HISTORY OF EXPERIMENTAL INVESTIGATIONS CONCERNING THE INFLUENCE OF ALCOHOL AND ALCOHOLIC DRINKS ON THE FUNCTIONS AND STRUCTURES OF THE LIVING ANIMAL BODY BY AMERICAN INVESTIGATORS.[1]

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So far as my knowledge extends, the first experimental investigations concerning the effects of alcohol on the living body in this country were devised and executed by me during the last half of the year 1850. They constituted part of a more extended inquiry concerning "the influence of different kinds of food and drink on the functions of calorification and respiration, as indicated by the changes of temperature and the variations in the quantity of carbonic acid gas exhaled during expiration in the healthy human system; and the changes which the several constituents of the blood undergo in their relative proportions during the passage of that fluid through the secreting organs and some of the non-secreting structures of the human body." The results of the whole inquiry were embodied in an essay read by me in the annual meeting of the American Medical Association, in Charleston, S. C., May, 1851, under the following title: "An Experimental Inquiry Concerning Some Points in the Vital Processes of Assimilation and Nutrition." The facts and deductions set forth in the essay were listened to with

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marked attention, but were so much at variance with the popular doctrines of the day that I received only a vote of thanks, without a reference of the paper for publication in the transactions of the Association. It was published, however, in the *North-Western Medical and Surgical Journal*, Chicago, September, 1851, Vol. 4, pages 169–190. It should be noted that the experimental inquiry under consideration was executed less than nine years after the publication of the celebrated essay of Baron Liebig, in 1842, on "Organic Chemistry in its Relations to Physiology and Pathology," which was the real foundation of modern organic or physiologic chemistry.

On strictly theoretical grounds he divided all food, or ingesta, into two classes, called carbonaceous and nitrogenous. In the first he included the articles composed chiefly of oils or fats, starch, and sugar, and the alcohols. In the second he included those composed of vegetable and animal albumin, fibrin, etc. As those belonging to the first were composed essentially of only the three elements, oxygen, hydrogen, and carbon, they were regarded as incapable of entering into the nutrition or growth of the organized structures of the body; but were supposed to unite with the oxygen furnished through the lungs, and to be converted into carbon dioxide and water with the evolution of heat, to sustain the temperature of the living body, or deposited in the form of fat in the tissues. Consequently they were very generally designated as "respiratory food;" and alcohol was placed at the head of the list. Those articles belonging to the second class being composed of the four elements, oxygen, hydrogen, carbon, and nitrogen, were regarded as the only ones capable of assimilation and of entering into the nutrition and growth of organized structures. The classification was so simple, and the theory on which it was based so plausible that it was almost universally accepted and quickly incorporated into all our literature, both medical and secular. Lehman, however, a contemporary of Liebig, and eminent as a chemist, denied the correctness of the latter's chemico-physiologic doctrines. While a student of medicine, the subject of animal heat and its connection with the respiratory function attracted my attention, and a discussion of the subject constituted my graduate thesis in 1837. When, five

years later, the important essay of Liebig made its appearance, I read it with much interest, and during the next few years I met with so many apparently well authenticated facts not in harmony with his claim that foods composed essentially of fat, starch, sugar, and the drinks containing alcohol were simply oxidized and converted into carbonic acid, water, and heat in the living body, that I planned and executed the "Experimental Inquiry" of 1850–51. It embraced five distinct series of observations and tabulated records.

The first was instituted for the purpose of ascertaining the temperature and the amount of exhaled carbonic acid in a healthy adult man at 7 A. M., before breakfast; at 10 A. M., two hours after breakfast; at 12 M., before dinner; at 3 P. M., two hours after dinner; at 5 P. M. and at 8 P. M., two hours after supper, while living on an ordinary mixed diet of vegetable and animal food. The objects sought were to ascertain the variations of temperature before the regular meals and when digestion was in its most active stage, and the average for the twenty-four hours, and the same in regard to the proportion of carbon dioxide exhaled. The observations on a mixed diet were continued more than two weeks. The second series consisted of the same detailed observations on the same individual while limited during three full days to a diet consisting of pure boiled rice with a little white sugar. After a return to a mixed diet for a week, the same individual was limited for three days to a diet consisting exclusively of egg albumin and a very small amount of dried beef, and the same detailed observations were made as in the second series. We thus gathered the data concerning the temperature and exhaled carbon during an ordinary mixed diet, one exclusively carbonaceous, and one equally exclusively nitrogenous.

They all showed the lowest temperature in the morning, before the breakfast; an increase of from 1° to 2.5° F. after each meal, reaching the maximum about two hours after a 1 o'clock P. M. dinner. The average temperature for the twenty-four hours was 0.5° F. less under the strictly carbonaceous diet than either the mixed or that exclusively nitrogenous. The proportion of carbon dioxide in the exhaled air also varied, but not strictly parallel with the variations of temperature. Under

the carbonaceous diet the proportion of exhaled carbon reached its maximum about 12 M., under the mixed diet about 3 P. M., and under the nitrogenous not until 7 P. M.

The fourth series of observations were made on the same individual under the influence of alcohol, and with the same apparatus. Having learned from the preceding experiments that the temperature of the body was uniformly increased during the active digestion of ordinary food, the time chosen for testing the effects of alcohol was from 9 P. M. to 12 P. M., the supper having been taken at 6 P. M., and consequently its digestion completed before the alcohol was taken. In a room well aired and kept at a comfortable and uniform temperature, at five minutes before 9 P. M. the temperature, proportion of carbon dioxide in the exhaled air, and pulse rate were noted, and at 9 P. M. four ounces of brandy diluted with water were taken at once. At 9: 45 P. M., the pulse rate had increased ten beats per minute, the proportion of exhaled carbon dioxide diminished, but the temperature had remained the same. At 10 P. M. the pulse rate was only five beats faster than natural, and exhaled carbon was further diminished, and the temperature slightly less. At 11 P. M. the pulse rate had returned to its natural standard, the temperature had decreased 0.2° F., and the amount of exhaled carbon had perceptibly increased. At 12 P. M., three hours after the alcohol was taken, the temperature had fallen 0.5° F., and the proportion of carbon dioxide in exhaled air was the same as when the experiment began.

On another evening this experiment was repeated with the same results. During the first two hours after taking the alcohol there was a sensation of exhilaration or dizziness in the head, a sense of lightness or less consciousness of body weight, and less tactile sensibility in the hands and feet. Previously to the foregoing experiments, Dr. Prout, of London, had shown that the presence of alcohol in the system diminished the exhalation of carbon dioxide, and his observation had been corroborated by M. M. Bouchardet and Sandras, but they did not note the effect on the temperature at the same time. The result of all these experiments "compelled me to suppose that all digestible substances, whether carbonaceous or nitrogenous, are assimi-

lated and appropriated with more or less facility to the nourishment of the organized textures of the body;" and "that the *carbonic acid* from the respiratory process, like the secretions from the skin and kidneys, is a true product of the disintegration or metamorphoses of the structures of the body, while the *temperature* depends directly on those changes that take place in the nutritive and organic actions." [See *N.-W. Med. and Surg. Journal*, Vol. 4, p. 180.]

In October and November, 1852, I repeated the experiments with alcohol in the form of both brandy and wine, in connection with Dr. Henry Parker, then a resident of Chicago.

The same precaution was taken to avoid having the action of the alcohol complicated by the presence of ordinary food in the stomach at the same time, as in the previous experiments. Oct. 18, 1852, at 8: 30 P. M., the temperature under the tongue was 98¼° F., pulse 76 per minute, respirations 17. Three ounces of brandy were then taken, diluted with water, the temperature of the room being kept uniform at 70° F. *Thirty minutes* later the temperature was 98° F., the pulse 84, respirations 17. In thirty minutes more, or one hour after the brandy had been taken, the temperature was 97¾° F., pulse 77, respirations 17. Two and a half hours after the brandy, the temperature had fallen to 97½° F., pulse to 75, and respirations to 16. Directly before taking the brandy, and at the end of every half hour, a given quantity of exhaled air was collected in a graduated glass tube over mercury, and then transferred to a solution of caustic potash. The quantity of *carbon* dioxide markedly decreased during the first two and one-half hours, and then slowly returned to the same amount as before the experiment began. On Nov. 8, 1852, the foregoing experiment was repeated with the same apparatus and regulations, except that the alcohol was taken in the form of *eight ounces of port wine* instead of three ounces of brandy. The effects were the same in kind, and nearly the same in degree. In both, the sensations recorded were those of dryness in the mouth and fauces, a feeling of exhilaration and some dizziness in the head, some general feeling of numbness or lack of sensibility throughout the whole system, and a sense of heat in the stomach and face. These various sensations continued for nearly three hours, after

which they slowly disappeared. The experiments with alcohol in October and November, 1852, were included by Dr. Henry Parker in his "Prize Essay on the Difference between Stimulants and Tonics," presented to the Illinois State Medical Society at its annual meeting in La Salle, June, 1854, and published in the Transactions of the Society for that year, pages 55–107. A careful noting of all the experiments thus far noticed will show that the physiologic effects of such hydrocarbons as starch, sugar, and oils on the living body, and those of the alcohol class are radically different.

The first when taken were digested, assimilated, and maintained the full natural temperature, pulse rate, and exhalation of carbon dioxide with no disturbance of the nervous, cerebral, or metabolic functions, while the alcohol was plainly imbibed from the stomach undigested, circulated with the blood, directly diminishing nerve and cerebral sensibility like other anesthetics or narcotics, and decreasing both temperature and exhaled carbon. Consequently the classing of it with other carbonaceous foods as a supporter of respiration and animal heat was erroneous, and led to very important errors in practice, some of which still exist. For instance, the observed fact that the daily use of moderate doses of alcohol, as a mug of beer or a glass of wine three or four times a day, generally increased the amount of fatty tissues, and the experiments of Bœcker, of Germany, showing that moderate doses of alcoholic liquor lessen the sum total of eliminations, and cause increased weight, gave rise to the inference that such use of alcohol might prevent the development of tuberculous and other diseases characterized by persistent emaciation, and arrest or retard their progress after they had commenced.

The inference was sanctioned by some eminent medical men, and consequently cod-liver oil and Bourbon whisky soon became the most popular remedies for both the prevention and cure of pulmonary tuberculosis at the middle of the present century. To test the correctness of this doctrine by as near experimental methods as possible, I began early in 1855 to take notes of every unmistakable case of pulmonary tuberculosis coming under my observation, both in hospital and private practice, a reliable history of which I could get extending back

one year or more before any symptoms of the disease had commenced. During that year I gathered the history of thirty-seven cases, and made them the basis of my address as President of the Illinois State Medical Society, at the annual meeting in Vandalia, June 4, 1856, which was published in the Transactions of the Society for that year. During the succeeding four years the number of my cases was increased to 210, and a pretty full account of them was embraced in a paper read in the Section on Practice of Medicine at the annual meeting of the American Medical Association in New Haven, Conn., June 5, 1860, and published in the Transactions of the Association for that year, Vol. 13, pp. 565–676. Of the 210 cases, 140 were males and 70 females; 85 were natives of Ireland; 60 of the United States; 25 of Norway and Sweden; 20 of Germany, and 15 of England, Scotland, and Wales. Of the whole number, 68 had used some form of alcoholic drink, fermented or distilled, almost daily for from one to twelve years before any symptoms or signs of tuberculosis were noticed. Some had drunk only beer at the rate of three or four glasses a day; others drank chiefly wine, and a larger number all kinds of liquor. All were thus *habitual* drinkers, yet only 15 were recognized as *drunkards*, 5 of whom were admitted into the hospital with *delirium tremens*. The number who had used alcoholic drinks periodically or irregularly, and were regarded as moderate drinkers was 91, while 51 were total abstainers from all alcoholic liquors. Of those patients who remained under observation until death, belonging to the first class, the average duration of the disease was only 19 months; of those of the second class, 23 months; and those of the third class, 25 months. Many of those belonging to the first class or division of habitual drinkers were in such circumstances and with such habits as were as favorable for testing the influence of alcohol on the development of tuberculosis as could have been devised. But instead of affording any evidence of exerting any preventive or retarding influence, the use of alcohol appeared both to favor the attacks of the disease, and to hasten the fatal termination. This conclusion is also sustained by the Fiske Prize Essay of Dr. John Bell, of New York, published in the *American Journal of the Medical Sciences*, in 1859.

In 1857 Dr. Wm. A. Hammond, then a member of the medical staff of the U. S. A., presented an essay to which was awarded a prize by the American Medical Association, and which contained a detailed account of his experiments with albumin, starch, and gum as food. He confined himself for ten consecutive days to a diet of albumin and water. After an interval, during which he used an ordinary diet, he confined himself for ten days exclusively to starch and water, taking a given quantity at each mealtime. Among his conclusions concerning the effects were the following: "That albumin may be assimilated into the system in such quantity as to furnish a sufficiency of both nitrogen and carbon to the organism;" and "that starch can be assimilated by the absorbents in more than sufficient quantity to sustain the respiratory function." This last conclusion was proved by the fact that during the ten days of living on starch there was no loss of body weight and an increase of 1.8° F. of temperature; while during the ten days of albuminous diet, there was more than *five pounds* loss in body weight, and no loss of temperature.

During the last three days of the experiment with albumin the urine became albuminous, and during the same stage of progress with starch the urine became saccharin, with other symptoms of diabetes. Subsequently Dr. Hammond experimented with alcohol, first on the dog, and later upon himself. When alcohol diluted with water was introduced into the stomach of the dog, it was rapidly absorbed and easily detected in the blood, the various organized structures of the body, in the urine, and in the exhalations from the lungs or air passages. When he gave the dog only very small doses, and very largely diluted, as in the weaker wines, he was not able to detect it in the organized structures, but still detected it in the pulmonary exhalation with the aid of a solution of bichromate of potassa in sulphuric acid. He also executed three series of experiments with alcohol on himself. Instead of attempting to determine the effects of living on alcohol and water alone for several days, as with albumin, starch, etc., he first took four drams of alcohol diluted with an equal quantity of water at each meal for five consecutive days. The quantity of his ordinary food had been found just sufficient for all the needs of the system without loss or gain in weight. Note was taken of the total amount of ingesta and of excreta each day, the body weight, etc. During the five days the amount of carbon dioxide and water exhaled from the lungs was diminished; the urine was also decreased, both in quantity, and in solid constituents; the pulse was increased in frequency, and there was decided headache, with a sense of heat in the surface, and marked indisposition to exertion either mental or physical. Yet at the end of the five days he had gained in weight nearly half a pound.

His second experiment was with the same quantity of alcohol for the same length of time, but with an ordinary diet so much limited in quantity as to cause a daily loss in weight of one quarter of a pound and a general sense of weakness. The alcohol lessened his sense of hunger and weakness, and produced less headache, but caused the same decrease of excreta, and an increase in weight. The third experiment was with the same quantity of alcohol at each meal with a quantity of ordinary food in excess of the natural requirements of the system. This resulted in the same decrease of pulmonary, renal, and other excretions, and increase in body weight, while the headache, frequency of pulse, and general indisposition were more marked than in the first experiment. A full account of the foregoing experiments by Dr. Hammond may be found in his volume entitled "Physiological Memoirs: Treatise on Hygiene," published in 1863. Notwithstanding the plain evidences of a direct anesthetic effect of the alcohol on the whole nervous structures of the body, his only important inference was that the alcohol united rapidly with the free oxygen in the blood, thereby evolving carbon dioxide, water, and heat, and to that extent *conserving* the tissues. Consequently he still called it erroneously accessory or indirect food, instead of a paralyzer of nerve sensibility and of tissue metabolism, which was really the effect it produced. Regarding the experiments I executed in 1850 and 1852 and directly corroborated by those of Dr. Hammond, as positively proving that alcohol, when taken into the living body, reduces temperature, nerve sensibility, and all metabolic changes in direct proportion to the quantity taken, it was still claimed that in small doses it exhilarates the mind and quickens the movements of the heart, and consequently

it must be a cardiac and cerebral stimulant. With the hope of getting some explanation of this apparent incongruity, in April, 1867, I instituted two additional experiments in which I sought more exact knowledge of the effect on the circulation by using the sphygmograph.

On April 6, 1867, four hours after dinner, when stomach digestion had been completed, the temperature was carefully noted by the thermometer under the tongue; the rate of pulse and other qualities as indicated by the sphygmograph were recorded. Then four ounces of Bourbon whisky were taken diluted with water. The same observations in regard to temperature and conditions of the pulse were made and recorded every half hour, until two full hours had passed. A series of observations in all respects similar were made on April 11, except for the whisky, four ounces of sherry wine were substituted. The several sphygmographic lines were preserved as a part of the record. It will be seen that under the influence of the whisky the temperature diminished three fourths of a degree Fahrenheit in one hour, while under the influence of the same quantity of wine, it diminished one half a degree in the same length of time.

Under the influence of whisky the rate of pulsations fluctuated, increasing during the first hour from 83 to 89, and decreasing during the second hour from 89 to 85 per minute. Under the influence of the wine the rate steadily decreased from 78 to 71 per minute. The qualities of the pulse, as indicated by the sphygmograph, are the same in kind, differing only in degree in the two experiments.

The lines show that each pulse expands the artery to a greater extent and more abruptly than before the alcoholic liquor was taken, and that the commencement of contraction is equally sudden, while the whole line becomes more wavy or irregular; thereby much resembling the *pulse lines* when the arterial coats are weakened by fatty degeneration, or as in such diseases as typhoid and typhus fevers. This indicates relaxation of the vessels from diminished action of the vasomotor nerves and consequent retardation of the blood currents. The inference placed on record at the time is as follows: "The presence of alcohol in the blood interferes with normal vital

affinities and cell action in such a manner as to diminish the activity of nutrition and disintegration, and consequently to diminish the dependent functions of elimination, calorification, and innervation; thereby making alcohol a positive organic sedative instead of a diffusable stimulant, as is popularly supposed, both in and out of the profession." [See *Chicago Medical Examiner*, September, 1867, Vol. 8, pages 522–526.] In 1882–83, Professor Martin, of Johns Hopkins University, planned and executed a very ingenious series of experiments to determine the action of alcohol directly upon the heart of the dog. Having rendered the dog unconscious, and isolated the heart and lungs from nervous connection with the brain and spinal cord, he caused the heart to be supplied with blood containing alcohol in proportion varying from one eighth to one per cent. Further details would occupy too much space, but his results I give in his own words as follows: "Blood containing one eighth per cent by volume of absolute alcohol has no immediate action on the isolated heart. Blood containing one-fourth per cent by volume, that is, two and a half parts per thousand of absolute alcohol, almost invariably diminishes remarkably, within a minute, the work done by the heart; blood containing one half per cent always diminishes it, and may even bring the amount pumped out by the left ventricle to so small a quantity that it is not sufficient to supply the coronary arteries." His experiments demonstrated also that under the influence of the alcohol the heart became so much dilated that the ventricles failed to empty themselves completely by each systole. An interesting account of his experiments was communicated to the Medical and Chirurgical Faculty of Maryland, in 1883, and published in the *Maryland Medical Journal* for September, 1883. The same was copied into the *Journal of the American Medical Association*, Vol. 1, pages 307, 308.

In 1889–90, Dr. Edward T. Reichert, Professor of Physiology in the University of Pennsylvania, aided by an improved calorimeter for determining the rate of both heat production and heat dissipation with the actual temperature of the animal, performed eighteen experiments on dogs. Each experiment was continued six consecutive hours after the administration of a given quantity of alcohol proportioned to the weight of the

animal. In sixteen of the eighteen experiments the average heat dissipation was diminished, in a less ratio, however, than the diminution of heat production, and the actual resulting temperature of the animal was lowered. In only two cases was the resulting temperature slightly increased. [See *Therapeutic Gazette*, Feb. 15, 1890]. The experiments of Professor Martin were repeated by Hammerter [*Johns Hopkins University Biolog. Lab. Stud.*, November, 1889] and his conclusions sustained, but Egleton [*University Med. Mag.*, September, 1890] and Gibbs, by varying the mode of injecting, concluded that small doses produced both increased frequency of pulse and increase of blood pressure, but only of very temporary duration, while large doses lessened both.

One of the most important experimental investigations concerning the "Physiological Actions of Alcohol" is that of Dr. David Cerna, of the Medical Department of the University of Texas, as given in his paper published in the "Transactions of the Pan-American Medical Congress," Vol. 1, pp. 396–429.

His experiments were conducted on frogs and dogs, and were specially designed to ascertain the effects of alcohol upon the peripheral nerves, on the circulation of the blood, on respiration, on body metabolism, on animal heat, and on digestion. He records five experiments on frogs, three with small doses which produced slight and temporary increased reflex action, and two with larger doses that directly diminished the reflex and finally destroyed life. He says that in frogs thus killed by alcohol, "the nerves respond to electric stimulation very slightly or none at all." For testing the effects on the circulation eleven experiments on dogs are recorded, in which 20- and 25- per-cent solutions of alcohol were used as injections into the general circulation either through the external jugular or femoral vein. When the quantity of alcohol injected was small, there was shown an increase in both frequency of pulse and blood pressure, continuing from five to twenty-five minutes, followed by a decline of both. When larger quantities were uted, both pulse and pressure were diminished from the beginning. In many of the foregoing experiments the effect on respiration was noted, and six additional ones are recorded, in two of which the

vagi nerves were severed. The record shows that in all the experiments the respirations were, from the beginning, diminished in frequency and depth and "giving rise to a lower quantity of air passing in and out of the lungs, than in normal conditions." This effect the experimenter attributes to the direct depressing influence of the alcohol "on the respiratory centers in the medulla oblongata."

In regard to body metabolism and digestion, Dr. Cerna records no additional experiments, and only few concerning animal heat, but refers freely to experiments by others, from which he concludes that "the drug [alcohol] lessens the excretion of tissue waste, both in health and disease."

In 1893, Dr. J. H. Kellogg, of Battle Creek, Mich., in a paper read at the annual meeting of the American Medical Temperance Association in Milwaukee in May, and subsequently published in the *Medical Temperance Quarterly*, July, 1893, in which he gave a summary of the results of numerous experiments to determine the influence of alcohol on nerve sensibility, cerebral sensibility or mental action, on muscular co-ordination, on muscular strength, and on digestion. In determining the first three objects he used the chronometer designed by Virdin, of Paris; in the fourth he used a mercurial dynamometer of his own devising; and his observations regarding digestion were based on no less than 2,000 analyses of the contents of the stomach after a test breakfast. His conclusions were as follows: "From the facts above given, it may be fairly concluded that the results of the administration of 1 oz. of alcohol internally, are (1) to diminish nerve activity; (2) to diminish cerebral activity; (3) to impair the co-ordinating power of the brain; (4) to lessen muscular strength; (5) to decrease digestive activity to a notable extent." The only apparent exception noted was in relation to muscular strength. When the test was applied within the first fifteen minutes after the alcohol was swallowed, it showed a slight increase of strength, but after one or two hours it was always diminished.

Dr. Kellogg, in a brief paper read in the Section on State Medicine, at the annual meeting of the American Medical Association in May, 1895, gave the results of experiments showing the effects of alcohol on the quality of the urine; it

having been clearly proved by Bouchard and Rogers that urine from healthy subjects contained several toxic ingredients besides its urea. Dr. Kellogg first found the quantity of urine from a man in good health that was required to kill a rabbit of given weight. Then giving the man 8 ounces of brandy and receiving the urine passed during the first eight hours he found that its toxicity to rabbits had diminished one half. The toxicity of that passed during the second 8 hours was not diminished quite so much, while that passed during the third 8 hours had regained nearly the same degree of toxic effect as before the brandy had been taken. More direct or positive proof that the presence of alcohol in the healthy living human system directly diminishes the activity of the kidneys in eliminating the toxic elements derived from tissue metabolism or bacteriological ptomains, could not be furnished.

In 1894 Dr. Chittenden, of Yale University, reported that the urine of dogs kept under the influence of alcohol for eight or ten days, contained 100 per cent more uric acid than in the natural condition.

The *American Journal of Medical Sciences*, 1896, contains the full report of an interesting investigation concerning "the influence of alcohol and alcoholic drinks upon the chemical processes of digestion," by Drs. Chittenden and Mendel of Yale. The experiments were not conducted during digestion in the living stomach, but in laboratory apparatus, in which the digestive fluids were allowed to act upon various food substances of the proteid class under definite and constant conditions. Nineteen experiments were made with absolute alcohol, and twelve with pure rye whisky, in proportions varying from 0.5 to 6 per cent. When the proportion of alcohol added to the digestive liquids was less than two per cent the digestive activity was slightly increased in many cases, but not in all. When the proportion of alcohol was two per cent or more, the digestive activity was uniformly decreased in direct ratio to the quantity used.

Their experiments with brandy, rum, and gin, showed in all cases decreased digestive action. They also executed many experiments with sherry and claret wines; with ale, porter, and lager beer. In eight experiments with sherry wine the digestive

activity was decreased in all but one. In six with claret in which the proportion of wine was two per cent or less, the digestive action was decreased in three, very slightly increased in two, and no change in one. When the proportion of claret was increased to three per cent, decreased activity was shown in every case. And the same was true in all the experiments with ale, porter, and lager beer. C. F. Hodge, Ph. D., professor of physiology, in Clark University, made a report in the *Popular Science Monthly* for March and April, 1897, detailing three series of "Experiments on the Physiology of Alcohol." One series was designed to test the influence of alcohol on the growth of yeast; and it was shown that the presence of so small a quantity of alcohol as one thousandth of one per cent (two drops to the gallon) caused considerable retardation, which was increased by every additional proportion of alcohol until it reached fourteen per cent, when all growth was arrested. This was the uniform result of fifteen experiments. The second series of experiments was on four healthy, active kittens between one and two months old. They were all treated alike, except to two of them was given daily by means of a stomach pump 1.3 grams of alcohol diluted with water, and to the other two was given in the same manner the same quantity of pure water. The doses of alcohol were gradually increased until they reached 3.6 grams, when plain symptoms of intoxication were produced. The experiment was continued four months, during which the two kittens receiving the alcohol steadily failed in health, while the two receiving only water continued to thrive, and were as sprightly as ever.

Drs. Berkley and Friedenwald, in the Pathological Laboratory of Johns Hopkins University, under the direction of Professor Welch, made some very important investigations concerning the action of alcohol on the leucocytes of the blood and the nerve cells of the brain. The presence of alcohol in the circulating blood greatly diminished the activity of the leucocytes, and caused shrinking or irregularities in the corpuscles with diminished hemoglobin. Many of the nerve cells of both cerebrum and cerebellum were shrunken, and more or less degenerate, and in some places surrounded by paralyzed or dead leucocytes. In 1897, Dr. A. C. Abbott, first assistant in the

Laboratory of Hygiene, University of Pennsylvania, reported the results of experiments on rabbits to ascertain the "influence of acute alcoholism or their normal vital resistance to infection." Several healthy rabbits were inoculated with the same proportionate quantity of streptococcus pyogenes. One half the number were given diluted alcohol through a stomach tube, daily, sufficient to produce symptoms of intoxication. To the other half no alcohol was given. The alcoholized rabbits became sick quicker and suffered much more severely than those receiving no alcohol. The same effect was produced after inoculation with the bacillus coli communis; but with the virulent staphylococcus pyogenes aureus there was less difference [see *Journal of Experimental Medicine*].

Dr. John D. Kales, when demonstrator of histology in the laboratory of the Northwestern University Medical School, Chicago, executed a series of experiments with the spectroscope and microscope on blood drawn by hypodermic syringe from the heart of a living rabbit and mixed with alcohol in varying proportions from one to ten per cent of the latter. He found when the alcohol in proportions varying from one to five per cent was mixed with the freshly drawn blood diluted with distilled water, it made no perceptible change in the oxyhemoglobin spectral bands at ordinary atmospheric pressure and a temperature of 98° F. Neither was there any evidence of the oxidation of the alcohol. But when the pressure was diminished by means of the air pump to the extent of 710 millimeters of mercury, the hemoglobin was rapidly reduced by surrendering its oxygen, which did not combine with the elements of the alcohol present, but escaped in a free state. It was further shown that the rapidity of reduction of oxyhemoglobin was increased by increasing the proportion of alcohol used; and when reduced in contact with alcohol it was less capable of re-oxygenation than when reduced without the presence of the alcohol. In 1894 Dr. I. H. Orcutt, of Owatonna, Minn., published a monograph in which he details the results of several hundred experiments with the sphygmograph to show the effects of alcohol on the circulation in healthy persons, and claims that in all cases it diminishes the force and frequency of the heart's action in direct proportion to the quantity of alcohol taken.

Dr. Horatio C. Wood, in his address on Anesthesia, in the International Medical Congress in Berlin, 1890, said: "In my own experiments with alcohol, an eighty-per-cent fluid was used, largely diluted with water. The amount injected into the jugular vein varied in different experiments from five to twenty c.c.; and in no case have I been able to detect any increase in the size of the pulse, or in the arterial pressure, produced by alcohol, when the heart was failing during advanced chloroform anesthesia. On the other hand, on several occasions, the larger amounts of alcohol apparently greatly increased the rapidity of the fall of the arterial pressure, and aided materially in extinguishing the pulse."

During the past year Professor Atwater, of Wesleyan University, Conn., conducted a series of experiments on a man confined in a cage with apparatus for determining the amount of nitrogenous and carbonaceous material taken into the system and the amount escaping therefrom. Six experiments were conducted, each continuing four days. In four of them the person took an ordinary mixed diet with coffee; in the other two he took from two to two and a half ounces of alcohol each day instead of an equivalent amount of carbonaceous food. A part of the alcohol was taken with his regular meals, mixed with his coffee, and the remainder was drunk between the meals, diluted with water. [See Bulletin No. 69, U. S. Agricultural Bureau]. Professor Atwater's conclusions are that "the alcohol was oxidized; *i. e.*, burned as completely as bread, meat, and other ordinary foods in the body and in the same way; that in the oxidation, all potential energy of the alcohol was transformed into heat or muscular energy. In other words, the body transformed the energy of the alcohol just as it did that of starch, sugar, and fat; and that the alcohol protected the materials of the body from consumption just as effectually as the corresponding amounts of sugar, starch, and fat." Consequently, he insists that alcohol to the extent of from two to two and a half ounces per day for an adult, must be considered as food and not poison. The sole object of the experimenter appears to have been to prove that a certain amount of alcohol can be oxidized and thereby converted into carbon dioxide and water with evolution of heat, in the living body,

but he explicitly states that he took no note of the effects of the alcohol on the hemoglobin and leucocytes of the blood the functions of the nervous and cerebral structures, or on the more important secreting structures of the body. Consequently he bases his conclusions on a single attribute of food; *i. e.*, oxidation, to the exclusion of all other necessary qualities, apparently forgetting that the adoption of so restricted a basis would compel him to include ether, chloroform, morphine, and many other anesthetic and narcotic drugs in his list of foods; for all of them undergo more or less oxidation in the living body.

The foregoing list of experimental investigations concerning the influence of alcohol on the living body, conducted in this country during the last half century, is sufficient to demonstrate, when correctly interpreted: (1) That ethyl alcohol does not belong, in physiological influence, to the same class as starch, sugar, and fat; instead of being digested, assimilated, and converted into natural elements of the blood and tissues, it enters the blood, and circulates through every part as alcohol, the same as ether, chloroform, morphine, and other drugs; (2) that it diminishes animal temperature by diminishing the activity of natural metabolism generally, and by lessening the force and efficiency of the circulation; (3) that it lessens the functions of all nerve structures, both sensory and transmitting, and thereby diminishes the acuteness of the special senses, and the activity of mental processes indirect proportion to the quantity of alcohol present; (4) that it impairs the corpuscular elements of the blood, lessens the activity of the leucocytes, and favors tissue degeneration in the direction of fatty, fibroid, and sclerotic changes; (5) that it lessens every force or energy known in a living body; namely, muscular force, nerve force, mental force, heat force, and vital or protoplasmic force, both animal and vegetable.

That the first of these propositions is correct was not only fully demonstrated by both myself and Dr. Hammond in living several consecutive days on nothing but starch and water, doing our daily mental and physical work and maintaining all our bodily functions in their normal condition, while the taking of less than two ounces of alcohol daily, resulted in direct disturbance of nearly all the functions, both physical and mental, but those of Dr. Hammond also demonstrated the presence of the alcohol in the blood and tissues unchanged by its passage through the digestive organs. The same has also been shown by many chemists in both Europe and America. Therefore, the classing of alcohol with starch, sugar, and fat, as hydrocarbonaceous food by Liebig, was a most unfortunate error, as it has nothing in common with the three last named except that it is composed of the same three elementary substances. Instead of being a product of vegetable or animal growth or vital evolution like them, it is a toxic product of fermentation; and instead of undergoing digestion and assimilation like them, it enters the blood unchanged and exerts more or less disturbing influence on every function of the living body.

The second proposition, that alcohol diminishes the temperature of the human body, as first demonstrated by me in 1850–51, next by Lichtenfels and Frohlick in 1852, by Dr. B. W. Richardson in 1866, and by many others, is no longer disputed by any well-informed parties. The correctness of the third proposition is not only well sustained by the ingenious experiments of Dr. J. H. Kellogg, and some of those of Dr. Cerna, but it is still more amply demonstrated by those of J. J. Ridge, B. W. Richardson, Lauder Brunton, Kraepelin, and others in Europe. The fourth proposition is not only fully justified by the investigations of Drs. Berkley and Friedenwald already detailed, but also by those of B. W. Richardson, Delearde, A. C. Abbott, and by all who have investigated the results of chronic alcoholism.

The fifth and last proposition is a legitimate corollary from all those preceding it, and is sustained by all the experiments showing that alcohol diminishes tissue metabolism, animal heat, nerve sensibility, muscular strength, mental activity, and protoplasmic germination, as detailed by Bocker, Hammond, Richardson, Parkes, Ridge, Hodge, Kellogg, and others too numerous to mention. The inference that I drew from my experiments in 1850–51, that the maintenance of animal heat and the exhalation of carbon dioxide were the direct result of cell or tissue metabolism, and not from the oxidation of alcohol or any other unorganized matter in the blood, has since been

more fully demonstrated by the investigations of Fick, Wislicenus, Vort, Pettenkoffer, and Pfluger. Consequently the presence of alcohol in the blood and tissues of the living body, repairs no tissue, and liberates no natural force or vital energy, but by its narcotic or anesthetic properties it diminishes both metabolism and the evolution of all varieties of organic or vital force in direct proportion to the quantity present. And so far as it unites with the free oxygen in the blood it diverts that amount from its action on the organized matter in promoting metabolism, and thereby prevents the natural evolution of more heat than is liberated by its own oxidation. Therefore, it displays none of the attributes, and is capable of serving none of the purposes, of food in the living body; and there are but very few morbid or pathologic conditions for which it can be used with benefit as a medicine; and even for these, other anesthetics, as chloroform and ether, are more efficient.