop (I am following the views of the authors of [27], any errors are of my responsibility). A protein called Notch will give the starting point where everything will be built, that is, it gives the polarity to the body structure. Seven more signalers are involved on this WNT patterns the anterior posterior axis (AP) and triggers the dorsal ventral axis (DV); Bmp patterns the DV as well as the development of mesodermal structures outside the head, like bone structures, muscles, heart; Fgf guides the mesoderm and the non cephalic neural system towards their destination; Shh will provide a gradient to differentiate motor and somatic neurons; Pax will sign the formation of neural tissue and eyes and Hox will say what every somite or segment of the body will form, for example the type of muscles, bones, limbs, wings or antenna will form at each segment; Para-Hox will sign the formation of structures of the posterior body of the gastrula, like the brain, mouth, gut. There are many other signalers, which are “conducted” by these 8 types of proteins, which here are only mentioned by their vertebrate function in shaping the body during gastrulation and (though there are a rich variety of equivalents in other animal phylums, with different names). Each one of these have a dozens or hundreds of antagonists and triggers, but I will focus on only the ones which are more widespread within phylums.

Note here that this is some kind of “magic”, that like an illusionist “defying” gravity, it seems to defy evolution. There is a reason for this, which will be explained in the next session. In any case, I rather call these genes as the 8

Immortals, in homage to Taoism, or the Chinese culture in general. Each one with its functions, moods, deeds and working in ways, though imperfect, that affects the life of mortals.

Taking the chordate as an example, we have that on it there is a groove called a primitive node, where notch will actuate and cause the multiplication of cells of germinal tissue called mesoderm, it is the Fgf that will control the direction it will take. The later will grow, proportional to the size for the embryo, and it further promote its elongation by sending signals to the multiplication of mesoderm, more to the AP, determined by Wnt, and less to the (DV), according to Bmp. The notochord will develop in AP direction, followed by mesoderm on its sides. It will grow from the primitive node to the cephalic region. This node will send waves of Fgf, through the mesoderm immediately lateral to the notochord, to the opposite edge of the gastrula or where a somitomere or somite is formed. The former will be the first one to form, and will yield muscles, some cranial nerves and bones of the head under influence of Para-Hox and Pax. The somites, under influence of Bmp will form bones, muscles; under the influence of Hox, each will form the a specific set of these structures (eg., arm, legs, belly and rib cage) muscles; under Shh, excreted by the notochord, will concomitantly induce the formation of somatic and motor neurons. Curiously, the influence of Para-Hox and the Notch gradient will be in a place beyond the the neural plate (which was formed from ectoderm by influence of Pax) and the oral membrane, the heart, which will begin as a simple cavity along the extreme cephalic portion of the brain. Pax, in general, will trigger the formation of tissues, that will lead to the formation the organs, like the pancreas, eyes, teeth, and parts of the brain like the pons. Shh and Bmp will trigger the closing of the neural plate. The Bmp, Notch and Wnt will work together to push the heart towards the thoracic region and close the ventral part of the embryo.

These proteins, or their homologues (and a few analogues), are found in almost all animals, with similar functions. Even some jellyfish and sponges have them, since their larval form have a bilaterian related shape, and they swim until they find they metamorphose into a medusa (in the case of cnidarians) or a sessile form. So, the strength of this type of organization is its topological flexibility, which can, metaphorically speaking, transform a doughnut into a coffee cup (topologically equivalent to a torus), that is, it can change the body plan with great creativity, like a child playing with a Mr. Potato Head, exchanging the mouth with the anus and turning the back (dorsal) with the front (ventral) organs. In fact, this is what actually happens between Deuterostomes (greek for correct mouth), which includes, but not restricted to, Hemichordates and vertebrates, and Protostome (primitive mouth) which includes, for example insects, molluscs and annelids. Both of these groups have bilateral symmetry and all are topologically equivalent to a torus (gut + surface of the body). Those who don't, do have them at least in larval form.

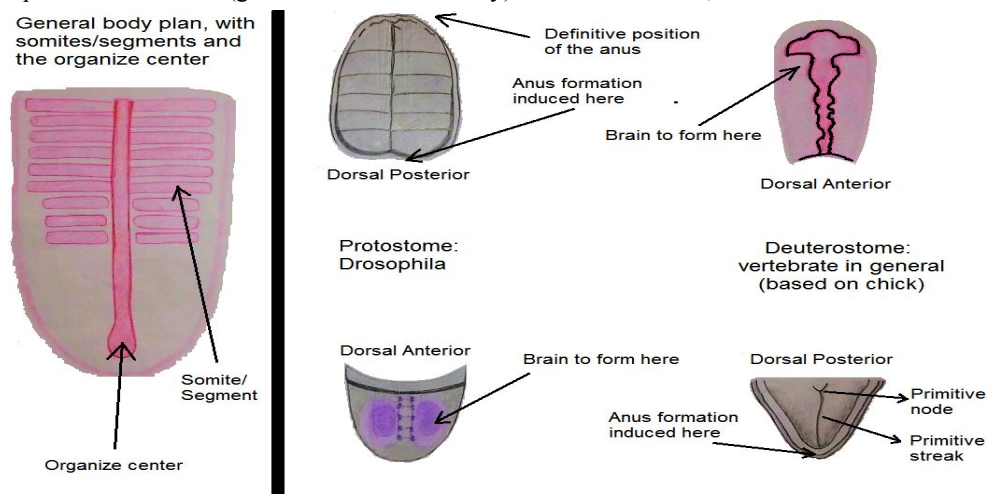


Figure 2: On the left we have the general body plan of a bilaterian, excluding the cephalic and caudal parts. On the right, we have an example of a protostome and a deuterostome. We can see the characteristic AP inversion. But note that, at least in the case of the drosophila, the anus formation is induced when the invagination of the gastrula is in its most closed form, making the anal region touch the cephalic region. The anal region is in the dorsal version, pointing to the cephalic direction. Nevertheless, considering the 180° inversion in relation to the deuterostome case, it points to the same way of the letter. I was not able to find if this is a coincidence or not. Anyway, it ends up migrating to the caudal region. Also, this migration makes sure the dorsal-ventral orientation of the deuterostomes and protostomes are inverted. Interestingly, the order of the homologous Hox genes in segments/somites tend to be the same in both groups.

### 3. Long term stability

So, coming back to the initial premises, that the purpose of life is to propagate a chemical reaction and its aim to self-regulate, notice that the absence of reproduction in the definition of life as well as the capability of reproduction. That's because, a priori, there is nothing that stops those reactions to go on forever. Reproduction is a consequence of life, given that the system will accumulate malfunctions by increasingly disturbing the determined states. So, before it breaks down, another copy is produced, without the accumulated malfunctions. But this is a localized effect. There is no clear telling where life begins or ends according to this definition. So, the chemical reaction eventually makes matter pass through all ecosystems, atmosphere, and even go to the mantle, causing new types of substances to form, such as petroleum, diamonds. This also implies, that, there is no reason, at a fundamental level, to say that all life is one. All ecosystems are like one organism. This, at a basic level, is similar to the Gaia Hypothesis. But it goes into a more chaotic level. The geological forces and, even cosmic powers, are too great at all rather short time scales (~150 million years) and sudden climatic changes caused by changes in the rotation axis of the earth, may induce glaciations and land masses may cause the increase or decrease of global temperatures. But each change selects, among all organisms, a tendency to increase resilience towards these catastrophes.

The Snowball Earth event was like the main catalyst for this. During 300 million years, the continents were mostly located in the South Pole and nearly all Earth was frozen. Sometimes completely, sometimes it retracted letting some small patches of free water free around the equator. What is interesting is that at its end, following the transitional Ediacaran period, the famous Cambrian Explosion happened, which means that all present phyla appeared in a time period of a mere 30-50 million years from what it was before mere colonies of protozoa. The most parsimonious explanation that I can think of, in this case, is that the small spaces, during the long ice age, close to the surface, where nutrients could be found, were opening and closing in rapid frequency, due to variation in the ice surface, such that the most diverse changes in environment were constantly happening.

When ice fully retreated, life was ready to manifest in many new environments, now with a very sturdy body plan, that could be easily adapted, that is, in rather small timescales. An extreme example of this are starfishes, where, though the larva are bilaterians, a n-gon structure is generated within it, and eventually it sheds the remaining body, so that the adult has a more complicated body form. In another example, the famous *Drosophila melanogaster*, a fruit fly, changed the proteins that give origin to the body plan for other equivalent, though non-homologous, like the case of bicoid gradient, replacing wnt, that comes from synthesized from RNA from the egg. It is until the 13th cycle of cell division, where which other proteins from the larva take over and rapidly segment and with a few more divisions.

So, as life spread into many new niches, new challenges had to be faced. From this point, though, life was exposed to catastrophic impacts from asteroids and volcanisms, while before it was quite isolated, given that organisms were small and hidden from large scale impacts. At every world catastrophe, new types of organisms occupied the oldest ones, and the general strategy led many families of animals to increase the neural capacity. In the most recent glaciations, which has been happening in the last 2 million years, some genera of monkeys could achieve to extreme

levels of brain capacity, yielding an extremely high level of mental capability. And of all these species, only one remained, the *Homo sapiens sapiens*.

## **4. Human beings represents the conclusion.**

As a corollary of the “extended gaia hypothesis”, where life becomes sturdier when it relates to Nature, we can say that any society of organisms is, to a large extent, an organism itself. It may vary in complexity from a spectrum that includes parasitism, cooperation, colony up to a multicellular being (from the perspective of individual cells). Human societies can be seen as a type of organism and as such, it can be ascribed aims and intentions. It is, though, hard to identify which are those, since we usually only have access to either individual or tribal views. We can see that each individual human or the society to it belongs have shared needs. Unlike all beings in history, these needs require planning to be fulfilled, like, how much area is required for crops, what is the distance between places and how long does it take to transport goods. So, at this level, the mindless laws start to be understood and be applied, and by applying them, it gives society and individuals alive new needs. So, life, by the means of human mind, begin to ascend the laws of mathematics from mindless level to a mindful stage, when it is applied to physical laws, in order to predict and plan activities. It is no wonder that the earliest marks of organized society was the use of tally marks to count, dated from before 20,000BCE. See the case of Shango Bone[21] and the use of tokens that preceded written language, in mesopotamia, around the 5th millennium bce[22]. That gradually escalated, to the extent where it was possible to write equations to enhance technology and revolutionize human life through the use of applied science.

So, at the present time, mathematics cannot be dissociated from people. It is here to help to fulfill desires and needs of humans. Thus, it can be used to change the intention and aims of society, based on how technology progressively changes everyone’s lives. But, we haven’t yet assumed fully the control of this symbiosis with mathematics. From the beginning organized civilization, we let the destiny in the hands of a few people, who do not always have much concern about the equilibrium of nature and mankind. We let them control both economy and politics, without the required care. On the other hand, Mathematics, allied with science, makes sure that not only all of us can get educated about the most advanced and up to date issues, but also provide each one of us the capacity to raise everyone else’s awareness about ecosystems, pollution and management of resources. So it is our duty to take control of our future and move above the level of a “brainless” civilization, where only an elite has the power over our destiny. Science shows the way to avoid catastrophes and how to live in harmony with nature, in a never ending interaction with mathematics(which is not mindless anymore).



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# Additional information.

About clock models:

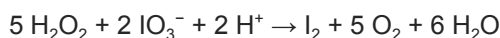
There is a small number of classes of chemical clocks, like:

Belousov–Zhabotinsky reaction, which consists of bromine and an acid.

The classical reaction is  $3\text{CH}_2(\text{CO}_2\text{H})_2 + 4\text{BrO}_3^- \rightarrow 4\text{Br}^- + 9\text{CO}_2 + 6\text{H}_2\text{O}$

Briggs–Rauscher reaction substitute bromate ( $\text{BrO}_3^-$ ) in the BZ reaction with iodate and adding hydrogen peroxide.

Bray–Liebhafsky reaction consists in the oscillation between iodate back and iodine.

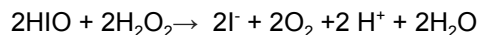
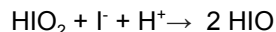
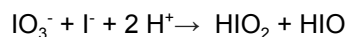


Net reaction:  $2 \text{H}_2\text{O}_2 \rightarrow 2 \text{H}_2\text{O} + \text{O}_2$

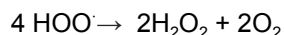
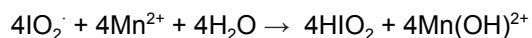
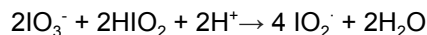
An approximate of the Briggs–Rauscher is a sort of combination of BZ reaction and Bray–Liebhafsky reaction is given as follows. It gives a very beautiful color change scheme when mixing is applied.

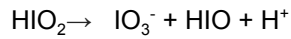
It consists of 3 branches, one involves the production of iodite ( $\text{I}^-$ ), the so called “non radical process”(A), and the other involves the production of hypiodous acid HIO (B), the “radical process”. Branch (C), there is production of  $\text{I}^-$ , though there is no such name in the literature, I think it is a more enlightening perspective to put in this way.

For A, we have the part where the solutions turns transparent, with production of iodide:

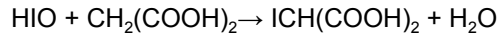


For B, we have the autocatalysis of  $\text{HIO}_2$  with the yield of HIO

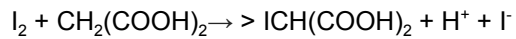
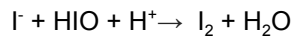




For C, we have the consumption of HIO.



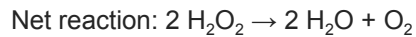
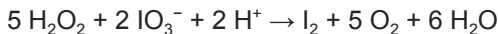
The change in colors happen with the variation in proportion of I<sup>-</sup>, HIO. If HIO > I<sup>-</sup>, we have amber; if HIO < I<sup>-</sup> we have dark blue. If both are in small quantities, we have clear transparent. Summing up the reaction with HIO > I<sup>-</sup> we have, by isolating the creation and decomposition of HIO and I<sup>-</sup> in different sides, we have



The reaction can vary in a cycle of more than 16 different succession states, with also varying smell.



Bray–Liebhafsky reaction consists in the oscillation between iodate back and iodine.



The two main models to describe a chemical clock are FKN mechanism, Brusselator and the Oregonator (a simplified model of the first). These are not like the Lotka–Volterra equations (which models predator prey systems or mutualism), since they necessarily have a limit cycle.

These oscillators reaction have no precise description up to date. What is available are models based on the initial and end species, with the main detected chemical species. Since this is a non linear model, it is not known whether or intermediate very ephemeral species play a significant role in the overall reaction. Apparently, there is a limit cycle, but there is also region of bifurcation and chaos in the parameter space. So, away from stable region, there is no guarantee that this will work. Given that in both theory and experiment have in common limit cycles, it has been possible to reproduce qualitatively well the characteristics