# Stress and Water



From the original article. Author: Ray Peat.

The biological idea of stress refers to the difficulty of adapting, and this involves energy, structure, and insight/orientation. Given enough energy, we can often adjust our structure to achieve full adaptation, and with insight, we can minimize the amount of energy and structural change needed, for example just by a change of pace or rhythm.

Change of structure can involve the growth of new cells, or the enlargement or modification of existing cells, and the shrinking or dissolution (apoptosis) of existing cells, allowing their substance to be used elsewhere. F. Z. Meerson's work gave a clear framework for understanding this, especially in relation to the adapting heart, and Eli Mechnikov's picture of the creative role of the phagocyte in growth can be seen as one of the most basic insights into biology.

A given structure makes possible a certain level of useful energy, and adequate energy makes possible the maintenance of structure, and the advance to a higher and more efficient structural level.

I have been using aging (menopause and the ovaries) and cancer (carbon monoxide as a hormone of "cellular immortality") to explore the issue of cell renewal and tissue regeneration. Yesterday, Lita Lee sent me an article about K. P. Buteyko, describing his approach to the role of carbon dioxide in physiology and medicine. Buteyko devoted his career to showing that sufficient carbon dioxide is important in preventing an exaggerated and maladaptive stress response. He advocated training in "intentional regulation of respiration" (avoiding habitual hyperventilation) to improve oxygenation of the tissues by retaining carbon dioxide. He showed that a deficiency of carbon dioxide (such as can be produced by hyperventilation, or by the presence of lactic acid in the blood) decreases cellular energy (as ATP and creatine phosphate) and interferes with the synthesis of proteins (including antibodies) and other cellular materials.

When I first heard of Buteyko's ideas, I saw the systemic importance of carbon dioxide, but I wasn't much impressed by his idea of intentionally breathing less. If the hyperventilation is produced by anxiety, then a deliberate focussing on respiration can help to quiet the nerves.

Knowing that hyperventilation can make a person faint, because loss of carbon dioxide causes blood vessels in the brain to constrict, I saw that additional carbon dioxide would increase circulation to the brain. This seemed like a neat system for directing the blood supply to the part of the brain that was more active, since that would be the part producing the most carbon dioxide.

In a nutrition class, in the late 70s, I described the way metabolically produced carbon dioxide opens blood vessels in the brain, and mentioned that carbonated water, or "soda water," should improve circulation to the brain when the brain's production of carbon dioxide wasn't adequate. A week later, a student said she had gone home that night and (interpreting soda water as bicarbonate of soda in water) given her stroke-paralyzed mother a glass of water with a spoonful of baking soda in it. Her mother had been hemiplegic for 6 months following a stroke, but 15 minutes after drinking the bicarbonate, the paralysis lifted, and she remained normal.

Later, a man who had stroke-like symptoms when he drank alcohol late at night, found that drinking a glass of carbonated water caused the symptoms to stop within a few minutes.

Realizing that low thyroid people produce little carbon dioxide, it seemed to me that there might be a point at which the circulatory shut-down of unstimulated parts of the brain would become self-sustaining, with less circulation to an area decreasing the $CO_2$ produced in that area, which would cause further vasoconstriction. Carbon dioxide (breathing in a bag, or drinking carbonated water, or bathing in water with baking soda) followed by thyroid supplementation, would be the appropriate therapy for this type of functional ischemia of the brain.

When there is circulatory stasis, the tendency of the blood to clot is increased. Normally, the legs are where small clots form most often, but the same thing is likely to happen in the brain when circulation is too slow. Carbon monoxide poisoning mimics multiple sclerosis by causing clots to form in the brain, in association with areas of demyelination. Physiologically, I think hypothyroidism, combined with high estrogen (which promotes blood clotting) is the main cause of MS, possibly overlapping with a variety of other demyelinating factors, such as tin, hexachlorophene, heme, and a deficiency of progesterone. One of estrogen's effects is to cause edema, probably because it blocks albumin synthesis, and the loss of blood volume associated with edema increases the tendency to clot.

People have examined the behavior of carbon dioxide dissolved in water when the water is in contact with the skin, as during a bath in carbonated water. Since the concentration of metabolic carbon dioxide in the living tissue was higher than the concentration in the water, it was assumed that $CO_2$ would move from the tissue into the water, "down its gradient." But the opposite happened, the carbon dioxide moved from the water into the tissue, against the gradient. This shows that we can draw false conclusions when we think of the body as a "watery system." The carbon dioxide is more soluble in living tissue than in ordinary water, and solubility is what governs the situation, not a context-free concentration gradient. Many natural springs that have a reputation for healing contain carbon dioxide and carbonates, which the body absorbs when bathing in or drinking the water.

Carbon dioxide is more soluble in oil than in water. In general, gases dissolve better in cold water than in warm water, and cold water has more affinity for fats than hot water does. In many ways, the water in cells acts as though it were colder than it is, and more oil-loving. The term "structural temperature" is used to describe the behavior of cellular water which, at body temperature, behaves like ordinary water at a lower temperature--it has a "lower structural temperature." There is a reciprocal action between the cell water and the material it dissolves, so that carbon dioxide tends to stabilize the normal high energy state of the cell. I will say more about cell water after saying a little more about Buteyko's focus on carbon dioxide.

Although it is easy to dismiss Buteyko's emphasis on the "Intentional Cessation of Deep Respiration" as a therapy, his work on the importance of carbon dioxide is sound. When I realized that many hypothyroid people compensate by producing huge amounts of adrenaline, which helps to sustain their blood sugar and their nervous energy, and that adrenaline tends to cause hyperventilation, I saw that "intentional regulation of respiration" might work in these people to reduce hyperventilation just as psychotherapy, reassurance, meditation, or taking a nap can help to control hyperventilation and other effects of excess adrenaline and anxiety. But using carbon dioxide, or a thyroid supplement to promote the body's formation of carbon dioxide, seems like a more logical approach to treatment of a carbon dioxide deficiency.

I have been concerned about the probable effects on the fetus of the silly panting respiration that is being taught to so many pregnant women, to use during labor. Panting blows out so much carbon dioxide that it causes vasoconstriction. Possibly the uterus is protected against this, and possibly the fetus produces enough carbon dioxide that it is protected, but this isn't known. Especially if the mother is hypothyroid, it seems that this could interfere with the delivery of oxygen to the fetus. Besides vasoconstriction, Buteyko points out that the Bohr effect, in which $CO_2$ causes hemoglobin to release oxygen, means that a low level of carbon dioxide decreases the availability of oxygen. If the Bohr effect applies to fetal hemoglobin, then this suggests that the mother's panting will deprive the fetal tissues of oxygen.

It is normal for the fetus to be exposed to a high concentration of carbon dioxide. Recent experiments with week-old rats show that carbon dioxide, at the very high concentration of 6% powerfully protects against the brain damage caused by oxygen deprivation (tying a carotid artery and administering 8% oxygen). (R. C. Vannucci, et al., 1995.) 2

I have talked to several people who get mild neurological symptoms around 2 to 4 AM, and since the symptoms are like those caused by hyperventilation, I think nocturnal low blood sugar and high adrenaline might produce relative hyperventilation and poor oxygenation, possibly with lactic acidemia. A sizable part of the population responds to intravenous lactic acid with a panic attack, and I think these people are hypothyroid ; if glycogen stores are low, lactic acid exacerbates the energy problem, and by displacing carbon dioxide could trigger hyperventilation. When a panic attack is induced by stress, it is probably because the stress is causing the production of lactic acid. Both sugar and carbon dioxide help to prevent panic attacks, according to some recent studies. (Dager, et al., and George, et al.)

Buteyko has made an unusual observation, which I think is important. He says that the oxygen deprivation resulting from a deficiency of carbon dioxide can cause increased arterial pressure, and also a dilation of veins, leading to varicose veins and hemorrhoids. (I discussed this behavior of the blood vessels in "A unifying principle.") In a lecture, Buteyko argued that a deficiency of carbon dioxide causes allergies, sclerosis, psychosis, tuberculosis, precancerous conditions, and other symptoms.

His list of diseases is reminiscent of Broda Barnes' work, in which he showed that tuberculosis, cancer, and atherosclerotic heart disease are endemic in hypothyroid regions.

This is where the issue of cell water comes in. Carbon dioxide, produced by oxidative cell metabolism, is associated with the high energy state of the cell. When something interferes with oxidative metabolism, lactic acid is produced instead of carbon dioxide. If the cell stays very long in this low oxygen state, it swells, taking up water. (The fatigued muscle, for example, can take up so much water in a short time that it weighs 20% more than before it began working so intensely that its energy needs far exceeded the availability of oxygen. This swelling is what causes the soreness and tightness of intense exercise. The swelling persists long after the liver has cleared the lactic acid from the blood.)

This swelling from taking up water is involved in one type of "edema," and in inflammation, or activation of the cells by hormones, as well as by simple oxygen deprivation. When the eyes have been closed for several hours, the cornea swells, because it depends on direct contact with the air for its oxygen, and the eyelid, whose circulation provides oxygen for its own cells, doesn't provide enough for the cornea.

Estrogen seems to work by blocking oxidative metabolism, and its first visible effect is to cause the stimulated tissue to take up water.

Anything that causes cells to take up water seems to stimulate cell division. For example, just putting cells in a hypotonic medium stimulates cell division (and a hyperosmotic environment stops cell division).

Years ago I noticed that various enzymes which are activated by estrogen are completely inactivated by cold, and I proposed that estrogen's effect was to raise the "structural temperature" of cell water. If estrogen-stimulated cells have a "high structural temperature," their ability to dissolve oxygen will be reduced. (Whatever the mechanism, estrogen does shift cells away from oxidative metabolism. I think many mechanisms are involved.)

Thyroid, which opposes estrogen's effects on cell energy, stimulates oxidative metabolism with the production of carbon dioxide, and reduces the water content of tissues.

Buteyko suggested that carbon dioxide directly supports immunity. Increasing the availability of oxygen and the production of ATP should be good for immunity, apart from any more specific effects. If it contributes to an effect on the "structural temperature" of cell water, and helps to raise the energy charge of the cell, $CO_2$ could be a major factor in opposing the action of estrogen. While the general effects of thyroid can be easily observed, many of its ways of achieving those effects are still not known.

Typical cancer cells are much wetter than normal cells, containing 90 or 92% water. It is possible that part of thyroid's anti-cancer, immune promoting effect is the result of the increased carbon dioxide it produces. Since lactic acid turns out to have a variety of "signalling" functions, including effects on white blood cells, it seems possible that carbon dioxide has a different set of signalling or hormone-like functions.

While I doubt that lactic acid produces intracellular acidosis (ATP hydrolysis produces acidosis; see Busa and Nuccitelli, and Sokoloff), it can produce temporary extracellular acidosis, besides any specific hormone-like action. This acidosis could be involved in autoimmune processes, since it can change cells' immunological reactivity. (Oh, et al.)

It is very likely that cancer patients lack carbon dioxide, because tumors produce significant amounts of lactic acid, which tends to displace carbon dioxide. It would be interesting to see whether supplemented carbon dioxide would decrease the cancer's production of lactic acid.

Short-chain fats are very soluble, and are quickly metabolized, so it is likely that coconut oil, which is rich in short and medium-chain fatty acids, will tend to decrease the production of lactic acid.

High pressure tends to act as a cell excitant (e.g., it can cause a muscle to contract), and in effect is raising the "structural temperature" of cell water. This suggests that the reduced pressure of high altitude would have the beneficial (antistress) effect of decreasing the structural temperature of cell water. This means that gases would have a higher solubility in cell water at high altitudes, which would tend to slightly offset the biological effect of the relative scarcity of air at high altitude. There is some evidence (Drost-Hansen, 1972) that reduced pressure increases the solubility of oxygen in cells. The presence of carbon dioxide should increase this effect. (Drost-Hansen discusses some examples of "anomalous" concentration effects of hydrocarbon/water mixtures, p. 254, in "Anomalous temperature and pressure dependencies of gas solubilities: Laboratory and field observations," Chemistry and Physics of Aqueous Gas Solutions, 233-256, 1975?) I think Drost-Hansen's reasoning suggests that the short-chain fatty acids might also increase the solubility of oxygen in cell water. If this is true, it suggests that coconut oil might have a very important antistress effect, sustaining efficient respiration during demanding situations.

Some of the other implications of thinking about the special nature of cell water are discussed in the works of Cope 3 and Ling. 4

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