the FELIX Letter
A COMMENTARY ON NUTRITION
NO. 15

BRAIN FOOD

If you're old enough to remember the heady era when psychosomatic interpretations began to dominate medical thinking — when patients were being referred in droves to psychiatrists for the wringing out of all possible psychogenic droplets from their bodily ailments — then you may breathe a sigh of relief with me for the current turnaround in clinical attitudes. Cautious acknowledgement now exists that tangible biochemical screw-ups may be at the root of both physical *and* emotional disorders.

Technological advances like the electron microscope and gas-liquid chromatography helped immeasurably to refine and expand our understanding of human cellular behavior, making it possible finally in the 1970's to identify and quantify all the fatty acids of the human brain. [Fatty acids are chains of carbon and hydrogen atoms usually from 16 to 22 carbons long, with a negatively charged carbon-oxygen group at one end.]

We Are Fatheads!

This research is proving to be a pivotal one. It took place during a period when the prostaglandins [PG's for short] were becoming the newest, hottest item on medical science's agenda, at the same time that the essential fatty acids were being accepted as the sole precursors for these powerful, mysterious regulators of human functions. [See *Felix Letter* 14 for background.] This newer information on the fatty acid makeup of the brain has yet to produce a sizable impact on the scientific community, particularly in terms of its nutritional implications. Nonetheless, the brain, which is about *50 to 60% lipid,** is now known to contain large amounts of two distinct derivatives of the fatty acids that *must be obtained from diet.* As researcher Dr. M.A. Crawford points out[1], ". . . one should ask what are the special [dietary] requirements for brain growth? If protein is of particular importance to *body* growth, are lipids of special relevance to the *brain*?"

*"Lipid" is the term for a large group of compounds containing fatty acids, including solid fats, oils, waxes, phospholipids, and glycolipids — the latter two being major lipids in brain.

Our Dynamic Membranes

All our tissues including the brain are built from billions of cells — like living, vibrating bricks — *each enveloped in a membrane made of specialized lipids.* Cellular membranes permit the dynamic exchange of the currencies of metabolism: oxygen, carbon dioxide, water, nutrients, enzymes, etc., within the cell and between the cell and its environment. Science doesn't yet understand all of the reasons why the brain and nerves, unlike other tissues, contain so much more fatty acids than protein. But since their business is the forming and transmitting of messages, one has to assume that lipids are nature's materials of choice for this function!

Essential Fatty Acids

The two essential fatty acids whose derivatives are the chief polyunsaturates in the brain are *linoleic* [lin-o-lay-ick], and *alpha-linolenic* [lin-o-lenn-ick], each a chain of 18 carbon-hydrogen groups.

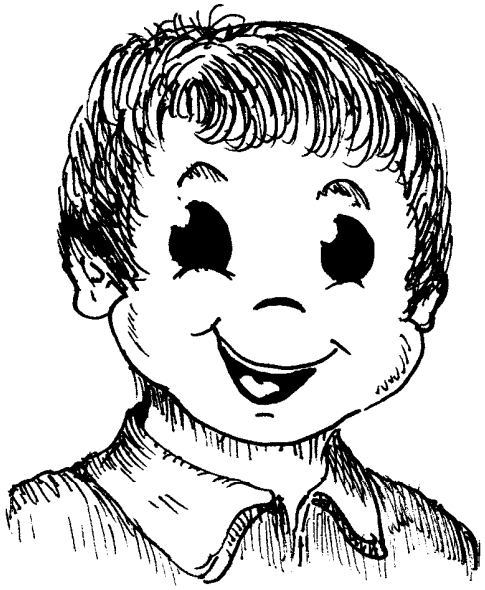
Our clever, marvelous bodies can make the other fatty acids from acetate, a simple molecule of hydrogen, oxygen, and two carbon atoms. We can make them into long-chain and short-chain fatty acids, and we can also "desaturate" the chains (remove two hydrogen atoms at a time), causing the fats to be more liquid or oily at body temperature. The fatty acids our body can synthesize are termed "non-essential," a misnomer if I ever heard one — would we bother to make them, otherwise?

We need linoleic acid and alpha-linolenic acid, too, and we *can't* synthesize them, so they have to come from food (hence "essential"). Not only do we require them for cell membrane structure, along with other fatty acids: we need them because they are the *only fatty acids* whose long-chain derivatives can become the magical and potent *prostaglandins* (PG's). This was not known in the 1930's when their essentiality was established, only that their absence from diet led to pretty grim consequences. Now that we are aware of the extraordinary effects the PG's have on human systems, we can understand why.

The Mystifying PG's

The PG's are produced in many tissues, including the brain, with the same PG sometimes having unique or opposite effects in different tissues. Some will constrict bronchial airways, while others will dilate them and relieve asthma. Some PG's cause blood to clot too easily, while others will strongly lessen clotting tendencies. One set of PG's increases nasal congestion; another opens nasal passages for comfortable breathing. New research

reported in *Science,* March 18, 1983, indicates that PG's in the stomach may normally stimulate production of a lecithin-like coating which protects the lining of the stomach from being digested by its own hydrochloric acid. Certain PG's instigate inflammatory reactions of the immune system, which can get out of hand, as in rheumatoid arthritis; while other PG's quell inflammations and relieve arthritic symptoms. The brain's fatty acids also produce PG's. It has been suggested that *imbalances in PG production in the brain* may be the common link in psychotic illnesses such as schizophrenia and manic depression. Research on the PG's is still in its beginning stages. The nutrition connection is that we do know that *the amount and kind of essential fatty acids that we get from our diet will affect the amount and kind of PG's that we will produce* — in the brain and elsewhere.



The following excursion into biochemical terms may help in understanding a current big conflict in the research community. The two essential fatty-acid families, "Omega 6" and "Omega 3", from which the PG's are made, are distinguished solely by the position of the carbon atom where the first desaturation, i.e., removal of hydrogen, takes place. In the Omega 6 linoleic family, it's at the 6th carbon atom of the 18-carbon chain. In the Omega 3 alpha-linolenic family, the first desaturation occurs at carbon 3. No matter how long the fatty-acid chain becomes or how many additional desaturated bonds are formed (our liver has the enzymes to accomplish all of this for us), the position of the first unsaturated bond *never* changes.

This seemingly minor alteration is enough to create fundamental differences in the functions of Omega 6 and Omega 3 fatty acids and in the prostaglandins formed from them. An Omega 6 fatty acid can never be transformed into an Omega 3, and vice versa.

A Debate Without Logic

More than fifty years after linoleic and alpha-linolenic were both deemed essential to growth and health, research arguments are still raging on whether alpha-linolenic is *really* essential. Strangely, even the knowledge gained in the 1970's that it was the source of one of the two dominant polyunsaturated fatty acids in the human brain seems not to have dimmed the controversy. *The dietary implications are vast, because modern dietary recommendations and food industry practices are heavily weighted towards the Omega 6 family.* Many nutritionists and pediatricians still declare that all necessary precursors for brain lipid development in human babies can come from the Omega 6 fatty acids alone.

Our bodies are magical, but they're not *that* magical! The two chief unsaturated fatty acids in the human brain even before birth are *arachidonic acid* and *DHA* (docosahexaenoic acid). *Arachidonic, an Omega 6* fatty acid 20 carbons long, with 4 unsaturated bonds, comes either directly from foods or can be formed from *linoleic. DHA, an Omega 3,* has 22 carbons and 6 unsaturated bonds. It's also found preformed in certain foods or can be made from *alpha-linolenic.*

If a pregnant woman doesn't eat enough foods containing linoleic and alpha-linolenic or their respective derivatives, her developing infant's need for these nutrients can only be met by robbing the mother's tissues. There is plenty of tragic epidemiological evidence of the havoc maternal deprivation can create in the unborn child. Smaller brains, fewer brain cells, diminished learning capacity — all of these have been found in children of severly undernourished mothers.

But how can we know that damage won't be done, too, by the kind of maternal undernutrition that comes not from stark hunger, but from misinformed choices?

The time during which a baby's brain is growing rapidly enough to be especially vulnerable to nutrient short-changing is broadly the second half of fetal life until 18 months after birth. Some investigators in lipids have made the observation that when essential amino acids — the building blocks of protein — are deficient in the diet, the *amount* of protein that can be made is reduced but the *quality* will be normal. *With essential fatty-acid deficiency, however, we get abnormal lipids that form abnormal cellular membranes.* Under the circumstances, how can newly forming brain and nervous tissue, which is 60% lipid, *not* be affected, even if in ways that are not clearly apparent?

Brain Good & Welfare

In the fetus, the need for arachidonic acid and DHA is demonstrated by their high concentrations in the mother's placenta. Although experimentation in this area is nearly impossible, there are indications that the unborn baby (and possibly the very young newborn) does *not* efficiently process linoleic acid into arachidonic, or linolenic into DHA, but rather depends on the mother's liver to do the converting. The placenta itself, some researchers believe, may also convert linoleic and linolenic into arachidonic and DHA respectively, or may preferentially choose them to pass into the fetus's circulation, where they quickly reach the brain. (More recently, it's been learned that arachidonic acid and DHA are the major unsaturated fatty acids in the *retina of the eye* as well! In males, they also exist in very high concentrations in the testis.)

Because the baby's brain continues to develop until almost two years of age, the quality of its diet in terms of essential fatty acids is important, naturally. In the early days of infant formula manufacture, the differences in fatty acid content of human and cow's milk were largely unknown or overlooked, until the appearance of severe deficiency symptoms in babies eventually prompted some improvements. Even at this late date, researchers in lipids admit that science knows much more about the fatty acids in cow's milk than in human's! (The commercial rationale is evident: human milk doesn't provide large-scale industry.)

Breast milk not only contains four times more linoleic plus linolenic than an equal quantity of cow's milk, it contains about eight times as much arachidonic and DHA! After the baby digests them, both arachidonic and DHA are absorbed very quickly from the blood into the infant's brain *intact;* that is, they do not undergo breakdown and resynthesis common to many other dietary fatty acids. Thus even the small amounts present in breast milk are completely available to the baby. (They are almost nonexistent comparatively in cow's milk.)

Advantages of breast feeding are rapidly becoming more widely acknowledged in pediatric practice, especially as a better understanding is gained of how the infant's changing nutrient needs are matched in quite a remarkable way by the mother's milk composition. Dr. Crawford[1] observed that in a 9-month study of ten nursing mothers, *their milk reflected their babies' needs for more DHA and arachidonic acid* during the early months when these highly unsaturated fatty acids were being laid down in the soft grey matter of the brain. Afterwards, there was a gradually higher content of oleic acid in the milk, as this mono-unsaturated fatty acid became needed for development of the stiffer myelin portions of the infants' nerves and brain[1]

The Modern Hunger

It seems pretty clear to me that children need both Omega 6 and Omega 3 fatty acids if they are to grow up healthy, happy, and *smart*. One scientist feels this may not be happening to a lot of babies. Donald O. Rudin got his medical degree from Harvard in 1948 and was director of molecular biology at the Eastern Pennsylvania Psychiatric Institute for 24 years. His studies with Dr. Paul Mueller on experimental biomolecular lipid membranes have appeared in leading scientific journals since the 1960's. A few years ago he left the Institute to write a book on the Omega 3 family of fatty acids (now awaiting publication). His hypothesis is that "the dominant illnesses in modernized societies, which range from bowel and heart disease to cancer and psychoses" may be "lipid-deficiency" diseases caused by *widespread depletion of the Omega 3 essential fatty acids.* The first stage of what he terms "the Modern Malnutrition" began with the acute vitamin B-deficiency epidemics of beriberi and pellagra "which decimated entire populations between 1880 and 1920" and were caused by "nontraditional food refining and selection patterns."

In the present stage of 'the Modern Malnutrition,' vitamin deficiencies are secondary to a deficiency of the "substrate," — the Omega 3 fatty acids for which the vitamins (and trace minerals) serve as catalysts.

Pellagra and beriberi each produced a variety of devastating physical and mental illnesses, but "it took half a century for the medical profession to turn from other explanations to accept beriberi and pellagra as nutritional deficiency diseases." The present illnesses caused by Omega 3 deficiency present a more complex clinical picture, Dr. Rudin says, because they also include symptoms of vitamin deficiency, since without adequate substrate the vitamins can't perform their critical functions. Not unexpectedly, medical science, he notes, is as adamant today in denying any possible nutritional connection as they were with pellagra in the 1920's.

Destroying Omega 3's

The best food sources of Omega 3 fatty acids are fish oils such as codliver oil, fish (especially "fatty" fish), seafoods, fresh seaweeds (their oils are lost in the drying process), and the northern hemisphere oils: linseed, walnut, wheat germ, and soybean, which are also good sources of Omega 6 linoleic acid.

Dr. Rudin says we have systematically depleted the dietary availability of the Omega 3's during the past 50 years, chiefly by "massive chemical refining (hydrogenation) of food oils, often using specific copper catalysts to selectively destroy Omega 3's . . . for the purpose of reducing rancidity and extending the shelf life of food oils."

Steel roller milling of grains has also diminished a substantial source of Omega 3 fatty acids. Additionally, we are "biasing" our diets by the current trend both in the food industry and the home towards using huge amounts of oils high in Omega 6 fatty acids but very low in the Omega 3's: corn, cottonseed, safflower, peanut, and sunflower.

When the oils are further processed into shortening or margarine, they present a newly discovered hazard, Dr. Rudin says, because they form unnatural "trans"-shaped fatty acids. [The molecules are stretched out instead of bent. When we eat these fats, the distorted unsaturated fatty acids are incorporated into cellular membranes, where they foul up our metabolic processes, scientists have good reason to believe — see *Felix Letter* #14. Contrary to current "heart" recommendations, margarine is NOT good for your heart and arteries and should be dumped in favor of pure northern oils and very modest amounts of butter!]

One result of the imbalanced Omega 6/Omega 3 ratio of modern diet, Dr. Rudin believes, is that *production of PG's from Omega 6 fatty acids is out of sync with our natural requirements.* The consequences may touch on all aspects of biological functioning, including the brain's. A number of researchers are discovering an association of schizophrenia and manic depression with too high or too low PG production.

Healing the Body-Mind

Dr. Rudin treated 12 severely mentally ill patients by having them take from *one to six tablespoons of linseed oil each day* in addition to their ongoing medication and vitamin-mineral supplements. Linseed oil from flax seeds, containing about 50% alpha-linolenic acid, is the richest vegetable source of this fatty acid. Dosage was adjusted according to the response observed. Several of the patients recovered in an unprecedented way from schizophrenic or depressive illness of many years duration, and on this simple regimen also found that their longstanding food allergies improved, chronic dry skin and dandruff cleared up, tinnitus (head noises) diminished, and they stopped feeling tired!

As further evidence that some of the major psychoses of today may be manifestations of pellagra-like nutrient deficiencies, he describes a 1973 study[2] on Capuchin monkeys who were reared from infancy on a standard laboratory diet, vitamins included, except that corn oil was the only source of Omega 3's. "Within 2 years all were reported to have developed drying skin problems and immune system damage, one developed a severe enteritis [intestinal inflammation], and two came down with self-mutilating behavior, tearing and slashing viciously at their own genitalia in a manner suggesting the van Gogh syndrome of schizophrenia and certain idiopathic mental retardations. Although these last two animals were sacrificed, all the others recovered within 2 months when placed on linseed oil supplements (2.5 to 5% of calories) except for residual signs of immune system damage. Since these animals always had adequate B vitamin intake, we may interpret this as the laboratory induction of pure substrate pellagra, since over the group as a whole, we see the classical Three D's of pellagra [dermatitis, diarrhea, and dementia]."

As Dr. Rudin points out, a 'placebo effect' attributed to linseed oil supplementation could hardly have applied to the poor little Capuchins!

In a pilot study involving 32 persons suffering from physical ailments of chronic duration, such as arthritis, bursitis, irritable bowel, and allergic manifestations, Dr. Rudin instituted a similar linseed oil regimen, with the addition of bran or psyllium seed in yogurt before meals for correcton of fiber and intestinal flora deficiencies. The rate of therapeutic success was really quite impressive! and in addition to improvement in their major problems, many of the subjects reported "side-benefits" of smoother skins, improved alcohol tolerance suggesting better liver function, and considerably diminished fatigue. Dr. Rudin comments:

> ***. . . Some workers now hold the dominant diseases of modernized societies to be new, nutritionally based, pellagraform yet lipid-related, and to range, once again, from heart disease to psychosis. It is an [unwarranted] assumption that our dominant diseases are unrelated to each other or are merely revealed by our diagnostic acumen and therapeutic success; and that hydrogenating millions of tons of food oils annually to destroy the rancidity-producing Omega 3 essential fatty acids is safe for primates [including, of course, man].***

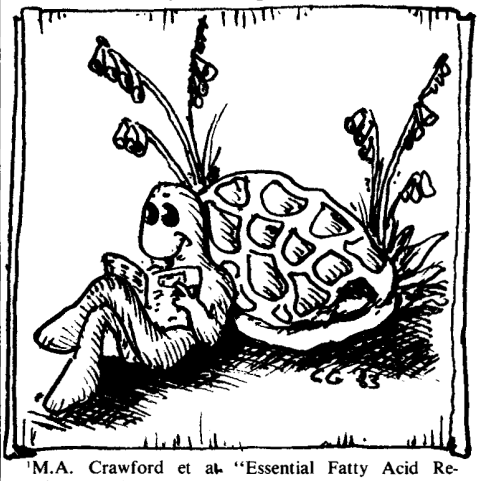
Exercising Control

I think the important thing for us to understand about our lipid cellular membranes and prostaglandins is that *we are given some measure of control over them through the foods we choose.* Not all the facts are in by any means, but it looks very much as if a regular intake of fish, seafoods, edible fresh seaweed such as dulse, and perhaps some codliver oil a couple of times a week, may push production of the PG's that *protect the heart and arteries.* It may also normalize blood pressure and reduce high blood triglycerides! Food from the sea — both plant and animal, including plankton on which whales feed — is extremely high in the long-chain highly unsaturated Omega 3's, DHA among them. We can therefore state without reservation: it is indeed *brain food* for the developing baby, before and after birth — whether the fatty acids reach the baby from the mother's diet through the placenta and later through her milk, or directly from the table.

Vegetarian Sources

Another way to especially nourish the nerves and brain, the retina of the eye, and, for males, the testis, is to switch to good sources of linoleic and alpha-linolenic acid, such as northern oils (linseed, walnut, soy, and wheat germ), dark green leafy vegetables, and whole seeds and grains, and trust our enzyme systems to convert linoleic and linolenic to the desirable long-chain fatty acids and PG's. My vegetarian friends and colleagues will probably wisely emphasize this route, and maybe explore ways of including fresh seaweed on a regular basis, as many seacoast peoples have traditionally done.

I like the idea that the fatty acids of our cell membranes, and the prostaglandins they produce, are open to dietary manipulation — as long as *we* can do the manipulating! — and that the constant flux that goes on in our cells represents options for renewal and recovery throughout our lives.—



[1]M.A. Crawford et al. "Essential Fatty Acid Requirements in Pregnancy and Lactation with Special Reference to Brain Development." In: *Progress in Lipid Research,* Vol. 20, Ralph T. Holman, Editor. Pergamon Press, N.Y., 1982.

[2]Fiennes, R.N., et al. "Essential fatty acid studies in primates: Linolenic acid requirements of Capuchins." *J. Med. Prim.* 2: 155-169, 1973.

Illustrations are by Clay Geerdes.

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