[Reprinted from Industrial and Engineering Chemistry, Vol. 18, No 7, page 679. July, 1926.]

The Relation of Light to Life and Health[1]

Some Biochemical and Clinical Aspects

By Weston A. Price

DENTAL RESEARCH LABORATORY, CLEVELAND, OHIO

HEALTH and disease are relative factors. The span of life has been more than doubled in the last century or two, owing chiefly to increased knowledge of the nature of life and the controlling forces which are active in bettering or injuring it. The mysteries of the vitamins are in the process of being unlocked by biologic science.

No constructive force has been known to man comparable with that of the sun's energy. Some of the mysterious properties of the vitamins are now being found to be associated with radiant energy phenomena and their effects. Animals are shown to go up or down in physical well-being in accordance with the presence or absence of radiant energy, natural or artificial, and of certain substances carrying so-called vitamins. The riddle of the health of the maritime dwellers of northern latitudes is found to be associated with the stored-up products of radiant energy found in aquatic life. Animal life as well as plant life must have radiant energy and its products.

One of the menaces that we have overlooked has been the blight upon health, happiness, and well-being resulting from a canopy of smoke which we hang as a great pall over our centers of civilization, quite effectively reducing the greatly limited radiant energy of the winter season. A larger knowledge of these laws will make more abundant health and happiness possible.

The application of these great principles must largely be made by chemical and industrial engineers.

THE average span of human life has been extended in two centuries from about twenty years to about fifty-six years, and most of this advance has come in the last fifty years. That this advance will continue to make possible an average of nearly seventy years is the confident hope of many earnest students of human welfare. Removal of the epidemic diseases which decimated civilizations as recurring besoms of death have been stopped and individuals are not now perishing by these avalanches. They are, however, dying largely of a group of affections called degenerative diseases. One in every ten of all funerals is a heart case, and in some communities, including some of our large cities, the statistics show a very much higher proportion. The great increase in longevity has been achieved largely through an increased knowledge of the nature of bacterial infections and the adoption of means for their control. In other words, the department of social life known as "preventive medicine" has been chiefly responsible for instituting the movements. They have always been assisted by the other sciences, such as engineering, construction, chemistry, etc.

Life's current today is flowing through channels quite different from those of preceding centuries. Biological sciences are revealing the nature of life and the subtle factors which determine its perfection and degeneration more or less suddenly. It has come to be realized that the emphasis has not been correctly placed, that the animal body is not so simple a machine as a combustion motor, that in addition to fuel there must be present activators which enable the body to utilize the fuel, that life is as dependent upon the solar radiant energy for the utilization of nourishment and continued function as upon bread and water and air, the absence of the 1/200,000 part of a gram of a vitamin or accessory food factor may make the difference between increasing life with normality and degeneration and premature death. In an important sense the outstanding opportunity for service to humanity seems to be passing from the anatomist, internist, and biologist to the chemist, physicist, and engineer, since ultimately life's processes are determined, and even controlled, by the simple laws of physics and chemistry. It will avail nothing of practical value if the biologist shall ascertain that ultra-violet radiation is absorbed by smoke and dust, unless the chemical and mechanical engineers shall find some way to retain the purity of the atmosphere, or provide a means for preventing noxious gases and smoke particles from reaching the atmosphere. Life cannot be realized in its fullest measure if childhood has been handicapped by faulty environment. The new era will place the chemist and the engineer alongside the biologist and specialist in preventive medicine as sharing not only an equal part in the great responsibility of human betterment, but also the surpassing joy of clearing the channel of life's great current so that function may reach efficiency and efficiency ever progress toward perfection. Surely by these means man becomes a copartner with his Creator in creation itself.

Chlorophyl and Hemoglobin

A discussion of the relation of light to life should include as a primary consideration the role of chlorophyl in green plants in the synthesis of starches and sugars in the presence of radiant energy. Von Baeyer and others have demonstrated that organic matter can be built up from carbon dioxide and water under the action of radiant energy in the presence of an inorganic colloidal substance. Baly has shown that calcium ions, when present in proper concentration in water through which carbon dioxide is being passed in the presence of ultra-violet radiation, produce a group of factors such that formaldehyde is formed, which in turn under the continued influence is changed to a starch and sugar. The chlorophyl of the green plant, under the chemical actions set up by the sunlight which it absorbs, is able to separate carbon from carbon dioxide and hydrogen from oxygen in water, and from these build up the hydrocarbon compounds which provide the materials for the growth of the plant and in which they are stored.

In animal life there are in the circulating blood stream substances which act in certain regards like chlorophyl of the green plants. One of these, the hemoglobin, forms the red coloring matter. When both chlorophyl and hemoglobin are changed with similar degradation methods, a final substance, etioporphyrin, is produced.

The role of calcium ions in plant and animal life is of profound importance. It has been shown that there have been no civilizations built up on the face of the earth where there is not an abundance of calcium, either in the soil or in the irrigation water. We are all familiar with the improvement in the lawn by the simple addition of a few handfuls of lime.

[1] Read before the Chemistry Session at the Second Chemical Equipment and Process Engineering Exposition, Cleveland, Ohio, May 10 to 15, 1926.

True has shown that nutrient chemicals may be present in the soil in ample quantity and yet be unavailable for the plant if calcium ions are not present, and further that the essential chemicals of the plant units are lost by a leaching process if ample calcium is not present in the bathing fluids. The role of calcium in plant life by its combining with pectic acid to form calcium pectate in the process of cellulose formation and plant growth is but another illustration of the dependence of plant life upon calcium in the process of growth. Similarly, animal life is dependent upon calcium for cell formation in the organs and tissues, as well as for the making

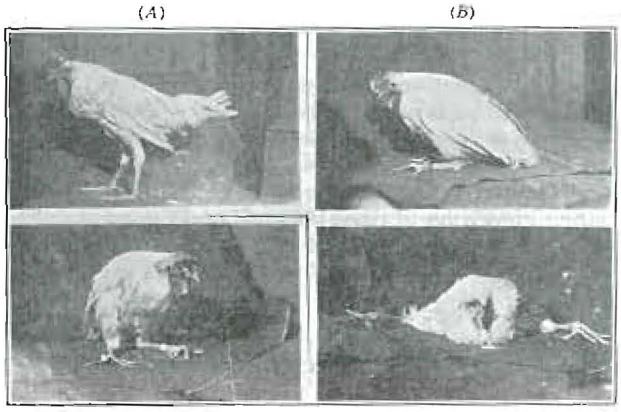


Figure 1—Progressive Weakening of Legs of a Chick Deprived of Radiant Energy, and on a Diet Low in Phosphorus and Antirachitic Factor. Control, Upper Left, Had Same Diet but Occasional Sunshine

of bone. This discussion will therefore be chiefly concerned with the influence of light upon life through the medium of making calcium available for its various functioning processes.

Effect of Light on Bone Formation

In order to make clear the nature of the chemical and physical forces which relate life to light and health, attention is called to four views of a chick (Figure 1) which has been on a diet deficient in phosphorus but ample in calcium. *A* is a control. In the presence of the available sunshine this chick remained apparently normal on this basic ration. *B*, *C*, and *D* show progressive stages of the weakening of the bones and muscles so that this chick has gone completely down. The only difference between the control and the chick shown in the three stages has been the absence of radiant energy from the sky. Their diet was the same.

This disturbance in the chick is anatomically quite similar to, though not identical with, the rickets of childhood. This disease is characterized by a delayed and abnormal bone growth with distressing warpage of the body contours as the result of faulty ossification. In childhood, teeth are affected simultaneously with the disturbance of the skeleton, but, unlike the bones of the body, the teeth cannot be reconstructed when once formed, and their defects are largely permanent. It is significant that rickets is not found in the West Indies, but becomes apparent as we go northward, becoming very prevalent in the north temperate zone. It has been estimated that in many of our large cities in the latitude of Cleveland approximately 90 per cent of all children under two years of age are affected by this disturbance. It is readily diagnosed by means of the X-ray, since there is a zone that is incomplete or imperfectly calcified. This zone can be shown with marked increase in calcification in a very few days after the individual so affected has been provided with a factor which compensates for one that has been missing in the previous conditions of life. Figure 2 shows X-rays of the bones of a chicken, the second taken 33 days and the third 64 days after the addition of a few drops of cod-liver oil daily to the ration, which had produced the condition in the absence of radiant energy. Figure 3 shows a chicken standing which a few weeks before was prostrated by lack of activator as shown in *A*. This change was produced by the addition of cod-liver oil to the same diet.

Under some of the stresses of natural environment and abnormal overload, adults readily become victims of calcium disturbances which, although the symptoms are different from those of young and growing life, are quite as distressing and far-reaching in their effects. Probably every one sees people suffering from conditions which are primarily due to disturbed calcium metabolism without associating the disturbance with faulty environment in the presence of normal or abnormal overload. The excessive decay suffered by prospective mothers is largely an evidence of a negative calcium balance resulting from inability to pay the calcium bills as time progresses.

Importance of Calcium in Body Tissues and Fluids

We have thought of calcium or lime as needful in the body for providing skeleton and teeth. We now find that every organ and tissue is dependent upon a normal level of calcium within the tissue cells and the fluids of the body. When the calcium level is too low, function is slowed up and disturbed. When suffering from this in the simple forms, such an individual has a lack of pep or lassitude, and finds the daily duties a drag; in the more severe forms nervous symptoms develop. Both anabolism and catabolism are seriously disturbed. The normal functioning needs of the body use up approximately 0.6 gram of calcium per day, and under the stress of overload the demand may be doubled or tripled. The diets of many individuals do not furnish an adequate minimum, and they are frequently compelled to borrow from their stores. Nature has a marvelous mechanism for storing calcium, for she uses the skeleton and teeth as a great depot to which she may go in an emergency. Most expectant mothers make a mortgage on their skeleton and teeth to secure adequate material for the new framework. During

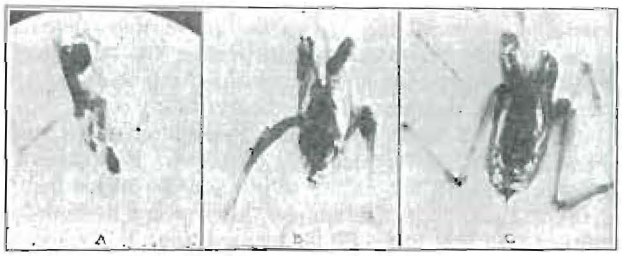


Figure 2—Three Roentgenographic Views of the Same Chick. *A*, when Down as the Last Chick in Figure 1; *B*, 33 Days Later than *A*; *C*, 31 Days Later than *B*. Note the Increasing Calcification

lactation the demand is quite as great as during pregnancy, for lime for the milk must be had even at the serious sacrifice of the mother's skeleton. It is not uncommon for cows that are being intensively milked to have their bones become so decalcified that spontaneous fracture will occur without any provocation. As the summer progresses there is often a marked change in the shape of the hip bones of dairy cows due to nature's borrowing from these storehouses as from all the bones of the body for the lactation period.

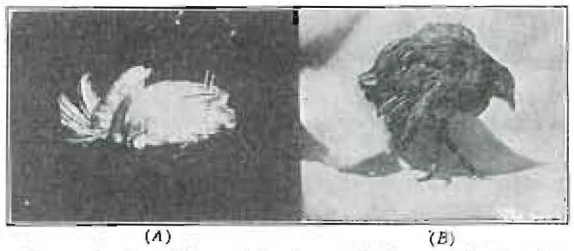
Under the stress of severe illness, such as fevers, the body is compelled to make a great draft upon the calcium of the skeleton. Dental caries becomes very disturbing at that time. We have not appreciated why we have used milk in all periods of physical stress. It is most significant that milk contains calcium, and phosphorus in a concentration approxi-

mately ten times that required in the blood. It furnishes not only protein, carbohydrates, and fats for fuel and cell metabolism, but the minerals, chiefly calcium and phosphorus, which are equally indispensable in fighting infection. Microörganisms growing in the human body produce toxins which disseminate through the tissues and fluids and in the process of their neutralization and elimination the body uses calcium, which of necessity is lost in the process. Disease, therefore, makes extreme demands upon the body for calcium, and when it is not available the capacity for defensive reaction is tremendously reduced and many an individual loses the fight because of the exhaustion of these essential weapons. The necessity for having an adequate supply of calcium in our food, and an adequate capacity for its utilization, is therefore apparent. Singularly large numbers of people perish for want of calcium on diets abundantly supplying it.

Monitors for Calcium Metabolism

The animal body is marvelously provided with monitors to supervise over great fundamental phases of vital function. These are spoken of as the glands of internal secretion. Without some of these life cannot exist, and all are needed for efficient normal life. Two small glands in the neck about as large as peas, the parathyroid glands, are chiefly the monitors for calcium metabolism. Several glands influence calcium metabolism, but with most animals the elimination of no other glands than the parathyroid produces death from resulting lowered calcium of the body fluids. Following their removal the animal loses weight, serum calcium goes down from an average of 10 to 11 mg. per 100 cc. of serum to 5, 6, or 7 mg., at which time the animal becomes very nervous and usually goes into convulsive spasms called tetany, which may last several hours or but a short time, usually terminating in death. If, however, prior to death there is injected into the animal some extract of parathyroid glands, the animal is restored and will continue to live in practically normal health provided a little of this extract is injected every day or two, but continuously. When the parathyroid glands are removed from rats, a change can be seen under the microscope in the structure of the growing teeth in as short a period as 5 days, and is marked in 15 days. These continually growing incisors readily break off when a little strain is put upon them, when their extrusion in normal growth processes has brought the point of weak structure within the zone of stress. The functioning of the parathyroid glands is essential for the maintenance of the quality of the blood which we may speak of as the solubility factor for calcium. The maintenance of the functional capacity of these glands seems to be directly related to certain activating substances which reach it through the circulating mechanisms of the body. When cholesterol, a lipoid which is rich in the skin and many of the body tissues, particularly the brain, is exposed to ultra-violet light or sunlight, it has the property of aiding the body in metabolizing calcium. Certain fats, particularly butter and egg yolk, contain substances capable of activating the metabolism of calcium. Cod-liver oil has this property in a concentration approximately four hundred times that of butter.

It is an interesting fact that the Eskimos of the far north, where the light is so restricted, live largely on sea life, particularly the fats of fishes, during the long winter. It is remarkable how the developing civilization has created what we may term an instinct. For example, the people living on the Isles of Lewis, north of Scotland, which are shrouded in fog and cloud, have a practice of taking as part of the diet for each day at least one stuffed cod's liver. Children are started on this ration in very early life. When our explorers have gone into the north seas for the winters, and have tried to subsist through the long period of darkness on canned foods, flavored to tickle the palate, they have developed diseases with which the Eskimos about them, whose diet they would scorn, would be unaffected.



(A) (B)

Figure 3—Two Views of the Same Chick on a Diet Low in Phosphorus and Deprived of Ultra-Violet Radiation. *A*, Completely Prostrated with Typical Weak Legs. *B*, Same Chick a Few Weeks Later, after Having Cod-Liver Oil Added to the Food. Note the Leg Deformity

Activation with Cod-Liver Oil and Ultra-Violet Light

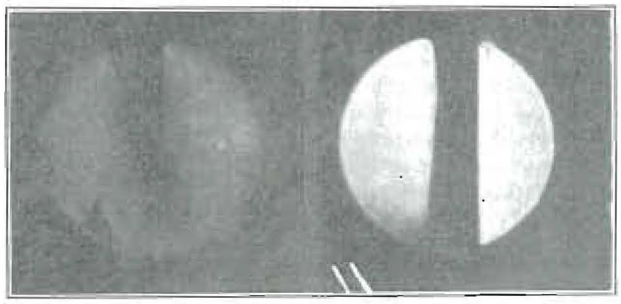
In order to demonstrate somewhat of the nature of the action of cod-liver oil and of ultra-violet light, chicks have been subjected to varying conditions as shown in Table I. The first control lot had as much sunshine as could be given during the day, and the last, 3 hours daily. All of these chicks were on the same basic diet, the variation being entirely in activation or light source. All except the two control groups were kept in darkness except for the turning on of ruby light twice daily for a couple of hours for feeding.

It will be noted from these data that, whereas with cholesterol, not activated, added to the food, all died, with the ac-

Table I—Comparative Studies of Different Methods for Modifying Treatment of Chicks on Low-Phosphorus Diet

Lot	Variable Condition	Deaths during days of experiment 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Dead	Living	Condition
1	Controls															0	9	Peppy; well feathered
2	Darkness and ruby lamp				1	2		1		1	1					5	0	All dead; weak legs
3	Same as 2 plus ultra-violet daily for 30 minutes			1				2								3	3	Peppy; well feathered
4	Same as 3 plus blue filter			2						1						3	3	Peppy; well feathered
5	Same as 3 plus heavy window glass					3	2	1								6	0	All dead; weak legs
6	Same as 2 plus cod-liver oil, 1 per cent					2	1		1							4	2	Retarded growth
7	Same as 6 but 0.1 per cent	1			1	2		1		1						6	0	All dead; weak legs
8	Activated cod-liver oil, sunshine, 0.1 per cent	1				2							1			4	2	Medium growth
9	Same as 8 but 1 per cent		2				2								1	5	1	Medium growth
10	Cod-liver oil activated 15 minutes, 0.1 per cent				1	1	2									4	2	Medium growth
11	Same as 10 but 1 per cent	1					1	1								3	3	Peppy; medium growth
12	Cod-liver oil activated 6 hours, sunshine, 0.1 per cent						1		1							2	4	Peppy; well feathered
13	Same as 12 but 1 per cent								1							1	5	Peppy; well feathered
14	Same as 12 but 5 per cent	1	2			2							1			6	0	All dead
15	Cod-liver oil activated ultra-violet 3 hours, 0.1 per cent	1	2				1									4	2	Retarded growth
16	Same as 15 but 1 per cent		1	1			2	1								5	1	Retarded growth
17	Same as 15 but 5 per cent							1								1	5	Peppy; well feathered
18	Raw cod-liver oil 5 per cent				1	3	1									5	1	Well feathered; medium pep
19	Cod-liver oil activated sun 30 minutes; rubbed on neck						1	2								3	3	Peppy; delayed feathers
20	Same as 19; raw cod-liver oil					1	2							1		4	2	Delayed growth; poor pep
21	Cholesterol activated ultra-violet, 1 per cent						1							1		3	3	Medium feathered; peppy
22	Same as 21 not activated, 1 per cent				1		4		1							6	0	All dead
23	1 per cent parathyroid extract				1											1	5	Medium feathered; fair pep
24	Food exposed to ultra-violet daily			2	1	1										4	2	Delayed growth
25	Exposed 3 hours daily to sunshine															0	6	Peppy; well feathered

tivated cholesterol, 3 lived; further, that with cod-liver oil, activated in the sunshine 6 hours, 5 per cent added to the food, all died, and by placing a heavy window glass in front of the ultra-violet obstructing the rays, all died. It should further be noted that rubbing cod-liver oil, activated 30 minutes in the snnshine, on the necks of the chicks saved 3 out of 6 and raw cod-liver oil used the same way saved 2 out of 6. Freshly made extract of parathyroid added to the food 1 per cent, saved 5 out of 6.



A—Kept in ice box *B*—Kept in incubator

Figure 4—Fogging of a Photographic Plate Produced by Cod-Liver Oil from Hydrogen Dioxide Formation

In order further to study the nature of these processes, chemical analyses were made of the blood to determine changes in certain of the calcium factors. In this series 66 chicks were used in each group. The results are shown in Table II. Of those under treatment, several had had distinctly higher total calcium than the controls. One of the methods of investigation of the influence of cod-liver oil was to rub it on a limited portion of the chicken's body, as the neck (Lot 20). This had a very marked effect on the level of the calcium of the blood and on the general physical condition of the chicks. Another group (21) was treated similarly with the cod-liver oil on the neck, except that it had been activated in the sun for 30 minutes, with an increase total calcium of the blood as a result. The inorganic phosphorus was also influenced by the various methods of the utilization of cod-liver oil.

Table II—Blood and Lymph Chemical Studies of Chicks by Groups

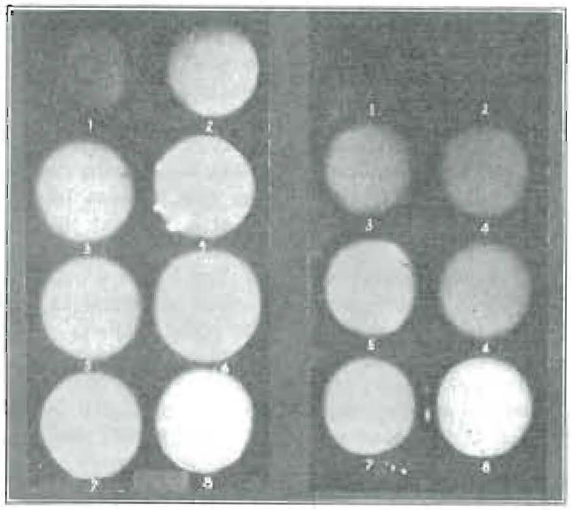
Group	Treatment	Gain Per cent	Calcium—Total	Calcium—Active	Inorganic phosphorus	Total Ca × ig. phos.
1	Controls; sunshine	63.8	9.96	8.14	4.52	45
2	Ruby light	154.7	10.28	8.3	4.83	49.65
3	U. V. 20 min. daily	111.6	9.25	8.3	4.1	37.92
4	U. V. 2 hours daily	95.7	8.53	8.13	4.1	34.97
5	1% raw C. L. O.	176.6	9.73	6.6	6.33	61.59
6	5% raw C. L. O.	57.7	8.95	8.33	5.26	47.19
7	10% raw C. L. O.	74.3	9.45	8.13	2.9	27.40
8	1% C. L. O.; 15 min. sun.	69.2	10.9	8.82	3.17	34.55
9	5% C. L. O.; 15 min. sun.	78.03	13.13	10.02	2.93	38.48
10	10% C. L. O.; 15 min. sun.	55.05	10.07	10.22	2.10	22.48
11	1% C. L. O.; 1 hour sun.	85.2	20.21		2.22	46.82
12	5% C. L. O.; 1 hour sun.	77.3	9.66	7.64	3.9	37.67
13	10% C. L. O.; 1 hour sun.	70.6	11.43	8.32	2.77	31.62
14	1% C. L. O.; 24 hours sun.	72.9	11.37	8.06	3.71	42.18
15	5% C. L. O.; 24 hours sun.	76.6	10.25	8.52	3.62	37.2
16	10% C. L. O.; 24 hours sun.	67.2	9.72	8.82	3.51	34.1
17	1% C. L. O; 24 hours U. V.	133.1	10.84	5.84	5.45	59.07
18	5% C. L. O; 24 hours U. V.	89.04	10.06	6.6	4.85	53.16
19	10% C. L. O.; 24 hours U. V.	36.8	10.42	8.32	1.94	20.20
20	Raw C. L. O. on necks	6.3	11.26			
20	Fluid from necks of 20		18.97	14.19		
21	C. L. O. 30 min. on necks	56.07	15.04	10.22	2.15	32.35
21	Fluid from necks of 21		27.14	18.09		
22	5% raw cholesterol	1.4	9.35	8.92	2.21	20.91
23	5% cholesterol, 30 min. sun.	26.1	10.25		4.77	48.90
24	10% raw butter	62.2	11.69	7.25	5.4	63.13
25	10% butter 24 hours U. V.	50.8	8.95	6.75	5.2	46.54

C. L. O. = Cod-liver oil
U. V. = Ultra-violet ray

Similar studies were made by making topical applications of cholesterol, both raw and activated (22 and 23), and showed greater total calcinm with the activated cholesterol.

Several of the chicks that were having cod-liver oil rubbed on their necks in each of the different groups developed large cystic sacs filled with serous fluid. This fluid was aspirated, pooled together for each group, and calcium determinations were made. Inasmuch as the circulating lymph and spinal, pleuritic, and ascitic fluids have total calcium levels from 40 to 60 per cent of that of the total calcium of the blood, and since the total calcium of these sera has approximated the diffusible calcium of the blood, it has been suggested that the differences in level of calcium in these sera and the blood are controlled by the diffusion through the tissues, the colloidal calcium being held back by the tissues. The total calcium of the blood of these sera was higher than that of the controls—namely, 11.2 and 15—while the controls was 9.9. If now we would anticipate the same general relationships between blood calcium and cystic fluid, as in ascites and lymph, we would have factors approximately half of 11 and 15. Contrary to expectations, the average total calcium of the fluid from the neck of the group receiving raw cod-liver oil applied topically was 18.9 instead of 5 or 6, and for the group having the activated cod-liver oil applied locally, 27 instead of 7 or 8. In other words, in this second group the total calcium level of the fluid in the neck was nearly twice that of the total calcium of the blood instead of half.

This seems to throw an important new light on the mechanisms of activation. Had a calcium salt been applied with the cod-liver oil, raw or activated, we might think that the calcium was absorbed by the tissue being treated. Since, in this case, however, the calcium of the aspirated fluid was higher than that of the blood stream, and since no calcium could reach this fluid except through the blood stream, there must have been established in the chicks a condition of increased solubility for calcium in this fluid, which in turn



Brand *A* No.	Brand *A* Exposure Minutes	Brand *B* No.	Brand *B* Exposure Minutes
1	Unexposed	5	20
2	5	6	30
3	10	7	40
4	15	8	60

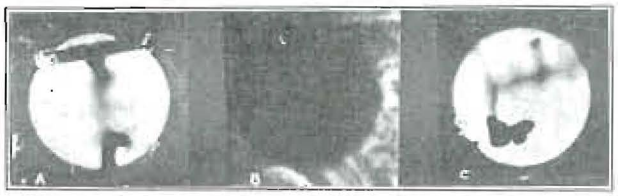
Figure 5—Progressive Increase in Capacity of Cod-Liver Oil to Fog a Photographic Plate with Increase of Time of Exposure of Oil to Sunshine or Ultra-Violet

influenced the blood to bring the blood total calcium higher than that of the controls. This also indicated that this fluid had a solubility factor enough higher than that of the blood to take calcium from the blood to it.

From the foregoing it will be noted that exposing the cod-liver oil and cholesterol to radiant energy, sunshine, or ultra-violet changes in a marked degree the effect produced by their use, and further that over-exposure produces deleterious effects. Evidence has been presented to the effect

that butter exposed to ultra-violet radiation for several hours was made distinctly poisonous for mice, though the above observation would indicate that it was not poisonous for chicks.

The effect of ultra-violet radiation on cod-liver oil, so exposed, has been further studied. When ordinary raw cod-liver oil is placed in a dish and over the dish is placed a photographic plate, the chemical action produces fogging of the emulsion, which is decreased by decreasing temperature, and increased by increasing temperature, as shown in Figure 4. *A* was placed in the ice box, but *B* in the incubator for equal periods of time. *A* had an obstruction made of tissue paper in varying thicknesses, from 1 to 20 layers. The latter proved to obstruct completely the gaseous substance which produced the chemical action. In *B* the obstruction was a piece of card.



Not exposed | Exposed to ultra-violet 30 minutes | Exposed to sunlight 1 hour

Figure 6—Effect on a Photographic Plate, with Exposure to Sunlight and Mercury Vapor Lamp

This photographic effect is not produced by radiant energy given off by the oil, but to gases, the chief of which is hydrogen dioxide. When cod-liver oil is exposed to ultra-violet light or sunshine, this capacity for fogging a photographic plate is markedly increased, as shown in Figure 5, for two brands of oil.

In Figure 6 is shown the effect of exposing an extract of pancreas in *B* to ultra-violet from mercury vapor lamp, 30 minutes, and in *C* to sunshine for 1 hour, in comparison with the same shown in *A* without exposure. It is important to note the marked difference in effect of the ultra-violet from the quartz vapor lamp and that of sunshine. The administration of calcium lactate with cod-liver oil produces entirely different effects, both clinically and as expressed in chemical constituents of the blood, from the administration of either of these substances alone.

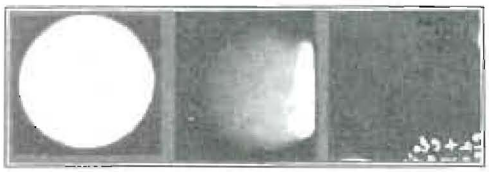
Figure 7 shows some observations on the effect of the addition of calcium lactate on the ability of cod-liver oil to fog a photographic plate. It will be observed that the capacity to produce fogging has been completely destroyed in *C*.

Calcium Utilization by Tissues

The previous studies have been concerned chiefly with characteristics of the forces which are acting upon the mechanisms of the body in influencing calcium metabolism. Other studies are revealing some of the factors involved in calcium utilization by the tissues. In the chemical analyses of the bloods of large numbers of individuals suffering from various phases of disturbed calcium metabolism, certain factors have been conspicuous. Chronic focal infections, such as infected teeth, may produce either localized disturbances in other parts of the body or metabolic disturbances without localization. One of the characteristics of such processes tends to be a decrease in the polymorphonuclears and an increase of the lymphocytes, which is quite the opposite picture to that which obtains in acute infective processes. Investigation has shown that many of the blood stream changes parallel disturbances of calcium levels. This is not strange, since all cells are directly influenced in their functional activity by the level of calcium within and without. When a piece of glass tubing about the size of the lead of a lead pencil and one inch long has infected culture medium put within it and the open end is placed under the skin of an animal, leucocytes in the blood pass into this glass tube as a result of chemotaxis and proceed to destroy the organisms. They will migrate approximately one-half an inch in 2 hours in a normal animal. When the calcium of the blood is reduced 10 per cent, they will migrate only about one-half as fast, and their rate of migration can be speeded up by placing calcium in proper form in the alimentary tract.

One of the forms in which calcium is present in the blood stream is nondiffusible, and probably in combination with a protein molecule the size of which prevents its passage through celloidin sac or animal membrane. In general, about half of the total calcium of the blood is in this form. The balance, while diffusible, is probably partly ionized and partly in combination with a substance or substances from which it can readily be released and thus become available for reactions in tissues. When the parathyroid glands are removed, it is chiefly the colloidal calcium that is reduced, perhaps by becoming expended through changing to diffusible as the diffusible is utilized. In normal blood about 10 per cent of the total calcium is in the blood cells. In certain infections, particularly in anemia, this factor seems to be greatly reduced. The administration of cod-liver oil, raw or activated, internally or by external application or with a salt of calcium, such as calcium lactate, will produce quite different effects upon various calcium factors of the blood and in certain respects different from the effect of the exposure of the surface of the body to ultra-violet.

Some idea of these general effects can be obtained from a review of the progressive changes produced by placing an infected tooth beneath the skin. Figure 8 shows a graph of the consolidated story of such an inoculation of a rabbit. The total calcium balance is the product of inorganic phosphorus and total calcium minus 40, and the active calcium balance is the product of active calcium and inorganic phosphorus minus 40. The horizontal line represents 40, and the figures above and below this line represent positive or negative calcium balance. All animals and all individuals whose



A—Activated cod-liver oil | *B*—Activated cod-liver oil 90%, calcium lactate, 10% | *C*—Activated cod-liver oil 50%, calcium lactate, 50%

Figure 7—Change in Effect of Cod-Liver Oil upon Addition of Calcium Lactate

calcium balance lines are below the base line are presumably in a pathological state. In over two hundred rabbits studied by placing an infected tooth beneath the skin, 75 per cent have died when the active calcium decreased to the vicinity of 5 or 6 mg. This rabbit was at the end of 7 days, therefore, in very grave danger. According to the history of previous cases, the animal would soon have been dead. At this point an injection was made of parathyroid extract, at which time, the leucocytic count, which had gone up during the first 4 days, was receding. With the three injections of parathyroid, which increased the solubility factor of the blood for calcium, all of the graphs rapidly moved upward. The leucocytic count improved, but this improvement was temporary. The rabbit soon began to decline. With this temporary improvement, at which time calcium was being taken

from the bones through the increase in the solubility factor of the blood for calcium, there was a marked loss in weight of the animal, coincident with the improvement in the clinical picture. The fuel for the defense was secured at the expense of the body tissues. At this point to check the further decline, and in order to pay the calcium bill from without, ac-

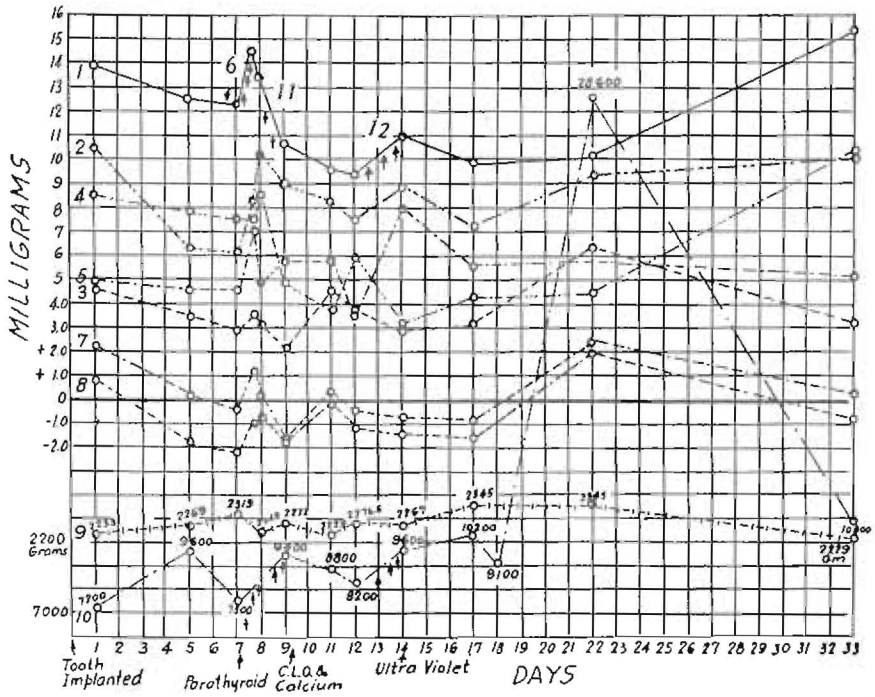


Figure 8—Changes Produced in Various Blood Factors by Placing Infected Tooth beneath Skin of Rabbit

(1) Total calcium, (2) active calcium, (3) inorganic phosphorus, (4) nondiffusible calcium, (5) diffusible calcium, (6) rabbit treated with parathyroid, (7) total calcium balance, (8) active calcium balance, (9) weight, (10) leucocyte count, (11) rabbit treated with cod-liver oil 30 minutes, (12) rabbit treated with ultra-violet ray 30 minutes. Note marked changes, especially of active calcium and response to treatments.

tivated cod-liver oil and calcium lactate on 2 days in succession were placed in the rabbit's stomach by tube. Again there was a marked improvement in the calcium balance, largely through the reënforcement of the metabolism of inorganic phosphorus. This improvement was again temporary. The total calcium came down progressively, at the figure marked (11) following the administration of parathyroid, but with the administration of the activated cod-liver oil and calcium lactate the active calcium came up rapidly to approximately its starting point. The rabbit was still carrying the infection, and a quantity of pus, making an abscess about as large as a hen's egg, had accumulated around the tooth. Ultra-violet irradiation, 30 minutes daily, was given on 3 successive days, at the point marked (12) on the total calcium line. Shortly after this the leucocytic count jumped from 9000 to 28,000. With this splendid defensive reaction the size of the accumulation about the tooth decreased to about that of a hickory nut so that the pus was no longer palpable. The calcium balance for both total and active calcium passed well above the zero line, the total calcium again mounted to and above its original normal, the tissue over the tooth broke down and the tooth was exfoliated and the animal was out of danger. At the time of this writing, 6 months after the experiment, the animal is apparently still in good health.

Importance of Sunlight in Modern Life

We have had many striking illustrations of the influence of sunlight on animal life. A rat that was deprived of both activator and sunlight to the extent that it was lying on its side and gasping as though nearly dead, within 2 hours after being placed in the bright sunshine was up and eating, and recovered on the same diet which had produced the disturbance, simply by giving it sunshine daily. Another and more striking illustration has occurred with a group of chicks, which were being depressed by a diet low in phosphorus but ample in calcium, while being deprived of sunshine or radiant energy. The depression was being carried too rapidly and simultaneously about two dozen of them became prostrated. Some were dead, many were gasping or had occasional twitching of the muscles. Eighteen of those that were apparently nearly lifeless were placed in bright sunshine and in 2 hours ten of them were standing up and four were eating. This was not due to change of temperature, since they were taken from a warm room. They were returned to a warm but darkened room except for ruby light, and in 24 hours all were dead.

The tremendous significance of this to modern life cannot be appreciated except by an intimate contact with these practical demonstrations. Chicks that were exposed daily to sunshine while on the deficiency diet did not break even though the ration was not properly balanced. When they became broken, however, there was not enough ultra-violet radiant energy able to penetrate the smoke screen of the Cleveland winter to bring them back to normal. If any city is to heed the lesson of these experiments, it will cherish the purity of the atmosphere so highly that no factor of economy or convenience will tolerate a smoke production such as has obtained during this last winter.

The ordinary radiant energy of the sun extends from infra-red through the visible spectrum, from about 7000° to about 4000° A., and into the ultra-violet about 1100° A. to approximately 2900° A. The atmosphere of the earth cuts off all radiation shorter than 2900° A. The volume of this radiant energy changes markedly with the seasons. Most

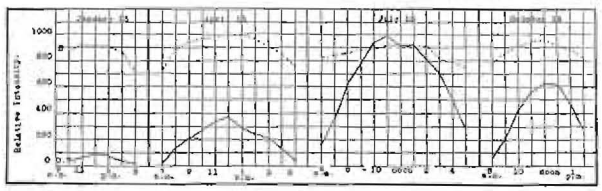


Figure 9—Intensity of the Sun's Energy by Seasons. (Dorno)

every one has had experience with this in photographic work. The length of exposure of midday in June and July is very different from that of midday in December and January. The ordinary photographic lens cuts off radiations at about 3300° to 3500° A., which is 500 to 700 units farther into the ultra-violet than the visible spectrum. Glass cuts off that part of the radiant energy from the sun which is most effective in producing activation of body chemicals for the proper utilization of calcium. Hence the efficiency of the sun bath behind a glass window is very much less than that obtained in the direct sunshine. Bnt glass is not the only obstruction to the ultra-violet radiation with which we have to

contend. Dust particles from volcanoes following violent eruptions are known to change the climate of large areas for many months, owing to the obstruction in the upper atmosphere of the floating gases and volcanic dust. Similarly, the artificial smoke screens which have been allowed to be produced over our centers of civilization become an extreme menace to modern life. Rickets and its associated disturbances are not found in countries with abundance of sunshine but becomes rapidly more frequent and serious as the north temperate zone is entered. Even in that latitude rickets is a disease of late winter and spring and is spontaneously cured in the summer as the direct result of the increased ultra-violet radiation of the spring and summer sunshine.



7 years, 4 months 11 years, 3 months 11 years, 6 months

Figure 10—Comparison of Progress of Calcification between the First Two Pictures and the Last Two Pictures. The Retained Deciduous Teeth Were Shed in One Month after Starting Treatment

A difference in the limit of ultra-violet radiation in winter and summer as expressed in length of ray has been measured by different observers in different locations. Hess has reported a series of readings (after Dorno) showing for December to February a limit of short ray at 3120° A.; in September to November, 3080° A.; March to May, 3010° A.; June to August, 2962° A. On clear days radiant energy is available for 5 hours in December to February, 13 hours in June to August. The difference in the ultra-violet radiation from the sun in different seasons has been graphically expressed by Dorno as reported by Hess (Figure 9). This shows even more graphically the relative intensity of the radiant energy in summer and winter. On a basis of 1000 units the energy for January would be approximately 100 for January, April 400, July 1000, and October 600.

During the winter of 1925–26 in Cleveland, there were several months with so much cloud that for about 85 per cent of the days the sun could not even be seen, and when it did appear, was visible for only a few hours. This condition obtains in the cities of the Great Lakes during all the period of open water when the air is colder than the water. When there is added to this cloud bank a dense smoke screen, a condition is provided which cuts off nearly all of the ultra-violet part of our spectrum even when the sun is visible. This smoke is, of course, deleterious to buildings and house furnishings, all of which is serious. It isnruining our foliage and parks, which gives reason for great cocern, but as serious as these are, they are greatly exceeded in importance by the injury to the health of the citizenship. We are not only cursing this generation which is grown up and the youth of today, but we are making it impossible for motherhood to function without the sacrifice of its very being as well as the blighting of the coming generation.

The first need is an appreciation of the seriousness of the problem. The next is a program for the removal of that part of the contributing factors which is within our power to prevent, which is certainly true of the smoke screen. We cannot remove the clouds. We cannot make the sunshine. We can, however, reënforce activation by artificial means. This does not mean that individuals should expose themselves to ultra-violet light from mercury vapor lamps, for these contain rays which are too short and are therefore injurious to be applied except under careful supervision. We can, however, do as the Eskimos have done for years—draw on the stored-up sunshine of animal and fish life, for this activator or accessory food factor is chiefly soluble in fats. It is also present to some extent in some of the green vegetables provided they have been grown under direct exposure to the sunshine and not under glass. Figure 10 shows the developing teeth of a child. Not only had the deciduous teeth been retained a couple of years over time, but the roots of the permanent teeth had not formed. With the administration of a specially activated cod-liver oil and a calcium compound made from milk, this boy's teeth developed about as much in 3 months as in the 3 years previous. In 3 months he grew 1 inch in height.

Over-activation of cod-liver oil makes an injurious product. One to 5 minutes in the bright summer sun and 5 to 15 in the winter are ample. Ten drops in a capsule is an average dose taken with 5 grains of calcium lactate. It is better to use raw oil than over expose. Never activate with quartz mercury lamp without filter.

This, then, is the opportunity of this generation to take some obstructions out of the great river bed of life's current. They are not beneath us, but we are putting them in the sky above us. We must look to the chemists and engineers of tomorrow for the greatest advance in human health conservation that has occurred in many decades. Surely no problem can more directly and intimately affect human welfare than the preservation of the purity of the atmosphere and therefore permit, as nature has intended, that the life which has been made for this environment shall not be blighted by the pollution of the atmosphere, thereby cutting off the radiant energy which is as essential for vital processes as are water and air and food.