The Entropy - Syntropy Inversion in Water
Part II
from Physics to Biology

John Grant Watterson [1]

1. The Two Natural Tendencies

We live in an expanding universe. On the grand scale, cosmologists tell us that the galaxies are speeding away from one another at an ever accelerating rate. On the small scale of our world, we also notice things disperse – there are forceful currents in the air and sea, our energy and resources supplies are being spread out and wasted. Overarching these processes of thinning, fragmentation and loss, physicists tell us is the unidirectional march of Nature towards the inevitable Heat Death of the Universe.

On the other hand, we also live in a contracting world. Earth's gravity is forever acting on us and our actions. It is all-pervading, we cannot shield our activities from it. Rain falls from above, objects that we neglect fall to the floor, great cities collapse in rubble onto the ground. All matter moves as close to the Earth's centre as possible. Perhaps also on the grand scale of the wider universe as well, black holes in the centre of galaxies pull their vast collections of stars together in unified formation as they spin.

Fantappiè's contribution to our understanding of these two natural tendencies is explained fully in Part I, following Di Corpo and Vannini (2010). In this present work, we recognize them as spontaneous flows of matter and energy, one outwards and the other inwards. I'll call them, the *entropic flux* and the *syntropic flux*, respectively. These terms refer to basic phenomena best described as movements, either of breaking up and escaping away into larger environments, or of fusing together and concentrating into smaller regions of space. Fig 1 shows simplified diagrams of this concept. Readers educated in physics recognize them as pictorial representations of "force fields" or "vector fields". But for more familiar examples let's look at some situations taken from the wider sciences.

All gases expand, especially hot ones. They have to be kept in a closed container. Another simple dispersion process is the diffusion of solutes in solution – dissolving a spoonful of sugar in your cup of coffee. Or the transfer of nutrients around the body carried by the blood supply, or the dissemination of pollen by the action of wind and rain. On the other hand, consider the separate molecules of that hot gas. Each molecule, viewed in isolation, is a stable unit made of atoms held together by bonds even as the gas itself expands. For example, the bonds that hold together a molecule of air, say a nitrogen molecule, are so strong that a lot of chemical energy is needed to break it apart. Molecules are nano sized solid objects. If the two tendencies are equally strong, then we say there is equilibrium. Or expressed another way, an environment experiencing both simultaneously – the dispersed and the connected – remains stable. This explains the long-lasting

[1] John Grant Watterson, 18 Tomanbil Terrace, Ashmore, Queensland 4214, Australia
jgwatterson@gmail.com

existence of the nitrogen molecule in air on the small scale, and also of the gas giants on the large scale. In the planet Jupiter, for example, the outward pressure at its centre is high enough to prevent its enormous gravity from pulling its gas molecules too close together and lighting up their nuclear fire. Or returning to our world, even though the air molecules of our atmosphere have enough thermal energy to exert a pressure of 1000 hectopascals – a force that constantly drives them outwards and upwards – the inwards and downwards force of gravity gives them a weight which is large enough to prevent them escaping from Earth, and so the size and content of our atmosphere remains constant (hopefully!).

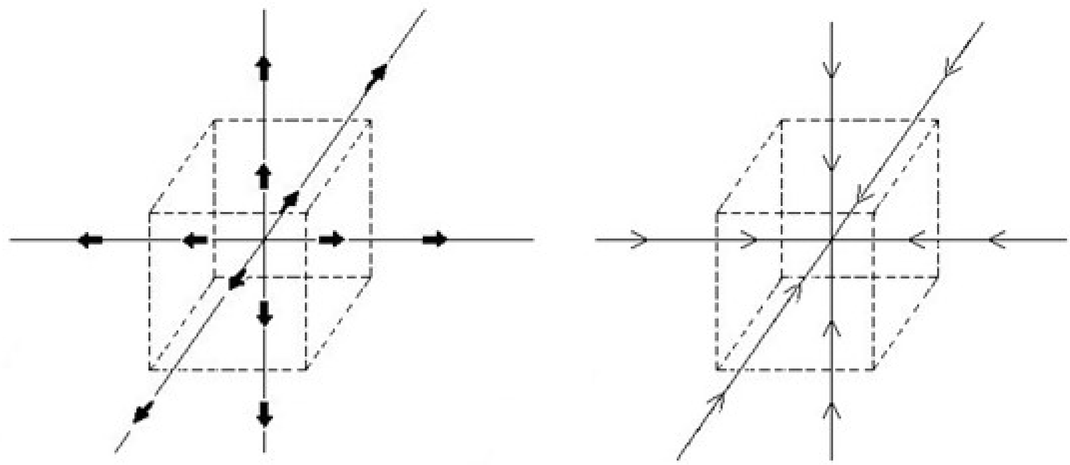

Figure 1. The Entropy and Syntropy Fluxes
Diagrammatic representations of the entropic (left panel) and syntropic (right panel) fluxes shown as lines in a 2D "force field". A more realistic representation in 3D would be appear as a "solid" or "block" sphere expanding (diluting) or contracting (concentrating).

In these examples, we have an entropic drive (pressure) balanced by a syntropic drive (chemical bonds/gravity) acting independently of one another within the same spatial environment. Such systems remain in equilibrium as long as there is no energetic exchange between the two hierarchical levels. However, in cases where there is exchange, then a dynamic comes into play. Consider the basic unit of life – the cell. Its outward growth is the result of cell division, which in turn is underscored by internal processes of contraction that control the movement of its constituents, which must be shared between the new daughter cells. In this multi-layered system we see an interdependence of the two drives, where demands made by one, on one level, stimulate energetic responses from the other, on another level.

We recall however, that according to established thermodynamic theory outlined in Part I, there is only one drive – the drive of entropy. And importantly, this is not to be understood as a drive in the usual sense of a basic underlying force, but simply as a passive process of ever increasing randomness in the distribution of all matter and energy, which as mentioned in the introductory paragraphs above, leads to the inevitable Heat Death of the Universe. This concept is enshrined in the Second Law of Thermodynamics. And in my experience from contact with physicists, this law is to be taken as the most fundamental of all the laws of physics. As the astronomer Eddington (1928) famously announced: ". . . *if your theory is found to be against the Second Law of Thermodynamics I can give you no hope, there is nothing for it but to collapse in deepest humiliation.*"

And further, gravity, which a spectator might think would be placed centrally by many physicists, especially by cosmologists, can be ignored as a drive, because it acts mechanically on masses. The weight of a body is a Newtonian force, and as such does not contribute to the all-powerful thermodynamic changes that underlie the inevitable dilution, decline and disappearance of the Universe's resources.

In Part I, we discussed at length how many thinkers have pointed out that this continual entropic dispersion and randomization of matter and energy, cannot enlighten us in our attempt to understand living matter and its evolution over time. Living matter conserves, it does not dissipate energy, and additionally, it becomes structurally more complex as it evolves. Yet in spite of these obvious facts, the fields of irreversible, or non-equilibrium thermodynamics, as well as some versions of chaos theory, have been developed over the last three decades, which claim to support the concept of the statistical basis of life, and thus keep the dissipative entropic flux as the single cause at the bottom of all natural processes.

I know of no biological evidence to support this claim. In fact, even the simplest of life forms, as for example, the plankton of the Antarctic ocean, are so efficient at capturing just a fraction of the little solar radiation that reaches their inhospitable world, conserving and converting it, that they are the very foundation of almost all marine animal life! They begin with this weak source of radiation and build energetic structures with it. And we see the same biological scenario on land, where we know what depends upon the output of plants? – the construction and maintenance of the entire animal kingdom!

The action of these basic life forms tells us that their biological function is to catch the energy available in a natural flux, in this case the sun's radiation falling on the Earth's surface, and diverting it to create another, higher form. Instead of producing heat, as the entropic flux of sunlight does, it is converted into chemical energy. All life forms are an organized assembly of energy converters – molecular machines which manipulate energy, pumping it upwards and downwards throughout the entire biosphere. They perform the steps of trapping, storing and transferring quanta across all its hierarchical levels from plankton to brain.

As I mentioned in Part I, I recognize that many researchers, especially those sympathetic to biology, have a negative response to the concept of "machine". So I stress again here, my meaning is not to convey the picture of mechanical, as an engineer would imagine, but simply as a mechanism, and even an abstract mechanism, that forms a defined conduit for energy to follow as it moves up and down, and thus avoid its randomization.

2. Following Carnot

The action of our man-made machines proceeds through similar basic steps. In the steam engine for example, heat energy is captured by water molecules, which increase their kinetic energy to such an extent, that they become high pressure steam. The steam then pushes a piston to give us usable mechanical force, rather than simply heating up the surroundings. So the piston in the cylinder is an arrangement of solid machine-parts that directs energy flow up to our macro world where, without this mechanism, the heat would simply further disperse on the molecular level – a process contributing entirely to the overall entropy increase of the Universe.

The Second Law of Thermodynamics tells us further that, even when a machine is operating and producing useful work, some of the energy – indeed usually most – will nevertheless be dispersed through fragmentation and so lost by spreading out into the surroundings. This is the basis of Clausius' famous dictum, that the entropy always increases during any natural process. He derived his overarching result through analysis of heat machines that deliver work by exerting pressure – the steam engines of the industrial age. As I've just outlined, those machines captured their energy from the entropic heat flux produced by burning fuel, collecting it and transferring it upwards through the thrust of the piston shown in Fig 2. Since the heat source is an outward flow, this mechanism is an example of an up-out action. (For a fuller description of types of work action, see my forthcoming book "The Pixel Machine" on www.thewaterpixel.com, or available free to interested readers on writing to jgwatterson@gmail.com).

However this is only half of the story. Upward energy transduction can also be achieved by a machine that pulls on the piston. Such a system depends on a mechanism operating in a syntropic flux, since its action captures energy from an inward flow. Its cycle in Fig 3, which shows that the working piston stroke is achieved by a pulling force, can be analyzed in the same way as Clausius did with Carnot's cycle. Energy transfer is again upwards to the macro level, so in this case we have an example of up-in action.

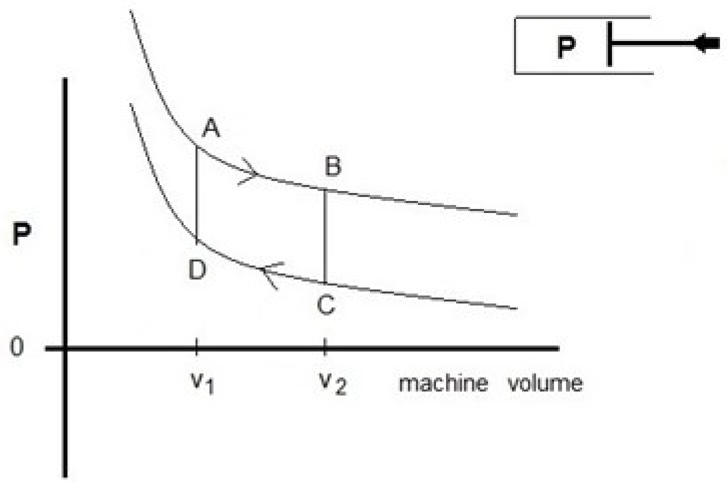

Figure 2. The Pressure Machine, or, up-out Work

The plot of pressure versus volume gives the work done by the piston machine as it pushes against an external load down the power-stroke, A to B, while expanding its volume. During the step B to C, the pressure of the working agent inside the cylinder drops (because the temperature of the steam inside the cylinder drops), so that the piston can be now pushed back along the return-stroke, C to D, by a lower external force than the piston exerted in the outward power-stroke, A to B. During the step, D to A, the internal pressure of the working agent is returned to its highest value (as new high pressure steam at the high temperature is introduced into the cylinder). In mathematical terms, the work performed in one turn of the complete cycle, ABCD, is given by the area under the high pressure plot AB, minus that under the low pressure plot CD.

thick arrow on piston shaft = pressure.

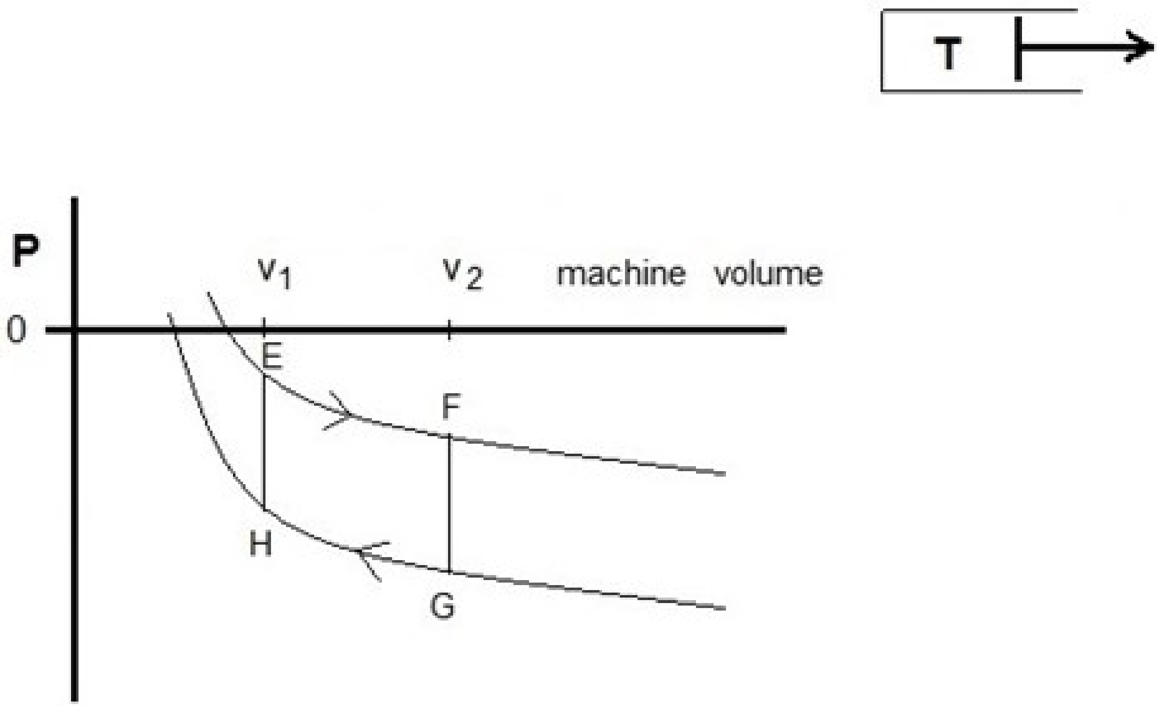

Figure 3. The Tension Machine, or, up-in Work
Plots of tension (negative pressure) versus volume gives the work done by the piston machine as it pulls on an external load up the power-stroke, G to H, while reducing its volume. During the step H to E, the tension of the working agent inside the cylinder drops (it develops a lower negative pressure), so that the piston can now be pulled back along the return-stroke, E to F, by a lower external force than the piston exerted in the inward power-stroke, G to H. During the step, F to G, the internal tension exerted by the working agent is returned to its highest value. In mathematical terms, the work performed in one turn of the complete cycle, EFGH, is given by the area above the low tension curve, E to F, minus the area above the high tension curve, G to H. In machines which change their volume, V, by osmotic mechanisms, the walls of the cylinder are semipermeable, since they must be surrounded by solutions acting as source and sink to supply solvent which enters, V1 to V2, and exits, V2 to V1. Hence the construction material here differs from the familiar steel of heat machines which are the basis of the Carnot cycle, where entry and exit of high-temperature steam or combustion gases is controlled by operating valves located in the cylinder walls.

thin arrow on the piston shaft = tension.

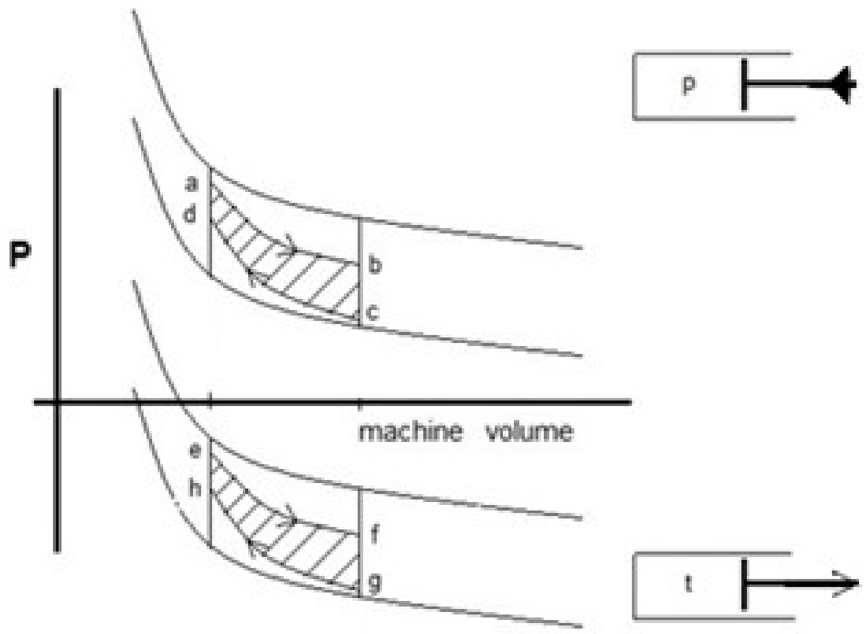

Figure 4. Real Work Cycles
Real machines do not produce work with 100% efficiency. The cycles, abcd, and, efgh, illustrated here enclose the shaded areas, which are smaller than the ideal maximum areas of the Carnot cycles. Clausius showed that the area difference in the positive pressure regime represents the entropy created in the environment by the lost heat. Analogously, the difference in area between the ideal and real cycles in the negative regime represents the syntropy created in the environment from wasted tensile forces.

thick arrow = pressure
thin arrow = tension

The plots of pressure shown in the figures are derived from Carnot's original thesis, "On the Motive Power of Heat", published in 1824. Such diagrams are idealisations only, which cannot be achieved by operating real machines. For that reason, the area they enclose represents the ideal, or maximum, amount of work we can gain from a given cycle operating between a natural source of energy (fuel) and a natural sink for the unused energy (environment). Therefore, it follows from the Second Law, that the area is smaller in a real machine (shaded area) due to inherent inefficiencies, as illustrates in Fig 4. The area enclosed between the ideal and real cycles represents the missing work which is not performed, and this in turn indicates the entropy created in the environment during a real, inefficient cycle.

In the negative regime of Fig 4, the same considerations apply. There is again less work achieved than in an ideal cycle, whereby the missing work is given by the difference in the cycle areas. However in this case, the energy is supplied by a syntropic flux, which produces an inward momentum to be exerted by the medium. The missing work now makes a positive contribution to the negative energy source so reducing its availability. In mathematical terms, the ideal power-stroke, GH, sweeps out a larger negative area than the real power-stroke, gh, does. So in this case, energy that failed to be captured by the machine remains in the external syntropic flux, where it fuses into fewer quanta, in contrast to energy lost in the entropic environment, where it splits into more quanta. We can go even a step further in the interpretation here and say, this result shows that information is lost, when syntropy is produced just as when entropy is produced. This follows because the number of quanta of the unused lost energy is reduced due to the concentrating influences in the environment, or put another way, individual energetic identities disappear.

3. Osmotic Mechanisms

Of course, gases cannot pull on pistons, so we must go to other systems to find examples of the inward-directed action driven by syntropic flux. In introducing the two natural fluxes earlier, gravity was presented as the all-pervading concentrating influence in our everyday environment. But in the biological world, by far the most important medium, which is able to exert both entropic and syntropic forces, is water. We saw how water, and liquids in general, possess the intriguing characteristics of being both part gas and part solid. Liquids are fluid because they can change shape to adjust to the shape of their container, but they keep their size because, like solids, they are held together internally. In the scientific terminology of physics: they exert pressure on the macro, but tension on the micro, level.

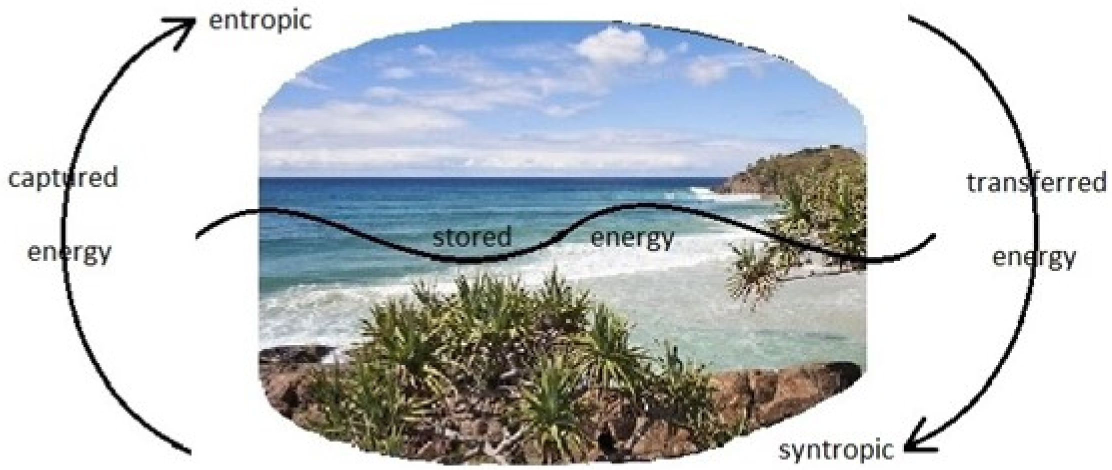

Figure 5. Earth, Sea and Sky
Leading on from Fig 3 of Part I, we have now more information about the triple-layered surface of our planet showing the overall cycle of outward and inward energy flows. Solar radiation produces the entropic drive by evaporation from the oceans (lifting water), while condensation provides the environment for the opposite syntropic (falling water) drive. Evolution proceeded in the layer where the energy could be stored, and not in an environment where the energy could be further dissipated and lost.

Let's recall how these properties have affected the environment of our planet, illustrated here now in Fig 5. It is natural that the biosphere would originate in the intermediate water layer, because that's where the clusters and anticlusters exert their opposing forces. Neither the gaseous nor the solid environment supplies the conditions whereby these forces can interact and play their roles as components of the 4 types of machines that operate in living systems.

As we saw illustrated in Part I Fig 4, the membrane which surrounds the frankfurter sausage, plays the role of a versatile machine part. In a pot of fresh water, clusters inside push causing the membrane to swell, and conversely, in salty water, anticlusters pull causing it to shrink. When a body of liquid is under macro tension, the individual molecules inside anticlusters push, rather than pull, on one another. In this case, molecules can be pushed through the membrane pores, even when there is macro tension in the solution they are leaving and macro pressure acting against them in the solution they are entering.

To us, the watery medium that is a gel appears to be stationary because it is solid, but on the molecular level movement continues within the anticlusters. This means, that although the medium is under tension on the macro level, the molecules are in motion and exerting pressure on the micro level. Although they are well known in biology, gels are not studied by chemists or physicists. Gels comprise 70-80% of living cells and have intriguing physical properties that are crucial for living matter. For example, every muscle cell, from the tiniest insect wing to the strongest weight-lifter's biceps, contracts as it develops active tension. Gels are the living medium, able to generate forces observable on our macro level illustrated in Fig 6.

However, perhaps the majority of biological activity is not mechanical, but enzymatic, that is, chemical changes catalyzed by proteins. The work of enzymes is not visible to us. It does not involve large-scale movement of matter, as we see in the work done by the pistons of our machines and the muscles of our bodies. When the antarctic plankton trap energy from the solar flux, they insert it into chemical bonds to build the constituents of their cells and fuel (ATP, sugar) to power their actions. Thus they do downward-directed energy transfer without changing their size, since chemical changes do not rely on overall size of the system, but on internal grain structure under the control of localized fragmentations and fusions.

To follow this argument, let's recall the concepts that flow from Fantappiè's insight:

- the entropic flux includes the processes of fragmentation and expansion, which result in dissipation due to spreading outwards into space (eg, as heat sources do),
- the syntropic flux includes the opposite processes of fusion and contraction, resulting in losses due to coalescence and shrinking in space (eg, as rain falling to earth does).

In Fig 4 we saw examples of expanding energy used to fuel up-out mechanisms, and of contracting energy used to fuel up-in mechanisms. These machines produce their work by causing changes in their volumes through expanding and contracting, or in the language of physics, through displacements in space. But now we consider mechanisms which do not cause mechanical changes, but transfer the captured energy downwards, shown diagrammatically as down-out and down-in action in Fig 7. These machines possess internal structures which alter the strengths of their chemical bonds. We recognize enzyme action as chemical work – work, because creating energetic molecules does not happen spontaneously. Indeed, the fact that Earth is covered in a vast array of energized unstable molecules synthesized by living matter, contrasts starkly with the surface chemistry of our sister planets. Their atmospheres are home to the small, stable, dead molecules of simple gases (eg, nitrogen, carbon dioxide, methane mentioned above), whereas our biosphere – the layer between the solid earth and gaseous sky – contains peptides, hormones and vitamins!

Let's extend these concepts a little deeper into the biological arena. The dynamics of living systems need energetic transfers to levels both above and below – upwards for mechanical changes to organize macro movement, and downwards for chemical changes on the micro level of metabolism. Living cells exhibit orchestrated transfer of material, for which they need chemical energy, that means, they have to be supplied by a fuel source, (sugar, ATP), so this type of mechanical activity – from fuel to force – is upward-directed. But naturally the fuels themselves need to be earlier synthesized by enzymes that insert solar energy into the chemical bonds of sugar molecules, and this type of activity is downward-directed. Living matter is therefore a layered organization of machinery that transfers energy between hierarchical levels of scale. That both transfer directions are possible within the medium of the cell, is a consequence of the switch that occurs naturally in the structure of liquid water – the cluster-anticluster inversion.

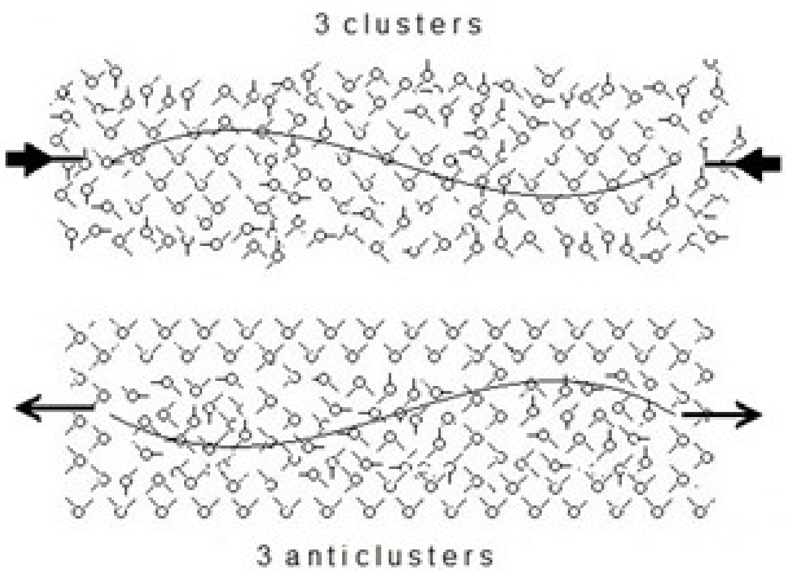

Figure 6. Clusters and Anticlusters
Pictorial representation of clusters showing structured regions of water molecules separated by randomly orientated fluid molecules, and anticlusters showing random regions isolated within the bulk phase of ordered gelled molecules. In fluid water (upper panel) there is pressure exerted on the macro level, and tension on the micro level. In gelled water (lower panel) there is tension on the macro level but pressure on the micro (molecular) level. Pressure and tension waves in the medium are discussed in my forthcoming book "The Living Pixel" on www.thewaterpixel.com.

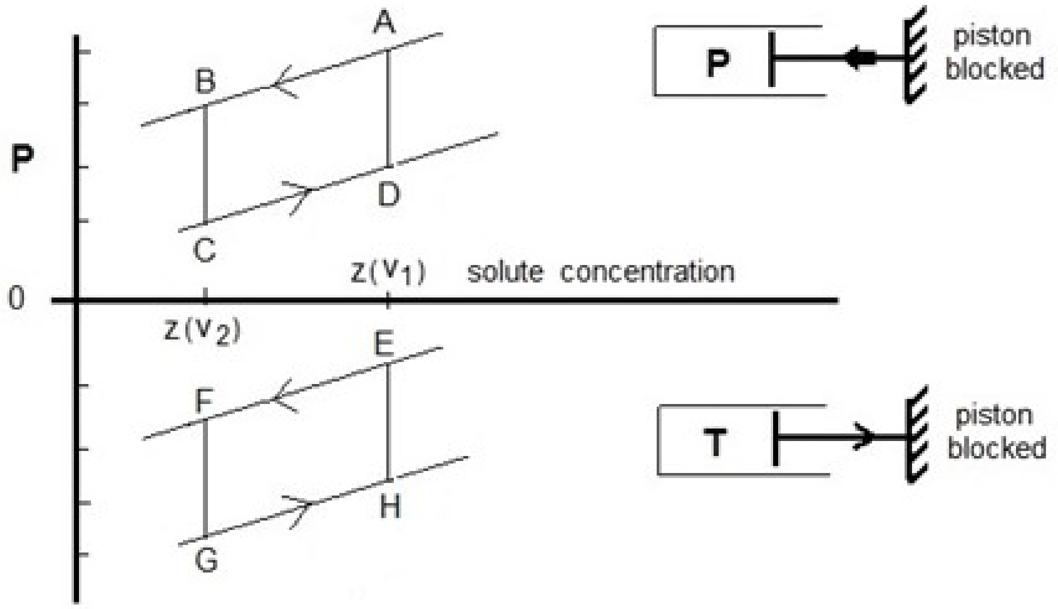

Figure 7. Cycles that Deliver Downward-directed Chemical Work
Machines which do not change their volume, do not perform mechanical work. In these cases, the osmotic forces they exert (pressure or tension) change the concentration of the solute molecules, z, in the machine according to van't Hoff's equation, P = P' + zkT, (where P' is the atmospheric pressure in the surroundings and kT equals Boltzmann's constant times temperature). The cycle ABCD of Fig 2 in the positive regime is replotted against z = Z/V rather than V, where Z is the number of solute molecules inside the machine with V held constant. Under this condition, the pressure exerted down the power-stroke, AB, reduces the solute concentration, as a result of solute molecules fusing together by forming new high-energy bonds to make larger molecules – chemical work produced by down-out action. In contrast, recall in Fig 2 the concentration of solute molecules, z, is reduced as V1 expands to V2 down the power-stroke, AB, while Z is held constant. In the negative regime, the cycle EFGH of Fig 3 is also now shown plotted against z. In this case, the tension exerted up the power-stroke, GH, increases z as a result of solute molecules inside the machine absorbing energy which breaks bonds producing smaller, but more energetic, molecules – chemical work produced by down-in action.

thick arrow = pressure, piston movement blocked
thin arrow = tension, piston movement blocked

Finally, we cycle back and revisit the historical events where this story began. I find it a supreme irony that in his analysis of Carnot's cycle, Clausius arrived at the concept of entropy. He was examining the mechanism that underpinned the success of Europe's industrialization, which resulted from the ability of the steam engine to deliver seemingly endless power from heat. This man-made engine was the first clear example of an upward-directed transducing machine. Its up-out action promised to deliver every imaginable type of work society needed. Yet Clausius' treatment revealed an overriding dynamic of a natural flux emphasizing fragmentation and loss – a revelation that led naturally to the concept of the Heat Death of the Universe.

Indeed, Clausius' analysis does not deal with the production of macro work at all, but with the fate of lost heat flowing in the opposite direction from source to environment. His concept gained strength shortly after he proposed it, when Boltzmann interpreted entropy increase as the randomization of all matter and energy, meaning that natural spontaneous processes were now seen as the result of blind chance at work throughout Nature. The further irony is that this world-view supports the Darwinist claim, that genetic mutations are random, and consequently, that evolution is itself also the happy result of a vast collection of unrelated accidents, which somehow miraculously produced life! – not chaos!

It is fascinating to speculate that, had Clausius instead analyzed engine structure rather than heat loss, he would have discovered the opposite law describing upward transduction. In such a world-view, it is energized forms in the environment that influence events, and so in that case, we would all have become Lamarckians rather than Darwinians!

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