Subject: Science
Article: 11

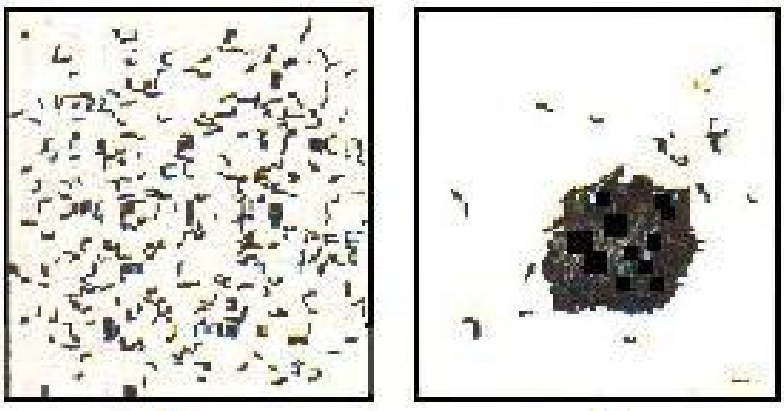
Order and Disorder

Doç. Dr. Haluk Berkmen

When we say that "***there is order***" we mean that the system in question is organized, regular, constant and in balance. It is believed, in general, that there are certain laws and rules behind the apparent order. This kind of thinking led to **determinism**, which has been the main guideline of scientific thought for many centuries. With the advent of Quantum Mechanics and Statistical Mechanics the scientific community started to develop mathematical models for dealing with the irregular, unpredictable, disorganized and chaotic nature of our universe and our surrounding. During the recent decades we came to the realization that a system which has reached a certain critical point can suddenly **self-organize**.

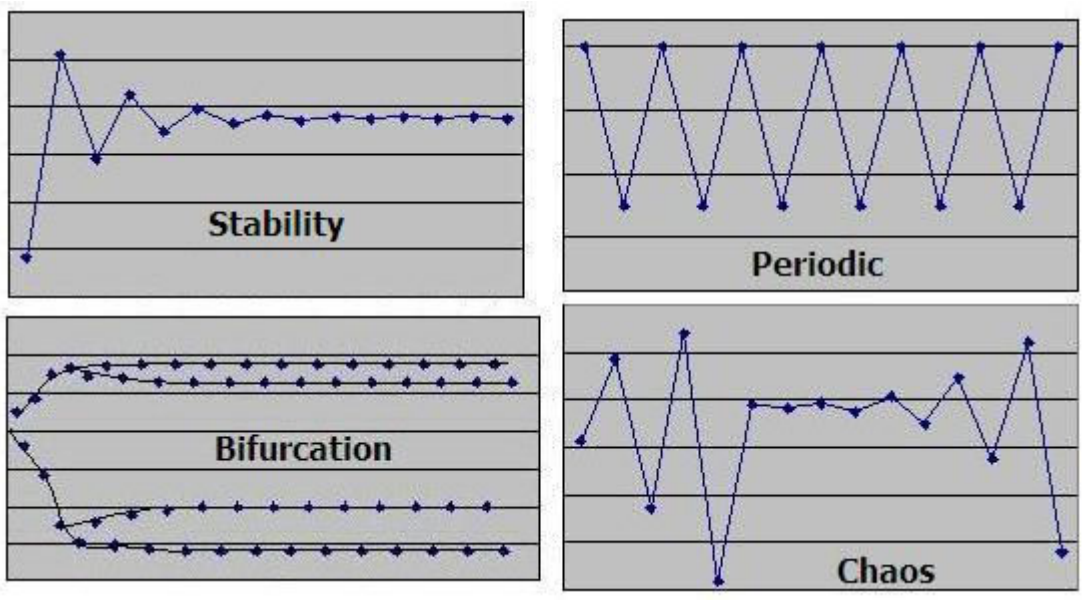
An important question among the physicists is "How and when does self-organization appear?" The study of self-organization is now a multi-disciplinary subject, with many practical applications. Self-organizing systems are inevitably open rather than closed, which means that there is at least one neighbor system with which they can exchange energy. They are also recursive and non-linear.

All living organisms (systems) exchange energy with the environment therefore they are open and have the capacity to self-organize. As a simple example, let us consider an aggregation of slime molds within an environment where plenty of food is available (figure A).



If the environment becomes poor in food and slime molds are threatened with starvation, they coalesce into a single supra-cellular mass (figure B). In the first case, the second law of Thermodynamics applies and Entropy increases. The molds spread inside the medium and there is no apparent order or sign of organization. At a certain critical point self-organization appears and molds are attracted towards the growing mass. The attracting center may or may not be a physical center. It is, in general, a mysterious focal point that has been named, **Strange Attractor**.

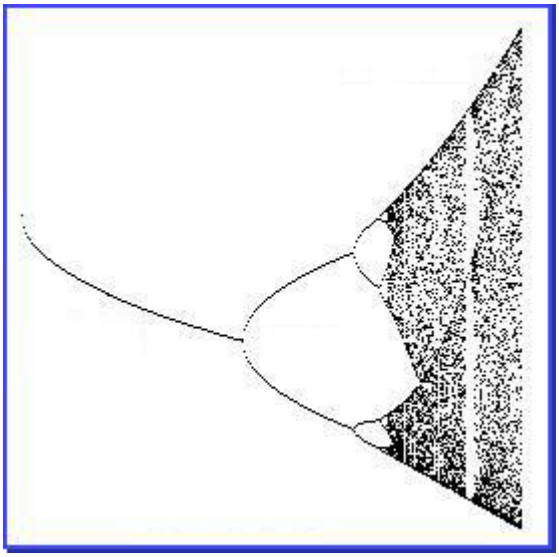
The strange attractor is a non-physical set having a recursive and fractal structure. It is self-referential and is the main agent creating self-organization. There can be several strange attractors acting on a given system. If there is a single attractor the system will come to equilibrium and a stable state will result. The center of the earth is a clear example for a single attractor. Another example is the sun attracting the planets. All planets revolve around the sun in definite elliptical trajectories. Thus, a single attractor can also give rise to regular and periodic motion. If there is more than one attractor the system can become chaotic and a bifurcation happens at a critical point or critical moment. The bifurcation can lead to new stable states or to total chaos. The **Spontaneous Symmetry Breaking** mechanism is a bifurcation that results in creating new stable states. The sudden change in the weather conditions and the starting of a storm can also be considered as a bifurcation happening suddenly at the critical point and giving rise to a chaotic situation. Since there are different influences starting a storm, such as temperature and pressure, we can accept that the storm is affected by at least two strange attractors.



The graphs above demonstrate the four different states that a system, which is self referential, can end up. In the top two graphs a single attractor is affecting the system. In the lower two graphs there is more than one strange attractor. As shown in the lower left graph, the system starts by bifurcating into two states and later on each branch bifurcates into two new states. This process may or may not continue ad infinitum. The graph on the right demonstrates total chaos.

In the chaotic regime there is no specific pattern of organization, but never the less the system does not explode and diverge away from its strange attractor.

If bifurcations continue to increase the result will be a multitude of interconnected states. This is what we call **plurality** and **multiplicity**. It is interesting to notice that it all started from a single state that bifurcated into two branches, as seen in the graph below.



In the present model of the universe there is a similar situation where a multitude of particles can come into existence from a single excited state. The first bifurcation creates two regions in which two universes are formed. These are: our universe where all particles are constrained to move slower than light and a mirror image universe where all particles are constrained to move faster than light. Further bifurcations will first create unstable particles and then the four elementary particles (n, p, e, v), which will form the atoms, the molecules and the stellar objects. Each bifurcation happening at a certain critical point.

In the present model of the universe there is only one equation, which contains only three parameters. That equation can exhibit all the different states and situations depicted in the graphs above. This equation is:

$$\mathbf{T(x) = px + qx^2 + rx^4}$$

The T function is the T-field mentioned in the previous chapters and the three constants p, q and r are called the "**order parameters**". They define the shape of the potential energy T. We see below the two graphs that have been obtained from the above equation by setting p = 0 and r equal to a negative number. The first graph represents the creation of a particle and its antiparticle, while the second graph represents the creation of an unstable particle decaying into a stable one. These graphs were discussed in article 6, **Baryons and Leptons**.

The four graphs shown in the top page, ***stability, periodic, bifurcation and chaos*** are also formed from the T(x) field equation. Small changes in the order parameters gave to strikingly different results. We now understand that order and chaos are not incompatible, but are quantum jumps that can pop-up at a

certain critical point. This happens because no natural system is isolated and closed. The interdependence is a **requirement for existence**.

Critical point ==>