M.A. PSYCHOLOGY

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THIAMIN (VITAMIN B_1), AND ITS EFFECT UPON LEARNING ABILITY.

INTRODUCTION

In recent years the Science of Nutrition has made tremendous strides. It has at last been recognized that our diet affects significantly our physical as well as our psychological well being. Although a great deal of work has been done on diets from the physiological standpoint, very few investigations have been concerned specifically with a psychological approach. The present experiment is designed to study an aspect of the Science of Nutrition from the psychological approach. While this undertaking was not concerned specifically with either the sciences of Psychology or Nutrition, it was an attempt to experiment in that region where the two disciplines overlap. It was an attempt to associate the two sciences. For it is on the overlapping areas of scientific disciplines that there remains much ignorance, and where research is needed.

The object of this experiment is to investigate the effect of a diet deficient in vitamin B on learning ability in rats. Further details will be given in the following chapters.

The writer of this thesis does not make claim to much originality. It was rather his attempt to verify the conclusions and to refine and improve the techniques of other workers. The work was begun on December 26,1939. It was concluded about August 24,1940.

The writer designed and constructed 25 rat cages, 3 Carr Mazes and 3 galvanized tin tanks.

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Chapter I.

THE STORY OF THIAMIN.

Over fifty years ago the Japanese Navy annually suffered an incapacitation of from twenty-three to forty per cent of its effectiveness. The cause was a disease known to the Japanese by the name Kakke. In America it is known by the name Beriberi. For centuries it has been widespread in the Orient. It was known in China as early as 2600 B.C., and recognizably described by Chinese physicians more than three hundred years ago. Its devastations among the Malay peoples of the peninsula and of the great islands of the East Indies are attested by the fact that the world at large has adopted the Malay term Beriberi for the disorder.

All rice-eating countries have shown a marked tendency to Beriberi. The explanation is simple. The masses of people of East Asia are very poor. They exist mainly on a diet of polished rice. In polished rice the kernal has been removed. It is this kernal that contains the vitamin B,and Thiamin.

As a result, Asiatic people lack an adequate diet and are susceptible to beriberi. It was the Japanese, however, who first afforded convincing evidence regarding its nature. The banishment of beriberi from the Japanese Navy was brought about by Takaki. Takaki's career is of some interest. He entered the Japanese Navy as a young medical officer in 1872. Before long he had fully determined that he must find some

cure for this dreadful malady, beriberi, which wrought havoc among his men. Accordingly, he first decided to improve his knowledge of medicine,and he went to London where he spent five years at St.Thomas's Hospital. He returned to Tokio and later was appointed director of the Tokio Naval Hospital,and thence set to work in real earnest on his problem.

In his reminiscences, published in an article in the Lancet in 1906, he says:

"Such conditions used to strike my heart cold, when I came to think of the future of our Empire, because if such a state of health went on without the cause and treatment of beriberi, our navy would be of no use in time of need."

He soon became convinced that the cause was due to a fault in the diet. Japanese sailors, he claimed, were as hygienic in their habits as European sailors, and there seemed to be no other way of accounting for beriberi except the difference in food they ate - largely polished rice.

He succeeded in persuading the Japanese Admiralty to let him make a number of experiments in the navy, "upon a scale of grand magnitude", as he expressed it. He proved his point in the following manner. A training ship had just returned from a six months' voyage around the world. The training ship was called the Riujo. On this ship there had been as many as 169 cases of beriberi; out of its total complement of 367 sailors and officers, no less than 25 had died.

As Takaki himself described it:-

"The fact was indeed alarming, and consequently a careful examination was made. .....The Taukuba, a training ship was then sent out to follow the same course as that the Riujo had taken, with a supply of food elements the relative proportion of nitrogen to carbon of which was one to fifteen. .....The result was that there was not a death from disease during the whole voyage."

Table I.

Takaki's Experiment.

Food	Diet on Riujo Wt.in oz.	Diet on Taukuba Wt.in oz.
Rice	27.78	32.16
Vegetables	9.56	12.41
Fish	4.85	6.56
Meat	2.18	8.02
Other foods not specified		Milk and Tea added
Total wt.of ration	50.37	78.38

The comparative results of the two cruises were surprising. The Japanese Admiralty decided to change the rations of the entire navy, with the result that the incidence of beriberi has never since 1885 risen to as high a figure as one-half percent of the force.

Table II.

The conquest of beriberi in the Japanese Navy.

Year	1878	1879	1884	1885	1886	1887	1888
No.of cases of beriberi	1485	1979	718	41	3	0	0
Percentage	33	39	13	0.6	0	0	0

Table III.

No.of cases of beriberi among prisoners in Japanese Navy.

Year	1883	1884	1885
No.of cases of beriberi	69	73	0
Percentage	61	57	0

Experimenters in Java showed by a study of statistics that prisoners in gaols who developed beriberi had been fed on polished rice or partly polished rice.

Table IV.

Beriberi statistics from prisons in Java.

Diet	No.of Prisoners	Cases of Beriberi
White rice	150,266	4,201
Partially polished rice	35,082	85
Unpolished rice	96,530	9

In a lunatic asylum an experiment was conducted by Fletcher, which proved that beriberi could be alleviated if steamed rice was used instead of polished rice.

Table V

A dietary experiment on beriberi in a lunatic asylum.

Diet	No.of patients	Cases of beriberi	Deaths
Polished rice	120	36	18
Steamed rice	123	26	0

Whenever polished rice has been the principal article of diet and beriberi has resulted, the substitution of unpolished rice for the polished has invariably vanquished the disease.

Takaki did not know, however, the specific nature of the shortage in the diet. The study of this problem was left for Eijkmann, a medical officer in the Dutch colony in Java. In his experiments in the study of this disease, he came across its counterpart in chickens, which, for the sake of economy, had been fed on waste rice from the hospital kitchens.

In Eijkmann's papers, published from 1897 to 1906, he clearly set forth his discovery that a diet of polished rice produces in fowls a condition of nutritional polyneuritis which appears to be essentially identical with typical beriberi in man, and that this disease was due to the lack of a substance essential to normal nutrition; this substance existed in rice polishings (i.e., in the outer layers and the embryo of the rice kernal) and also in other foods.

In 1901 Gringins took up the subject; he confirmed Eijkmann's earlier work and extended it to show that the anti-neuritic or protective substance which Eijkmann had demonstrated to occur in rice, occurs also in legumes and in this case not wholly in the outer layer of the seed. He also noted that the antineuritic substance seemed to disappear when the seeds (Phaseolus radiatus) were germinated.

Grinjins did not sueceed in isolating the antineuritic substance from rice polish. He then set out to determine whether the heating of unpolished rice (or of Phaseolus seeds) destroyed

the protective power. He fed four fowls on unpolished rice which had been heated to 120°C. Two died of polyneuritis after five or six months; the remaining two remained well after eleven months. Fowls fed on unpolished rice developed polyneuritis in three weeks; those fed on unheated unpolished rice enjoyed entire freedom from the disease.

Grinjins concluded that heating at about 120°C. destroyed much but not all the antineuritic substance of rice. Heating of beans (phaseolus) had a similar effect.

In 1906 Eijkmann described experiments designed to throw light upon the chemical nature of the antineuritic substance. It was soluble in water; was dialyzable, and was not readily precipitated from water solution by alcohol. Eijkmann found in his experiments that the antineuritic substance was entirely destroyed when unpolished rice was heated in an autoclave for two hours at 125°, and only partially destroyed at a temperature of 115°. Eijkmann also discovered that fowls rendered polyneuritic by feeding with grain heated in the autoclave could be cured by giving water extracts of raw grain but not by phosphorus compounds, prepared from such extracts. This discredited his contemporary Schaumann's theory, who ascribed the antineuritic property to some organic phosphorus compound. Eijkmann also shewed that curative substances could be administered either by the mouth or by injection.

At the same time Hopkins (1906,1912) Osborne and Mendel (1911) were carrying on work of a similar nature.

Hopkins shewed that milk and some vegetables contained organic substances soluble in water and alcohol, inducing growth

in young animals, fed upon mixture of purified foodstuffs; whereas when these foodstuffs were well purified and fed without accessory substances, growth always failed.

Between 1900 and 1910 there was accumulated indubitable evidence in support of the view that beriberi is essentially a nutritional disease, and may be prevented by consumption of any food containing the unknown antineuritic substance.

In 1910, Chamberlain and Vedder of the United States Army medical commission for the study of tropical diseases in the Philippines reported the eradication of beriberi from the native troops, and began a systematic search for the chemical identification of the antineuritic substance. They found this antineuritic substance, as I have mentioned before, to be soluble in water and cold alcohol; that it is not any one of a number of salts and organic phosphorus compounds which they tested; that it is capable of dialyzing readily through an ordinary parchment membrane, and is therefore a crystalloid rather than a colloid; that it is rather readily absorbed by bone black; can be decomposed by heat; is not soluble in ether, nor is it choline or a lipoid of the lecthin group; that it is neither argimene, histidine, asparagrene, nor any of the other amino acids which they traced.

They thought that the antineuritic substance might prove to be a nitrogeneous base but not an alkaloid.

In 1911 Fraser and Stanton had shewn the antineuritic substance to be soluble in both alcohol and water, stable to

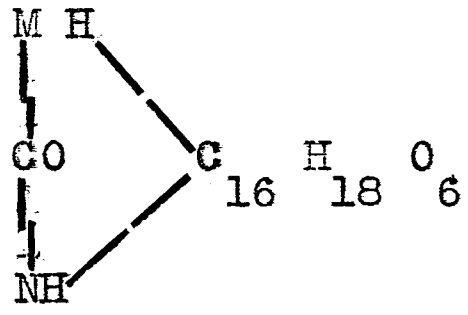
heat in acid solution and more readily destroyed in alkaline solution. In trying to isolate the protective substance they obtained an active filtrate by extracting rice polishings with 0.3 per cent hydrochloric acid and precipitating phytin by adding one and one half volumes of 95 per cent alcohol.

In 1911, Cooper and Funk reported that dried pressed yeast hydrolysed for twenty-four hours with 20 per cent sulfuric acid still retained its curative properties. This confirmed Fraser and Stanton's results concerning the antineuritic action of the alcoholic extract of rice polishings and carried the process further by finding that the active substance was completely precipitated from a water solution of the extract by means of a phosphotungstic acid and that on decomposing the precipitate with barium hydroxide an active substance devoid of phosphorus and free from carbohydrate and protein was obtained.

In 1911 Funk isolated from rice polishings a crystalline nitrogenous compound which he claimed to be the curative substance. He assigned the formula $C_{17}\ H_{19}\ O_4\ M\ (HNO_3)$ to this product.

In 1912 he corrected his previous claim that the substance was isolated in the form of a nitrate. His later evidence indicated that it was a free base probably belonging to the pyrimidine group analogous to ursol and thymine and possibly a constituent of nucleic acid.

The formula suggested was:-



In 1912 Funk isolated a similar substance from yeast, milk, on bran and lime juice. The yeast was treated in the following way. The alcoholic extract was evaporated and the residue hydrolyzed with sulfuric acid after which the solution was treated by precipitation first with phosphotungstic acid and with silver nitrate and barium hydroxide. In this method the bulk of the vitamin remained in the filtrate and could not be precipitated except after hydrolysis. This indicated that the vitamin was present in yeast in a combined form.

Schaumann in 1912 described the preparation of a crystalline active base similar to that of Funk. He proposed the theory that this substance functioned as an activator in the body helping to restore to normal the degenerated tissue.

In 1912 after much experimentation, Edie, Evans and Moore adopted a new method for the preparation of the active constituent from yeast:-

"Commercial fresh pressed yeast was extracted in the cold with successive quantities of methyl alcohol, filtered through the thick cloth and the filtrate, after being freed from alcohol by evaporation at room temperature with the aid of an electric fan, was mixed with sufficient plaster of

Paris to make it set. The matrix after standing over night was ground to a powder and extracted in a shaking machine with successive small portions of methyl alcohol made slightly acid with hydrochloric acid. The extract freed from alcohol as before was precipitated with basic lead acetate, the precipitate discarded and the filtrate freed from lead by hydrogen sulphide and then concentrated to a sirup in vacua at 38°C. This sirup was treated with absolute alcohol, the sticky hygroscopic yellow precipitate (creatinine,etc.) filtered off, the filtrate again freed from alcohol and then precipitated with silver nitrate and barium hydroxide. The precipitate was decomposed with hydrogen sulphide, filtered and the filtrate after being freed from hydrogen sulfide evaporated to dryness in vacuo at 38°. There was obtained in this way a small quantity of brown,sticky,hygroscopic mass, easily soluble in cold water and intensely active."

"A dose of 0.006 grain administered to a bird with a severe convulsion and lameness relieved the convulsions in four hours; the bird was flying strong in 20 hours, and the lameness disappeared in 48 hours.

Two further doses of 0.003 grain were given on the third and eighth days; the bird appeared normal, and gained weight on polished rice diet, but died on the 15th day,without return of lameness or convulsions."

They report that other results were equally favorable and that the doses of three milligrams correspond to 15 grams of yeast.

In 1912, Suzuki, Shimamura and Odake, Japanese workers, were also working on the antineuritic substance. These workers, working with rice polishings, gave this substance the name oryzanine. In 1912 their published paper represented the result of four years of chemical investigation of the antineuritic substance of rice bran. This was done quite independently of the other work in progress at the time.

In 1913 Vedder and Williams reported observations which raised the question whether rice polishings contained other than antineuritic substances, than the vitamin isolated by Funk, or whether one substance is only partially isolated by this method.

Three experimenters claimed that before any of Funk's papers had reached them in the Philippines they precipitated alcoholic extracts of rice polishings with phosphotungstic acid and decomposed the phosphotungstates with barium hydroxide, but did not succeed in getting any protective action with the material that resulted.

When they compared their own methods with that of Funk, they found that he had added 2.5 per cent hydrochloric acid to the alcohol used for the extraction, and by curative experiments had tested the various substances for activity by preventive methods.

By hydrolyzing the alcoholic extracts with 5% sulfuric acid, thereby modifying their procedure to conform with Funk's, they confirmed his results in curative experiments. It was seen that the extract prepared with a preliminary acid hydrolysis according to Funk differed from their

original unhydrolyzed extract in that the former was poisonous and promptly cured paralytic symptoms, and the latter was non-poisonous and only slowly curative. By Funk's method it was estimated that from 96 to 98 per cent of the curative substance is lost. Funk's method consisted of decomposing the phosphotungstic acid from the alcoholic solution by means of barium hydroxide, to reduce destruction of the vitamin, the method was modified by extracting the phosphotungstate precipitate repeatedly by prolonged shaking with 50 per cent alcohol and thereby removing the phosphotungstic acid from the alcoholic solution by means of barium hydroxide.

It was discovered after testing various fractions that polyneuritis of fowls was prevented not by the fraction containing Funk's base but also by the filtrate from it and even by the "prime fraction" precipitated by silver nitrate from neutral solution if this fraction were fed on sufficient quantity.

Vedder and Williams claimed that of these three groups of substances conferring protection only, one was promptly curative 1.O. the fraction containing Funk's base.

They claimed their extract to contain:

(1) A substance (Funk's base) which used in sufficient doses will both protect fowls from developing polyneuritis and promptly cure fowls that have already developed the disease.

(2) Two other groups of substances which will protect fowls from developing polyneuritis but which are incapable of promptly curing fowls already suffering from the disease. The latter group of substances, therefore,have entirely escaped previous discovery, because all other investigators who have so far attempted to isolate these vitamins have relied exclusively on curative experiments. Therefore, it appears certain that there are several groups of chemical substances that are capable of protecting fowls against polyneuritis gallinarium.

In 1913 Cooper described the preparation from animal tissue of a substance which cures polyneuritis in birds.

In 1914 Cooper made the first use of autolyzed yeast as a starting point for the isolation of the anti-neuritic vitamin.

In June, 1913, Funk published further studies upon the chemistry of the vitamin fraction of yeast and rice polishings. From yeast he obtained three kinds of substances. One had the composition of $Cy_2\ H_{19}\ O_9\ N_5$; one $C_{29}\ H_{23}\ O_0\ N_5$ and the third was nicotinic acid.

These were obtained by recrystallization from alcohol of the active fraction of yeast. The vitamin fractions from rice polishings yielded nicotinic acid and a substance with the formula $C_{26}\ H_{20}\ O_9\ N_4$.

In 1916 Seidell found that Lloyd's reagent, a special form of Fuller's earth effectively adsorbed the vitamin from autolyzed yeast solution.

When 50 grams per litre of the autolyzed yeast solution was used the vitamin was all adsorbed. The solid could be washed with successive portions of very dilute acid water and small amounts of alcohol, and finally dried in a vacuum desiccator. This provided prompt effective cures for pidgeons stricken with beriberi.

In 1916 Williams published an unsuccessful attempt at the isolation of the vitamin from rice polishings.

In 1917 Williams in a third paper described further work with synthetic substances from which he concluded that "the curative form of - hydroxypyridine is a pseudo base and that a structure more or less closely to the type of a betaine ring is probably an essential characteristic of antineuritic vitamins."

In the period 1915 - 1916 the vitamin was accepted, and that there was only one vitamin B which could prevent polyneuritis in rats and was necessary for growth. At this period also it was discovered that certain foods could prevent polyneuritis but not add to growth. In 1919 H.H.Mitchell realized that there must be two separate constituents in the vitamin -B. In 1926 Smith and Henricks definitely shewed the existence of two separate factors. The first was antineuritic and capable of being destroyed

by heat; the second was heat-stable, and necessary for growth. In the same year Goldberg,who studied the cause of human pellagra, found that a dermatitis, somewhat resembling pellagra, could be produced in rats by a deficiency of the heat-stable B factor.

In 1926 Vitamin B was thought to be a complex consisting of two components: (1) The factor which cured and prevented polyneuritis; (2) A factor necessary for growth, which could prevent dermatitis in rats, and which was thought to prevent pellagra in man. These two factors were called B_1 and B_2 in Britain and B and G in the U.S.A. The letter G was used in honor of Goldberg.

In 1927-28 three more factors were added to the B group. These were named B_3 B_y and B_5. These were discovered by R.R.Williams,Reader and Peters respectively.

In 1933 Kuhn and his associates isolated flavin from concentrates of B_2; they showed that pure flavin acted like B_2 in accelerating the growth in young rats. Kuhn did not claim that flavin prevented or cured dermatitis, but said it had a growth effect. He said that flavin should be only regarded as a component of Vitamin B_2.

In 1935 Gyorgyi found that flavin could neither prevent or cure dermatitis in rats. He suggested that the factor concerned with rat dermatitis be named Vitamin B_6.

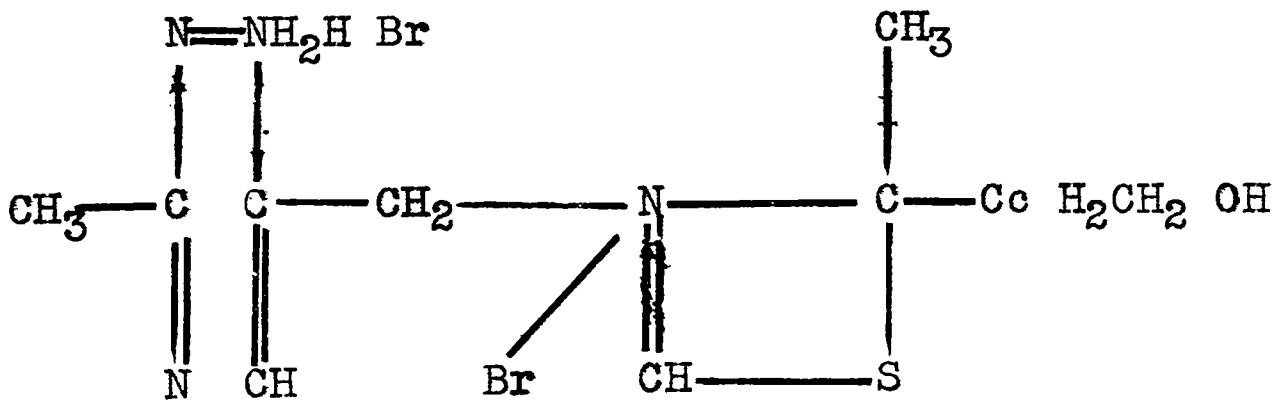
In 1936 Birch, Gyorgyi and Harris found that B_6 was quite distinct from the factor related to pellagra and to

check dermatitis.

The chemical work on the isolation of the various vitamins has been particularly successful in recent years. Vitamins A, B_1, two of the components of B_2, C, one of the D's and E have been isolated in pure form. Four of these components have been prepared synthetically. A man's requirements for one year of Vitamin B_1 can be purchased, as a synthetic substance, for $2.70 and a corresponding quantity of Vitamin C for $5.00, again using a synthesized substance. The most interesting aspect of vitamin study today is the study of their mechanisms of action in the body. Of the various B vitamins, only in the case of B_1 can anything definitely be said about the mechanisms of action.

Thus in 1938, after twenty-six years of constant research the vitamin preventative of the disease beriberi was finally isolated, its chemical constitution determined, and the vitamin itself synthesized at a cost far lower than that of recovering it from bran or rice polishings.

The chemical formula of the vitamin as given before the American Chemical Society by Dr. R.R.Williams, to whom credit is largely due for its accomplishment, is:



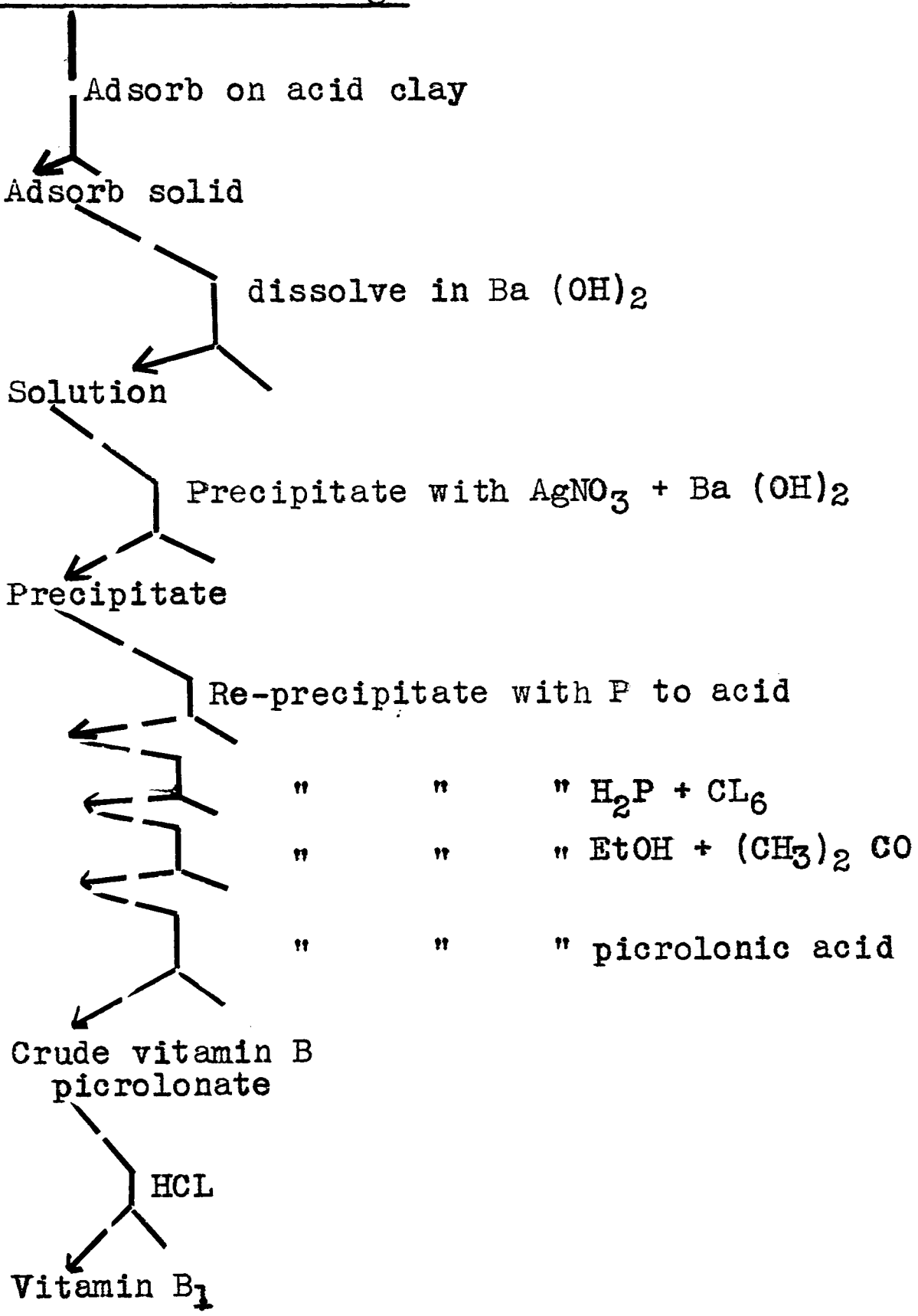
Curiosity is a great characteristic of the scientist. Chemists are not satisfied with the isolation of each vitamin, and the working out of its formula. The vitamin must be finally artificially made in the laboratory from its elements, synthesized. Only when this is done are we in a position to understand all sorts of questions about vitamins and how it works. As you have read, the isolation of vitamin B_1 was a tedious, meticulous task.

The method of isolating a vitamin, like that of any other natural substance present in a foodstuff or in animal or vegetable matter, involves treating the latter in turn with numerous precipitating agents, solvents,etc., and so gradually removing everything else, step by step, until finally only the vitamin remains. As "everything else" may amount to several thousand parts, and the vitamin to one part, the complexities of the chemist's work may be imagined. After each operation an animal test is usually carried out to see what has happened to the vitamin,whether, for example, it has got carried down on the precipitate, or remained in solution. Then another precipitation must follow to separate it still further from other things. As many animals must be used for each single test, and it all takes time, the whole thing is extremely laborious.
Among the most recent investigators, credit must be given to Windaus, of Germany, Otake, of Japan, Van Veen, of Java, and Peters, of Oxford.

1926
(Jansen & Donath)

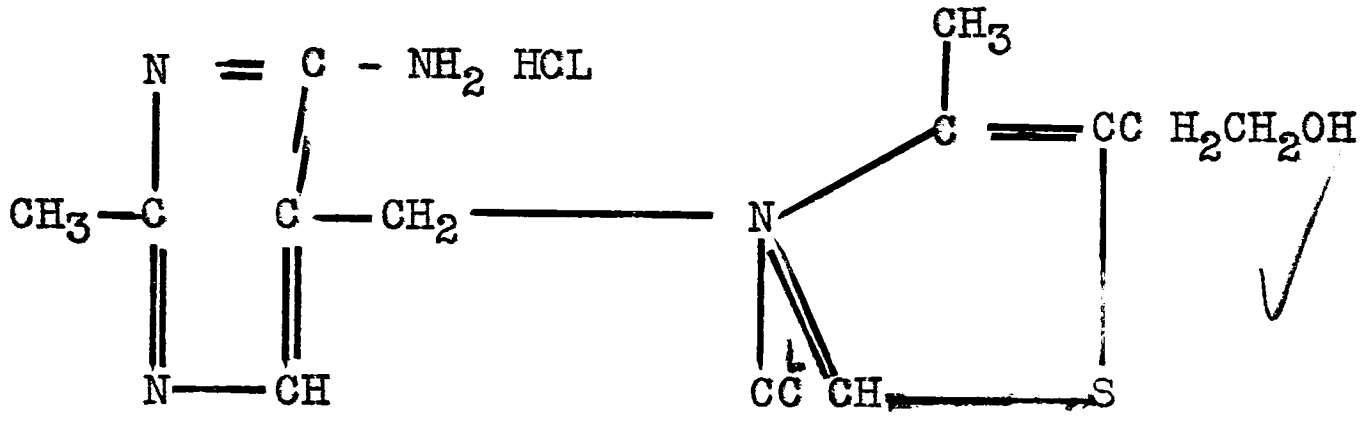
Isolation of Vitamin B.

Extract of Rice Polishings:



Hydrochloride ($C_{12} H_{16} N_4 OS_2$ HCL)

The structure of Thiamin now universally accepted is as follows:



"The most conspicuous feature of Thiamin Hydrochloride is its two nuclei. By treating the vitamin with sulphite, the workers were able to obtain one of these as a sulfonic acid, the other as a weak free base. By reducing the sulfonic acid with sodium in liquid ammonia, they were able to obtain a 2 5 - di-methyl - 6 - amino pyrimidine which was eventually duplicated by synthesis, after trying one after another the various compounds of the same composition in which the methyl groups are in other positions. They were also able to reproduce synthetically the oxo-sulfonic acid which they derived from the vitamin by hydrolysis of the primary produce of sulfite cleavage. As for the other product of sulfite cleavage, the weak base yielded on oxidation with nitric acid, 4 - methyl thiazole - 5-carbory acid, prepared synthetically by Wohmann nearly 50 years ago."

The synthesis of thiamin was discovered in a few months, whereas its isolation required over 25 years.

The synthesis of the thiazole portion came first by

the condensation of thiaformamide with bromacetopropyl alcohol. That of the pyrimidine is more roundabout and difficult, but follows along lines which had already become familiar in the course of producing the various pyrimidines needed for comparison purposes during the establishment of structure. Finally the two portions were fitted together and the properties of the natural product were duplicated. "

Already hundreds of Kilos of the compound have been produced commercially and it is finding an extensive use in medicine, even in well-fed America.

What will be the significance of a bountiful supply of this pure vitamin? Dr.R.R.Williams said in part:

"Now that the vitamin is abundantly available, what uses will it serve? First we shall mention the knowledge it will bring of the physiological function of this substance which is required for the growth and well being of all living things, both plant and animal. Yeast, bacteria, mushrooms, peas, tomatoes, beetles, birds,goats, monkeys, rabbits,rats, mice and men have all been shewn experimentally to use it as part of their normal process ..... A better knowledge of its behaviour will broaden the new science, and in many ways assist in the mastery of constitutional diseases, notably neuritis, arthritis and gout."

"Certain practical and immediate uses are already

evident. Although we have known for more than 20 years the cause and means of preventing beriberi, relatively little has been done in the Orient to curb it except perhaps in the Dutch East Indies.

Until the sale of polished rice is prohibited or restricted in the East, as has often been proposed by Samaritans, the disease will flourish, and there will be need for teaching it. ....."

"The number of people who are partly incapacitated by beriberi is much larger than the number who die. One authority estimates the total number of current cases in the Philippines at 150,000."

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Chapter II.

THE EFFECT OF DIET ON LEARNING ABILITY.

The theory that there exists a relationship between the condition of diet and learning ability is not entirely a popular notion. Blanton,(7) writes that "school physicians often claim that children are feeble-minded because of poor food and malnutrition resulting therefrom,"but he himself is inclined to doubt this.

Holt (22) is of the opinion that mental development and progress depend upon nutrition, even though he states that "there is not yet a great deal of reliable data available upon the relation of nutrition to school work."

Levine (26) expresses his belief that "malnutrition spares nothing, for even the emotional and mental life of the individual may suffer." E.V.McCollum's (27) conviction is that "American children cannot subsist upon a diet no better than that of the coolie without increasing the incidence of tuberculosis, dulling their mental capacity, and warping their personalities." Karl Pearson (14) said that "health and intelligence are correlated, although not very markedly." Since health is at times a function of diet, we may infer a slight relationship between diet and intelligence. Paterson's (36) critical review of the subject,

on the other hand, seems to show that we are without definite evidence that health and intelligence are related, except in certain non-nutritional diseases involving the nervous system.

Contrary to what might be expected, an examination of experimental evidence shows very little to support the belief that intelligence is markedly altered by diet. By intelligence is meant the complex functions measured by intelligence tests. Among one of these functions is the capacity to learn and is treated separately in the animal experiments. Blanton (7) made an extended study of malnourished children in the immediate war areas of Germany, and came to the conclusion that very few had suffered any permanent impairment of intelligence, although lack of energy and marked susceptibility to fatigue were noticeable. He writes that "not more than five per cent of the total school population have suffered injury to the nervous system such as to affect the intelligence permanently." One is inclined to doubt whether it was definitely known that an "injury to the nervous system" had occurred or that the effects upon intelligence were permanent. No direct experimental evidence on these points were presented. It is probably significant that in spite of "malnutrition of an extreme degree extending over three years", the distribution of mental capacity was discovered to be very much the same as would be expected under normal conditions. Blanton did not note any definite increase of the number of children suffering from psychoses

and neuroses.

Dowd (12) wrote that:- "undernourished children distribute themselves in tests of intelligence similarly to normal children". He concludes on the basis of re-tests following nutritional attention, that "the mental level is not affected, for while improvement was shown in all other respects the I.Q. remained substantially the same."

Smith and Field (40) compared an experimental group of twenty-five children who were 7% or more underweight according to the Baldwin-Wood tables, with a group of 36 normals. The experimental group was given health talks, daily health lessons, and school lunches. In addition to this, food record sheets were kept, a health chart placed in the room, and gold stars awarded for keeping all the rules. The National Intelligence Test was administered in December, and a second form of the same test in May. In that period the gain in weight by the experimental group was 26% above normal expectancy, while the normal group made the expected gain. This finding in weight was not paralleled by results in the intelligence tests. Indeed the control group gained more than twice as much as the experimental. Taking the figures as they stand, it might be assumed that nutritional care actually had an adverse effect upon intelligence! However, since no data on statistical reliability are given, caution is advisable and we can only say that a relation between intelligence and nutritional care seems doubtful. The authors say that mental gains may be made more slowly than

physical, and therefore would not be detected in the interval from December to May. That this may be true remains to be experimentally verified. Graper and Park (19) in their article on "The Effect of improved feeding on physical and mental development of undernourished and backward children", report marked gains in intelligence through improved feeding of 8 undernourished children with rather low I.Q's (Stanford-Binet), coming from poor homes where apparently there was ignorance concerning nutrition. They concluded that "a great deal can be done by proper feeding to improve the mental and physical conditions of children who are below normal." A critical study of their work makes one doubt whether intellectual capacity was improved through diet. We are not interested in the physical effects here. The question of statistical reliability was not considered, and there were only 8 subjects used. Added to this, there was no control group, and one is left without information on the effect of practice in taking the intelligence tests. Furthermore, the professional qualifications of those who gave the test was not stated, and the question of prejudice was not considered. Motivation due to special attention may have played a prominent part, but this is not referred to. In the light of these criticisms it is questionable whether there is any clear-cut demonstration that diet in and of itself can cause marked improvements in intelligence.

Rosenberg (38) selected 2 groups of 25 underweight children in each group. To one group he gave a dietary consisting of 1 quart of milk, nuts, whole grain cereal, fresh fruits, and fresh vegetables, but without meat or eggs. To the other group he gave a "representative American dietary". This experiment was prolonged for a period of 6 months. The gain in I.Q. (Stanford-Binet) for the two groups was .83 and .60 respectively. This difference is insignificant because it is less than a point. Again one is in doubt as to how much we can trust the results since there was an absence of figures on statistical reliability. This evidence seems to indicate that the I.Q. is not influenced by diet.

Nicholls (35) conducted an experiment in which 59 children, 9% or more underweight, were compared with children of the same sex, chronological age, and intelligent test scores but of normal height-weight. No differences were found in the opposite test, memory span for digits, attention tests (number work) and the motor coordination test. Note that the first three are the same as those sometimes used in intelligence tests. The normal weight controlled groups excelled in steadiness, tapping, grip and endurance. These tests emphasized the physical element as contrasted with the higher mental processes, which partly explains the superiority of the control group. Nicholls' experiment, we

notice gives little support to the theory that underweight children are mentally inferior to those of normal weight. Hunt, Johnson and Lincoln (24) studied nutrition classes consisting of children more than 7% underweight according to the Burk-Boas Height-Weight-Age Tables. Many psychological tests were given. On the whole, a small advantage in favour of the underweight group was found, but the difference in most cases was not statistically significant. The authors concluded that, "aside from extreme cases of malnutrition, of prolonged hunger or starvation, while like other pathological states would cause disintegration, we cannot say that malnutrition irrespective of other factors produces or runs hand in hand with mental defectiveness. In many types of mental processes the reactions of the undernourished child are equal or superior to the average of his age group. The traits in which he may prove less capable seem to be resistance to fatigue under response to uninterrupted or complex stimuli, and exaggerated emotional responses under normal stimulation." Again there seems to be no evidence to show that underweight children (malnourished) are psychologically inferior to those who are normal.

It is questionable whether height and weight are good indicators of the state of nutrition. Stalnaker (41) calls attention to the fact that the definition of "malnourished" and "undernourished" in terms of height and weight is an

extension of the term "nourishment" which has not yet been validated. Even if malnutrition had a direct effect upon intellectual capacity, height nor weight does not seem to constitute a promising approach to the problem.

Since rickets involves a disturbance of calcium and phosphorus metabolism, we may suppose that there may be mental effects. Peters (37) claimed that a very noticeable association of idiocy and rickets existed, and that "both idiots and rachitics showed a want of phosphorus and calcium in the bony system." Gesell (18) says there is no foundation for the belief that rickets is a causal factor in producing amentia, as claimed by older writers. After critically studying the problem he concludes that, "the retardational effect of rickets is less than is commonly supposed, and is transient in character." It is questionable whether the nervous system is fundamentally altered, even though the behavior output may be depressed.

Frank (15) investigated learning ability in white rats. She discovered that they took fewer trials and made fewer errors, but they consumed more time in learning than normal rats. In this experiment the unfavourable time may have been caused by motivation, and whether a detrimental effect can be claimed is doubtful. Frank found that normal rats were decidedly superior in a relearning test 3 months after. She seemed rather reluctant to attribute it to the

direct influence of rickets. This experiment indicated a lack of definite evidence that learning ability is fundamentally altered by rickets.

The suggestion that the nervous system can be permanently altered through a deficiency in vitamin B stimulated to discover the extent to which this may occur in human beings.

Hoefer and Hardy (20) made a study in this connection. It was found that breast feeding for a period of 4 to 9 months was more favorably associated with intelligence than breast feeding for a greater or shorter time. Maurer and Tsai said that lack of vitamin B played a part in this.

Maurer and Tsai's Experiment (30) which I shall outline in detail later claimed that normal rats were superior to Vitamin B depleted rats in maze learning. The generalizations of these authors (32) have been severely attacked, on the grounds that it is open to doubt as to how freely one may pass from rats to men.

Moreover, Hoobler, Outhouse, and Macy (23) and Macy, Outhouse, Graham and Long (28) have discovered that human milk is often lacking in vitamin B. Moore, Brodie, and Hope (34) find a similar phenomena in the case of the rat. Dennet (11) believes that cows' milk, and often human milk, does not contain an adequate quantity of this vitamin. Is the child with a high I.Q. one of the few fortunate enough to secure adequate vitamin B during the nursing period?

Most likely a plentiful supply of vitamin B is necessary for the full development of hereditary potentialities. Whether or not native intelligence and learning ability can be improved by a rich supply of vitamin B to lactating human mothers is open to argument, experimentation and question. There is also the question, whether or not an artificial diet need not depress intelligence, assuming that if it does, if there is a large supply of vitamin B. Balyeat (3,4) discovered in two studies that allergic children had considerably higher I.Q's than non-allergic children. Sixty-eight percent of the allergic children ranked in the superior group or above. Only twenty-five per cent of the non-allergic children ranked in that group. Balyeat is of the opinion that the brain cells in those with allergic tendencies are more irritable.

What is the effect of restricted diets? Miles (5) worked with 12 men whose body weights had been reduced 10%, and held at that level by restricting the intake of food. He found no trace of lessened ability to do college work while on the restricted diet for a period of 4 months.

Holck (21) discovered that "Fletcherizing" had no effect upon sleeping time, mental multiplication, and typewriting speed, but that typewriting accuracy was reduced. An improvement in the efficiency of solving chess problems was reported.

Tang, Chin, and Tsang (42) found that a vegetarian diet affected the learning ability of male rats unfavourably,

but had no effect on female rats. Most vegetarian diets have restrictions because it is hard to secure the required number of calories and a liberal supply of proteins when foods from animal sources are excluded. There is a great need for further experiments on quantitative and qualitative restrictions. However, the evidence so far indicates no fundamental reduction in learning capacity as a result of quantitative and qualitative restrictions in diet.

With the possible exception of vitamin B deficiency, the evidence which has accumulated up to the present does not support the theory that there is a marked effect of malnutrition upon intelligence and learning capacity. This does not mean, however, that malnutrition occurs without any psychological effects, since techniques used may have been inadequate. With improvement in measurements surprising discoveries may be uncovered.

How common is malnutrition, and how serious a problem is it? Devine (25) presented statistics in 1925 shewing that at least 4 million school children were suffering directly from malnutrition. Bliss (8) in his survey found that one-fourth to one-third of the children were underweight, and were assumed to be suffering from malnutrition. Cramer (9,10) is of the opinion that many people are in a chronic state of vitamin underfeeding and a lasting weakness in this may be carried over from infancy.

Thus this problem of nourishment is indeed a great one, and work in this field is desperately needed.

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CHAPTER III.

THE BIOCHEMISTRY OF THIAMIN.

A. VITAMINS.

Vitamins are organic substances, not related chemically to one another, indispensable to normal functioning of some one or more animal species. They are effective in small amounts, are not structural materials as the fats, carbohydrates and proteins, but are necessary for the chemistry of the cells. Knowledge of the vitamins comes through discoveries that substances of plant origin - the vitamins or provitamins of to-day - are essential for the well-being of many animals. Those species that do not require a given vitamin in their diet may have the ability to synthesize it from elementary compounds. This has been proved for the rat in the case of vitamin C. Absence of a vitamin results in the suspension, in all probability, of a single type of intracellular chemistry, necessary for the tissue concerned, and indirectly for the organism as a whole.

B. MORPHOLOGY OF VITAMINS.

Wolbach and Howe (1) attempted to discover the morphological results of a deficiency of each respective vitamin. They discovered that cells deprived of a function essential for the organism as a whole may survive and multiply.

Wolbach (1) states:

"We have endeavoured to find the initial tissue or cellular responses to each vitamin deficiency with the belief that the cells first to exhibit changes would be those in which

the vitamin was necessary for the performance of an essential chemical process. In some instances we have succeeded for the requirements of a morphological characterization but with all members of the vitamin B group, B_1 and B_2 components, we have failed, possibly because the chemistries involved are common to many tissues and concern energy processes not involving structural maintenance, and hence unaccompanied by distinctive morphological changes."

Thus we see that these experimenters were unable to find any specific morphological consequences to vitamin B_1 deficiency.

C. BERIBERI.

It is known that a diet which lacks vitamin B_1 will eventually cause beriberi in humans. This is evidenced in the Orient, where people exist mainly on a diet of polished rice.

Beriberi takes two distinct forms: (1) wet; (2) dry. In the wet type there is an accumulation of water in the tissues. In the latter, atrophy of musculature becomes prominent. In most essential respects the two forms are alike. In both there is numbness of the extremities amounting to anesthesia, yet exquisite tenderness of the muscles to pressure. In both, the patellar and other reflexes are either exaggerated or lost altogether. In both, the heart is affected by an accumulation of fluid in the pericardium. Fluid is usually present in the lungs. The right heart is most affected.

Death,which often comes suddenly after some exertion,is due to heart failure. Response to treatment is often dramatic in the acute fulminating type of the disease, though complete recovery from the secondary effects of the disease, if it has existed for a long time, is usually slow.

D. THE BIOCHEMISTRY OF VITAMIN B_1

In the absence of vitamin B_1, too much lactic acid accumulates in the body. Lactic acid is a substance produced continually in our muscles, whenever the muscles expand or contract. Usually this lactic acid is quickly converted into other substances again, as fast as it appears. When there is a shortage of vitamin B_1 in the food, however, the lactic acid cannot be disposed of in this way, and so accumulates. Japanese workers have shown this by measuring the amount of lactic acid in the blood of people and animals, after exercising them, comparing normal with beriberi patients. In normal people the amount of lactic acid increases transitorily after exercise, but is quickly restored to its normal value again. People suffering from beriberi get rid of lactic acid very slowly. L.J.Harris and Drury (3) discovered that the heartbeats of rats suffering from a deficient diet of vitamin B_1 beat half as fast as those of normal rats. They had bradycardia. The heart of the rat made only 250 beats per second, instead of the normal 500 beats per second. The low heart rate has to do with the excess of lactic acid, which cannot be eliminated without vitamin B_1.

The lactic acid poisons the heart muscles and prevents it from functioning at full rate.

Professor Peters of Oxford has shewn that the convulsions of beriberi, which are so noticeable a feature of the disease in animals, are due to the lactic acid becoming too excessive in parts of the brain, and thus poisoning the central nervous system. If some of the brain be taken from a pidgeon dead from beriberi, and placed in a test tube, it will be found unable to absorb oxygen at the proper normal rate. Add a trace of vitamin B_1 to the test tube and an improvement can be demonstrated in vitro. Recent experiments have also shewn that large amounts of a second substance, pyruvic acid, derived from lactic acid also accumulates in the beriberi animal.

E. THE SPECIFIC CHEMICAL ACTION OF VITAMIN B_1.

Vitamin B_1 is definitely concerned with carbohydrate metabolism. Professor Peters has provided us with a theory concerning the action of vitamin B_1 in curing and preventing polyneuritis. Peters says: "This vitamin is a catalyst used by the tissue at some stage in the combustion of carbohydrate. Defect in this stage within the central nervous system will lead readily to convulsions."

Thus the present theory of the action of vitamin B_1 is that carbohydrate metabolism proceeds to the pyruvic acid stage but is there halted in the absence of vitamin B_1. In the presence of the vitamin the pyruvic acid is oxidized and energy production from carbohydrate is normal in amount. Thus

vitamin B_1 has the action of a catalyst necessary for the combustion of carbohydrates. The vitamin permits the oxidation of pyruvic acid by brain tissue in vitro, and the explanation may be completely satisfactory for that tissue. Recently, evidence has accumulated to the effect that the principal function of the vitamin in the body generally is the synthesis of fat from carbohydrate. Whipple and Church (2) shewed that the main factor in the weight increases due to vitamin B_1 in rats is the laying down of fat. In their experiment, the only possible source of this fat was the dietary carbohydrate. These writers (2) produced further evidence by measuring respiratory quotients that carbohydrate is transformed into fat under influence of vitamin B_1. McHenry ( ) confirmed the production of fat from carbohydrate in the presence of the vitamin.

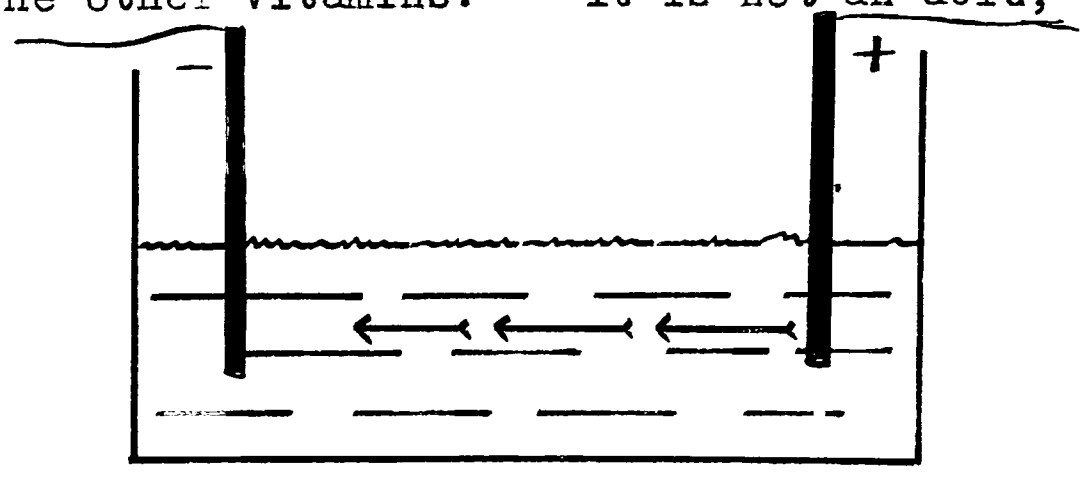
From experimental evidence up to the present date, we may advance the following hypothesis regarding vitamin B_1. Whether or not the vitamin is supplied, carbohydrate metabolism proceeds to the pyruvic acid stage. In the absence of Thiamin pyruvic acid accumulates, as has been shewn in pidgeons, rats and human subjects by workers. In the presence of Thiamin fat is synthesized, with pyruvic acid as an intermediary stage between carbohydrate and fat, although this has not yet been unproven. Recently Krebs and Johnson (4) have shown that hydroxy butyric acid can be formed from pyruvic acid by tissues.

The hypothesis attempting to correlate various pieces of published evidence is that vitamin B_1 is necessary for the synthesis of fat from carbohydrate. This does not discredit

the theory that Thiamin is concerned with carbohydrate metabolism, but alters the conception of the vitamin being a factor in energy production from carbohydrate to a broader view of carbohydrate utilization. An explanation is suggested for the disappearance of pyruvic acid when vitamin B_1 is supplied to avitaminous birds or animals and for the laying down of fat under such conditions. The action of the dietary fats in sparing vitamin B_1 might be through provision of the body with necessary fat which on diets poorer in fat would be synthesized by the animal from carbohydrate with the help of vitamin B_1.

F. SOME PROPERTIES OF VITAMIN B_1

When foods containing vitamin B_1 are heated above the boiling point of water, their activity is soon lost - the vitamin is destroyed - the more so if the solution is at all "on the alkaline side"; acid seems to help to protect it. Vitamin B_1 is chemically peculiar in that it contains sulphur, unlike the other vitamins. It is not an acid; it is a base.



Proof that vitamin B_1 is a base; Electrodialysis apparatus.

(Birch and Guha, 1931)

Vitamin B_1 activity travels to the negative pole. Hence Thiamin is positively charged. Thiamin dissolves easily in water, in alcohol and in most acid solutions. It does not dissolve in fats. If Fuller's earth, charcoal or certain other powders are thrown into the solution containing Thiamin, the vitamin adheres to the powder and is removed from the solution.

G. THE DISTRIBUTION OF THIAMIN.

One may find Thiamin present in many hundreds of living tissues, animal, vegetable and microorganic; it has been demonstrated to play an indispensible role in such a considerable number of them that the burden of proof now lies upon him who would dispute the universality of its function in living things. Yet it is present in tissues in very small amounts, usually less than one part per million. In seeds and certain special animal organs, such as the liver, it may rise to three to five parts per million; only in the germs of cereals and in the cells of cereal-grown yeasts does it rise to thirty to one hundred parts per million. The lower saprophytic plants lack the power to synthesize it adequately and always respond with evidences of more vigorous vital function when given a liberal supply from some external sources. Animals are unable to synthesize it from the elements at all. Only the higher plants can make it. Evidently they make it in the tops, probably in the leaves, transporting it thence to the roots which are unable to produce it. Many interesting experiments regarding its function with respect to root growth have been performed by Kogl, by Bonner

and by Robbins. It is to the latter that we owe some entrancingly interesting pictures which illustrate the fact that the growth of excised tomato roots in sugar solution depends quantitatively on the amount of Thiamin added. In some of the experiments the fact is brought out that a mixture of the intermediates from which Thiamin is made artificially will serve as well as Thiamin itself for many plants. This indicates that the power to effect the final step of synthesis is often present in organisms or parts of organisms which have never acquired or have lost the power to effect the entire synthesis. It also suggests strongly that Nature's method of synthesis is identical to the last step with that whereby the vitamin is made in the laboratory. Some plants show a more conspicuous need of the thiazole part, some of the pyrimidine part, presumably because they differ with respect to their synthetic capacities for each part. Some plants, like all animals, must have the fully formed vitamin and can not effect even the final step of synthesis.

What does it mean with respect to the realm of Nature as a whole? Its presence in seeds in large amounts is highly significant, especially in view of the fact that seeds are often also repositories of carbohydrate dedicated to the nourishment of the seedling during the process of germination until the young leaves turn their green surfaces to the sun. More and more it seems that man commits a crime against Nature when he eats the starch from the seed and throws away the mechanism necessary for the metabolism

of that starch by the plant. Since plants have synthetic powers which men lack, the latter have small prospect of successful utilization of the starch unaided by the plants' enzymic component.

In fact, as one surveys the situation in philosophical mood, it seems that Nature's entire economy of Thiamin is hand to mouth. Her synthetic powers are barely adequate to keep life as a whole moving forward. She has to resort to symbiosis, whereby the synthetic deficiencies of one organism are made good by the scant surplus of others. She utilizes the dead remains of some of her children that others may grow and propagate their kind. She transports the substance from favored parts to those which are deficient in their synthetic powers. Very widely is it true that a generous external supply of thaimin increases visibly the vigor of the life processes of plants and animals.

Mankind lacks an ample supply of thiamin because Nature generally must ration it carefully and further he refines his grains and cooks his food. So when he suffers from constitutional disease his weakest organ may often show a benefit from an artificial supply whether the weakness be due to heredity, to past damage or to present severe strain upon the body economy, as in maternity, hard physical labor or an infectious fever. The apparent want is probably rendered more widespread by the fact that in human society the physically unfit increasingly survive and propagate their kind through interruption of the process of natural selection by humanitarian effort.

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CHAPTER IV

A SYNOPSIS OF PREVIOUS WORK DONE.

Although an enormous amount of work has been done on diets, from the physiological standpoint, very few investigations have been concerned specifically with a psychological approach.

Miles,(7) working with a group of twelve human subjects, whose body weights had been reduced ten per cent, and held at that level by limiting the intake of food, found that in general the psychological effects were small.

Stone (13) reports that the degree of inanition in young rats just sufficient to maintain a given body weight results in a delay of the initial copulatory behavior. In his experiments Stone concludes:

"The awakening of capulatory ability in three groups of young rats held at maintenance for twenty days, followed by refeeding, was delayed as follows: (Median copulatory age in inanition group - median copulatory age of their littermate controls = delay of copulatory age).

(a) When the period of maintenance introduced between the ages of thirty and fifty days - midway between infancy and puberty - the resulting delay was 22.5 $\pm$ 0.93 days.

(b) With a period of maintenance introduced between the ages of thirty and fifty days - mid-way between infancy and puberty - the resulting delay was 22.5 $\pm$ 0.93 days.

(c) When the period of maintenance introduced between the

ages of twenty and fifty days - at the close of period of infancy - copulatory age was delayed 20.5 ± 1.51 days.

2. In two of the three experiments - inanition beginning at 45 and at 20 days - the variability of copulatory ages in the inanition groups was not significantly different from that of their proper controls. In the inanition group held at maintenance between the ages of 30 and 50 days, the amount of variability significantly exceeded that of their controls.

6 inanitions - 6 controls = 7.51 ± 1.37 days.

The causes of increased variability in this group were not ascertained.

3. The period of chronic inanition did not perceptibly alter the pattern and vigor of the initial copulatory response.

4. Generally speaking, the median body weight of the inanition males, when they first manifested copulatory ability corresponds more nearly to that of their controls copulating approximately twenty days earlier, than to normal males of their own age.

5. Greater variability of body weights in inanition groups, as compared with their proper controls, was found in the two experiments - inanition beginning at the age of forty-five and at thirty days. In the third experiment - inanition beginning at the age of twenty days - the variability was not significantly different.

6. The maturation of spermatozoa was delayed by an amount roughly approximating the delay of copulatory age at inanition groups held at maintenance between the ages of thirty to fifty days, and from twenty to forty days. A period of maintenance between the ages of 45 and 65 days caused little if any delay in the maturation of spermatozoa.

7. Development of the organs of intromission as well as other parts of the accessory reproductive apparatus was delayed in all inanition groups. The amount varied widely for individuals of each group. Quantitative data bearing on the amount of this variation was not collected.

The first world war demonstrated clearly that an intimate relationship exists between nutrition and reproduction. The birth rate fell in all countries suffering from food shortage, a fact attributable in part to malnutrition. This correlation has also been shewn in exceedingly fine detail by Evans and Bishop for the reproductive vitamin (4) ( ) and by Daniels and Hutton (3) for certain mineral salts. Stonaker (12) claimed that the activity of rats is closely associated with the sex cycle, and that this activity is highly responsive to changes in the nutritive plane of the animals.

Sure, Kirk and Smith (14) have shewn that vitamin B deficiency reduces the appetite causing a lessened food intake and loss of weight.

Anderson and Smith (1) were among the first experimenters to study the effect of diet upon learning ability. Specifically

their experiment was designed to study the effect of quantitative and qualitative stunting upon maze learning in the white rat. They reasoned in the following manner:

"If metabolism, reproduction and growth are so profoundly affected by inadequate nutrition, might it not be expected that the physiological process concerned with learning, memory and habit formation would also be altered by such conditions?"

Anderson and Smith used artificial diets. These rations were made up of purified food materials, the nutritive value of which had been determined. The control diet had the following composition:

	per cent
Casien	18
Lard	22
Corn Starch	51
Cod Liver Oil	5
Salts	4

Dried yeast was fed separately to provide vitamin B. On this diet, animals grow to maturity at the usual rate for the white rat in captivity. In the first experiment, one group of rats was fed the control diet, and a second group of rats was given a gliadin diet of the following composition:

	per cent
Gliadin	18
Corn Starch	51
Lard	22
Cod Liver Oil	5
Salts	4

The chief difference of these two rations lies in the quality of protein contained therein. The experimenters claimed that if the two groups of rats behaved differently, it was due to either:

(1) The difference in the stage of development;

(2) A specific effect of the protein deficiency;

(3) A factor conditioned by the low nutritive plane of the stunted animal, but independent of the type of stunting used.

A third group was stunted because of insufficient calorie intake. This was the quantitatively stunted group. In this experiment the stunted animals were subsequently realimented, and behavior tests made again at the appropriate time. These various groups of rats were put through mazes, and the results were compared. It was found that stunted rats were superior to normal rats in the maze, but realimentation brought the stunted rats close the normal both in weight and learning ability.

Anderson and Smith's (1) conclusions from these experiments are:

(1) "The process of stunting either by a chemically deficient diet, or by a diet of reduced calories,affects the behavior of an animal as measured by his learning and retention of the maze problem.

(2) Stunted rats are superior to rats that grow normally in relearning a maze.

(3) Realimentation, following the stunting process, brings the stunted animals nearer to the normal animals both with respect to their weight and their maze reacting ability."

As to errors, the control and qualitatively stunted groups were superior in relearning to the quantitatively stunted animals, and on learning a new maze both experimental groups made more errors than the controls. The original grouping was made on the basis of time records in a preliminary maze test, but the error records were not equated, and the qualitatively stunted groups had a larger initial error score than the others.

A very probable explanation of these results is a difference in motivation between the groups, as a food incentive was used and the stunted rats were probably more highly motivated. The results of this experiment seem to indicate that the use of a learning situation in which food motivation is used is a doubtful procedure in experiments dealing with the relation of diet and learning ability.

Frank (5) investigated the effect of a ricket-producing diet on the learning ability of rats. He found that rats with active rickets learned the maze in fewer trials than normal rats, and with fewer errors, but consumed more time in learning. The difference disappeared with realimentation. Miss Frank concluded that if differences in learning ability do exist in normal, rachitic and underweight rats the usual maze technique is inadequate for their demonstration. Frank claimed that her experiment was twofold:

(1) "To compare the maze learning ability of albino rats upon a ricket-producing diet with that of rats on an adequate dietary regime.

(2) To determine whether any difference which might be noted was transitory or persistent."

"The maze-learning was tested during the period of active rickets, and again when recovery had been affected."

In this experiment the age of the rats were from 30-60 days; they weighed from 55-60 grams. Littermates of the same sex and the same weight were assigned to three groups: (1) normal controls; (2) rachitics controls; (3) underweight controls.

Two Carr mazes were used. Maze I tested learning during the period of active rickets, and maze II after recovery. Retention of maze I was tested three months after the initial learning.

Diet: A modified McCollum diet was used.

Rolled Oats . . . . .)	25%
Ground whole wheat . . . . .)	
Ground whole yellow corn	23.5%
Casein	15%
Klim	10%
Calcium carbonate	0.5%
Sodium chloride	1%

Weekly supplements of lettuce and cabbage and occasional allotments of liver were used. This diet without the supplementals was used for the normal and underweight controls during the learning of maze I and for all rats during the learning of maze II

and retention tests on maze I. Rickets were produced by means of the McCollum diet No.3143 (3) and later by Sternbock-Black diet No.2965 (6).

Summary:

Frank found that rats with active rickets learned the maze in fewer trials than normal rats, and with fewer errors but consumed more time in learning.

In 1929 Maurer and Tsai (6a) reported their experiment called "Vitamin B deficiency in Nursing Young Rats and Learning Ability." Their purpose was to "determine the effect of various deficient diets upon the learning ability of the first, second and succeeding generations of rats of known heritage, and to correlate these findings with the anatomical and chemical changes in their nervous system."

Their report dealt with the number of trials required to learn a standard maze by 71 first generation rats, some of which were depleted of vitamin B during their nursing period. The results were somewhat surprising. It was found that normal rats of seventy days old learn on the average three times better than vitamin B deficient rats of the same age, and two and a half times better than vitamin B deficient rats of ninety days old. The significance of these results are striking when we compare them with those of Anderson and Smith (!) As you will recall, these experimenters fed rats on diets which contained incomplete protein or insufficient calories. They found

these rats superior to normal rats in maze learning. Their stunting produced no harmful effects, and increased the incentive of the stunted animals. These results are also striking, when compared with those of Frank (5) The latter found, as you will recall, that rats with active rickets learned the maze in fewer trials than normal rats and with fewer errors, but consumed more time in learning. This difference disappeared with realimentation.

Maurer and Tsai's (6a) experiment compares more favorable with that of Fritz. (6) Fritz studied the effect of vitamin B deficiency and an unfavorable salt mixture on maze performance. The deficiency in diet took place with adult rats, and during the time of the maze tests. The deficient animals shewed consistently lower learning scores as a group. The results of Maurer and Tsai may also be compared with those of Hoefer and Hardy, who correlated the intelligence quotients of public school children with the method of feeding during their early life, and found that those children who had been breast fed from six to nine months ranked highest, the artificially fed next, and the entirely breast fed for the first eighteen months lowest in their test scores. In this latter experiment, however, adequate control of the diet,environment and heritage was lacking. The results can only therefore be interpreted as suggestive.

Maurer and Tsai have opened a new field in the study of the problem of the relation of the nervous system to learning ability.

In 1932, Mr.F.Fritz (6) reported an experiment called

"Maze performance of the White Rat in Relation to Unfavorable Salt Mixture and Vitamin B deficiency." His experiment differed from previous workers in the following respect:

(1) Vitamin depletion did not take place until the rats were ninety to one hundred days of age.

(2) The tests were taken simultaneously with the depletion in diet.

(3) The vitamin deficiency was accompanied by an unfavorable salt mixture.

This was the important dietary difference from Maurer and Tsai. This was the first experiment that was concerned with faulty mineral content of diet and its effect upon behavior. This also was the first experiment to study the effect of vitamin deficiency upon the behavior of mature rats which had received a normal diet from birth. In his article, Fritz claimed that his experiment was an attempt "to relate certain faulty synthetic diets, known to have harmful physiological effects, to the maze behavior of practically mature white rats." He used the following diets for his experimental groups:

Group II

Unfavorable Salt Mixture

	Per cent
Casien	20.0
Yeast	5.0
Butter	5.0
Bone Ash	3.0
$FeSo_y$ $7H_2O$	0.5
Na I	0.5
Dextrin	06.0

Group III - Unfavorable Salt Mixture and Vitamin B deficiency

	Per cent
Casein	20.0
Butter	5.0
Bone Ash	3.0
$FeSo_y$ $7H_2O$	0.5
NaI	0.5
Dextrin	71.0

The group II diet would be considered adequate were it not for the unfavorable salt mixture. The group III is identical with the group II diet except that yeast is withheld and an equivalent weight of dextrin is added. In this way the vitamin B is excluded without materially changing the diet. In both diets the salt mixture is referred to as unfavorable since the minerals are not present in the optimum amounts as compared to successful salt mixtures, such as the McCollum No.185 (8) diet, or that of Osborne and Mendel (10).

The amount of iron salt is quite above the optimum. Starkenstein ( ) reports that ferrous salts have a poisonous effect upon rabbits, dogs and frogs. The degree of effect varies considerably with the animal, the kind of salt and the amount of salt used. If iron is administered hypodermically in large quantities it has toxic effects. In this diet the iodine content of the diet is above the optimum. Small doses produce symptoms of "cutaneous eruptions, mental depression",etc. Iodine in minute quantities is probably a necessary constituent of an adequate diet. Fritz concluded that the deficient animals showed consistently poorer learning scores as a group. Here again we see a relationship between vitamin B and learning ability, as well as an unfavorable salt mixture and learning ability.

In 1931 Maurer and Tsai again reported another experiment on "Vitamin deficiency and Learning Ability." This experiment was similar to the one in 1929. The technique was improved considerably. The conclusion of the experiment was:

"With all criteria of measurement, thirty-six normal rats exhibit a better average and median score in maze-learning than thirty-six animals which have been depleted of vitamin B complex through their mother's diet during the nursing period. Normal rats are about twice as efficient as the depleted animals. The maze pattern used was designed by Carr of the University of Chicago. The incentive employed in this maze was a vitamin concentrate rich in vitamins B and E."

Concerning the incentive, the authors state:

"After the depleted animals were weaned, they were given a week of vitamin rich diet so that their body weight was brought nearer to that of the control animals. On the other hand when the control animals were sixty days old they were fed on the B free diet for a few days to slightly check their rate of growth without depleting them. This makes the two groups equal in their strength of incentive."

In 1934, Bernhardt (2) published a verification of Maurer and Tsai's experiments. The title of the experiment was "The effect of vitamin B deficiency during nursing on Subsequent Learning in the Rat."

All previous studies on this subject have employed a food incentive in the learning situation. Bernhardt used the escape-from-water incentive. In Anderson and Smith's experiment (1) stunted rats were found to be superior to normal rats in the maze, and realimentation brought the stunted rats close to normal both in weight and learning ability. The probable reason for this is a difference in motivation

between the groups, since a food incentive maze was used and the stunted rats were,most likely, more highly motivated. This experiment indicated that the use of a learning situation in which food motivation is used,is a doubtful procedure in experiments dealing with diet and learning ability. Again Frank (5) concluded from her experiment that if differences in learning ability exist in normal, rachitic and underweight rats, the usual maze technique is inadequate for the demonstration.

In Maurer and Tsai's experiment, we again see an inadequate incentive. They write: "After the depleted animals were weaned they were given a week of vitamin rich diet so that their bodyweight was brought nearer to that of the control animals. On the other hand, when the control animals were sixty days old they were fed on the B-free diet for a few days to slightly check their rate of growth without depleting them. This makes the two groups equal in their strength of incentive."

The incentive used in this experiment was a vitamin concentrate rich in vitamins B and E. It would seem that the manipulation of the diet previous to the learning trials in order to try to equate the weights of the groups had an unknown and uncontrolled effect on subsequent learning. There is some doubt, however, as to whether the two groups were equal in their strength of incentive.

Bernhardt tried to verify the conclusions of Maurer and Tsai under different conditions. These differences were:-

(1) An escape-from-water incentive, in place of hunger motivation.

(2) A different maze pattern.

(3) A different type of learning problem named multiple choice.

Bernhardt, (2) realizing the difficulties and faults of the food incentice, and seeing that it was impossible to know the specific effects of dietary differences on hunger motivation, used the escape-from-water incentive.

Ruch (11) had demonstrated that even though food was more effective than water as an incentive, the difference between the two was slight. He writes:

"It is concluded that the escape-from-water method of motivating animal learning is well adapted to maze procedures. This method has particular value where it is necessary to employ motivation which is independent of the hunger drive."

BERNHARDT'S RESULTS.

Maurer and Tsai shewed that early deficiency of vitamin B did result in poorer learning scores on a food incentive maze. Bernhardt showed that this effect was also present with a different maze pattern, a different incentive, namely, escape-from-water, and with a different type of learning test - multiple choice - as well as in relearning the maze after two months.

Thus we can conclude that a deficiency of vitamin B during the nursing period in the life of white rats has an

adverse effect on the learning ability of rats, even if vitamin B is given in abundance during the time of the learning tests. In this Experiment also, the effect of Vitamin B deficiency on learning would probably have been greater if several factors were not in operation. Most likely Bernhardt did not succeed in making vitamin B depletion complete in this experiment. He fed the mothers a normal diet previous to the birth of the experimental litters, and it was possible that the rats when born had a certain amount of vitamin B storage.

The results of this experiment, as well as those of Maurer and Tsai, when compared with the results of Fritz (5,6) and Frank, demonstrate that the effect of early deficiency in vitamins is greater than a like deficiency with mature rats.

In 1935, Moore and E.Mathias published an experiment called "The Effect of Vitamin A and B Deficiency on the Maze Learning Ability of the White Rat." This experiment differed from the other studies of the effect of vitamin deficiency in two respects, the choice of the vitamins studied, and the use of the varied criteria for learning. Tsai and Maurer, as you will recall, removed from their experimental diets the vitamin B complex which contains vitamins B or B_1, vitamin G and the other factors of the complex.

To recapitulate: Fritz (6) studied the combined effects of vitamin B complex deficiency and an unfavourable salt mixture, and could draw no conclusions as to the effect of vitamin B complex alone.

Moore and Mathias ( ) observed the effect of a deficiency

in vitamin B_1, which was removed from the diet without changing the B_2 and the rest of the B complex content. The deficient diets differed from the control diets only in the absence of the vitamin; in all the three groups the proportions of protein, fat and carbohydrate were kept constant. In this experiment the difficulty of inequality of the incentive for different groups were encountered. The results were that the control groups learned the maze much easier than the experimental group.

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CHAPTER V.

THE PRESENT EXPERIMENT.

The present experiment differs from previous ones in the following respects:

(1) An escape-from-water incentive, combined with the Carr Maze was used.

(2) Pure synthetic Thiamin Hydrochloride was used, in place of the yeast used in previous experiments.

(3) Each litter was divided into two control groups and one experimental group. This was done to make heredity as constant as possible.

A. OBJECT OF EXPERIMENT.

The purpose of this experiment was to investigate the effect of a deficiency in Vitamin B during the nursing period on the subsequent learning in the rat, and to verify the work of previous experimenters.

During the first few weeks after the birth of the rat, the nervous system is in a very undeveloped state. It was thought that a lack of vitamin B during this period would result in the development of a nervous system less than normal, and thereby produce learning ability below normal. White rats were ideal subjects for this experiment. The use of human subjects involved a complexity of factors which made it practically impossible.

B. SOME PHYSIOLOGICAL EFFECTS OF VITAMIN DEFICIENCY.

In this aspect of vitamin work, much has been done. Sure, Kirk and Smith ( ) shewed that vitamin B causes a lessened food intake and loss of weight by reducing the appetite. McCarrison,as quoted by McCollum and Simmond,(14) demonstrated that while there was a functional and degenerative change in every tissue of the body, the effect on the brain tissue was the least.

Jackson (7) shewed that the brain weight in rats whose body weights had been held constant from three to eight weeks of age remained about constant while other organs shewed a tendency to growth and still others shewed a loss of weight. Jackson and Stewart (9) re-fed rats after early underfeeding, and found that although other parts of the body returned to normal weight, the brain had been affected in some way by the inanition, so that its later growth on ample re-feeding was retarded behind the body as a whole in its ultimate growth in weight.

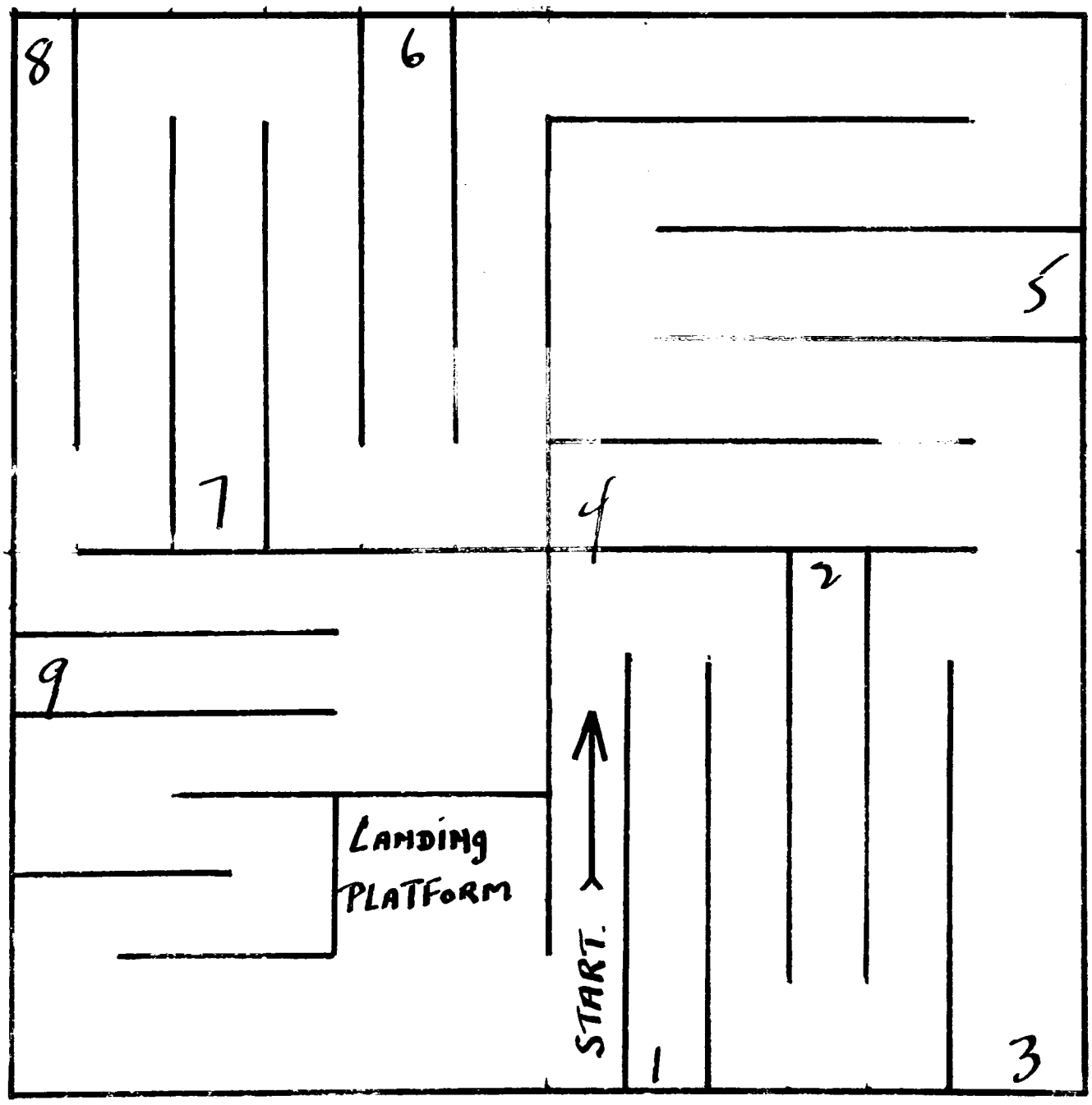
Because of the plasticity and immaturity of the nervous system at birth, vitamin deficiency at this period might have a serious effect because of its interference with the normal formative process.

The survey of literature, which I have just made, on the relationship of diet to learning indicates that there is some effect at least on learning in rats when there is a deficiency in diet; this effect is probably greater when the deficiency occurs early in the life of the animal. The present experiment is an attempt to verify the conclusions of Maurer and Tsai,

and Bernhardt under different conditions, which I have already summarized at the beginning of this chapter.

C. DISCUSSION OF NEW TECHNIQUES.

(1) In this experiment I combined the escape-from-water incentive with the maze designed by Professor Carr of the Psychology Department of the University of Chicago. This has been used as standard apparatus in the field of comparative psychology. This maze contains nine culs-de-sacs.



Carr Maze.

The Carr Maze was constructed 3 feet long, by 3 feet wide, by 20 inches high. A galvanized tin tank was constructed; the maze fitted into it perfectly. The maze was then submersed in 10 inches of water in the tank so that 10 inches of it appeared above the surface.

Because the food incentive had proved unsatisfactory in other experiments, the escape-from-water incentive was used. In fact, it is very difficult to know the specific effect of dietary differences on hunger motivation. McDougal has suggested escape-from-water motivation. Ruch (16) has demonstrated that although food was more effective than water as an incentive, the difference between the two was very slight. He writes:

"It is concluded that the escape-from-water method of motivating animal learning is well adapted to maze procedures. This method has particular value when it is necessary to employ motivation which is independent of the hunger drive."

THE MAZE.

This maze was constructed so that the rats could not cling to the sides or the partitions. The sides of the alleys of the maze were thoroughly waxed, so that it was difficult for the rats to cling on to them. Also the pathways were made six inches wide so as to preclude straddling. The water was kept at room temperature. After any trial, each rat was dried and returned to a cage. At eight weeks, rats were given one trial every other day. Half of the experimental groups and half the control group were run each day. If the maze was not learned

in 35 trials, they were put through the maze daily. The time in seconds was taken the instant the rat touched the water, until he reached the landing platform. If a rat entered a blind alley with at least one third of his body (i.e.,his head and forefeet), an error was recorded. A retrace was counted when a rat retraced at least one whole section of the maze, and only one retrace was counted no matter how far the rat retraced. The criterion of learning was eight correct out of 10 consecutive trials.

(2) Concerning Diet.

Maurer and Tsai used the following diet:

Constituents	Control	B-depleted
	per cent	per cent
+ Egg Albumin (extracted)	20	20
Minerals (Mendel & Osborne)	4	4
Dextrin	29	29
Starch	23	35
Agar	2	2
Butter	5	5
Cod Liver Oil	5	5
Yeast	7	0
Wheat Embryo	5	0

+ Egg albumin, dextrin, and starch are all extracted free of vitamin B-complex.

Bernhardt gave the mothers of the experimental group a B-free diet, until the litters were removed. The mothers of

the control group were given the same B-free diet with 6 per cent brewer's yeast added. When the litters were four weeks old, they were taken from their mothers, and both groups were placed on the same diet, namely, the B-free diet plus 6 per cent yeast.

On the other hand, Moore and Mathias changed their diet. They removed from their experimental diets the vitamin B complex "which includes vitamin B_1; the anti-neuritic vitamin, preventing polyneuritis and vitamin B_2 or G, the pellagra preventive" and the rest of the B-complex contained in yeast. Fritz (4) however, studied the combined effect of vitamin B-complex deficiency and an unfavorable salt mixture, and was thus unable to draw conclusions as to the effect of vitamin B-complex deficiency alone. In Moore and Mathias' experiment, an opportunity was given to observe the effect of a deficiency of vitamin B_1 which was removed from the diet without changing the B_2 or G, and the rest of the B-complex content.
The deficient diets differed from the control diets only in the absence of vitamin B_1. The B-deficient was the same as the adequate diet except that vitamin-free casein and dried autoclaved yeast (autoclave to destroy vitamin B) were used.

The Diet used by Moore and Mathias.

Diet	Control	Vitamin B group.
	per cent	per cent
Casein	20	20 (vitamin free)
Starch	51	51
Crisco	8	8
Butterfat	12	12
Dried Yeast	5	5 (autoclaved)
Salt Mixture	4	4

In my experiment, the diet of Moore and Mathias was used. One innovation was made. There were two control groups. One group was given the normal diet (No.I) with yeast and wheat embryo as the source of the vitamin B-complex. Another control group was given the same diet, but synthetic thamin was substituted for yeast and wheat embryo. (Diet No.II). The experimental group was given the same diet without any of the vitamin B-complex (Diet No.III).

D. THE SUBJECTS AND THE PROCEDURE.

At birth, litters were assigned to the experimental and control groups. Each litter was reduced to six rats at birth. Again, each litter was divided into three groups, with two rats in each group. Attempts were made to include a male and a female rat in each respective group. By so doing it was calculated that heredity could be kept as constant as possible. In all, there were 15 litters of rats, making a total of 90 rats. Since each litter was divided into three groups at birth, three large groups of rats, with 30 in each group (approximately 15 males and 15 females) were obtained. One group of 30 rats were nursed by mothers fed on the normal diet with yeast and wheat embryo. (Diet No.I). Another group of 30 rats were nursed by mothers fed on the normal diet with synthetic thiamin substituting for yeast and wheat embryo. (Diet No.II). A third group was nursed by mothers, fed on a diet deficient in vitamin B-complex.

When the litters were 4 weeks old, they were taken away

from their mothers and all groups were given the normal diet with yeast and wheat embryo.

Group	Diet
Group I	Normal Diet plus wheat embryo and yeast.
Group II	Normal Diet with synthetic thiamin replacing yeast and wheat embryo.
Group III	Vitamin B-free Diet

Thus the only difference in the diet of Group I and III was that vitamin B complex had been removed from the food of the nursing mothers of the experimental group during the period of four weeks, when they were nursing the litters, while the mothers of Group I were given a normal diet.

Sure (18) has demonstrated that the quantity of vitamin B in the milk of the nursing mother rat is proportional to the vitamin B content of the mother's diet, so it was assumed that by removing vitamin B from the diet of the mother, I was depleting the litters as well. The removal of vitamin B during this period of 4 weeks may not have been complete or the same for all rats of the experimental group. There may have been a certain amount of storage of vitamin B in the mothers, and this storage may have varied from rat to rat. In an article, Osborne and Mendel (15) discuss about vitamin storage; they conclude that, "when an adequate supply of vitamin B is lacking in the diet, the store of this factor in the liver tissue, when it is ordinarily found in abundance, becomes largely

depleted." This does not prove, however, that any of this storage can be passed on to the pups by the mothers. McCollum and Simmonds (14) state that "vitamins A and B pass into the mother's milk only when they are present in the diet of the mother." If this statement is true, then the experimental group of animals does not receive any vitamin B complex during the first four weeks of nursing.

Since the mothers were fed on a normal diet before the litters were born, because it was thought that they must be in the best state of health, in order to survive the ordeal of bearing young, the young rats may have had a certain amount of storage of vitamin B. Rats also differ in their abilities to withstand dietary deficiencies. In this experiment there seemed to be no doubt that the experimental group of rats was affected by vitamin B deficiency. This was evidenced by the fact that there was a higher mortality rate and a lower average weight in the experimental group.

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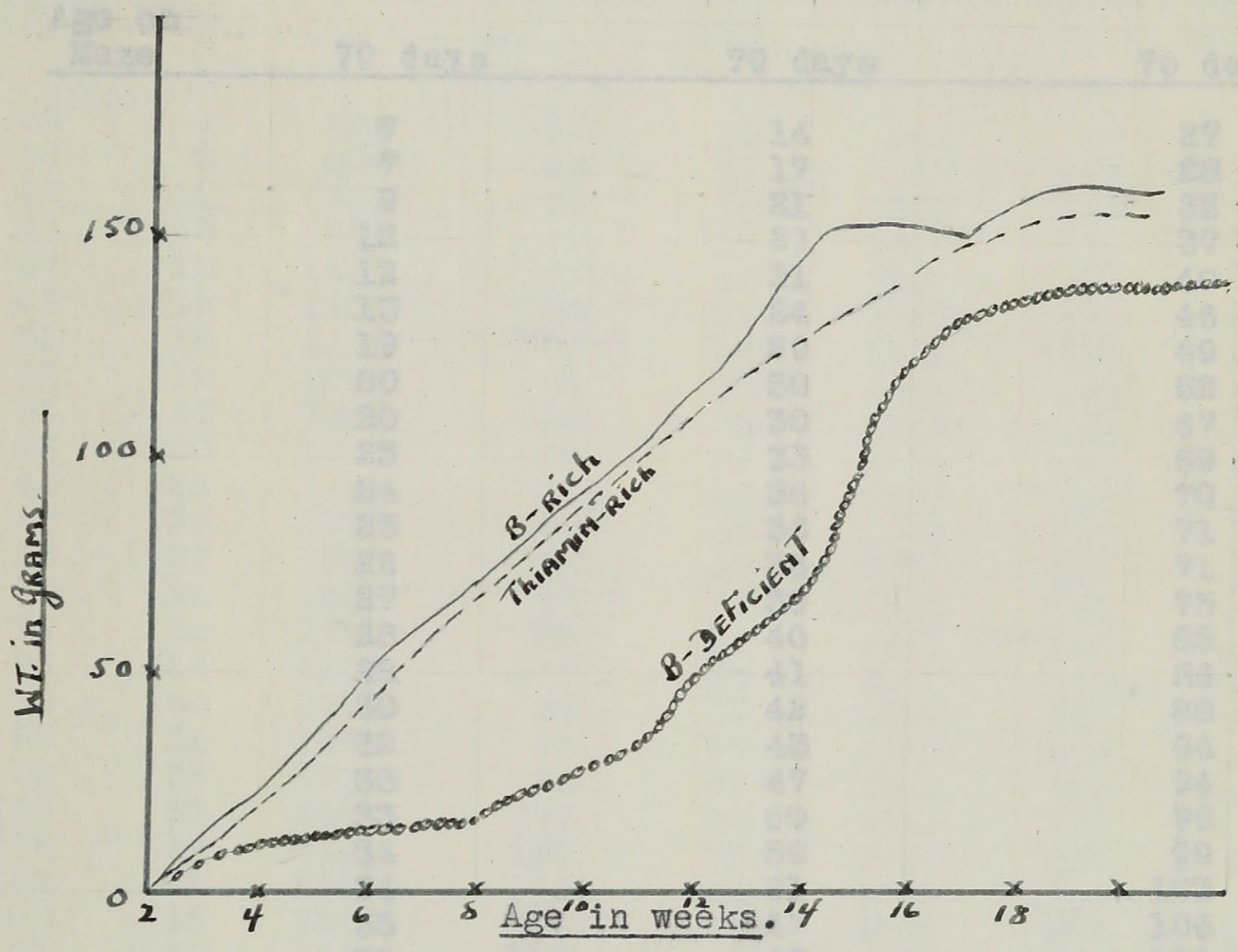
CHAPTER VI.

RESULTS AND CONCLUSIONS.

Average weight of the Rats.



The average weight curves of the three groups are presented above. The normal and thiamin group is, on the average, heavier than the experimental group. However, the average difference in body weight between the three groups of animals was very slight. The experimental groups did not increase as quickly as the control groups after the first four weeks.

RESULTS.

Number of Trials.

(Arranged in order of magnitude according to each criterion.

Group	Control	Thiamin	Depleted
Dietary Condition	Vitamin B rich while nursing	Thiamin rich while nursing	Vitamin B depleted while nursing
Age on Maze	70 days	70 days	70 days
	7	14	27
	7	17	28
	9	21	33
	12	21	37
	12	21	40
	13	24	46
	19	29	49
	20	30	52
	20	30	67
	23	33	69
	24	36	70
	25	36	71
	26	36	71
	27	39	75
	28	40	82
	28	41	86
	30	42	88
	32	43	94
	33	47	94
	33	50	99
	34	59	99
	34	61	103
	35	67	106
	35	69	139
	45	80	167
	62	85	172
	65	86	177
	65	102	184
	66	114	302
	85	121	421

RESULTS

(Arranged in order of magnitude according to each criterion.)

Vitamin-B-rich			Thiamin-Rich			B-Depleted		
No. of Errors	No.of Retrac-ings	No.of Seconds	No.of Errors	No.of Retrac-ings	No.of Seconds	No.of Errors	No.of Retrac-ings	No.of Seconds
22	6	820	37	10	960	87	20	1251
27	8	836	42	11	994	101	21	1287
40	11	920	44	14	1023	107	24	1365
43	13	1002	49	15	1097	121	24	1764
47	15	1121	50	15	1121	136	25	1821
47	15	1156	53	16	1167	139	28	1854
52	18	1189	56	18	1212	139	31	2005
53	19	1293	57	20	1224	148	33	2121
62	20	1309	58	23	1236	153	33	2137
62	20	1474	60	24	1239	155	34	2181
64	25	1489	66	27	1251	155	34	2206
65	26	1547	68	28	1365	162	36	2218
66	26	1660	72	30	1374	164	37	2237
72	26	1693	80	31	1403	168	39	2304
79	28	1772	85	34	1452	175	39	2318
83	28	1803	87	35	1508	197	39	2375
86	30	1882	92	37	2001	201	42	2479
89	31	1884	96	37	2459	208	43	2564
90	32	1916	98	37	2742	214	44	2606
100	32	2093	104	38	3083	219	47	2691
105	32	2141	107	39	3692	239	49	3748
105	32	2267	110	40	3931	247	51	4003
105	35	2343	123	42	4006	253	56	4817
121	36	2360	125	42	4125	272	56	4947
128	37	2564	130	42	4332	276	64	4971
142	39	2731	145	43	4441	280	69	5672
142	40	3506	156	45	4793	284	70	5774
144	40	3515	172	46	4821	293	87	6077
154	40	4721	190	49	5009	397	101	6431
179	41	4881	210	52	5016	462	101	8621

RESULTS.

Average Scores in Maze Learning

Group	No.of Animals	No.of Trials		No.of Errors		No.of Retrac-ings		No.of Seconds
B-rich	30	31.8	16.97	70.25	64.25	26.7	10	1440.1
Thiamin rich	30	49.7	27.57	90.77	40.82	31.1	39.8	2468.7
B-deficient	30	104.9	80.14	205.4	75	39.9	32.2	3228.5

- Standard Deviation

Median Scores in Maze Learning

Group	No.of Animals	No.of Trials	No.of Errors	No.of Retrac-ings	No.of Seconds
B.rich	30	28	81	28	1787.5
Thiamin rich	30	40.5	86	34.5	1480
B-deficient	30	84	186	39.5	2346.5

Model Scores in Maze Learning

Group	No.of Animals	No.of Trials	No.of Errors	No.of Retrac-ings	No.of Seconds
B-rich	30	33	105	32	-
Thiamin rich	30	36	-	37	-
B-deficient	30	99	155	39	-

SUMMARY

1. Fifty two rats were nursed from birth for four weeks by mothers whose diet was deficient in vitamin B. About 21 rats died. The remaining thirty were given a normal diet from four weeks on. Thirty rats were given a normal diet in which synthetic Thiamin was used to replace yeast and wheat embryo. Thirty rats were fed the normal diet, and were used as the control group.

2. The vitamin B deficient group was less in weight in every stage of the experiment than the Thiamin group, and the Thiamin group in turn was slightly lighter than the normal control group.

3. There was not much difference between the three groups in preliminary swimming, as measured by time.

4. At eight weeks of age the three groups were given learning trials in the "Carr water maze", relearning in the same maze two months after completing learning.

5. There was a consistent difference in favor of the control group in the trials with the maze. The control group learned in a fewer number of trials than the Thiamin group, and the latter in fewer trials than the B-depleted group.

CONCLUSIONS.

The results of this experiment are in accord with the findings of previous investigators. A vitamin B-deficient diet for young rats during the nursing period affects subsequent learning ability when the rats are mature. It was also found that a normal diet with synthetic thiamin replacing the vitamin B complex, given to nursing young rats, has a slight effect on subsequent learning ability.