No. 58

the FELIX Letter

A COMMENTARY ON NUTRITION

1991

ALL THAT WE CAN BE

"The fact that evolution concerned different ways of getting food is such an obvious statement and the business of eating is of such a commonplace nature, that its central importance has been overlooked. ...The origin of movement was possibly just a by-product of the production of abundant high-energy molecules from food and oxygen."

"The chemicals that make up the body were born in a star....The origin of life is inseparable from the origin of chemicals."

--Michael A. Crawford
THE DRIVING FORCE: Food, Evolution, and the Future (Michael Crawford & David Marsh, Harper & Row, 1989).

In early 1983, I began chasing down research on Omega-3 fatty acids, and one study electrified me. Dr. Michael A. Crawford described two special kinds of fats all mothers needed throughout pregnancy and breast-feeding, to assure that the brains of their babies would develop to full capacity. A baby's brain depended on special foods its mother had to eat! Crawford reported that the two essential families of fats, Omega-6 and Omega-3, provided the crucial building blocks. The child who did not get enough of these essential fatty acids from the mother before birth, and from breast or bottle feeding afterwards, might end up with a smaller brain, one with fewer cells than normal.

I was not alone in my ignorance. My college textbooks and my physiology, biochemistry, and nutrition professors at U.C. Berkeley in 1975-77 gave short shrift to any requirements the infant brain might have for two unique sets of dietary fats.

Evolution: A Game of Chance?

In *The Origin of Species* [1859], Charles Darwin proposed that all forms of life evolved through a process of "natural selection." A new species was the result of successive inheritable "random variations" which, when they happened to be useful in adapting the organism to its environment, encouraged the "survival of the fittest."

Crawford argues in *THE DRIVING FORCE* that the principles of chemistry and nutrition take away at least some of the "randomness" in evolution. In our time, we know what wasn't known to Darwin (1809-1882): that the basic chemistry of all Earth's life forms is the same. Could this have happened by purely random design? Crawford thinks not.

Think for a moment of a swirling cloud of hydrogen gas gradually becoming compressed tighter and tighter by gravitational forces. Compressed gas heats up. As heat and compression in what is evolving into a new star mounts in force, hydrogen atoms fuse to form *helium*. "...at such a temperature and pressure the alchemist's dream comes true: hydrogen, which is the simplest and smallest element, fuses to make higher elements... Indeed, all the elements that exist are built in this way."

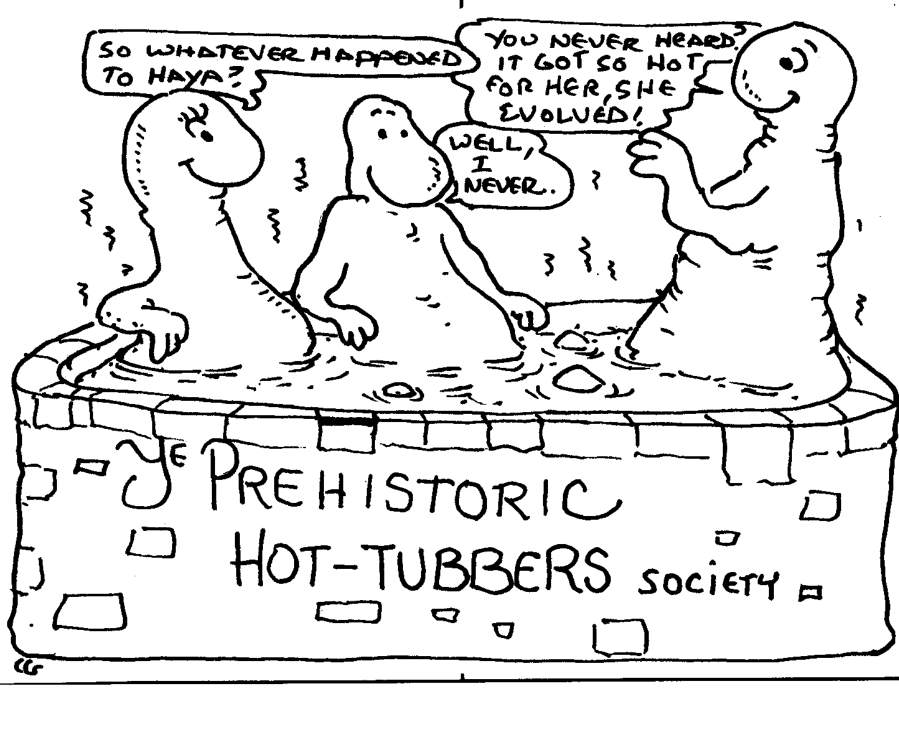
Earth probably spun off an exploding star that hurled element-filled debris into space. Our planet inherited these elements still seething in white-hot heat. "The remains of that heat persist today and the interior of the earth is still molten, covered by a solid crust so thin that in proportion to the planet's size it is like a sheet of paper wrapped around a football." (Scary thought, isn't it. We get a 'sample' when fiery gases and lava explode out of a volcano.)

Temperatures inside a star are too hot to allow elements to combine, but our newly-formed planet cooled down enough to make the next step in building life possible: *the joining of elements to form the first compounds*. "The union of elements was not a matter of chance. If we place a number of chemicals in a test-tube and raise them to a certain temperature, we can predict quite accurately not only which compounds will form but also in what proportions. ...The evolution of compounds, like the evolution of life, follows its own rules and what to individuals looks like chance, is actually an inescapable law."

Alphabet Soup

At first, water boiled away as fast as it formed, only gradually cooling over a 700 million year period into pools which collected in craters. Rich in carbonates, sodium, potassium, ammonium, and phosphates, the warm chemical broths encouraged more compounds to form. Lightning storms provided electrical energy to spark even more complex couplings.

Scientists have discharged electrical sparks through mixtures of gases composed of carbon, hydrogen, nitrogen and water vapor and--eureka!--out of this energized brew came *amino acids* (the building blocks of protein, and, with heating, 'daisy-chains' of them



called proteinoids),* as well as molecules that can become the "base pairs" of DNA and RNA, a cell's self-replicating genetic material.**

Once the 'chemicals of life' were there, only the right conditions were needed. *Our form of life is based on chemical reactions of carbon compounds in water between 0-100 degrees Centigrade.* As the earth's crust cooled down, carbon compounds in the warm primordial waters did what came naturally!

Energy-trapping molecules (e.g., high-energy phosphates) were drawn into collaboration to create energy for the cell by a simple means: protein is an energy-acceptor. Energy donors and energy acceptors gravitate towards each other in the same way negative and positive charges bring atoms together. "The essential components of a primitive cell are not much more than energy receptors: proteins, DNA and RNA. ...Once the happy union of DNA-energy-proteins began to coordinate their activities, something that was recognisable as living matter had appeared."

The laws of chemistry which had built the first living cell "continued to regulate and shape all its progeny from that day to this."

*We know from test tube experiments that amino acids [all carbon-based] will not only appear on their own, *but will link spontaneously in 'daisy-chain' molecules.* These 'proteinoids' will shape themselves "into tiny spheres and behave in some respects like living cells. In the right medium they will actually grow until they reach a certain size and then start 'budding.' These buds eventually break away to form new spheres which in turn grow and divide." They are synthesizing proteinoids!
When they do, proteinoids are acting like true enzymes. Enzymes made of 'real life' protein are catalysts that can clamp two molecules together or break them apart. "We can therefore assume that even before life appeared, enzymes would have been at work producing biochemicals," just as proteinoids do in test tubes.

**In man or bacteria, DNA contains sequences of "base pair" molecules that code for the production of proteins needed by the organism for its structures and functions. Two strands of DNA with complementary base pairs are wound around each other in the famous "double helix." To replicate themselves, when the cell divides they uncoil and each strand makes a new complementary strand.
Before there was life, the base pairs on a single strand of DNA would be drawn towards complementary base pairs on another strand by chemical forces, with predictable coiling of the two strands around one another. Just as biologists today who study gene sequences can force DNA molecules in test tubes to unwind by applying heat to them, Crawford suggests the fierce heat of the day caused double helices to uncoil. Strands of DNA with varied base-pair sequences would float around in the 'soup,' connecting and coiling around one another in the cool of the night, and uncoiling in the heat of the day. Gradually, DNA having the more stable base-pair sequences would become the most common. Nature's efficient self-replicating molecule was ready for business!

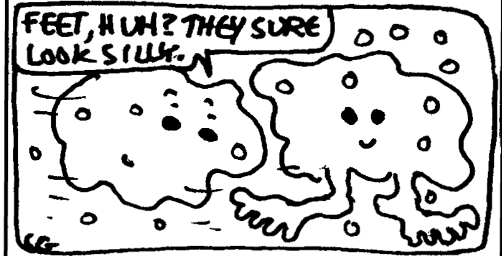
The Breath of Life

Our planet is about 4.6 billion years old. A little more than a billion years later, fossils show evidence of the*blue-green alga,* a one-celled life form that, like plants today, derived its energy from sunlight. Undoubtedly, other unicelled forms of life such as bacteria and viruses existed, too. Blue-green algae (still going strong today) dominated the planet until about 600 million years ago, when evidence of slightly more complicated life appeared--unicelled forms containing a nucleus. From then on, it was a quick march--only a million years or so!--before multicellular life became abundant.
How are several billion years of sole dominance by blue-green algae related to the explosive appearance of complex life forms, starting about 500 million years ago? Crawford says*oxygen* is the key.

Blue-green algae are much like chloroplasts in plants which use sunlight for energy and release *oxygen* into the atmosphere (from water and carbon dioxide). From the beginning, free oxygen was in short supply. Every element that could had combined with it; oxygen-hungry molecules continued to swallow it up as fast as blue-green algae spit it out. However, one fine day (or millenium), a turning point came. For the first time on earth, free oxygen became available to living things.

Organisms can produce a lot more energy with oxygen than without it. Early oxygen-users harnessed some of that extra energy into *movement*, allowing them to cruise around for food in the primordial 'soup,' i.e. develop twitching parts that carried them thither and yon.
"In the case of the single-celled paramecium, the surface is covered in tiny hairs which 'row' in an astonishingly co-ordinated manner." Crawford says that this simple use of harnessed energy to cause a muscle fiber to twitch developed eventually, "with many additional subroutines, into the use of fins, wings and legs."

We have a problem at this juncture, folks. Crawford makes a convincing case up to the point where teentsy-weentsy organisms are careening around in the warm mulligatawny, but his sketchy path from amoebae to complex life forms requires something like a leap of faith on my part.



Fats Are Us!

Unicellular creatures simply surround their food and move by twitching or oozing along. They don't need a blood supply or nerves. Multicellular creatures ***do***, because they have lots of cells to feed and to inform. What more logical way than through a vascular and a nervous system? In 'higher' animals and man, the heart pumps blood filled with oxygen and nutrients to every nook and cranny, while the brain coordinates the nervous system. There's a catch, though. It has to do with oxygen and some molecules that aren't as important to unicellular creatures as they are to us.

"**O**ne of the first systems to develop in the human embryo is the neural tube out of which grow the spinal cord and the brain. ...But it is paralleled by the development of the heart which pumps blood and nourishment to the developing tube. ...The priority given to the nervous system as an energy user is absolute. ....a staggering 60 to 70 per cent of the newborn's energy from food and reserves is used by the brain for growth and maintenance." Even as adults our brain uses 20 per cent of our energy. Its critical dependence on nutrients and oxygen from the blood is such that after no more than five minutes without oxygen the brain is dead.

A new biochemistry came into play. The cardiovascular and nervous systems depend on special lipid or 'structural' fats. "Protein and DNA chemistry had been the name of the game for the bacteria and blue-green algae. The higher organisation of multicellular systems introduced the chemistry of membranes....the chemistry of lipids."

Highly unsaturated Omega-6 and Omega-3 fats impart fluidity to lipid membranes of the brain, blood vessels, and photoreceptors of the eye. "The brain sends and receives many millions of messages every second and is the most membrane-rich system in animals. Blood vessels are also highly dependent on membrane fluidity...that allows them to absorb the pressure waves generated by the pumping heart." Photoreceptors in the retina of the eye need fluid membranes to receive photons of light and speed the information to the brain.

Now comes the rub. These polyunsaturated fats are exceptionally vulnerable to attack by--you guessed it--*oxygen!* The brain requires large amounts of oxygen to stay alive yet, paradoxically, can be zapped by it! So can polyunsaturated fats in all membranes throughout the body. So there it is. Oxygen makes complex life forms possible but also may become their undoing. Unicelled critters probably can go on forever unless eaten or killed, but we get slowly oxidized to death!

One scientist calls it "biological rancidification!" *Felix Letter* readers, I trust, stay "fresh" as long as possible by consuming protective anti-oxidants in foods and/or supplements, such as vitamins C and E, beta carotene, and the mineral selenium.

Life began in mineral-drenched seas. Even today, the sea has the most abundant wealth of life and species. It has, however, far less *oxygen* than fresh water or, of course, air. "Was oxygen the attraction, driving the move on to land...?" First, there was a move to highly-oxygenated *fresh* water. Oxygen allows eight times more energy to be produced in living systems. "The next biggest jump in oxygenation is to leap right out of the water altogether."

Eggs of marine creatures are tiny because the hatchlings emerge into a nutrient-laden environment. Fresh water creatures make larger eggs, because while the water contains more oxygen, other nutrients are scarcer and the egg has to be filled with them to give the young a good start.

The eggs of land animals such as amphibia, reptiles, and birds had to be larger still. (Think of dinosaur eggs!) "Each of their eggs had to contain all the water the developing embryo would need as well as all the nutrients." But the power to build these larger eggs came from the energy boost they were getting from extra oxygen.

Now, another element enters the story: *calcium*. It was the principal nutrient needed by the new land colonizers for the *shells* of their eggs. And while the buoyancy of water supports creatures large and small, every land animal must support its own weight. For this, it must have a sturdy skeleton. Fish have thin bones, and sharks use cartilage-like material instead of bone. Only the shellfish at the land-water interface: mussels, oysters, etc., are rich in calcium.

They could have been a good source of calcium for the first amphibians. By then, plants had already colonized the mineral-rich land. The early animals who fed on them got nutrients including calcium for making far stronger bones than those in fish. Today, the elephant and rhinoceros build their massive skeletons from plant foods alone, and the carnivores keep their own bones strong by eating the bones of plant-eaters!

A large slice of Crawford's life as a biochemist and zoologist has been spent in Africa, and there in 1965 he investigated the El Molo people because of the curious fact that they all had *bent legs*. Was it a genetic trait? No. He learned that passers-by who joined the tribe, opting for a pleasant life by a huge, jade-colored freshwater lake, bore straight-legged children whose legs bent permanently as soon as they learned to walk! The El Molo lived almost entirely off the flesh of fish caught in water that proved to be very low in calcium. Their other surroundings were desertlike and provided little food. Essentially, their diet was high in phosphorus and low in calcium--the perfect formula for weak weight-bearing leg bones!

Crawford proposes a novel theory for the evolution of flying creatures, again using nutrients as his basis. The little European hedgehog spends a lot of its time climbing trees in search of a favorite food, snails. One scientists suggests that its quills which it doesn't use for defense or aggression were developed so that the hedgehog could *bounce*. And bounce it does, quite literally, when it falls, which is often! The quills are similar to those in a bird's feathers, but the hedgehog eats calcium-rich snails and its bones are strong.

Birds, on the other hand, might have evolved from little animals which leaped at the abundant insects in the air, not only getting practice at jumping and falling, but also a diet of calcium-poor insects! Fruit-eating and nectar-drinking birds also get little calcium. The great predators of the air, the eagles and vultures, "live on a high-phosphorus low-calcium diet and have maintained a light body-to-wing-span ratio."

Our Big Brain

The classical view of evolution has *Homo sapiens* evolving a big brain from a little one. ***Crawford believes we merely kept the large brain-to-body ratio we had as a small mammal*** (the squirrel, for example, has as big a brain proportionately as we do). He doesn't think we took to the tree-tops, either! He says the apes that did became larger, but their brains didn't keep up. Since we were never in the trees, we never descended to the grassy Savannah to learn to stand on our own two feet--another widely accepted scenario. We did something smarter. We went to the water.

Five or more million years ago, dolphins, like other land animals attracted by sea food, left the land and became marine mammals. Some, like seals, often stay near land and give birth on it. Crawford speculates one branch of the apes that became man "found that the sea offered a wealth of food and a way of life that was congenial, much in the way that we enjoy the seaside today. This species would have taken to the shores of the freshwater lakes and rivers as well..."

The theory was first proposed by Sir Alister Hardy in 1960, and expanded on by Elaine Morgan in 1982 in *THE AQUATIC APE.* [I recommend it and her insightful, witty *DESCENT OF WOMAN,* 1972.] Crawford doubts that early man was wholly aquatic and thinks it more likely that he developed at the land-water interface, where he had the best of both worlds--the sea's food and protection, plus fresh water and edibles from inland waterways and forests.

Besides presenting Hardy's arguments for our aquatic origins *[See FELIX LETTER #35 for details]* Crawford adds some of his own which weigh against Savannah origins. African animals evolving in the Savannah developed remarkable adaptations to conserve precious body water and withstand equatorial heat. Man, on the other hand, sweats like a hippo--another animal that spends a good part of its life in water!--nor does he have the other 'Savannah' mechanisms for staying cool and saving water, but rather is like the sea mammals in this respect. Furthermore, our love for lakes, seas, and rivers is passionately expressed throughout recorded history by our devotion to swimming, bathing (indoors and out), fishing, water sports, boat-making, sailing, exploring, even water birthing!

Crawford's chief argument against Savannah origins is *the size of our brain.* In the tropical grasslands, as horses, deer, lions, etc. evolved from small creatures, their brains became proportionally smaller. An animal which escaped this fate is a ***marine mammal, the dolphin,*** whose brain-to-body ratio is even closer to man's than is the chimpanzee's !

We're back to nutrition again. "Had man been a Savannah species he would, like all other Savannah species, have found it difficult to obtain the long chain fatty acids in his food, especially docosahexaenoic acid [DHA, an Omega-3]. He would have had difficulty in satisfying the nutrient requirements for his brain and visual system; which may well have happened to certain hominid offshoots."

In the lakes and seas and on the shores, things would have been different. "He would have had available Omega-6 fatty acids from land seeds, protective anti-oxidants, and high concentrations of arachidonic acid preformed, from small land mammals, from freshwater foods and coastal seafoods as well as from marine mammals. He would also have had an abundance of the [DHA] which is missing in the food chain of large land mammals."

While proportions of the essential fats in various tissues and organs can vary widely in different animal species, *all mammals have a 1:1 ratio of Omega-6 to Omega-3 fatty acids in the neural lipids of the brain.* The highly unsaturated arachidonic and Omega-3 DHA are the most prominent. When food sources of these remained perennially scarce, as they did in the Savannah, brain size simply lagged behind as body size forged ahead. The sea, however, nurtured big bodies *and* big brains!

The Future

If nutrients made us what we are, what of today? Evolution, as we know from the loss of thousands of plant and animal species, can go forward or backward. Crawford says, "*Homo sapiens* evolved on the wild, unsophisticated foods of nature for 99.8 per cent of his existence." We had to resort to raising crops and domesticating animals about ten thousand years ago, when we outgrew the food supply of our wild Edens. That's when civilization began and there's no turning back, but we have new biochemical tools we can use to gain perspective on our nutritional past....and future.

For example, the modern practice of confining beef cattle to pens and stuffing them with high-energy feeds, gives us animals whose muscles are heavily infiltrated with hard storage fat, "in a sense the rubbish dump reserved for burning as fuel," while good structural fat disappears. In contrast, the little fat that wild cattle have is rich in Omega-6 and Omega-3 structural fats. Three and a half ounces of meat from wild species provide 106 calories, only 36 of which are from fat, 'good' fat at that. The same amount of so-called "lean" beef from domestic cattle provides 265 calories, *144 of which are from fat,* almost all of it "waste" fat. Coronary disease, today's big killer, may be related to our over-reliance on foods that load us with the wrong fats and deprive us of the ones we need!

The Japanese live significantly longer than any other large nation. They have a very low rate of heart disease and of colon and breast cancer. Traditionally they have eaten little meat, although prosperity is beginning to change that. "The Japanese can be said to be the one remaining successful hunter and gatherer culture, but they specifically hunt and gather the *sea*.. They eat five times more fish than the British." (And at least six times more than Americans!) Japanese children, by the way, are coming up with significantly higher IQ scores than their American counterparts.

Crawford says pointedly, "If one asks that conventional question about the 'fittest' today (one could use the quantitative measurement of the financial markets, exchange rates, trade surpluses, drive and financial intelligence), the Japanese recommend themselves as being pretty fit. Based on the growing budget deficits of 1981-9 in the USA and the growing surplus cash in Japan, the USA has collapsed into a position of such debt that the Japanese could just about buy up the USA in the remaining 11 years of this century."

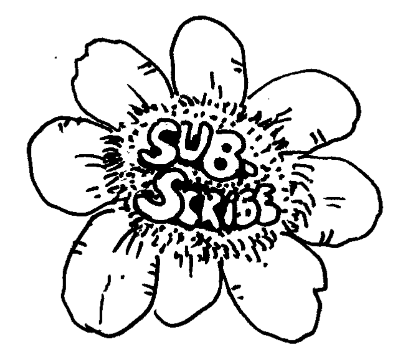
Would feasting, as Japan's people do, on seafood and sea vegetables make us smarter and healthier, and keep us that way? Biochemical research is making it easier each year to single out the elements that went into making us a unique species. Crawford was one of the first scientists to discover, for example, that breastmilk provides the special fats a baby needs for its brain cells, but cow's milk definitely does not! I'm still waiting for pediatricians, dietitians, and formula-makers to catch up with this desperately important knowledge. I *was* heartened to read this March in the conservative journal of*The American Dietetic Assoc*.. the following breakthrough recommendation by Dr. Joyce A. Nettleton, in her review article, "w-3 Fatty acids: Comparison of plant and seafood sources in human nutrition" :

It's crucial that pregnant or lactating women include sources of EPA and DHA in their diet on a regular basis so that adequate amounts of these fatty acids are available to the unborn or nursing child. Long-chain w-3 fatty acids should also be included in all infant formulas as well as in parenteral and tube-feeding formulas.

Since there's plenty of evidence that improved nutrition makes people taller in just a few generations, Crawford thinks there's an even chance the right nutrients could make succeeding generations *smarter* as well. Thus he emphasizes how important it is to focus on the education as well as nourishment of girls and young women. "Yet in our present day world, two-thirds of women are illiterate and only 1 per cent own property." The changes whereby all children will have plenty of good foods, "especially those important to the nervous and vascular tissue," will come about when we "build a world society willing to share its resources and control its populations to eliminate the miseries of poverty, hunger and malnutrition..."

Crawford tells us: "Different animal species have different requirements and in the mammals this truth is reflected in the composition of their milks which are rich in protein on the one hand for fast body growth, or rich in essential fatty acids on the other when the postnatal focus is on brain growth. In the human species the highest specialisation, which stands out head and shoulders above other species, is the brain and it is built in the womb of the mother." ❑

For a number of years beginning in 1960, Dr. Crawford was a biochemistry professor and wildlife researcher at the University Medical School at Makerere in Kampala, Uganda. Presently, he heads the Dept. of Nutritional Biochemistry at the Nuffield Institute of Comparative Medicine at the Institute of Zoology in London.



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The Felix Letter, P.O. Box 7094, Berkeley, CA 94707, is published independently by Clara Felix and supported solely by subscription. Descriptive list of issues plus sample issue is $1. Subscriptions $11 (six issues). Canada & Mexico $12, U.S. funds only.