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JOHNS HOPKINS

THE A. B.–Z.

OF

OUR OWN NUTRITION

HORACE FLETCHER'S WORKS

The A. B.-Z.
of OUR OWN
NUTRITION

By HORACE FLETCHER
Author of "Menticulture," "Happiness," "That Last Waif," "Glutton or Epicure," Etc., Etc.

EXPERIMENTALLY ASSISTED BY
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WITH INCREASE OF ENDURANCE?

TO ALL THESE VITAL QUESTIONS,
THIS BOOK ANSWERS ONLY "YES."

VERIFY THIS BY PERSONAL EXPERIMENT.
IRRESISTIBLE DESIRE FOR PHYSICAL EXERCISE
WILL FOLLOW, AS A MATTER OF COURSE,
PROBABLY FRUITING IN USEFUL ACCOMPLISHMENT
BY THE SAME INVITATION OF HEALTHY IMPULSE
WHICH CAUSES CHILDREN TO PLAY TIRELESSLY.
DO RIGHT YOUR FEEDING OF THE BODY.
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Introduction

DO WE EAT TOO MUCH?

(*A propos of the Scientific-Military Experiments at Yale University*)

Do we eat too much?

Nine out of every ten physicians tell us "Yes," and tell us true!

How much too much?

Luigi Cornaro suggested that all persons in his time ate more than was necessary; most persons ate twice as much as was good for them; and some, who were extravagantly gluttonous, ate ten times as much as was their most economic need; and Cornaro, who was a dissipated wreck at forty, reformed his manner of eating and lived to be a hundred to prove his declaration.

Experiments carried on in this country and in Europe during the past five years confirm this estimate of habitual excess; but fortunately they have also revealed a natural protection, heretofore unappreciated, available to all, which can regulate the appetite to suit the real needs of nutrition and thus avoid the dangerous excess which predisposes to discomfort and disease.

Luigi Cornaro lived more than three hundred years ago. His charmingly frank and interesting autobiography has been published in English upwards of forty times in different new editions, and no one has disproved the possibility or probability of his claim. We all know that Cornaro was right. We know, in a general way, that the great Italian dietitian and philosopher was wise and uttered wisdom, and we are told that most, if not all, of the diseases which pain, worry, and afflict us are caused by indigestion or mal-assimilation of food, the result of some indiscretions of eating. The questions then are "What are our indiscretions?" "How can we avoid them?" and "What is the new discovery that will protect us and, at the same time, add to the pleasures of the palate and of living?"

The answers to all these queries will be found herein, as will also an explanation of the very active interest which is being taken just now in the problem of human nutrition by scientific and military authorities, as evidenced by the Yale investigation.

The author has, in collaboration with several others, found a way how *not to eat too much* while eating *all that the appetite desires,* and in a way that leads to a *maximum of good taste* and at a *minimum of cost and waste,* but it is necessary to test many persons of different physiques and varying temperaments, and also to test other methods of attainment of economy, to learn what is best for general application, and that is what is being done at Yale.

The cost to the pocket that is saved by economic nutrition is of little matter as compared with the saving of the waste of energy and the menace of disease.

Nature certainly never intended that we should weaken, depress, and distress ourselves in the way that is common to present-day living, as is made evident by the prevalence of discomfort and disease relative to our daily food. Nature's plan of evolution does not work that way in general, does not retrograde in the progress of the improvement of plants and dumb animals, and certainly does not intend that Man, the First Assistant of Nature in the cultivation of things and in the domestication of the powerful natural forces, should suffer and become degenerate contrary to her general law.

If we are agreed upon the foregoing, let us ask ourselves a few questions.

Without any undue egotism, may it not be possible for a generation of human beings, who have progressed so far in intelligence as to be able to move things by steam, to communicate across the ocean even without wires to guide our messages, and to see clearly through objects that are as dark as night to the unassisted human eye with the aid of an artificial light, to learn the secret of right self-nutrition and practise it in a manner that will not deprive us of the maximum of pleasure which Nature invariably gives as a reward for conformity with her beneficent requirements? May we not assume that beings who have learned to breed and train horses to race with human intelligence, and to run, trot, or pace a mile in less than two minutes, may also train themselves to have the proportional relative speed, endurance, and longevity that has been attained by race horses through man's care, and to enjoy the pleasure of living that is evident in these favoured animals, mere servitors of man though they be?

If this disparity of man is due to ignorance arising in self-neglect, which is the usual accompaniment of genius, may we not now, at the beginning of the pregnant twentieth century, rest for a moment from discovering, developing, and improving the world outside our personal selves and concentrate our attention for a while on learning to know and care for ourselves? May we not, at least, give "horse sense" attention to such a vital interest?

In the midst of the present confusion which exists among opinions as to the right conduct of life and activity, and the best manner and system of diet to be used to secure health and efficiency, it seems almost a vain appeal to call for concert of action in a matter of common and persistent neglect. Each person, as his own keeper, is careless, and in matters of bodily management no one feels called upon to be his brother's keeper; but this is merely the lethargy of oversight and consequent ignorance, and this book is published to call attention to the oversight and to attempt to dispel the ignorance.

At the present moment of writing (October, 1903) there are quartered at New Haven, Connecticut, twenty privates of the Hospital Corps of the United States Army and three non-commissioned officers, under the command of Assistant Surgeon, Lieutenant Wallace DeWitt.

These men and officers, while they are under regular army discipline and are performing duty in conformity with their oath of enlistment, are yet volunteers. They are from the same corps, if they are not the same men, which furnished volunteers to investigate the causes of yellow fever in Cuba, whose heroism resulted in stamping the fever out of the islands and in that more effectually protecting our coast states from its yearly incursions. These are the same men who generously refused to accept the offered bounty. This latter expression of exalted manhood is evidence of what humanity is whenever there is real need for heroes to serve the general good. They refused to *sell* themselves as risks for money, but they freely *offered* themselves as subjects of scientific investigation for the benefit of their fellows and of mankind at large.

The duty that the soldiers are engaged in at Yale has no element of risk, and need not have any feature of monotony or tediousness in it, much less has it the romance of sacrifice, for it deals with an attempt to restore normality and does not consort with disease. But the service being rendered by these guardians of our health, these soldiers of hygiene, is even more important than was the service rendered in stamping out yellow fever, for it deals with an enemy much more subtle, treacherous, common, and deadly than Yellow Jack. Yellow fever calls for a halt and an immediate attempt at cure, and further, for stringent defence to extermination; but indigestion and the American plague, *dyspepsia*, work their evils slowly but surely to cut off our best men and loveliest women in their prime and to rob us of their richest product and of their maturest wisdom.

The investigation at Yale is a link in a chain of effort that has developed in logical sequence and has been planned to effect a cure of the common ignorance and practice relative to right human nutrition in its relation to profitable thinking and doing; and to discourage the personal neglect which has been responsible for the existing ignorance, this book is issued to show what may easily be done and what has been done, so far, in this direction. It is a compilation of important knowledge which has been born of recent scientific research but which is hidden away from common comprehension in scientific publications; and it relates the story of the development of which this book is an exponent. Herein are given the reasons why the government and the most eminent scientists in the line of researches in nutrition are coöperating so earnestly and so unusually in a commonweal inquiry.

About ten years ago, at the critical age of forty-four, the author was fast becoming a physical wreck in the midst of a business, club, and social tempest. Although he was trained as an athlete in his youth and had lived an active and most agreeable life, he had contracted a degree of physical disorder that made him ineligible as an insurance risk. This unexpected disability, with such unmistakable warning, was so much a shock to his hopes of a long life that it led to his making a strong personal effort to save himself. The study was taken up in systematic manner, account of which is too long to relate here; but the eager auto-reformer soon learned that his troubles came from *too much* of many things, among them too much food and too much needless worry; and realising the danger ahead, he sought a way to cure himself of his disabilities by the help of an economic food supply, as did Luigi Cornaro; but what is even more important, he found a way to enjoy the smaller quantity of food much more than any plethoric luxury can give, and arrived at the method by a route that showed a means of conserving a healthy economy and an increased pleasure of eating, at the same time, in quite a simple and scientific manner, that any one may learn and practise without any ascetic deprivation whatever. Cornaro buried the real clew to his economic and pleasurable success with his body, owing to his vague generality of description of his method. The author is determined not to make the same mistake, and thereby bury *his* key to a happy and easy life.

The secret of the method is all told in this book and is confirmed herein by both theoretically scientific and scientifically practical authority; but the experiments which are being conducted at Yale by Professor Chittenden, in coöperation with Surgeon-General O'Reilly of the army, of which the *Daily Press* has given notice, together with experiments which are in progress in many university laboratories in this country and in Europe, are for the purpose of explaining the "reasons for things" by complete scientific reasoning, so that none may doubt the disadvantage and sin of dietic ignorance and carelessness.

The acceptance of the theory and method of the author at the great Battle Creek Sanitarium, after more than a year's trial, and elsewhere among curative agencies, and their adoption and use as the first requisite of treatment, of which the public have not so generally heard, are indorsements coming from practical, intelligent, and expert sources of experience and judgment, and hence they are of the utmost value and significance.

This introductory chapter is being written after the "clippings" of newspaper comment relative to the presence of the soldiers at Yale have begun to come in. The majority of comments are generous in spirit, but indicate a lack of complete understanding which this "Introduction" is intended to correct.

Some of the comments are couched in ridicule, and express pity for the poor soldiers who are being "misused" as subjects of starvation in an investigation which promises to make starvation a rule in the army. To the writers of such trifling and unfair paragraphs let me, one of the fraternity in an amateurish way, beg consideration of the following.

The campaign that has been started is against a common enemy of mankind, and of the American and English nations in particular. In our successes in agriculture, manufacture, and commerce we have cultivated insidious, luxurious temptations which bring all of us some ill and many of us, or our loved ones, fatal disease and premature death. The advance agent of these enemies of ours is Eating-and-drinking-too-much.

The officers and men of the army and the eminent scientists of our country and those of all nationalities who have entered into the campaign with us, and the great power of the sanitaria joining as practical nurses, demonstrators, and exponents of the reform, are all working for you and for everybody. It is voluntary service and has already cost some of the volunteers much time and patience and also a considerable sum in money.

You, gentlemen of the Press, wielders of the helpful or careless pen, have a conspicuous pulpit and a far-reaching influence. No one can escape you. In the search for the news of the day you are encountered at every turn in your editorials or your paragraphs. In this campaign we need your assistance to make the coöperation between the army and science easy and effective. They are too busy working for you and your best interest to stop to argue to correct your misunderstanding, but the cause will feel the benefit of your assistance.

Encouragement has powerful influence in stimulating effort and also in creating and conserving conditions in which men may "do their best." What we are trying to learn is, what man *may* do, under favourable conditions of knowledge and confidence, to relieve his body of the *strain of energy-taxing labour* in disposing of the waste *which any excess of food imposes.* It is a constructive experiment and not a mere statistical measurement. Appreciation and applause assist; doubt and ridicule obstruct.

The soldiers and physiologists are too busy studying indigestion and possible proteid poisoning and what-not-other causes of intemperance, disease, and suffering to ask you to assist in spreading only serious report and right suggestion relative to the importance and purport of the investigation, but it is my privilege to ask it for the general good.

Just another word of introduction and then will follow some *postintroductory* coincidences relative to the work in hand, and then an attempt to lay out a ten-page chart of the personal responsibility in the care of the body and the nourishment of the mind by aid of an economic and most satisfactory nutrition, so as to make conservation of energy as easy as possible and life well worth the living. The scientific support from the pens of professional observers is, however, the real meat of the book, for which compiler and reader alike are and should be grateful.

In serving in the humanitarian ranks in a commonweal campaign one should not need to use the concealment of modesty, nor should he fail to speak with all frankness. What are the motives behind all this energy to reform the eating habits of the people? The question has been so often asked that it is better thus publicly answered.

No one concerned in the campaign has any personal monetary interest in any kind of food, prepared or otherwise. The movement began in a suggestion carried by an accidental word given to the author by a friend, an old-time friend in Japan, and a friendship never to be forgotten, as related in the author's book "Menticulture." Pursuit of menticulture led further to the discovery that the best mental results could not be accomplished in a body weakened by any indigestion, any mal-assimilation of nutriment, any excess of the waste of indigestion. Then came the quest for the causes of malnutrition, which were soon found, by study of the natural sequences and by going behind the hypotheses of text-book authority, to arise in the careless ingestion of food, its neglect in the mouth, and the consequent glut of unassimilable excess within the body, necessitating enormous expense of brain and body energy to get rid of the excess.

When the secret of the potency for good of a rationally economic alimentation was revealed to the author, was confirmed by several colleagues of different ages and both sexes, and was tested by work and endurance measurement, and also by the test time, it became necessary to have given to it the indorsement of highest authority in order to have the information credited. The new rediscovery was a simple matter, something everybody thought they knew all about because it had been under their nose all their life and was one of the commonplaces of every-day living, but for that very reason it failed to receive credence, and the backbone of the doubt was habit — lifelong habit — and this was hard to break even in those who accepted the theory of economic nutrition as a logical conviction. It was also necessary to prove that it was not personal idiosyncrasy that favoured us, its advocates.

It is in pursuit of the latter desideratum that the officers of the army, the scientists, and the great humanitarian health-restoring institutions have entered upon conclusive investigations, each in their own way, to chart out a law of economy that will be generally applicable and which, it is hoped, can be understood by kindergartners and mothers for the benefit of the present and of coming generations.

It was just stated that no one concerned in the inquiry was interested in any food product or in any personally profitable business concern, and mention of the Battle Creek Sanitarium, so widely known as the pioneer in fostering the pure food and prepared-cereal manufacture, may cast a doubt upon the matter in the minds of those who do not know that the Sanitarium organisation, in its every department, is a philanthropic, humanitarian institution. It is the parent and feeder of the American Medical Missionary Cause, which already has established branches in something over sixty localities situated in or near large cities in different parts of the world, chiefly America. By perpetual charter all the profits revert to the spread of the work and the employees serve for a mere pittance, deriving their major compensation from enjoyment of the altruistic work.

The old prejudice against the human race which declared that " everybody had an axe to grind," that there was " a nigger in every woodpile," and such like slanders, must be modified in the light of recent altruistic development. Altruism has always been existent and had a great new birth with the beginning of our era, but it was never before so frankly put upon a business basis as it is now, and this is fast being applied to every department of business activity. It is now done, not in the name of any particular creed or cult, or for future reward, but because *it pays* — first, last, and all the time.

In the study and pursuit of menticulture the author has found that working for the common good is as necessary to happiness as working for self, and that the retroactivity and reciprocity of the idea multiplies the profits indefinitely.

The sequence of profitable, altruistic interrelation is stated in the "Explanation" of the chain of the A. B. C. Life Series, of which this book is one of the links.

Aside from those actively engaged in the several investigations to whom reference is often made, the author wishes to express special gratitude to Sir Michael Foster and to Professor Henry Pickering Bowditch of the Board of Scientific Assessors. Unselfish and unremitting in their assistance and encouragement, the author's work has been made easy since their interest was enlisted.

Sir Michael, as Member of Parliament in England, and as a physiological savant, knows that economic nutrition is the key to England's welfare, as well as the basic necessity of temperance, morality, health, and efficiency, as is expressed in the two documents from him reproduced in the "Report of a Plan for an International Investigation into the Subject of Human Nutrition" and in his "Note" on the Cambridge examination of the author and Dr. Van Someren at Cambridge University laboratories, given herein.

Professor Bowditch, as a distinguished physiologist, publicist, and especially as the President of the Children's Aid Society, of Boston, Massachusetts, often mentioned as the model institution of its kind in the world, realises that the effort of the author to secure basic knowledge relative to right nutrition, adaptable to kindergarten teaching and home training during the impressionable period of youth, is of the greatest importance in social reform.

A trial suggestion relative to ways and means of *beginning right* with *all the children* and thus insuring a regeneration of the classes most in need of reform, in not longer than two decades, is outlined in the author's appeal for the waifs of society, entitled "That Last Waif; or Social Quarantine."

Whenever there is any disposition to slack up in patience or enthusiasm to accomplish the ultimate end aimed at, the picture of the waif in that story is flashed back by memory, and there can be neither forgetfulness, indifference, nor repose until "that last waif" has been given *at least a chance of choosing* between the right and the wrong, the good and the bad.

POSTINTRODUCTORY

[Just before "going to press" the author has received a letter from his esteemed colleague, Dr. Hubert Higgins, giving the gist of interviews with an eminent European physiologist and with a famous American chemist and dietitian, which so well describes the attitude of the scientific mind towards the problem of human nutrition that the scientific mentor of the writer advises its addition to the book.

By the same post there arrived a letter from Dr. J. H. Kellogg, the life and director of the Battle Creek Sanitarium, expressing practical appreciation, the result of demonstration, of what is being done to solve the problem.

Eliminating the personal element and keeping the ultimate object in view, these communications are coincidentally *a propos* and intimate to our "Introduction"; hence their reproduction here.

Numerous other letters and extracts from communications received by the writer, bearing upon this subject, from the above and other sympathetic friends are reproduced in "The

New Glutton or Epicure," a free and easy companion of this book, intended to appeal to a variety of readers.

When it is known that the proceeds of all the publications of the author are dedicated to the promotion of the objects they advocate, reference to them or advertisement of them cannot be considered inappropriate. — HORACE FLETCHER.]

EXTRACTS FROM DR. HIGGINS' LETTER

PALAZZINA TASSO,
CAMPO S. POLO,
VENEZIA.

October 3, 1903.

DEAR MR. FLETCHER, — A. appears to me to have an exceedingly broad and philosophic grasp of the problem of nutrition.

He recognises that all present data are subject to criticism, and that there are no scientifically accurate data available because

(*a*) Observations are taken over too short a period.

(*b*) They have mainly dealt with one side of the problem, — the output of muscular work.

(*c*) The observations are not sufficiently complete.

He acknowledges that cleavage products from food broken down in the intestines by bacteria are the cause of

(*a*) Inefficiency
(*b*) Diseases
(*c*) Mental derangements.
(See Mott's work.)

He recognises that the majority of people eat far too much. He puts this in the following way. If a "mediæval devil" had wished to discover the most subtle and most effective way to destroy mankind mentally, morally, and physically, he would have arranged for them to be supplied with tasty, well-cooked foods, wines, etc.; in short, he would have used every means to tempt, confuse, and pervert their appetite. He would also have arranged every possible means to prevent their being in the fresh air and taking exercise. He thinks one has here the picture of modern civilisation.

He talked in a very interesting and instructive manner about the necessity and value of exercise and a muscular body for the maintenance of good health. He has evidently worked at and thought a good deal about this side of the subject.

He regrets that there are not more people who realise the huge importance of understanding the nutrition problem for the sake of the progress of humanity. He would like to join all those who are interested in forming an international society, as far as I understood him.

He is most keen on getting subjects, such as myself, for study over a very long period of time, — two to three years, — as he very justly observed "Muscular output is a very small part of the measure of a man's efficiency. Mental efficiency, manual dexterity, and other psychological tests are necessary." He seemed very much interested in my idea of making a large number of curves of daily observations. He said that it appeared to him to offer the best means of ultimately measuring the degree of deviation from the subject's optimum state of health.

He argues the necessity of getting some scientific definition of health.

The phrase that reduces all these people to contemplative silence is this.

"You acknowledge that the state of knowledge is insufficient to prescribe a diet for any individual that he should take daily; or in other words, that there is very little accurate knowledge of the nutrition problem."

Reply. "Yes. I do not feel I could prescribe a diet for any one with any degree of confidence."

"Very well, then. Why should not the body have or acquire the quality that all animals have, in a free, natural state, of knowing what their body wants by appetite and taste?"

This is more or less how you put it to me when I first met you at Cambridge. Its full significance did not dawn on me till much later; till, in short, I commenced the study of my desires at Cambridge.

Now this point of view is the rock on which we stand, and is the cause of H.'s and A.'s interest, and as H. said, is the "most fascinating idea" he ever heard.

It had very much the same effect on A. He was reduced to silence. The more you think of it the more you see there is no answer that could contradict it.

He then admits that

(*a*) The food should be finely divided.
(*b*) That it should be thoroughly insalivated.
(*c*) That in all probability most diseases are caused by dietetic error.
(*d*) That we have still to find the optimum health and the optimum diet.

He only kicks at the low proteid. Now I don't care a "kuss" for the low proteid, as such, or high proteid. Proteid like everything else will be demanded by the appetite when it is wanted.

Our great danger, to my mind, is the tendency so strongly exemplified by some of prescribing diets and quantities and the length the time food should be chewed.[1] Now the very errors we are fighting against are the prescription of methods on insufficient information or knowledge. *You have gone straight back to Nature. There is your strength* in convincing the scientific world, and we must study the problem from that point of view if we are to get any great degree of success.

A. had nothing to say when I told him that I did not hold by either high or low proteid but only by my appetite and taste, developed by ample mouth opportunity to discriminate, which I hoped, in time, to understand more thoroughly than I do now. He told me that he feared that there would be great physical deterioration after a long period of low proteid. I said that I did not believe it would be the case by your method. For instance, right in the midst of a long period of most satisfactory low-proteid supply, I once ate nearly a whole

[1] Appetite alone can judge accurately of the former, and the true Swallowing Impulse is the limitation of the latter. If we study the natural instincts, the rest will take care of itself.

chicken with some ham at Penegal. I could not get saliva for anything else.[1] In short, then, I insisted only on thorough mastication to protect taste and appetite, and had no other theories. I was only concerned in observing the factors determining my taste and appetite. I would be more than contented to leave the question of minimum and maximum quantity of proteid to be settled in the future after normality had been established by practical demonstration.

Yours faithfully,

HUBERT HIGGINS.

EXTRACTS FROM DR. KELLOGG'S LETTER

BATTLE CREEK, MICH.
October 7, 1903.

MR. HORACE FLETCHER.

DEAR FRIEND, — Yours of September 30th just reached my hands and I hasten to reply.

I saw a newspaper note in reference to the soldiers which the government has selected for the dietetic experiments, and also read an interesting article in the *Popular Science Monthly.* You have accomplished a great good thing in enlisting these scientific and military men and interesting them in the investigation of this

[1] This is very strong evidence that appetite knows what to do and when to do it, if you study and consult it and give it a chance to prescribe.

wonderful reform. The marvellous thing about it is that these busy men of science should have so readily undertaken an investigation which involves so much surrender and self-denial, at least, at the start. I know you are absolutely right. My personal experiences and observations confirm me. In the experiments you mention, which I made in reference to the daily ration for ordinary persons, I simply sought to ascertain, as have others, how much and what kinds of food people are in the habit of using, taking no account of the possible excess or the careless manner in which they eat. The figures I got were sixteen ounces of starch; 1.2 ounces fat, and three ounces proteids, — approximately 2,500 calories. In observation of patients I have seldom found one able to eat this amount. Personally, I habitually eat scarcely half as much. My breakfast to-day was the yolks of two eggs, two or three tablespoonfuls of corn flakes, a moderate-sized potato, and a couple of peaches. At dinner I shall take a little more.

I have been so busy with my patients and the new building, getting things organised, that I have not done as much as I ought to in the way of promoting your splendid reform; but I am going at it now in good earnest. I feel it is one of the greatest things in sight, and it fits right in to all the other things I am trying to do. I feel that I owe you continually a great debt for the efforts you have made and the splendid work you are doing, which will accomplish more for the uplifting of humanity than all that Carnegie and Rockefeller are doing with their millions. What they are doing is mainly to perpetuate old errors, while you are bringing out new truth of basic importance, and a kind Providence has certainly inspired you to do this grand work.

I thank you for all your good thoughts towards us, and assure you the loving encouragement your letters always contain is very much appreciated, and sometimes it gives us a mental uplift just when we need it. The road we are travelling over is not altogether free from thorns. All your suggestions are gratefully received. I remain,

Faithfully yours,

J. H. KELLOGG.

A. B.–Z. PRIMER

EXPLANATION

THIS is a condensed presentment of a subject of basic importance to everyone, supported by numerous appendices of great scientific weight.

The special object of such brevity and elementary treatment of the subject is:

1. To accentuate the facts showing how little we really have to know and do in connection with our sustenance in order to have the NATURAL AUTOMATIC PROCESSES done rightly and healthfully.

2. To permit busy persons who will take our dictum as gospel and our advice as sound to learn their necessary share in their own nutrition in the least possible time, leaving the less credulous and more curious to study the appendices at leisure and at will.

3. For some ten years it has been the ambition and the aim of the older and non-professional author to embody the fundamental essentials of human responsibility in self-understanding and self-management in not more than ten pages of coarse print that a child could understand and that mothers and teachers might commit to memory and never forget.

This is only a first trial-attempt to fulfil the ambition and the aim; but the appendices show the assembling and concentration of scientific and militant forces which will not allow this subject of primal human interest to remain longer the most neglected of educational departments.

SOME PERTINENT QUESTIONS

WILL the reader not ask himself the following questions?

1. How much do I know about my own nutrition?

2. Do I know the particular need and purpose of my last meal and what it is likely to accomplish?

3. Considering my body as an engine, would I accept myself as a competent engineer on my own examination and confession?

4. Were I an iron and steel automobile, instead of a flesh and blood automobile, which I really am, could I get a license for myself, as a *chauffeur*, to run myself with safety, based upon my knowledge of my own mechanism and the theory and development of my power?

5. Were I an owner of valuable live-stock, would I employ a farm-hand or a stable man, even at so low a wage as fifteen dollars a month, who knew as little about the proper feeding of my animals as I know about the proper feeding of myself and my children?

6. Should I employ such an ignorant attendant for my live-stock, and catch him worrying them during their feeding, and hurrying them away from their fodder to hitch them up for work, would I not have the man arrested for cruelty to animals? And yet this is what is habitually done to children!

7. Do I appreciate how important it is to learn sufficient of the requirements of economic and healthy nutrition to enable me to escape the depressing and debilitating effects of a faulty nutrition.

8. How can I religiously "ask a blessing" upon food and then immediately sin by treating it in a manner abhorrent to the natural requirements?

9. If "cleanliness is next to godliness" is it respectable for me to slight my proper feeding in a manner that I know may induce putridity of excreta through indigestion and that *may* produce fatal disease?

10. With All Eternity ahead of me, cannot I afford at least 1/48* of my time for careful feeding of my body in a manner known to favour physical health; mental keenness; firmness of character; enjoyable temperance; sexual vigour without morbidity. In fact, general respectability and efficiency?

Having duly reasoned out logical answers to the questions, may they not seem sufficiently important to be remembered and respected as a DIETARY TEN COMMANDMENTS?

* The Yale test reported herein by Professor Chittenden showed the possibility of full alimentation according to the requirements of Economic Nutrition in from 24 to 26 minutes daily, which is less than 1/48 of a day. Beginners of the practice of careful mouth-treatment of their food *may* require more time, but, whatever it may be, it is worth it. A little care for a short period will establish a right habit, and then no further tedious attention nor unusual time will be necessary to accomplish a perfectly healthy nutrition.

The Psychology of Nutrition

A — APPETITE ATTENTION APPRECIATION

APPETITE is the most important factor in digestion (vide Pawlow).

NORMAL APPETITE is indicated by a desire for *some particular* simple food accompanied by a "watering of the mouth."

FALSE APPETITE is a general discontent of the body, indefinite of description. It is often expressed by "all gone-ness," or stomach craving, and calls for *something*, ANYTHING! to smother the discomfort of present or recent indigestion. It is like the thirst which follows a debauch.

IGNORE FALSE APPETITE, and WAIT for a RETURN of NORMAL APPETITE. It will come as soon as body repairs have been effected by natural agencies and more material is required. No one was ever injured by intelligently and calmly waiting for an appetite. No one ever starved to death for lack of appetite. Most human ills come from forcing appetite, anticipating appetite, abuse of appetite in some form.

APPETITE is the most important factor in nutrition. This estimation is based upon evidence given more fully in the various appendices, but the measure of its importance may be briefly stated, as follows: —

First In its normal state, Appetite is a perfect indicator of the bodily need of nutriment and moisture, both as to quantity and as to the chemical elements required at the moment.

Second APPETITE is a creature of the mind and does not attach to a tissue. It can be as easily changed, from abnormal to normal, by suggestion, as can the mind itself, and is not like a solid, the form or habit of which has been set in a mould. Whoever has once experienced a bad oyster and has abhorred oysters ever after will substantiate this claim regarding the caprices of appetite.

Third APPETITE can be easily comprehended and read and the degrees of its satisfaction understood by simple attention and study for a brief period (vide Van Someren).

Fourth ATTENTION is necessary to create APPRECIATION, and appreciation is absolutely necessary to stimulate the secretion and flow of gastric and other digestive juices (vide Pawlow).

Fifth ANGER, or shock of any kind, and WORRY, or any of the pessimistic depressants, stop digestive activity and cause indigestion (vide Cannon).

Sixth MENTICULTURE should begin with its application to selection (through a normalised appetite) of nutriment for the body, and continue to aid digestion by right thinking.

It is very easy to cultivate calm and fortify against surprise, shock, and anger if the nutrition of the body is carefully attended to. The physical and the mental equipments are beautifully reciprocal and necessary to each other in promoting MENTICULTURE.

B The Mechanical and Chemical Physiology of Nutrition

BUCCAL DIGESTION

THROUGH

MOUTH THOROUGHNESS

Mouth treatment of food, which permits, aids, and includes insalivation (mixing with saliva), and which is both actively digestive in its functions and preparatory to final digestion, is the only *actual mechanical responsibility* we have in our nutrition; and, in connection with favourable A conditions, insures perfect digestion. It has been so fully and clearly explained in some recent articles, "Observations on Mastication," by Dr. Harry Campbell, F.R.C.P., physician to the Northwest London Hospital, printed in the "Lancet" of July 11th, 18th, 25th, and August 8th, 1903, that reference to the articles, reprinted herewith, is all that is necessary here.

In giving attention to careful mouth-treatment of soft or liquid foods until they are absorbed by the Swallowing Impulse the best health and economic results are obtained. It should, at least, be tried.

This will not be found to be a tedious operation after a little practice, when the habit of attention and care has been formed. On the contrary, a new appreciation and enjoyment of taste will be acquired, the delight of which has to be experienced to be understood.

Some hints on learning how to *read* the appetite, *command* the attention, and *masticate* and *swallow* food material *properly* follow.

First; Last; and All the Time Be sure that you are really hungry and are not pampering False Appetite. If true appetite that will relish plain bread alone is not present, wait for it. Especially beware of the early-morning habit-craving. Wait for an *earned* appetite, if you have to wait till noon. Then: "Chew," "Masticate," "Munch," "Bite," "Taste" everything you take in your mouth (except water, *which has no taste*), until it is not only thoroughly liquefied and made neutral or alkaline by saliva, but until the reduced substance all settles back in the (glosso-epiglottidean) folds at the back of the mouth and excites the Swallowing Impulse into a strong inclination to swallow. Then swallow what has collected and has excited the impulse, and continue to chew *at* the remainder, liquid though it be, until the last morsel disappears in response to the Swallowing Impulse. Never forcibly swallow anything that the instincts connected with the mouth show any disposition to reject. It is safer to get rid of it beforehand than to risk putting it into the stomach.

Sip and taste milk and all liquids that have taste as the wine-tasters do. They never drink wine and yet they get all the enjoyment there is in it and waste none. In a very short time sipping and tasting liquids and masticating and tasting solid food for "all they are worth" will become an agreeable and profitable fixed habit.

WHETHER WE "EAT TO LIVE OR LIVE TO EAT," WHY NOT DO AS ABOVE?

Z The True Chemical End-Point of Digestion

THE DIGESTION–ASH WHAT IT SHOULD BE LIKE WHEN IT IS NORMAL

First In adults; or, in children after the eruption of teeth and the ingestion of solid food: The non-liquid and non-gaseous waste of the human body, which, in its normal state, is not offensive, should be very small, in quantity, should be pillular in form, either separate or massed together; should have no odour when released, should take on no odour on standing, should be entirely aseptic (non-poisonous); should drop freely from the exit, leaving nothing behind to wash or wipe away. It *may* not be collected in the intestines of full-grown and elderly persons, when normal, as above, in sufficient quantity to require or necessitate emptying oftener than from twice a week to once in two weeks; according to age, activity, etc.; and should neither invite nor justify the description "it is not that which goeth into a man that defileth him but that which cometh out."

Second Economic Digestion-Ash (solid *excreta*), as a daily average for an adult of 140 lbs. (10 stone; 63.5 kilos), including moisture, when released, should not weigh more than two ounces (56.70 grams). An average of less than one half this amount of waste has been secured in test experiments.

Third The true test of healthy Z is absence of odour and completeness, ease and cleanliness of delivery. Frequency or otherwise, does not so much matter. Quantity too, is not so important; but with foul odour there is disturbance, strain and danger.

The normal man is a cleanly being with all excreta inoffensive; and by these tokens he may be his own private judge.

Why is it that barn-yards are tolerable to the human senses while open *dépôts* of human excreta are fever-breeding nuisances and intolerable to beasts and humans alike?

This curse of putrid excreta caused more deaths from enteric fever during the Boer War in South Africa than all other causes. It is equally a menace to health and even to life while being formed and carried in the body.

Fourth Offensive excreta are quite certain evidence of neglect of the self-controllable parts of our own nutrition. They are the tell-tale condemnation of ignorance or carelessness. Each person should learn to read the true bulletins of his health conditions in his waste-products of digestion.

Z is the form the body *must* assume to render emptying of the digestion-ash natural and easy. Man was built to squat on his heels in defecating, and sitting erect on a modern seat is like trying to force a semi-solid through a kinked hose. HEALTHY HUMAN EXCRETA ARE NO MORE OFFENSIVE THAN MOIST CLAY AND HAVE NO MORE ODOUR THAN A HOT BISCUIT.

A. B.-Z. FIGURE

TO ILLUSTRATE THE "DIVISION OF LABOUR"

First. **A** Psychic Environment / Mental State } This involves:

APPETITE (to select for) / ATTENTION (to prepare for) / APPRECIATION (to assist in) } DIGESTION

(Absolutely necessary to secure secretion and flow of the digestive juices: Vide Pawlow and Cannon.)

Second. **B** BUCCAL-DIGESTION / MOUTH-TREATMENT } This involves:

MECHANICAL (teeth) / CHEMICAL (salival) } THOROUGHNESS

(Absolutely necessary to secure complete digestion and avoid the putridity incident to bacterial decomposition: Vide Campbell and Van Someren.)

INTERMEDIATE The twenty-three letters between "**B**" and "**Z**" represent but an inadequate proportion for the spelling of the enormous share Nature assumes in our welfare, marvellously performing her forty-seven forty-eighths share in the secret laboratory of the alimentary canal.

Third. ***Z*** The true chemical end-point of digestion, by which each self-respecter may know how well he has respected his "A" and his "B," and how faithfully he has performed his one forty-eighth share in the promotion of his own most fundamental interest.

PREFACE

TO 1906 EDITIONS

SINCE the former introductions were written much success has been attained in further advancing the reforms advocated in the *A. B. C. Life Series*. Professor Chittenden has published his report on the Yale experiments in book form in both America[1] and England,[2] and his results have been accepted in scientific circles the world over as authoritatively conclusive.

At the present writing the most important Health Boards of Europe[3] are planning to put the new standards of dietary economy into practical use among public charges in a manner that can only result in benefit to the wards of the nations as well as make an important saving to the taxpayers. In the most important of these foreign public health departments the Health Officer of the Board has himself practised the newly established economy for two years, and his plans

[1] Physiological Economy in Nutrition: The Frederick A. Stokes Company, New York.

[2] William Heinemann: London.

[3] The author is not yet permitted to publish the particulars of these reforms in process, but he has official information regarding them and is in full sympathy with them.

are formulated on personal experience which fully confirms Professor Chittenden's report and that of the author as herein related.

At a missionary agricultural college, situated near Nashville, Tenn., where the students earn their tuition and their board while pursuing their studies, a six months' test of what is termed "Fletcherism" resulted in a saving of about one half of the drafts on the commissary, immunity from illness, increased energy, strength and endurance, and general adoption of the suggestions published in the several books of the author included in the *A. B. C. Life Series.*

In the various departments and branches of the Battle Creek Sanitarium in America, and widely scattered over the world, some eight hundred employees and thousands of patients have been accumulating evidence of the efficacy of "Fletcherism" for more than three years, and scarce a month passes without a letter from Dr. Kellogg to the author containing new testimony confirming the *A. B. C.* selections and suggestions.

The author has received within the past two years more than a thousand letters bearing the approval of the writers with report of benefits received which seem almost miraculous, and these include the leaders in many branches of human occupation — physiologists, surgeons, medical practitioners, artists, business men, literary workers, athletes, working men and women, and almost every degree of mental and physical activity.

One of the medical advisers of King Edward, of whom the King once said: "He is a splendid doctor but a poor courtier," follows the suggestions of these books in prescribing to his sumptuous clients.

HISTORY OF DEVELOPMENT

AND

SUPPORTING EVIDENCE

SUMMARY OF THE FOREGOING PAGES BY AN EXPERIMENTER OF ONE MONTH'S EXPERIENCE

(*Requested and given as a test of effectiveness*)

The entire principle of economic nutrition is simple and practical. It does not prescribe that we shall follow any special diet nor do away with any of our meals. It simply requires you to throw present habits and conventions to the winds, and for a little time try the experiment of giving the matter of your every-day living honest, intelligent thought.

Eat all you crave, but do not eat more than this simply because you have been in the habit of doing so. See to it that each morsel put into your mouth is thoroughly masticated and mixed with the saliva before going down into the stomach, which is not equipped to perform the work which the teeth and salivary glands were given you for. The stomach will struggle bravely to overcome the abuse which you heap upon it, but in spite of all it can do to manage hastily chewed food, undigested portions remain which clog the intestines and interfere with the healthy conditions which Nature intended.

The appetite is given as an indicator of what the body requires. If you crave potato, the system needs starch, which the saliva makes digestible, but which the acids of the stomach cannot dissolve. Other needs of the system are similarly indicated. Take the trouble of asking your appetite the question, instead of accepting the conventional number of courses simply because they are set before you. The appetite will close the valve when you have eaten enough, if you will give it a chance.

Suppose your time for eating is limited; in twenty minutes you could not eat slowly the luncheon which you usually select. Then eat that much less. The amount of food which you can eat and thoroughly masticate in twenty minutes will give you more nourishment and will sustain you better than twice the amount thrown into the stomach in the same manner in which a man usually packs a trunk.

Why is it that so many men require a "bracer" at eleven o'clock? Because they have loaded their stomachs with a heavy breakfast, and instead of gaining nourishment from it, the smothered organ is doing its best to tear the undigested morsels to pieces, that they may pass into the intestines and prevent sickness, or even death. The time finally arrives when it finds itself unable to do this, and then comes acute indigestion, or something worse, and the system becomes run down, ready to receive typhoid, or any other germs which happen to come along.

Do you know why griddle-cakes hurt you? Because the syrup, which is cane-sugar, — and as such is indigestible, — is allowed to pass through the mouth and down into the stomach, without being properly mixed with the saliva, which makes it digestible. As soon as it enters the stomach it becomes acid and interferes with everything it meets. Had the cakes been properly masticated and mixed with the saliva, the cane-sugar would have become grape-sugar, and in this form it is easily digested.

Why is it that stout people are advised to avoid starchy foods? Economic nutrition does not advise this. Potatoes, eaten too hastily, when not craved by the appetite, supply the system with a superabundance of starch, and this is fat-inducing. Potatoes are supposed to produce fat; but if your appetite craves potato, and you properly masticate it, eating only as much of it as satisfies your appetite, the system absorbs it all, leaving nothing to produce fat. On this same principle economic nutrition assures that the same food, taken in accordance with its requirements, will add to one man's weight and decrease another's, simply because proper care of the stomach supplies the vital organs with the necessary materials to form each individual person after the model which Nature intended for him. If Nature intended him to be slight, economic nutrition will not make him heavy; if Nature intended him to be muscularly strong and heavy, economic nutrition will not reduce his weight. In each case he will enjoy that perfect condition which Nature intended him to possess without fat encumbrance.

Did you ever try to reason out why it is necessary for athletes to go into training? Simply because, in order to get the best use of their strength, they are obliged to spend some number of weeks or months in overcoming false conditions which they have brought upon themselves. Any person who lives in accordance with the simple requirements of economic nutrition has nothing of this kind to overcome, but is in perfect condition all the time.

The requirements of economic nutrition are not hardships but pleasures. Proper mastication and insalivation (mixing with saliva), give your sense of taste far greater gastronomic enjoyment than you have ever before had. If you are a wine drinker, try insalivating a little port wine; but it must be good wine, for this is a severe test. A sip will quench your immediate desire and give you more pleasure than a whole glass gulped down. The professional tea-taster does this in tasting tea; he never allows himself to drink any tea at all, for drinking anything that has taste destroys the delicacy of the sense of taste. But he will tell you that he gets more real enjoyment out of the little he takes than he previously gained from drinking a larger amount. The same thing applies to the professional wine-tasters; they never drink any wine, and yet they enjoy the taste of wine as drinkers never can do. These men adopt this method as a business; is their commercial advantage of greater importance than your health and happiness, and even life itself?

Is it not ridiculous that the average man is so ignorant of the engine which supplies him with all his activity and upon which depends every action of his life? Could you tell, were you asked, the particular need and purpose of your last meal and what it is likely to accomplish? Consider your body as an engine: would you accept yourself as a competent engineer on your own examination and confession? Would you employ a chauffeur to run your automobile who knew as little about its mechanism and requirements as you do about your own stomach? Yet which is of greater importance? Were you the owner of valuable live-stock, would you dare entrust their care to a farm-hand or stableman who knew as little about their proper feeding as you know about your own proper feeding or that of your children?

Have you ever stopped to think why the excrements are foul and odorous? Simply because undigested food, which should have been so masticated as to give the body nourishment, is thrown off by the stomach into the intestines, there to decay and produce this unclean condition. If the dead carcass of a cow is lying in the road, it is removed before it has an opportunity to decay and thus become filthy and dangerous. Yet how much more safe it would be for the carcass to lie where it was than for you to take portions of it into your intestines and allow it to decay there instead of in the road? In other words, food is intended to be eaten that nourishment may be gained from it, and when you only gain a part of the nourishment, you prostitute your stomach and take tremendous risks of germ diseases in your body.

These facts are set forward thus simply in the hope that they may impress the reader as they have impressed the writer. Economic nutrition is not a joke, is not a fad; it is solely an appeal to self-examination and self-instruction in the most vital question of all the world, since upon perfect nutrition depends not only health, but strength, mental acuteness, moral tendencies, attractability to others, happiness, and, in fact, life itself.

FIRST SCIENTIFIC RECOGNITION OF THE PRINCIPLES OF ECONOMIC NUTRITION OUTLINED IN "GLUTTON OR EPICURE"

[With the exception of a brief review of *Glutton or Epicure*, by Dr. Joseph Blumfield, of London, published in *The Lancet*, no scientific or professional recognition of the principles of an economic nutrition attained by means of thorough buccal digestion was gained until issue of the following paper by Dr. Ernest Van Someren, of Venice, Italy.

The previous autumn and winter had been devoted to experiments by Dr. Van Someren and the writer, in co-operation with Dr. Professor Leonardi, for twelve years Professor of Chemistry in the University of Pavia, Italy. In the spring and summer of 1901 the field of experiments was changed to Mendel Pass, *bei* Bozen, Süd Tirol, Austria, and related to endurance work in climbing mountains and bicycle runs among the Dolomites.

Dr. Van Someren's paper attracted the attention of Sir Michael Foster, Professor of Physiology at the University of Cambridge, England, and Permanent Honorary President of the International Congress of Physiologists.

Professor Foster entered into correspondence with Dr. Van Someren, and this was followed by an invitation to Dr. Van Someren and the writer to attend the Congress which was to convene in Turin, Italy, during the month of September following. At the Congress Dr. Van Someren presented a technical thesis on the probable causes of the economy attained, and gave a demonstration of the movement of his Swallowing Reflex in relation to food in the process of liquefaction and preliminary digestion in the mouth.

Following the Congress we received an invitation to visit Cambridge, England, and submit to tests of nitrogenous measurements in the Physiological Laboratory of the University, under the direction of Dr. F. Gowland Hopkins; and also to an examination of the bacterial flora incident to the nitrogenous estimations, under the direction of Dr. George H. F. Nuttall.

The report of the experiments in the Chemical-Physiological Department is given in the "NOTE" of Sir Michael Foster, which follows Dr. Van Someren's paper, but the bacterial examination was not carried far enough to warrant a scientific report, owing to difficulty of obtaining, at the time, sufficient data. — HORACE FLETCHER.]

WAS LUIGI CORNARO RIGHT?

A PAPER READ BEFORE THE PHYSIOLOGICAL SECTION OF THE BRITISH MEDICAL ASSOCIATION, AUGUST, 1901, BY ERNEST VAN SOMEREN

Mr. President and Gentlemen:

Being a general practitioner, it is with some trepidation and an apology that I present myself before this section. The reasons for my doing so are: First, that I believe that a hitherto unsuspected reflex in deglutition has come to light which has an important bearing on health, the prevention of disease and on metabolism. Second, that any theory whatever, based on a possible physiological function, claiming to diminish, as this does, the amount of sickness and suffering now existent, should have serious investigation. Third, that I desire to enlist your skilled help in the consideration of the theories I have doubtless crudely erected on my premise.

According to the "Encyclopædia Britannica," "Luigi Cornaro (1467–1566) was a

Venetian nobleman, famous for his treatises on a temperate life. From some dishonesty on the part of his relatives, he was deprived of his rank and induced to retire to Padua, where he acquired the experience in regard to food and regimen which he has detailed in his work. In his youth he lived freely, but after a severe illness at the age of forty, he began under medical advice gradually to reduce his diet. For some time he restricted himself to a daily allowance of 12 ozs. of solid food and 14 ozs. of wine. Later in life he still farther reduced his bill of fare, and he found that he could support his life and strength with no more solid meat than an egg a day. So much habituated did he become to this simple diet that when he was about seventy years of age the addition, by way of experiment, of 2 ozs. a day had nearly proved fatal. At the age of eighty-three he wrote his treatise on the 'Sure and Certain Method of Attaining a Long and Healthful Life.' And this work was followed by three others on the same subject, composed at the ages of eighty-six, ninety-one, and ninety-five, respectively. 'They are written,' says Addison ('Spectator,' No. 195), 'with such a spirit of cheerfulness, religion, and good sense, as are the natural concomitants of temperance and sobriety.' He died at the age of ninety-eight." Some say of 103!

Now, was Luigi Cornaro right? Did he make use of a physiological process unknown to us of the value of which he was not cognisant? To live to an advanced age, must we be as temperate as he, reducing the quantity of our food to a minimum required by Nature?

That we all eat more than we can assimilate is unquestionable. How can we determine the right quantity? Instinct *should* guide us, but an abnormal appetite often leads us astray. Nature's plans are perfect if her laws are obeyed. Disease follows disobedience. Wherein do we disobey?

We live *not* upon what we eat, but upon what we digest; then why should undigested food, recognisable as such, be deemed a normal constituent of our solid egesta?

Something like the following must be a common experience to general practitioners, especially to those practising on the Continent. The patient comes to see us and volunteers the information that he or she has the "gout," "rheumatic gout," or "dyspepsia." Symptoms are asked for. The case is gone into carefully for causation. An appropriate diet and an appropriate bottle of medicine prescribed. As the patient leaves the room, we may, or may not, call attention to the fact that both teeth and saliva are meant to be used. The patient returns, better, *in statu quo*, or worse. If better, he remains so while under treatment, and relapses when he returns to ordinary habits. If unaffected, or worse, we try again and again, until we despair, then take or send him to a consultant. Temporary benefit, possibly owing to renewed hope, results; but finally the unfortunate gets used to his sufferings and, if he can afford it, is sent to join the innumerable hosts that wander from one *Bad* to another, all Europe over, trying, praising, and damning each in turn. Their manner of living is, of course, at fault. Nature never intended that man should be perpetually on a special diet and hugging a bottle of medicine, nor did she ordain that he should go wandering over the map of Europe drinking purgative and other waters.

Though early yet to speak with certain voice, it would seem that we are provided with a Guard, reliance on which protects us from the results of mal-nutrition. There seems to be placed in the fauces and the back of the mouth a Monitor to warn us what we ought to swallow and when we ought to swallow it. The good offices of this Monitor we have suppressed by habits of too rapid eating, acquired in infancy or youth.

Last November my attention was called by Mr. Horace Fletcher, an American author living in Venice, to the discovery in himself of a curious inability to swallow, and a closing of the throat against food, unless it had been completely masticated. My informant stated that he noticed this peculiarity after he had begun to excessively insalivate his food, both liquid and solid, until all its original taste had been removed from it. Any tasteless residue in the mouth, being refused by the fauces, required a *forced* muscular effort to swallow. He further told me that since adopting this method of eating he had been cured of two maladies, adjudged chronic, the suffering from which rendered him ineligible for Life Insurance. His weight now became reduced from 205 lbs. to 165 lbs. He had practised no abstemiousness, had indulged his appetite, both as to selection and to quantity, without restraint, and for the last three years had enjoyed perfect health.

After his cure, he was accepted without difficulty for insurance, the last examination finding him an unusually healthy subject for his age. Having leisure, he had spent three years in investigating the cause of his cure, had pursued experiments upon others, and had extended his inquiries, both in America and Europe, until our meeting in Venice. He had also published a statement and inquiry in book form, entitled "Glutton or Epicure," which had been reviewed by the "Lancet."

For nearly a year I also had been experimenting on myself and others with various diets, and was ready to believe that in the *manner* of taking food and not altogether in its varying *matter* lay perhaps its protean effects on our system. I at once adopted the same method of eating. At the end of six weeks, I noticed that not only did the fauces refuse to allow of the passage of imperfectly prepared food, but that such food was returned from the back to the front of the mouth by an involuntary, though eventually controllable, muscular effort taking place in the reverse direction to that occurring at the inception of deglutition.

What actually happens is this: Food, as it is masticated, slowly passes to the back of the mouth, and collects in the glosso-epiglottidean folds, where it remains in contact with the mucous membrane containing the sensory end-organs of taste. If it be properly reduced by the saliva it is allowed to pass the fauces, — a truly involuntary act of deglutition occurring. Let the food, however, be too rapidly passed back to these folds, *i.e.*, before complete reduction takes place, and the reflex muscular movement above referred to occurs. The process of this reflex is as follows: The tip of the tongue is involuntarily fixed at the backs and bases of the lower central incisor teeth by the anterior fibres of the geniohyoglossi muscles. With this fixed point as fulcrum, the lower and middle fibres of these muscles, aided by those of the stylohyoid and styloglossi muscles raise the hyoid bone, straighten out the glosso-epiglottidean folds, passing their contents forward, by the fauces, the opening of which is closed by approximation of its pillars and contraction of the superior constrictor. The tongue, arched postero-anteriorly by the geniohyoglossi, palato, and styloglossi muscles, laterally, by its own intrinsic muscles, is approximated to the fauces, soft and hard palates in turn, and thus, the late contents of the glosso-epiglottidean folds are returned to the front of the mouth for further reduction by the saliva preparatory to deglutition.

The word reduction is used for the reason that all foods tested, without exception, give an acid reaction to litmus, when served at table. The reflex muscular movement occurs in the writer's case from five to ten times during the mastication of each mouthful of food, according to its quantity and its degree of sapidity. As often as it recurs, the returned food continues to give an acid reaction, while food allowed to pass the fauces is alkaline.

Saliva, flowing in response to the stimulation of taste, seems more alkaline than that secreted in answer to mechanical tasteless stimulation. It is found that the removal of original taste from any given bolus of food coincides with cessation of salivary flow and complete alkaline reduction. The fibre of meat, gristle, connective tissue, the husk of coarse bread and cellulose of vegetables are carefully separated by the tongue and buccal muscles and rejected by the fauces. To swallow any of these necessitates a *forced* muscular effort, which is abnormal.

Adult man was not originally intended to take his nourishment in a liquid form, consequently all liquids having taste, such as soup, milk, tea, coffee, cocoa, and the various forms of alcohol, must be treated as sapid solids and insalivated by holding them in the mouth, moving the tongue gently, with straight up and down masticatory movements, until their taste be removed. Water, not having taste, needs no insalivation and is readily accepted by the fauces.

In explanation of the phenomenon described, the following theory is advanced: The fauces back of the tongue, epiglottis, in short, those mucous surfaces in which are placed the sensory end-organs of taste and "taste-buds" (the distribution of which, by the way, has yet to be explained), that these surfaces, readily becoming accustomed to an alkaline contact by excessive insalivation and consequent complete alkaline reduction of the food, afterwards resent an acid contact and express their resentment by throwing off the cause of offence by the muscles underlying them.

This phenomenon must not be confused with the cases of rumination and regurgitation, which from time to time are recorded. The food in this case is not swallowed, nor does it pass any point from which it can be regurgitated. Eighty-one individuals of different nationalities and from several classes of society whom we have studied are now in conscious possession of their reflexes. These seem readily educated back to normal functions by all who seriously and patiently adopt the habit of what seems only at first to be excessive insalivation.

The dictum "bite your food well" that we so often use, has no meaning to those suffering from the results of mal-assimilation and mal-nutrition, especially should they have few or no teeth of their own. I make so bold as to state that dyspepsia *et morbi hujus generis omnis* will cease to exist if patients be persuaded to bite their food until its original taste disappears, and it is carried away by involuntary deglutition.

The important point of the whole question seems to be this alkaline reduction of acid food before it passes on to meet subsequent digestive processes elsewhere, which then become alternately acid and alkaline.

In the first few months of infant life, when saliva is not secreted, Nature ordains that mammary secretion be alkaline. With the eruption of teeth come an abundant flow of saliva and a synchronous infantile capacity for managing other foods. This flow of saliva depends on a thorough demand and use to maintain its generous supply. It is just at this time that children learn to bolt their food, — the demand fails, with a consequent detriment to the salivary glands, digestive processes, and the system generally.

A, B, C, and D were placed on an absolute milk diet. A drank his milk in the ordinary way, and at the end of three days begged to discontinue the experiment owing to disgust at the monotony of the diet. B, C, and D continued the experiment for seventeen days, insalivating the milk, but to a varying extent, B the least and D the most. Though D took most milk, he excreted least solid egesta, C excreting less than B. Can one infer that increased insalivation of a non-starchy food insured its better digestion and assimilation? Each subject took as much milk only as his appetite demanded, D taking the most, which never exceeded two litres daily. The weights of the subjects after the usual sudden drop of the first three days remained remarkably even until the end of the experiment. B, C, and D all relished the diet, and it satisfied the requirements of their appetites, but they experienced an increasing monotony.

As long ago as the seventeenth century, before the transformation of matter into energy by the animal organism, known as Metabolism, was understood, the fact was recognised that by the lungs, kidneys, skin, and intestines, substances no longer useful to the organism were eliminated, the retention of which proved harmful. The nature of these substances was unknown, but it was noted that however much the food was increased the weight of the body remained the same. In other words, a state of complete nutritive equilibrium was maintained.

The following table contains the *résumé* of two experiments in which a state of complete nutritive equilibrium was maintained by individuals of about the same weight, on widely different quantities of food similar in quality. The subjects of the experiments were a laboratory assistant of Dr. Snyder, of the U. S. Department of Agriculture, and the writer. The experiment of the former was made primarily to show the relative digestibility of the several articles of diet, potatoes, eggs, milk, and cream:

	Dr. Snyder's Experiment. Published in Bulletin 43	Writer's Experiment.
Age of subject	22 years	30 years
Duration of experiment	$4\frac{1}{3}$ days	5 days
Number of meals . . .	13	10
Weight at beginning .	62.5 kilos.	57.3 kilos.
Weight at end	62.6 kilos.	57.5 kilos.
Potatoes (daily average)	1587.6 grammes	159.4 grammes
Eggs (daily average) .	411.08 grammes	124.7 grammes
Milk (daily average) .	710 c.c.	710 c.c.
Cream (daily average)	237 c.c.	237 c.c.
Daily urine	1108 grammes	1098 grammes
Daily fæces	204 grammes	18.9 grammes

The daily diet of Dr. Snyder's subject consisted of three and one-half pounds of potatoes, eight eggs, a pint and a half of milk, and half a pint of cream. The writer's diet of twelve ounces of solid food (like Luigi Cornaro) consisted of three eggs, the remainder of the twelve ounces in potatoes, and an equal quantity of similar liquid food to that taken by Dr. Snyder's subject. The exercise of the laboratory assistant comprised his daily routine of laboratory work, while that of the writer consisted of six sets of tennis, or an hour and a half on horseback, with an hour to an hour and a half's walk or climb daily, in addition to much reading and writing.

In each case complete nutritive equilibrium was maintained, although the author subsisted on three-seventeenths of the solid food taken by the other subject.

Again, cannot one infer that better assimilation and less waste resulted from the better preparation of the smaller quantity of food by insalivation? Surely, too, there must be less daily strain on the intestinal canal, and body generally, in getting rid of 18.9 grammes of inoffensive dry waste, than in getting rid of 204 grammes of humid, decomposing, and offensive matter.

"Considerable importance has been attached to the normal action of the bacteria in the intestines; and it has even been supposed that the presence of bacteria is essential to life. Such a view has recently been shown to be erroneous by an elaborate and painstaking research carried out by Nuttall and Thierfelder, who obtained ripe foetal guinea-pigs by means of Caesarean section carried out under strict antiseptic precautions. They introduced the animals immediately into an aseptic chamber through which a current of filtered air was aspirated, and fed them hourly on sterilised milk day and night for over eight days.

"The animals lived, and throve, and increased as much in weight as healthy normal animals subjected to a similar diet for the purpose of controlling the results. Microscopic examination at the end of the experiment showed that the alimentary canal contained no bacteria of any kind, nor could cultures of any kind be obtained from it.

"The same authors, in a subsequent paper, described the extension of their research to vegetable food. This was also digested in the absence of bacteria. Under such conditions cellulose was not attacked. Hence they consider that the chief function of this material is to give bulk and proper consistency to the food so as to suit the conditions of herbiverous digestion." (Schäfer's "Text-Book of Physiology," vol i. p. 465.)

Now, inasmuch as bacterial digestion has no place in the animal economy, surely it can only occur at the expense of the organism?

Can micro-organic action take place in the intestines without the production of toxins and the consequent absorption of these toxins into the blood?

We know that the metabolism of a cell is determined by the general physical environment of the whole organism, by supplies of oxygen and water, on nervous impulses, and, what chiefly concerns this argument, on the nature and amount of the pabulum supplied to it. This pabulum is derived from the alimentary canal.

Are not even those of us who may be enjoying seemingly the best of health supplying to our tissues pabulum containing mild toxins, thus causing an increased katabolic action to occur in each individual cell of our bodies?

Are not the blood elements, floating in a plasma containing such toxins, rendered resistent, weaker, less capable of fulfilling their functions as carriers and combatants of disease?

Are not their and our lives, in consequence, more painful and shorter than they need be?

Would not the elimination of these toxins render us less liable to disease? And is not their presence an important element in predisposition to disease?

When this reflex is restored micro-organisms get no further than the stomach. They are destroyed there by the acid gastric juices, then only stimulated to their full and normal secretion by the presence of a sufficiency of alkaline substance. Undigested matter having been eliminated, micro-organisms, still existing in the intestines, deprived of their means of subsistence, decrease, and, in time, may cease to exist. The body no longer absorbs the toxins these produced. To this fact may be ascribed the increase of mental energy, the general physical betterment, the cessation of morbid cravings for food and drink and of those of a sexual nature, which are noticed and experienced.

What has just been stated is based not entirely on experimental evidence but somewhat upon inference. The inference seems justified because the excreta, more especially of the intestines, but also of the kidneys and skin, become almost odourless and entirely inoffensive. The solid egesta are voided thickly covered with mucus, leaving the end of the bowel dry and clean. The sense of cleanliness can only then be appreciated to the full, for it is internal as well external. *Flatus* is no longer produced. The urine is inoffensive and seems to be materially changed in quality, as shown by chemical analysis. Uric acid, the chlorides, and, more markedly, aromatic sulphates are reduced in quantity.

Owing to deliberation in eating, necessitated by this new habit, satiety occurs on the ingestion of considerably less food. By carefully studying one's self I believe it possible to cultivate an instinct which will regulate not only the quantity but the quality of food that the body may need, and that in the *normal health* of a full-grown body, no more food either in quantity or quality should be supplied than suffices to supply diurnal waste. Any excess must result in pathological processes.

Although there results enhanced pleasure in the taking of all foods, rich and simple, and especially in the appreciation of good wines, the quantities of these foods and beverages that suffice to fully satisfy the appetite are much smaller than before, while there is a marked preference for the simpler kinds of food. The writer now can imagine no more pleasurable meal than one consisting of good brown bread, eggs, butter, cheese, and cream. These, with fresh vegetables and a very little fruit, form his staple diet. This tendency and preference for simple foods is the general experience among those who have recovered their reflexes of deglutition.

Following on the ingestion of a lessened quantity of food and on its better assimilation, there is less waste, the egesta are voided less frequently, sometimes only once in five to eight days.

The lower bowel is not the reservoir it formerly was. So hæmorrhoids cease from troubling and constipation cannot exist. For this same reason the body, at the beginning of the practice, commences to approximate to its normal weight, increasing or decreasing as the individual's environment demands.

A few more words only need be said. It has been easy to state the results of experiments and observations: but the acquiring of this new reflex, while pursuing daily occupations, is not easy, and needs more than a little patience and much serious thought. The habits of a lifetime cannot be changed in a few days or weeks. The shortest time in which the reflex has been re-established is four weeks, and this only by avoiding conversation at meal-time and concentrating the attention on keeping the food in the mouth until complete alkaline reduction has taken place and sapidity has disappeared.

In closing I wish to maintain as a fact, gentlemen, of the truth of which you will only be convinced by actual experience, that by the restoration of this reflex and in complete dependence on its use, there lies true health, the establishment of a condition of stable nutrition and the possible abrogation of two great predisposing factors of disease, mal-assimilation and mal-nutrition. Unless there be among you, as in the " Cities of the Plain," a parlous minority who possess this reflex and take your food as you ought, none of you are in the enjoyment of such health as you might have. A like punishment will be meted out to you as was visited on those cities, for you will all be consumed long before your day by the unnecessary combustion in your bodies caused by the circulation in them of toxins, the product of undigested and decomposing food.

The writer, bearing in mind the warning suggested by the Frenchman whose donkey died as soon as he had reduced his food to a single wisp of straw, finds that he is taking less and less food. While his mind is open as to his arriving at the final diet of Luigi Cornaro, yet it is easily conceivable that living a similar life of retirement in a placid environment, it would be quite possible to do as he did. Hence the title of this paper and the queries at the commencement.

The objects in publishing and distributing this paper are twofold: to make the subject as widely known as possible, and to solicit the aid of colleagues in investigating it more fully.

There is ready at the service of the general practitioner an important and potential therapeutic agent in the saliva of his patients and in the use *ad finem* of their salivary digestions.

By any chance should readers of this paper wish to ask any questions, the writer will be happy to communicate with them.

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Piazza San Marco,
Venice, Italy.

Editor's notes. (1) Confirmatory evidence of the correctness of the deductions made in this paper has begun to come in from many professional sources and notably from a famous child specialist who avers that children would follow the natural requirements in eating were it not for artificial food, bad example, and bad teaching.

(2) In a report of a paper read before the *Société de Biologie*, Paris, France, March 15th, 1902, by M. Max Marckwald, of Kreuznach, "ON DIGESTION OF MILK IN THE STOMACH OF FULL-GROWN DOGS," the following appears: "Hence these experiments confirm those of Horace Fletcher and Ernest H. Van Someren on the importance of prolonged mastication" (*translation*). Referring, as the latter statement does, to mastication (insalivation) of liquid, it gives an important suggestion relative to some probable causes of uncertain or defective digestion in human nutrition.

THE CAMBRIDGE TESTS

[In connection with a report of the Cambridge Examination the writer wishes to acknowledge the interest and assistance of Dr. Francis Gowland Hopkins, head of the Physiological-Chemical Department of the Physiological Laboratory of the University; Dr. George H. F. Nuttall, in charge of the Bacteriological Section of the Pathological Laboratory; Mr. Sidney W. Cole, Mr. Robert Barrett, and Dr. Hubert Higgins, both for practical work in the laboratory and in serving as test-subjects. To Dr. Higgins so much is due that it is difficult to measure. Since our first meeting in Cambridge, Dr. Higgins has been unremitting in his study of the subject and in consideration of its application to human betterment. Having the altruistic temperament inborn and not yet smothered by disappointment, the good doctor has consecrated himself to the service of poorer humanity, and his inspiration in so good a cause is wonderful motive power behind the native desire to do good. The statement of Dr. Higgins' experiences in pursuit of an Economic Nutrition is given in his own manner in the new edition of *Glutton or Epicure*, which is being published coincidently with this volume in the A. B. C. Life Series.

At the time we were in Cambridge, Dr. Hopkins and Mr. Cole had just published their paper in the *Journal of Physiology* (English), describing their isolation of the tryptophane element of the proteid molecule which had eluded chemists from the beginning. In tryptophane they found embodied the odourous indol and skatol which appear so offensively in the putrid decomposition of proteid. In the excreta of the test-subjects in our Economic-Nutrition-Inquiry these malodorous substances did not appear, and hence another question is opened up to investigation relative to the putridity of human excrement under ordinary conditions of carelessness, and the absence of putridity in the case of nutrition accomplished by aid of thorough buccal treatment of food preparatory to digestion.

It is a matter of interest, relative to the patience required in science, to state that Dr. Hopkins and Mr. Cole were fourteen months searching for the fugitive tryptophane element after they received their first clew to its whereabouts. When isolated, tryptophane masses in a substance having the appearance of silver, but not the solidity of that metal.—HORACE FLETCHER.]

EXPERIMENTS UPON HUMAN NUTRITION

Note by Sir Michael Foster, K.C.B., M.P., F.R.S.

In 1901 Dr. Ernest Van Someren submitted to the British Medical Association, and afterwards to the Congress of Physiologists at Turin, an account of some experiments initiated by Mr. Horace Fletcher. These experiments went to show that the processes of bodily nutrition are very profoundly affected by the preliminary treatment of the foodstuffs in the mouth, and indicated that great advantages follow from the adoption of certain methods in eating. The essentials of these special methods, stated briefly and without regard to certain important theoretical considerations discussed by Dr. Van Someren, consist of a specially prolonged mastication which is necessarily associated with an insalivation of the foodstuffs much more thorough than is obtained with ordinary habits.

The results brought to light by the preliminary experimental trials went to show that such treatment of the food has a most important effect upon the economy of the body, involving, in the first place, a very notable reduction in the amount of food — and especially of proteid food — necessary to maintain complete efficiency.

In the second place this treatment produced, in the experience of its originators, an increase in the subjective and objective well-being of those who practise it, and, as they believe, in their power of resistance to the inroads of disease. These secondary effects may indeed be almost assumed as a corollary of the first mentioned; because there can be little doubt that the ingestion of food — and perhaps especially of proteid food — in excess of what is, under the best conditions, sufficient for maintenance and activity, can only be deleterious to the organism, clogging it with waste products which may at times be of a directly toxic nature.

In the autumn of 1901 Mr. Fletcher and Dr. Van Someren came to Cambridge with the intention of having the matter more closely inquired into, with the assistance of physiological experts. The matter evoked considerable interest in Cambridge, and observations were made not only upon those more immediately interested, but upon other individuals, some of whom were themselves medical men and trained observers.

Certain facts were established by these observations, which, however, are to be looked upon as still of a preliminary nature. The adoption of the habit of thorough insalivation of the food was found in a consensus of opinion to have an immediate and very striking effect upon appetite, making this more discriminating, and leading to the choice of a simple dietary, and in particular reducing the craving for flesh food. The appetite, too, is beyond all question fully satisfied with a dietary considerably less in amount than with ordinary habits is demanded.

Numerical data were obtained in several cases, but it is not proposed to deal with these in detail here, as they need the supplementary study which will be shortly referred to.

In two individuals who pushed the method to its limits it was found that complete bodily efficiency was maintained for some weeks upon a dietary which had a total energy value of less than one-half of that usually taken, and comprised little more than one-third of the proteid consumed by the average man.

It may be doubted if continued efficiency could be maintained with such low values as these, and very prolonged observations would be necessary to establish the facts. But all subjects of the experiments who applied the principles intelligently agreed in finding a very marked reduction in their needs, and experienced an increase in their sense of well-being and an increase in their working powers.

One fact, fully confirmed by the Cambridge observations, consists in the effect of the special habits described upon the waste products of the bowel. These are greatly reduced in amount, as might be expected; but they are also markedly changed in character, becoming odourless and inoffensive, and assuming a condition which suggests that the intestine is in a healthier and more aseptic condition than is the case under ordinary circumstances.

Although the experiments hitherto made are, as already stated, only preliminary in nature and limited in scope, they establish beyond all question that a full and careful study of the matter is urgently called for.

For this fuller study the Cambridge laboratories do not possess at present either the necessary equipment or the funds to provide it. For the detailed study of the physical efficiency of a man under varying conditions, elaborate and expensive apparatus is required; and the advantages claimed for the special treatment of the food just discussed can only be fully tested by prolonged and laborious experiments calling for a considerable staff of workers.

It is of great importance that the mind of the lay public should be disabused of the idea that medical science is possessed of final information concerning questions of nutrition. This is very far indeed from being the case. Human nutrition involves highly complex factors, and the scientific basis for our knowledge of the subject is but small; where questions of diet are concerned, medical teaching, no less than popular practice, is to a great extent based upon empiricism.

But the scientific and social importance of the question is clearly immense, and it is greatly to be desired that its study should be encouraged.

M. FOSTER.

April 26th, 1902.

REPORT OF A PLAN FOR THE INSTITUTION OF AN INTERNATIONAL INQUIRY INTO THE SUBJECT OF HUMAN NUTRITION

[Sir Michael Foster's "Note" (preceding) and Professor Chittenden's article in the *Popular Science Monthly* (following), which form a part of this book, show a common want of exact knowledge relative to human nutrition not at all creditable to human intelligence at the beginning of the twentieth century; but they both offer hope of relief from this discreditable stigma in systematic study of the question. For this purpose an international inquiry was proposed, a plan was drawn up under advice of Sir Michael Foster, and the matter was given to the writer to promote by the best means available.

The Carnegie Institution seemed, at the time, the most likely supporter of such a scheme; but owing to an embarrassment of applications for support of American science needs, it was considered best not to attempt any foreign or even international benefaction, for the present at least, and hence other means of furthering the inquiry were sought.

The invitation of Professor Chittenden to repeat the demonstration of food-economy made by the author and Dr. Van Someren at Cambridge, England, of which Sir Michael Foster's "Note" treats, at the laboratories of the Sheffield Scientific School of Yale University, led to the discovery that New Haven already possessed an equipment suitable for the inquiry much more complete than the plan Professor Foster had outlined as being desirable.

At Yale were found not only a very well-adapted chemico-physiological laboratory with some of the most active and scientifically respected research talent of the world in charge, but the laboratory stood only three minutes away from one of the best furnished gymnasiums in the world, under a director who is an M. D. of twenty years' experience, as well as a famous athlete and author of an athletic manual. It so happened that this gymnasium was especially suited for assisting in a research into the very causes of human efficiency, or lack of it, which nutrition is supposed to affect.

Only forty minutes from New Haven by rail, — a distance not greater, as measured by time separation, than from one side of London to the other, — at Middletown, Conn., stood also the recently completed calorimeter of Professors Atwater and Benedict ready for making a calorimetric trial-balance measurement of metabolism attained and chemically estimated in the tests at New Haven.

After the Yale demonstration, of which Professor Chittenden's article, previously mentioned, treats, the author responded to an invitation from Professor Atwater and submitted himself to a 32-hour confinement in the calorimeter for confirmation of the results obtained at New Haven.

This experience in the calorimeter at Middletown was very significant and instructive. The author was the first test-subject used in the newly completed calorimeter. The oxygen-measuring attachment of Dr. Benedict that completed the apparatus and gave a complete trial balance of the metabolism of the subject under examination was as yet untried, but it proved its integrity within the fraction of one per cent and registered as accurately as necessary for all practical purposes. So much for the machine; but it measured a result which is of the greatest importance to the human race. The author had just demonstrated the possibility of running the human machine on half the heat, on one-third of the fuel, and with only one-tenth of the waste, as represented by the waste, or ashes of digestion. Not only was this done while in pursuit of the ordinary activity of present-day life, but under stress of 'Varsity-Crew exercise, as reported by Professor Chittenden and Dr. Anderson. Had this demonstration been made relative to steam engines or electrical motors, the information would have been revolutionary in establishing new values for things industrial and commercial.

Its significance relative to human profitable possibilities is even more important than if related to steam or electrical power. The possibility of economy in the human machine gives also a hope of immunity from the common diseases which now afflict mankind.

The trial of the calorimeter as a measuring machine and the trial balance of the economic metabolism which the author had attained by five years of careful attention to the natural requirements of nutrition were epoch-making events coincidently related, and for them the author here makes this distinguished claim — not on account of any accomplishment of himself, but as a promise of great possibilities for human betterment.

Here follows a reproduction of the plan just referred to, with *fac-simile* of the signatures of the distinguished physiologists who approved the plan and consented to serve as " Assessors." To this list should have been added the name of Professor Ozawa, professor of physiology at the University of Tokio, Japan; but time and distance did not permit gaining the required understanding and assent. Professor Ozawa's connection with the inquiry would make it not only international but interhemispherical and interracial as well, and this possibility of scientific coördination and coöperation is typical of the harmonising wave that is fast enveloping the earth for the benefit of mankind.

I give a copy of the document entire, with estimates of cost, etc., just as it was originally drawn and intended only as a trial suggestion, to be modified by circumstances. — HORACE FLETCHER.]

PROPOSAL TO FOUND AN INTERNATIONAL LABORATORY OF RESEARCH FOR THE STUDY OF NUTRITION IN ALL ITS ASPECTS

Notwithstanding the enormous development which the study of Experimental Physiology has undergone during the last half-century, and the constant multiplication of physiological laboratories fitted in a manner which enables them to be used as places of research as well as of instruction in the methods of physiological inquiry, it has appeared to many physiologists that a great need remains to be supplied by the establishment of an International Laboratory of Research, devoted primarily, if not exclusively, to the investigation of problems connected with the Nutrition of the Animal, and particularly of Human Organisms, — studies particularly, and in the first instance, from the point of view of the relation of the food consumed by the animal body to its output of energy, either in the form of heat or mechanical work.

The reason for establishing such a laboratory, available for the use of investigations of all nations, is to be found in the fact that the researches which are now called for, in order to place upon a firm foundation our knowledge of food and its relations to the activity of the organism, necessitates an assemblage of apparatus and machinery so specialised and so costly that they are not to be found collected together even in the best equipped of the physiological laboratories of Europe or America, which all subserve in the first instance the purposes of systematic instruction. Undoubtedly, unquestionably, certain of the great and costly appliances of research are to be found in particular laboratories, as, for instance, in those of Berlin, Munich, Paris, and Turin, but there certainly exists no laboratory in which the investigator can find assembled under one roof all the specially fitted chemical, physical, and even bacteriological appliances which he may need to employ in the investigation of the Phenomena of Nutrition.

A more precise conception of the nature of the proposed laboratory may be formed if reference is made to certain groups of appliances which such a laboratory should possess and be able to place at the disposal of the scientific men coming to it for facilities which may be denied them at home. It should possess a complete set of respiration chambers of various types, and especially should be provided with the "Atwater Respiration Apparatus;" the most perfect appliances for the analyses of gases should be available; it should be provided with the most perfect calorimeters of various types, both for the investigation of the calorimetric value of the foods experimented on, and for the determination of the heat produced by man or by the lower animals, — the subjects of observation. The laboratory should possess, besides, the most perfect appliances for the measurement of work done by man and by animals ("ergostat," "ergograph"), and a set of balances of the highest perfection capable of weighing with accuracy very heavy loads. These characteristic appliances of a laboratory specially designed for placing our knowledge of

Animal Nutrition on a thoroughly sound basis must be superadded to the ordinary means for pursuing with success researches in Pure Organic, Physiological, and Physical Chemistry, as well as in Bacteriology.

Outline of the Proposed Subjects of Research to be Undertaken in the Proposed International Laboratory

1. To determine with greater precision than has yet been possible the efficiency of the animal organism considered as a machine in which potential energy of the organic constituents of food is converted into mechanical work. The knowledge that we already possess has shown that in the animal we have an engine infinitely more efficient as a utiliser of the potential energy supplied to it than any appliance yet constructed, or which we can, in the present state of physical science, construct. A still more precise study of the actual efficiency of the animal as a whole, as well as of certain of the vital organs which are mainly concerned in mechanical work, and a more thorough investigation of the processes whereby — for instance, in the muscles — the potential energy of stored-up chemical compounds is, as appears certain, directly converted into mechanical work, is not only desira-

ble in the interest of the ultimate object of the work of the Laboratory, but possesses a high degree of theoretical interest, even from the point of view of Pure Physics. To sum up: One of the first objects of the investigations to be carried out in the projected Laboratory should be "the more precise determination of the minimum transformation of energy which corresponds to mean and accurately determined conditions of the animal body, and of that of man in particular."

2. We are acquainted with the fact that the potential energy which is utilised by the animal is supplied to it with the least wear and tear to, or strain upon, its mechanism by non-nitrogenous organic constituents of food which must belong to the groups of starches and sugars or fats, but that the continued existence of the organism demands, as an essential condition, the introduction of a certain proportion of albuminous matter. In spite of numerous very fine investigations on this subject, the yet more precise determination of the minimum quantity of the albuminous constituents which are absolutely necessary or desirable, under the most varying conditions, is eminently desirable, especially in the light of recently recorded facts, amongst which are those to be referred to under 3 (following): —

3. Certain very noteworthy observations made by Messrs. Horace Fletcher and Ernest H. Van Someren have shown that an excessively prolonged mastication and insalivation of food leads to remarkable results in respect to the diminution of the total quantity of food necessary to keep the body in a state of health, and to, as is alleged, a remarkable improvement in the digestive functions as well as of the general health of the individual. It appears highly important thoroughly to investigate the remarkable phenomena discovered by Messrs. Fletcher and Van Someren, and to determine how far they may lead to a modification of or improvement in the dietary of healthy individuals and of persons in a state of disease.

4. Indeed, it may truly be said that the average diet of man, that is to say, the absolute and relative amount of certain food-stuffs on which an average man should live, is at present, to a large extent, determined in an empirical manner. It is most necessary that this should be determined in an exact manner, since it is at least possible that a more complete knowledge may reveal that the good results thus obtained empirically are only reached by means of an excess of one element being counterbalanced by excess of another element, and thus open up a way to considerable economy. The changes needed

for variations from the average, to meet certain conditions, are also at present, to a very large extent, determined empirically, and these also most certainly ought to be determined in an absolutely exact manner.

5. The researches of Pawlow on the conditions which influence the activity of the secreting glands of the organs of digestion, upon the relation of their activity to the nature of the food ingested, upon the influence exerted by the secretion of the glands situated in one part of the alimentary canal, upon the activity of glands situated lower down, indicate lines of research only recently opened out, but the importance of which in reference to the problems of nutrition is probably great.

6. Similarly, the facts which have in recent times been ascertained in reference to the remarkable influence exerted by the so-called "internal secretion" of certain ductless glands on the general metabolism, the part played by the pancreas in reference to the transformations of sugar in the body indicate yet other lines of research to be carried out in connection with the main inquiry.

In conclusion: The final problem of the work of the proposed Laboratory will be to ascertain the conditions which will "render it possible to obtain from the human machine, under varying conditions, the highest efficiency at the least cost."

The value of results which may be thus obtained, considered from the point of view of social, political, and administrative economy, is hardly to be exaggerated.

Suggestions as to Staff and Personnel of the Proposed International Laboratory

For the coördination and general direction of the several investigations, the services of an eminent physiological chemist (preferably one having the principal European languages at his command) is essential.

Such a director would need at least two efficient permanent technical assistants, as for instance, one to deal with the problems of Organic Chemistry, and another competent to deal with the problems of Physical Chemistry. Other assistants might be necessary, but it would probably be desirable that the Institute should have the power of subsidising, for a longer or shorter period, men who would undertake special investigations in coördination with the general work, and who would thus be, as it were, temporary assistants. This would be quite apart from the general hospitality of the Laboratory offered by the Institute to other investigators.

ESTIMATES FOR THE PROPOSED LABORATORY

INITIAL OUTLAY

Director	$5,000		$5,000
Permanent and Temporary Assistants	7,500	to	10,000
Other General Maintenance	5.000	to	7,500
	$17,500		$22,500

With regard to the second item, the permanent assistants would be required at the outset, but the temporary assistants would be taken on as opportunity offered. Less than even the lower estimate might suffice at first.

Regarding the third item, also, the maximum might not be required in the beginning.

SUGGESTIONS AS TO DESIRABILITY OF LOCATION

The place fitted for the establishment of an International Institute should be one which can be reached with comparative facility by investigators of the different nationalities. It must be one free from the objections due to national susceptibilities. It should also be, if possible, a place agreeable to live in; a place where work can be carried on through the year; and a place where expenses, both the personal expenses of the investigators, and the general expenses of the Institute, are not excessive. Venice has been suggested as a place fulfilling the above requirements. It can be reached readily from all parts of Europe, and is as accessible to Americans as any other European city. Living is very cheap, and, indeed, all expenses are very moderate.

On sea level itself, Venice is within near distance of very high altitude, and hence offers facilities for the study of the effects of climatic influence on nutrition. It is also sufficiently near the Regina Margherita Laboratory, on Monte Rosa, to enable the observations made at the two places to be coördinated. Venice is, moreover, a cosmopolitan centre; and persons of many different nations and races might readily be obtained as subjects for observation and experiment.

On the other hand, it may be regarded as essential to the complete success of the proposed Institute that both the director and those engaged in investigation should have ample opportunities of ready and frequent intercourse with eminent men engaged in investigation in Physics, Chemistry, and the allied sciences. The help which is thus gained by intercourse with men at the very head of various scientific inquiry cannot be supplied in any other way. There is also an urgent reason for ready access to a most thoroughly equipped scientific library. It is also essential that the Institute should have facility of obtaining, or of getting constructed, with the least possible delay such apparatus as it might need. These essentials cannot be supplied otherwhere than in great centres of scientific activity. A small university cannot supply them. If they are insisted on, the Institute must be located in a place which has metropolitan distinction and holds not only a large but an active university. The choice of a situation, from this point of view, in Europe, is thus almost limited to such places as Paris, Berlin, Vienna, or London. Of these London probably best recommends itself for international purposes.

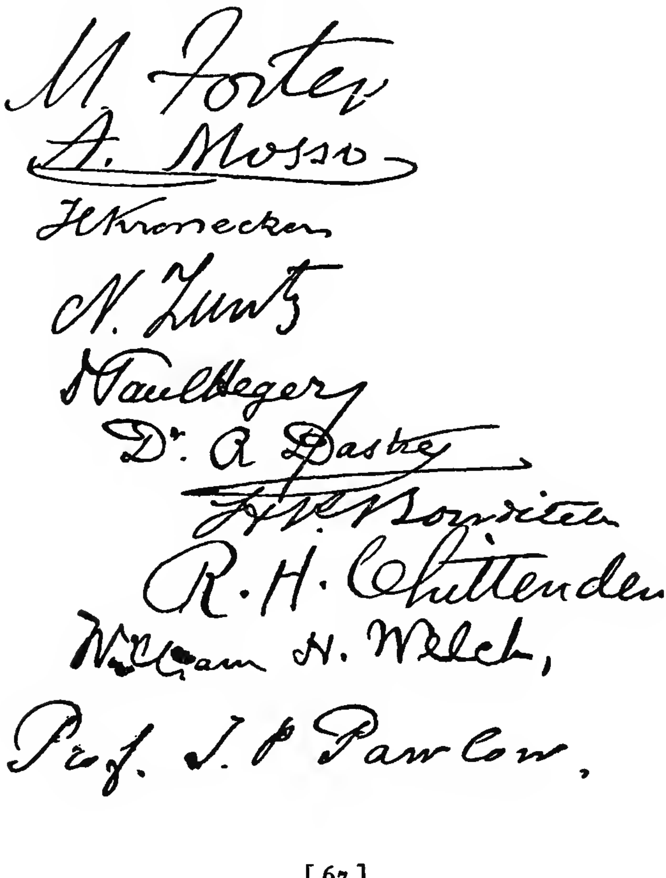
But, on the other hand, London is distinctly an expensive place to live in. Indeed, all expenses there are great, and the same may be said of any great metropolitan centre. Moreover, London cannot be reached from the countries of Europe without sea transit.

The choice between such a place as London and such a place as Venice must depend upon the relative weight attached, on the one hand, to the scientific advantages dwelt on above, and, on the other hand, to the advantages other than scientific.

Suggestions as to Management of the Proposed International Institute

It is proposed that: First, there should be a small body of trustees who should undertake the financial responsibility; and, Second, a board of scientific assessors, representing several nations, who, in conjunction with the director, should exercise general supervision of the work of the Institute. Such a board need meet only at rare intervals, much being done by way of correspondence. The expenses which the members incur in the exercise of their functions ought to be met out of the funds of the Institute.

The following have expressed willingness to act as scientific assessors: —



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DR. PROFESSOR HENRY PICKERING BOWDITCH, Professor of Physiology, Harvard Medical School; Second President American Physiological Society; President of the Children's Aid Society, Boston, Mass., etc.

PROFESSOR RUSSELL H. CHITTENDEN. Director Sheffield Scientific School of Yale University; Professor of Physiological Chemistry in Yale; Present President of the American Physiological Society, etc.

DR. PROFESSOR WILLIAM H. WELCH. Professor of Pathology in Johns Hopkins University, Baltimore, Maryland; President of the Rockefeller Institute of Preventive Medicine, etc.

DR. PROFESSOR J. P. PAWLOW. Director of the Department of Experimental Physiology in the Russian Imperial Military School of Medicine, etc.

PERSISTENT SCIENTIFIC DOUBTS

[Notwithstanding the report of the Cambridge examination of the claims for an economic nutrition advanced by the authors, American physiologists were still doubtful if a nitrogenous economy like that reported could be maintained, and the writer was invited to submit to further tests at the Physiological Laboratory of Yale University, under direction of Professor Russell H. Chittenden, Director of the Sheffield Scientific School, and President of the American Physiological Society, and Dr. Lafayette B. Mendel.

The following article, first published in the *Popular Science Monthly*, June, 1903, is a report of that test, and indicates a desire to carry the investigation further to include a variety of test-subjects.

In response to Professor Chittenden's request, the Trustees of the Bache Fund of the National Academy of Sciences appropriated $1000 towards a more extended inquiry; and other means having been assured, a project of experiments was taken under consideration.

One of the difficulties encountered was the control of test-subjects for a sufficiently long time to make conclusive estimates relative to the minimum needs of nitrogenous food in relation to the common occupations of life. Few if any volunteers, with the leisure and interest fortunately possessed by the writer, were available outside the laboratory force itself, and there were serious objections to using for test-subjects the same persons who did the chemical analyses and estimated the results.

In this dilemma the good fortune of a meeting with Surgeon-General O'Reilly of the United States Army and with General Leonard Wood — the former on his way to Madrid to attend a medical congress, and the latter *en route* to the Philippines to take command there — happened to the writer on the S. S. *Commonwealth*, on a voyage to Italy in April, 1903.

Both these officers are medical men and research enthusiasts. They had fought yellow fever together, in coöperation with martyr Dr. Major Walter Reed, in Cuba, and the fame of their success was being talked of as one of the great triumphs of pathologic, or hygienic, science at the time of the meeting.

There was ample time on the steamer to discuss a subject of such mutual and general interest, and both officers had had, in service, experiences that led them to believe that the results obtained by the writer and his colleagues were the common possibilities of all persons under right conditions of alimentation.

General O'Reilly was of the opinion that the corps he commanded could furnish intelligent and earnest test-subjects for nutrition investigation, as it did in the yellow fever case. In the yellow fever investigation privates and officers alike had volunteered to act as test-subjects, even though their lives were at stake and many had already been sacrificed. It is to their great honour, also, that they refused to receive the bounty that was offered for test-subjects, preferring to serve science and humanity freely as volunteers rather than sell themselves as experimental risks. From such material General O'Reilly was sure that capable assistants could be secured to test the not at all dangerous or disagreeable economies of nutrition that the projected inquiry wished to solve.

Armed with letters of recommendation to the President and to the Secretary of War from General Wood, and an invitation from Surgeon-General O'Reilly to call on him if coöperation on his part were desired, the writer returned to the United States and consulted with Professors Chittenden and Bowditch relative to the desirability of army coöperation. It was believed to be just the thing wanted to facilitate the inquiry, and the writer proceeded to Washington to effect the combination.

General O'Reilly had already had the matter under consideration and was quite ready to draw up a project for presentation to the Secretary of War when Mr. Root should return to Washington from his summer vacation.

Twenty privates and three non-commissioned officers of the Hospital Corps of the United States Army under command of Dr. Lieutenant Wallace DeWitt are now quartered at

New Haven in coöperation with the staff of the Sheffield Scientific School. It is the intention to learn, if possible, how little nitrogen is necessary to secure the best human efficiency; and also, if possible, to ascertain some measure of the evil effects of an excess of nitrogenous food as well as excess of food in general upon human efficiency.

The writer is grateful for the good fortune of being able to be of service in a development of interest in a subject which is of vital importance to the human race. He has enjoyed the benefits of an economic nutrition and knows its value.

The practical proof of a subject of personal application must come from such personal application. Each person must be his own doctor and his own scientist in the matter of his alimentation or he runs the risk of running amuck in his health economy. There is not so much to learn, neither is there very much to do to insure right alimentation, perfect digestion, and continuous good health; but the little required of us must be attended to with no lapses of attention. — HORACE FLETCHER.]

PHYSIOLOGICAL ECONOMY IN NUTRITION

By Russell H. Chittenden

Director of the Sheffield Scientific School of Yale University

Among the many problems awaiting solution, none is of greater importance for the welfare of the individual and of the race than that which relates to the proper nutrition of the body. Man eats to live and to gain strength for his daily work, and without sufficient nutriment the machinery of the body cannot be run smoothly or with proper efficiency. The taking of an excess of food, on the other hand, is just as harmful as insufficient nourishment, involving, as it does, not only wasteful expenditure but, what is even of greater moment, an expenditure of energy on the part of the body, which may in the long run prove disastrous. While it is the function of food to supply the material from which the body can derive the necessary energy for its varied activities, any excess of food over and above what is needed to make good the loss incidental to life and daily activity is just so much of an incubus, which is bound to detract from the smooth running of the machinery and to diminish the fitness of the body for performing its normal functions.

A proper physiological condition begets a moral, mental, and physical fitness which cannot be attained in any other way. Further, it must be remembered that lack of a proper physiological condition of the body is more broadly responsible for moral, social, mental, and physical ills than any other factor that can be named. Poverty and vice on ultimate analysis may often be traced to a perversion of nutrition. A healthy state of the body is a necessary concomitant of mental and moral vigour, as well as of physical strength. Abnormal methods of living are often the accompaniment or forerunner of vicious tastes that might never have been developed under more strictly physiological conditions. Health, strength (mental and physical), and moral tone alike depend upon the proper fulfilment of the laws of nature, and it is the manifest duty of a people hoping for the fullest development of physical, mental, and moral strength to ascertain the character of these laws with a view to their proper observance. Poverty, crime, physical ills, and a blunted or perverted moral sense are the penalties we may be called upon to pay for the disobedience to Nature's laws; penalties which not only *we* may have to pay, but which may be passed down to succeeding generations, thereby influencing the lives of those yet unborn.

There is to-day great need for a thorough physiological study of those laws of nutrition which constitute the foundation of good living. It is a subject full of interest and promise for the sociologist and economist, as well as for the physiologist. We need a far more complete knowledge than we possess at present of the laws governing nutrition; we need fuller knowledge of the methods by which the most complete, satisfactory, and economical utilisation of the diet can be obtained; we need to know more concerning the minimum diet and the minimum amount of proteid or albuminous foods on which health, mental and physical vigour can be permanently maintained; we need to know more fully concerning the influence of various forms of food on growth and recuperative power; we need more complete knowledge regarding the rôle of various dietetic and digestive habits, fixed or acquired; the effects of thorough mastication, insalivation, and the influence of two versus three meals a day upon the utilisation of food and hence upon the bodily health. Further, we need more concise information as to the effect of the mental state upon digestion and nutrition. These and many other problems of a like nature confront us when we attempt to trace the influence of a proper nutrition upon the condition of the body. These problems, however, all admit of solution, and in their solution undoubtedly lies the remedy for many of the personal ills of mankind.

The foregoing thoughts have been suggested by observations recently made in the writer's laboratory on the amount and character of the food actually required by a healthy man in the maintenance of bodily equilibrium in periods of rest and physical work. Our ideas at present are based primarily upon observations as to what civilised peoples are accustomed to do, and not upon what they need to do in order to meet the demands made upon the body. Sir William Roberts has well said that the palate is the dietetic conscience, but he adds that there are many misfit palates, and we may well query whether our dietetic consciences have not become generally perverted through a false mode of living. The well-nigh universal habit of catering to our appetite on all occasions, of bowing to the fancied dictates of our palates even to the extent of satiety, and without regard to the physiological needs of the body, may quite naturally have resulted in a false standard of living, in which we have departed widely from the proper laws of nutrition. Statistical studies carried out on large groups of individuals by various physiologists have led to the general acceptance of dietary standards, such as those proposed by Voit, of Munich, and Atwater in this country. Thus the Voit diet for a man doing moderate work is 118 grams of proteid or albuminous food, 56 grams of fat, and 500 grams of carbohydrates, such as sugar and starch, with a total fuel value of 3,055 large calories or heat units per day. With hard work, Voit increases the daily requirement to 145 grams of proteid, 160 grams of fat, and 450 grams of carbohydrates, with a total fuel value of 3,370 large calories. Atwater, on the other hand, from his large number of observations, is inclined to place the daily proteid requirement at 125 grams, with sufficient fat and carbohydrate to equal a total fuel value of 3,500 large calories for a man doing a moderate amount of work; while for a man at hard work the daily diet is increased to 150 grams of proteid, and with fats and carbohydrates to yield a total fuel value of 4,500 large calories. These standards are very generally accepted as being the requirement for the average individual under the given conditions of work, and it may be that these figures actually represent the daily needs of the body. Suppose, on the other hand, that we have in these figures false standards, or, in other words, that the quantities of foodstuffs called for are altogether larger than the actual demands of the body require. In this case there is a positive waste of valuable food material which we may calculate in dollars and cents; a loss of income incurred daily which might be expended more profitably in other directions. To the wage-earner with a large family, who must of necessity husband his resources, there is in our hypothesis a suggestion of material gain not to be disregarded. The money thus saved might be expended for the education of the children, for the purchase of household treasures tending to elevate the moral and mental state of the occupants, or in many other ways that the imagination can easily supply. This kind of saving, however, is purely a question of economy, and in some strata of society would be objected to as indicative of a condition of sordidness. It has come to be a part of our personal pride to have a well-supplied table, and to eat largely and freely of the good things provided. The poorer man takes pride in furnishing his family with a diet rich in expensive articles of food, and imagines that by so doing he is inciting them to heartier consumption and to increased health and strength. He would be ashamed to save in this way, under the honest belief that by so doing he might endanger the health of his dear ones. But let us suppose that this hypothetical waste of food is not merely uneconomical, that it is undesirable for other and weightier reasons. Indeed, let us suppose that this unnecessary consumption of food is distinctly harmful to the body, that it is physiologically uneconomical, and that in our efforts to maintain a high degree of efficiency we are in reality putting upon the machinery of the body a heavy and entirely uncalled-for strain, which is bound to prove more or less detrimental. If there is truth in this assumption, our hypothesis takes on a deeper significance, and we may well inquire whether there are any reasonable grounds for doubting the accuracy of our present dietary standards.

In this connection it is to be remembered that the food of mankind may be classified under three heads, viz., *proteid or albuminous*, such as meat, eggs, casein of milk, gluten of bread, and various vegetable proteids; *carbohydrates*, as sugar and the starches of our cereals, and *fats*, including those of both animal and vegetable origin. The proteids are characterised by containing nitrogen (about 16 per cent), while the fats and carbohydrates contain only carbon, hydrogen, and oxygen. The two latter classes of foodstuffs are burned up in the body, when completely utilised, to carbonic acid (a gas) and water, while the proteid foods, beside yielding carbonic acid and water, give off practically all of their nitrogen in the form of crystalline nitrogenous products in the excreta of the body. Proteid foods have a particular function to perform, viz., to supply the waste of proteid matter from the active tissues of the body, and this function can be performed only by the proteid foods; hence the latter are essential foodstuffs without which the body cannot long survive. Fats and carbohydrates, on the other hand, are mainly of value for the energy they yield on oxidation, and in this connection it is to be remembered that the fuel value of fats per gram is much larger than that of carbohydrates, viz., 9.3 : 4.1, or more than twice as great. Further, it is to be noted that the various foodstuffs cannot be utilised directly by the body, but they must first be digested, then absorbed and assimilated, after which they gradually, in their changed form, undergo decomposition with liberation of their contained energy, which may manifest itself in the form of heat or of mechanical work. The thoroughness with which foods are digested and utilised in the body must therefore count for a great deal in determining their dietetic or nutritive value. Moreover, it is easy to see how an excess of proteid food will give rise to a large proportion of nitrogenous waste matter, which, floating through the system prior to excretion, may, by acting on the nervous system and other parts of the body, produce disagreeable results. A mere excess of food, even of the non-nitrogenous variety, must entail a large amount of unnecessary work, thereby using up a proportional amount of energy for its own disposal, since once introduced into the body it must be digested and absorbed, otherwise it undergoes fermentation and putrefaction in the stomach and intestines, causing countless troubles. When absorbed in quantities beyond the real needs of the body, it may be temporarily deposited as fat; but why load up the system with unnecessary material, thereby interfering with the free running of the machinery? In other words, it is very evident that the taking in of food in quantities beyond the physiological requirements is undesirable, and may prove exceedingly injurious. It is truly uneconomical, and defeats the very ends we aim to attain. Instead of adding to the bodily vigour and increasing the fitness of the organism to do its daily work, we are really hampering the delicate mechanism, upon the smooth running of which so much depends.

Why, now, should we assume that a daily diet of over 100 grams of proteid, with fats and carbohydrates sufficient to make up a fuel value of over 3,000 large calories, is a necessary requisite for bodily vigour and physical and mental fitness? Mainly because of the supposition that true dietary standards may be learned by observing the relative amounts of nutrients actually consumed by a large number of individuals so situated that the choice of food is unrestricted. But this does not constitute very sound evidence. It certainly is not above criticism. We may well ask ourselves whether man has yet learned wisdom with regard to himself, and whether his instincts or appetites are to be entirely trusted as safe guides to follow in the matter of his own nutrition. The experiments of Kumagawa, Sivén, and other physiologists, have certainly shown that men may live and thrive, for a time at least, on amounts of proteid per day equal to only one-half and one-quarter the amount called for in the Voit standard. Sivén's experiments, in particular, certainly indicate that the human organism can maintain itself in nitrogenous equilibrium with far smaller amounts of proteid in the diet than is ordinarily taught, and, further, that this condition can be attained without unduly increasing the total calories of the food intake. Such investigations, however, have always called forth critical comment from writers on nutrition, indicating a reluctance to depart from the current doctrines of the Voit or Munich school; and, indeed, it may justly be claimed that the ordinary nutrition experiments, extending over short periods of time, are not entirely adequate to prove the effect of a given set of conditions when the latter are continued for months or years. Thus, Schäfer writes: "It may be doubted whether a diet which includes considerably less proteid than 100 grams for the twenty-four hours could maintain a man of average size and weight for an indefinite time. It has frequently been asserted that many Asiatics consume a very much smaller proportion of proteid than is the case with Europeans. The inhabitants of India, Japan, and China chiefly consume rice as the normal constituent of their diet, which contains relatively little proteid; and this has been advanced as an argument in favour of the view that the minimal amount of proteid is much less than that ordinarily given as essential to the maintenance of nutritive equilibrium. It must, however, be stated that we have no definite statistics to show that, in proportion to their body-weight, Asiatics doing the same amount of work as Europeans require a less amount of proteids; indeed such evidence as is forthcoming is rather in favor of the opposite view." This statement is typical of the attitude of physiologists in general on this important subject. Why not candidly admit that the matter is in doubt, and, with a due recognition of the importance of the subject, attempt to ascertain the real truth of the matter?

The writer has had in his laboratory for several months past a gentleman (H. F.) who has for some five years, in pursuit of a study of the subject of human nutrition, practised a certain degree of abstinence in the taking of food and attained important economy with, as he believes, great gain in bodily and mental vigour, and with marked improvement in his general health. Under his new method of living he finds himself possessed of a peculiar fitness for work of all kinds, and with freedom from the ordinary fatigue incidental to extra physical exertion. In using the word abstinence possibly a wrong impression is given, for the habits of life now followed have resulted in the disappearance of the ordinary craving for food. In other words, the gentleman in question fully satisfies his appetite, but no longer desires the amount of food consumed by most individuals.

For a period of thirteen days, in January, he was under observation in the writer's laboratory, his excretions being analysed daily with a view to ascertaining the exact amount of proteid consumed. The results showed that the average daily amount of proteid metabolised was 41.25

grams, the body-weight (165 pounds) remaining practically constant. Especially noteworthy, also, was the very complete utilisation of the proteid food during this period of observation. It will be observed here that the daily amount of proteid food taken was less than one half that of the minimum Voit standard, and it should also be mentioned that this apparent deficiency in proteid food was not made good by any large consumption of fats or carbohydrates. Further, there was no restriction in diet. On the contrary, there was perfect freedom of choice, and the instructions given were to follow his usual dietetic habits. Analysis of the excretions showed an output of nitrogen equal to the breaking down of 41.25 grams of proteid per day as an average, the extremes being 33.06 grams and 47.05 grams of proteid.

In February a more thorough series of observations was made, involving a careful analysis of the daily diet, together with analysis of the excreta, so that not alone the proteid consumption might be ascertained, but likewise the total intake of fats and carbohydrates. The diet consumed was quite simple, and consisted merely of a prepared cereal food, milk, and maple sugar. This diet was taken twice a day for seven days, and was selected by the subject as giving sufficient variety for his needs and quite in accord with his taste. No attempt was made to conform to any given standard of quantity, but the subject took each day such amounts of the above foods as his appetite craved. Each portion taken, however, was carefully weighed in the laboratory, the chemical composition of the food determined, and the fuel value calculated by the usual methods.

The following table gives the daily intake of proteids, fats, and carbohydrates for six days, together with the calculated fuel value, and also the nitrogen intake, together with the nitrogen output through the excreta. Many other data were obtained showing diminished excretion of uric acid, ethereal sulphates, phosphoric acid, etc., but they need not be discussed here.

	Intake					Output of Nitrogen		
	Proteids	Fats	Carbohy	Calories	Nitrogen	Urine	Fæces	Total
	Grams	Grams	Grams		Grams	Grams	Grams	Grams
Feb. 2	31.3	25.3	125.4	900	5.02	5.27	0.18	5.45
3	46.8	40.4	266.2	1690	7.50	6.24	0.81*	7.05
4	48.0	38.1	283.0	1747	7.70	5.53	0.81*	6.34
5	50.0	40.6	269.0	1711	8.00	6.44	0.81*	7.25
6	47.0	41.5	267.0	1737	7.49	6.83	0.81*	7.64
7	46.5	39.8	307.3	1852	7.44	7.50	0.17	7.67
Daily Av.	44.9	38.0	253.0	1606	7.19	6.30	0.60	6.90

*Average of the four days.

The main things to be noted in these results are, first, that the total daily consumption of proteid amounted on an average to only 45 grams, and that the fat and carbohydrate were taken in quantities only sufficient to bring the total fuel value of the daily food up to a little more than 1,600 large calories. If, however, we eliminate the first day, when for some reason the subject took an unusually small amount of food, these figures are increased somewhat, but they are ridiculously low compared with the ordinarily accepted dietary standards. When we recall that the Voit standard demands at least 118 grams of proteid and a total fuel value of 3,000 large calories daily, we appreciate at once the full significance of the above figures. But it may be asked, was this diet at all adequate for the needs of the body — sufficient for a man weighing 165 pounds? In reply, it may be said that the appetite was satisfied, and that the subject had full freedom to take more food if he so desired. To give a physiological answer, it may be said that the body-weight remained practically constant throughout the seven days' period, and further, it will be observed by comparing the figures of the table that the nitrogen of the intake and the total nitrogen of the output were not far apart. In other words, there was a close approach to what the physiologist calls nitrogenous equilibrium. In fact, it will be noted that on several days the nitrogen output was slightly less than the nitrogen taken in. We are, therefore, apparently justified in saying that the above diet, simple though it was in variety, and in quantity far below the usually accepted requirement, was quite adequate for the needs of the body. In this connection it may be asked, what were the needs of the body during this seven days' period? This is obviously a very important point. Can a man on such a diet, even though it suffices to keep up body-weight and apparently also physiological equilibrium, do work to any extent? Will there be under such condition a proper degree of fitness for physical work of any kind? In order to ascertain this point, the subject was invited to do physical work at the Yale University Gymnasium, and placed under the guidance of the director of the gymnasium, Dr. William G. Anderson. The results of the observations there made are here given, taken verbatim from Dr. Anderson's report to the writer.

On the 4th, 5th, 6th, and 7th of February, 1903, I gave to Mr. Horace Fletcher the same kind of exercises we give to the Varsity Crew. They are drastic and fatiguing and cannot be done by beginners without soreness and pain resulting. The exercises he was asked to take were of a character to tax the heart and lungs, as well as to try the muscles of the limbs and trunk. I should not give these exercises to Freshmen on account of their severity.

Mr. Fletcher has taken these movements with an ease that is unlooked for. He gives evidence of no soreness or lameness, and the large groups of muscles respond the second day without evidence of being poisoned by Carbon dioxide. There is no evidence of distress after or during the endurance test, *i. e.*, the long run. The heart is fast but regular. It comes back to its normal beat quicker than does the heart of other men of his weight and age.

The case is unusual, and I am surprised that Mr. Fletcher can do the work of trained athletes and not give marked evidences of over-exertion. As I am in almost constant training I have gone over the same exercises, and in about the same way, and have given the results for a standard of comparison. [The figures are not given here.]

My conclusion, given in condensed form, is this: Mr. Fletcher performs this work with greater ease and with fewer noticeable bad results than any man of his age and condition I have ever worked with.

To appreciate the full significance of this report, it must be remembered that Mr. Fletcher had for several months past taken practically no exercise other than that involved in daily walks about town.

In view of the strenuous work imposed during the above four days, it is quite evident that the body had need of a certain amount of nutritive material. Yet the work was done without apparently drawing upon any reserve the body may have possessed. The diet, small though it was, and with only half the accepted requirement in fuel value, still sufficed to furnish the requisite energy. The work was accomplished with perfect ease, without strain, without the usual resultant lameness, without taxing the heart or lungs, and without loss of body-weight. In other words, in Mr. Fletcher's case at least, the body machinery was kept in perfect fitness without the consumption of any such quantities of fuel as has generally been considered necessary.

Just here it may be instructive to observe that the food consumed by Mr. Fletcher during this seven days' period — and which has been shown to be entirely adequate for his bodily needs during strenuous activity — cost eleven cents daily, thus making the total cost for the seven days seventy-seven cents! If we contrast this figure with the amounts generally paid for average nourishment for a like period of time, there is certainly food for serious thought. Mr. Fletcher avers that he has followed his present plan of living for nearly five years; he usually takes two meals a day; has been led to a strong liking for sugar and carbohydrates in general and away from a meat diet; is always in perfect health, and is constantly in a condition of fitness for work. He practises thorough mastication, with more complete insalivation of the food (liquid as well as solid) than is usual, thereby insuring more complete and ready digestion and a more thorough utilisation of the nutritive portions of the food.

In view of these results, are we not justified in asking ourselves whether we have yet attained a clear comprehension of the real requirements of the body in the matter of daily nutriment? Whether we fully comprehend the best and most economical method of maintaining the body in a state of physiological fitness? The case of Mr. Fletcher, just described; the results noted in connection with certain Asiatic peoples; the fruitarians and *nut*arians in our own country recently studied by Professor Jaffa, of the University of California; all suggest the possibility of much greater physiological economy than we as a race are wont to practise. If these are merely exceptional cases, we need to know it; but if, on the other hand, it is possible for mankind in general to maintain proper nutritive conditions on dietary standards far below those now accepted as necessary, it is time for us to ascertain that fact. For, if our standards are now unnecessarily high, then surely we are not only practising an uneconomical method of sustaining life, but we are subjecting ourselves to conditions the reverse of physiological, and which must of necessity be inimical to our well-being. The possibility of more scientific knowledge of the natural requirements of a healthy nutrition is made brighter by the fact that the economic results noted in connection with our metabolism examination of Mr. Fletcher is confirmatory of similar results obtained under the direction and scrutiny of Sir Michael Foster at the University of Cambridge, England, during the autumn and winter of last year; and by Dr. Ernest Van Someren, Mr. Fletcher's *collaborateur*, in Venice, on subjects of various ages and of both sexes, some account of which has already been presented to the British Medical Association and to the International Congress of Physiologists at its last meeting at Turin, Italy. At the same time emphasis must be laid upon the fact that no definite and positive conclusions can be arrived at, except as the result of careful experiments and observations on many individuals covering long periods of time. This, however, the writer hopes to do in the very near future, with the coöperation of a corps of interested observers.

The problem is far-reaching. It involves not alone the individual, but society as a whole, for beyond the individual lies the broader field of the community, and what proves helpful for the one will eventually react for the betterment of society, and for the improvement of mankind in general.

INTRODUCTION TO DR. HARRY CAMPBELL'S CONTRIBUTION ON THE IMPORTANCE OF MASTICATION

[Since the publication of Van Someren's paper, " Was Luigi Cornaro Right?", read before the British Medical Association, and reprinted elsewhere in this volume, much more attention has been given to the study of mastication than had been previously reported. Mr. Gladstone's advice to his children, which was commonly current and was repeated whenever mastication was mentioned, was usually accompanied and met by an amused smile that showed that the full importance of better mouth-treatment of food was not appreciated. *Glutton or Epicure*, a little book by the present writer, published in 1898, insisted on thorough use of the functions of the mouth in alimentation but did not go into the anatomical, physiological and dental details.

Dr. Harry Campbell of Northwest London Hospital has performed this latter service to science and humanity, with splendid carefulness, and must have devoted much time and study to the collection of evidence and suggestion which is given here following in full, reprinted from the *London Lancet*.

The authors acknowledge with much gratitude, the courteous permission of both Dr. Campbell and of the editor of the *Lancet*, to reprint all four articles which composed the series.

In our own study of the subject of mouth-treatment of food we have been led to give more credit to the chemical feature of preparation than Dr. Campbell yet attributes to the chemical side of the problem. Comminution of hard food is of first importance, undoubtedly, but insalivation and neutralisation or alkalinisation are, seemingly, much more easily and quickly accomplished in the mouth than farther on in the alimentary canal. The intestines *can* do all in the way of digestion, even if the mouth and stomach are passed and their assistance in the digestive process is entirely neglected, but it is done at tremendous disadvantage in the supplementary digestive tract of the intestines. We have proven the economy of letting the mouth do *all it can,* by the insalivation (sipping and tasting) of liquids that have taste up to the point of compulsory swallowing (a sucking-up by the Swallowing Impulse which naturally occurs in the course of treatment in the mouth if not fought against too strongly). If Dr. Campbell will extend his observations to liquids, say milk, and for a sufficiently long time to measure results by continued economy of assimilation and saving of solid excreta, he will find that it pays to let the mouth do all it can do, and that while it *cannot do too much* it *may do too little.* The natural instincts of the mouth, or those that attach to the mouth, become much more discriminating also if exercised on liquids as well as on solids. This they do not learn to do so well if sapid liquids are habitually rushed past their field of discrimination.

Taste enjoyed in the mouth is good, and a good part of the pleasure of living comes from taste gratification, but taste that returns from the stomach and is belched by eructation or is lingeringly reminiscent in the mouth or nose is indicative of indigestion.

Hence it is better to dissipate taste in the mouth, which is the sole region of taste. Spirits tasted into absorption in this way leave no odour upon the breath, and asparagus munched and tasted to the limit in the mouth, carries no odour to the urine. Even the stale and disagreeable odour of onion or garlic can be neutralised by saliva and killed in the mouth.

It is extremely difficult to get observers to practise tasting taste out of liquids as the wine tasters do, and as the tea tasters *have to do or die;* or, at least, become useless in their profession. Once the efficacy of the liquid-tasting precaution in digestion is understood, however, to swallow anything but pure water without tasting it into absorption produces a shock. This care becomes instinctive quite easily and regulates itself automatically. It is also a distinct gain to the gustatory possibilities, which are very limited at best.

When the body will tolerate spirits tasted into it — not poured into it — at all, which is not often when the nutrition is normal (only in damp or cold weather, as a general thing, and then in the case of the writer only at rare intervals, say two or three times a year), the spirit will mix quickly with the saliva and become neutralised sufficiently to excite the Swallowing Impulse. Continue sipping the spirit for a time and you will note that there comes a point where the saliva and the spirit do not mix, do not neutralise; the mouth becomes unduely full of liquid without any relaxation or invitation of the Swallowing Impulse; and the really instinctive inclination will be to *spit it out.* It is a clear indication that the body-*toleration* has been fully taxed; there is no longer any bodily need for alcohol — in fact, there is no longer natural toleration — and the secretion sent down into the mouth is evidently mucous for a washing-out process, and is not alkaline saliva for assisting in a utilisation function.

It is quite uncanny to observe the nicety of mouth-discrimination and the consistency of it as related to similar substances under similar conditions, if one learn to read it with precision and intelligence.

With increased ease of digestion, which comes with more thorough attention to solid foods alone, the ordinary observer will think that he has accomplished the whole of the possible benefit. It is only when he gives sufficient time to liquids also, to get the added delight and relief that salivary respect of them brings, that the whole of the beneficence of mouth-service is realised. Follow this discrimination and care to a comparative measurement of the waste of digestion, the solid excreta, and note the increased proportionate gain in assimilation and the value of the economy will be appreciated. Try the different treatments on milk for a month; fifteen days with drinking and fifteen days insalivating (sipping and tasting) the milk to the limit, and keep account of quantity of intake required to satisfy appetite and maintain body-weight; and also note carefully the condition and quantity of the fæces. In the one case you will find the waste to be *fæces* indeed, and unmistakably worthy of the name; but in the case of sipping, tasting and insalivating the milk to the full satisfaction of the appetite, the *digestion-ash* will assume quite a different amount and character and deserve a change of name. The proportions of the saving in our own experiments have approximated the difference between three and ten; that is, on a reduction of only one-third the quantity of food commonly ingested, but fully satisfying the sipping and tasting appetite, the quantity of solid excreta was only one-tenth of the other and of quite a different character, æsthetically considered.

While these suggestions do not discredit or affect the value of the purely mechanical side of the treatment as given by Dr. Campbell, and are not intended to be controversial, they are ventured as an amendment to be worked out in regard to liquids, which are, in fact, only an extreme of the pultaceous foods against which Dr. Campbell warns us as being subtly dangerous.

There is another point in our experiences and observations of the largest importance that may appropriately be introduced here: The treatment of all liquids in the manner suggested prevents intemperance of drinking as effectively as it does intemperance of eating.

When food is filtered into the body after having become liquified and made alkaline, or, at least neutral, by saliva, the appetite is given a chance to measure the needs of the body and to discriminate against excess. As soon as the point of complete saturation of any one deficiency is reached, the appetite is cut off, as short as possible to imagine, with no indication of stomach fullness. It will welcome a little of proteid in beans, cheese, eggs, or in some other of its richer forms, and then turn to sugar or fat in some of their numerous forms. Thirst for water will assert itself for a moment, sometimes asking but for a drop and again for a full glass, and afterwards, when near the point of complete saturation, appetite will hesitate for a moment, as if searching around for some rare substance, and may find its final satisfaction in a single spoonful of a sweet or a sip of something in sight.

The appetite satisfied by the infiltering process is a sweetly appeased appetite, calm, rested, contented, normal. There is no danger from the flooding of intemperance, for there is not even toleration of excess either of more food or of more drink, and this contented appetite will remain in the condition of contentment until another need has really been earned by evaporation or destructive katabolism.

In the teaching of this physiology and psychology of alimentation to the children of England, lies the only true solution of the drink question, which is now the curse of the nation.

Dr. Campbell has made such a splendid case for the mechanical side of mouth work, that it is the hope of the writer that he will give equally careful consideration to the chemical and psychological sides, and in a completeness of observation render inestimable service to his country, to science, and humanity. A decade of trial on the inmates of an infant orphan asylum will show the possibilities for the nation in a single generation, if broadly applied. It might lead to an effective intemperance, inhibition, or quarantine, and that is all any nation needs of advantage to make it independent of the world and truly great. — HORACE FLETCHER.]

OBSERVATIONS ON MASTICATION

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SECTION I. From *London Lancet*, July 11, 1903

THE EFFECTS OF MASTICATION

The primary object of mastication is to break up the food so as (1) to facilitate the swallowing of it, and (2), still more important, to insure its intimate admixture with the digestive juices, not only within the mouth, but throughout the entire digestive tract. Mastication has, however, other important and far-reaching effects. Thus it promotes the flow of saliva and, when properly performed, secures a due insalivation of the food; it increases the quantity of alkaline saliva passing into the stomach; it stimulates the heart and circulation; and it finally influences the nutrition of the jaws and their appendages by stimulating the local blood and lymph circulation. Now to consider these various objects and effects of mastication.

Mastication facilitates swallowing. — Many foods cannot be swallowed without first going through some preparation in the mouth. Soft, moist, pultaceous foods, such as milk pudding and porridge, can be and often, indeed, are swallowed with little or no preliminary chewing. On the other hand, it is a mechanical impossibility to swallow large lumps of tough food, or very dry food, even though, like flour, it be in a finely divided state. Dry food needs first to be well moistened; and it is not surprising that it promotes a more abundant flow of saliva than moist food, though the secretion thus excited may be poor in ferment. Hence it follows that if we desire to give foods which compel mastication, they should be tough or dry. On the whole, vegetable foods necessitate more thorough mastication than animal. The carnivora can scarcely be said to masticate at all the flesh which they consume; they simply tear off portions, and forthwith swallow them whole. Cooked flesh, however, does require mastication, owing to the coagulation of its proteids. The herbivora, on the other hand, unlike the carnivora, have to subject their food to considerable mastication before it can be swallowed; but they generally masticate it far more than is needful to render swallowing mechanically possible, as is exemplified in the act of rumination, the object here being to facilitate the admixture of the digestive juices with the food.

According to Van Someren, if the habit of masticating efficiently is once acquired, the food is not swallowed before it is converted into the liquid state, the swallowing of unmasticated lumps being effectually prevented by a pharyngeal reflex.

Mastication, by breaking the food up into small particles, enables it to be brought into intimate contact with the digestive juices. — Such comminution is especially needful in the case of raw vegetable foods of the tougher kind, in order to break up their cellulose framework, and to set free the contained starch, proteids, and fats. Foods of this kind, unless masticated, yield practically no nutriment to the organism. I cannot too strongly emphasise the fact that before man learned to break up the cellulose framework of his vegetable food by cooking he was compelled to subject it to laborious mastication. But, while thorough comminution is especially needed for vegetable food when raw, it is also needed for many cooked forms of it also, — as, for example, solid batter pudding and new underbaked bread, heavy lumps of which, passing into the stomach, may seriously hamper the work of that organ. Such substances are indigestible essentially by virtue of their impermeability to the digestive juices, and they gain in digestibility in proportion as they are comminuted. The indigestibility of new bread would appear to be wholly due, not to any peculiarity of chemical composition, but to its tendency to elude the teeth and form a sodden mass impermeable to the digestive juices, while the more powdery stale bread is more easily broken up both in the mouth and within the stomach. Cabbage, again, owes its indigestibility to the fact that it is allowed to pass into the stomach in large masses, while the well-known digestibility of cauliflower and minced spinach is due to the fineness of their division; were cabbage as finely minced as spinach usually is it would be equally digestible.

Turning now to animal food it has to be remarked that while in the raw state it may be readily digestible with little or no previous mastication, since massive pieces of it are readily attacked by the digestive juices, the like is much less true of animal food the proteids of which have been coagulated and rendered less permeable by cooking. Large lumps of hard-boiled egg or overdone meat, for instance, may obstinately resist gastric digestion; indeed, as with vegetable so with animal foods, their relative digestibility depends more upon physical consistence than chemical composition; beef is generally more indigestible than mutton and pork or veal than either, not so much by virtue of chemical composition as of physical consistence; the indigestibility of cheese illustrates the same truth; the individual nutritive ingredients of this substance — the proteids and fats — are not in themselves indigestible; casein in the form of protein or plasmon is known to be easy of digestion, and butter is one of the most digestible of fats; but in cheese the two are welded together into a comparatively impermeable mass, which is apt to escape comminution by the teeth and to pass down into the stomach in the form of solid lumps. A plain, wholesome cheese well masticated or intimately mixed with other foods, as in macaroni cheese, is quite easily digested by the majority.

I do not, of course, deny the influence of the chemical factor. Undoubtedly food may disturb digestion by virtue of its chemical composition, apart altogether from its physical characters; thus, while cooked goose-fat sets up violent irritation in some, others cannot tolerate eggs in any shape or form, and innumerable idiosyncrasies in respect of special articles of diet are met with which are essentially referable to chemical composition; but making due allowance for this chemical influence there can, I think, be little doubt that the digestibility of the more common articles of diet, both animal and vegetable, depends in the main upon their physical constitution, *all of them tending to be equally digestible when reduced to the same degree of comminution.* This, if true, is, I need scarcely say, a fact of the greatest practical importance, for it amounts to this: that we may often allow to those with very weak digestions foods which are generally considered indigestible, provided that they be thoroughly comminuted, whether by mastication or artificial means.

Mastication promotes the flow of saliva and the insalivation of the food.—The more efficiently food is masticated the greater is the salivary flow, and the more intimately is it mixed with the saliva, or, as we say, insalivated. The saliva has apparently no effect on fats; whether it acts on proteids seems more doubtful, though by some authorities the penetration of these by the alkali of this fluid is said to aid in their subsequent digestion; on starch, however, the saliva acts very potently, and hence mastication plays a special part in promoting the digestion of starchy foods. Indeed, if only mastication be persisted in long enough, starch may be wholly converted into maltose within the mouth, and it need scarcely be said that it is better for the individual himself to manufacture his maltose in this way than that he should take it ready made for him in the form of one of the many "malt extracts" on the market. Patients are often forbidden starchy food, while they are allowed the maltose which they can quite well manufacture in their own mouths. Provided they be sufficiently insalivated, there are few starchy foods which are indigestible, not even excepting the proverbially indigestible new potato. These remarks are especially applicable to children, as will be more particularly insisted on later.

Mastication increases the amount of alkaline saliva passing into the stomach, and this not only prolongs the period of starch digestion within this organ but, by its influence upon the reaction of the gastric contents, influences all the digestive processes taking place there. I shall have occasion to point out later that a deficient supply of alkaline saliva in the stomach predisposes to certain forms of indigestion.

Mastication acts reflexly upon the stomach.— It is now known that the act of mastication influences the stomach reflexly, promoting the flow of gastric juice and thus preparing the stomach for the entrance of food into it. If the œsophagus of a dog is cut so as to allow the swallowed food to escape instead of passing into the stomach, it is found that the mastication of food causes a considerable flow of gastric juice. Food introduced into the stomach unaccompanied by mastication is less effective in promoting the gastric flow. It is probable that the influence of mastication on the flow of gastric juice is largely produced through the medium of psychic influences, for the more efficient the mastication the more is the sense of taste affected.

Mastication stimulates the heart and so promotes the general circulation. — This stimulating action may be partly due to its local action on the flow of blood and lymph in the jaws and accessory parts, and partly to a reflex influence, but whatever the explanation there can be no doubt of the fact. Hence the mere chewing of a non-nutritive substance, such as gum arabic, is stimulating, and, doubtless, the stimulating effects induced by the chewing of such articles as tobacco and betel are largely to be explained in this way.

The Influence of Mastication on the Jaws and Adjacent Structures

This subject is of such importance that it needs to be dealt with in some detail. By "adjacent structures" I mean the masticatory muscles, tongue, teeth, salivary glands, the nasal passages and sinuses pertaining thereto, the naso-pharynx, soft palate, and tonsils.

The muscles of mastication. — Let me at the outset draw attention to certain anatomical points, in connection with the muscles of mastication. These are (*a*) their massiveness; (*b*) the very close relation of the pterygoids to the naso-pharynx; and (*c*) the outward direction of the pterygoids.

(*a*) It is not until one studies the muscles of mastication closely that one comes to realise their massiveness. Their large size, in relation to the bony structures in connection with them, is well shown in a vertical transverse section of the head carried through the ascending ramus of the mandible[1] (see Fig. 1). It is evident that the functional activity of so large a mass of muscle tissue cannot but exercise considerable influence on the nutrition of the neighbouring parts.

(*b*) The pterygoid muscles, springing as they do from the internal pterygoid plates, must necessarily be in close relation with the naso-pharynx, especially the internal pair, which take their origin from the internal aspect of the internal plates. I would further point out that the external pair, although they diverge from

[1] Dental surgeons now speak of the upper jaw as the maxilla, and of the lower jaw as the mandible.

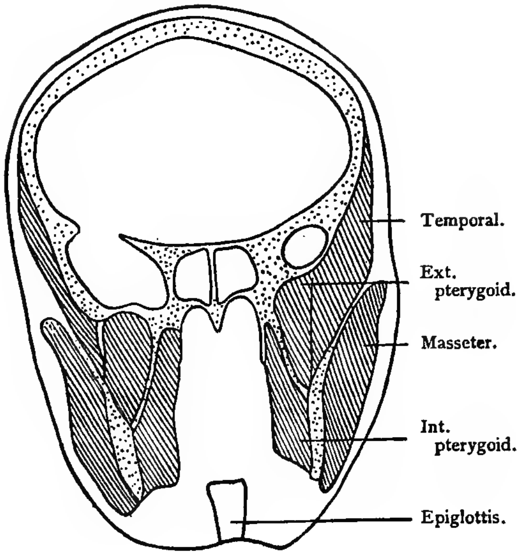


FIGURE 1. — Vertical transverse (slightly oblique) section through the head on a level with the epiglottis. The massiveness of the system of masticatory muscles is apparent.

the naso-pharynx on their way to the mandibular condyles, yet remain on a level with that cavity. This close relation of the pterygoids to the naso-pharynx is, if I mistake not, of great importance in relation to the etiology of "adenoids."

(*c*) Of the two pairs of pterygoids the external pair pass in the more outward direction, forming with the sagittal plane of the head an angle of 45° (see Figs. 1 and 2). In consequence of this direction they tend by their contraction to pull the pterygoid plates and posterior parts of the maxilla away from the sagittal plane of the head, and thus to secure the normal width of the posterior nares. It is these muscles which bring about the lateral movements of the mandible, causing the lower teeth to move laterally and sagitally across the upper, the food being in this way far more effectually ground than by a mere vertical pressure of the teeth against one another. These lateral movements are, as we shall see, less pronounced among the moderns than among primitive peoples.

The influence of the contraction of the masticatory muscles on the local circulation of blood and lymph. — When a muscle is at rest the blood

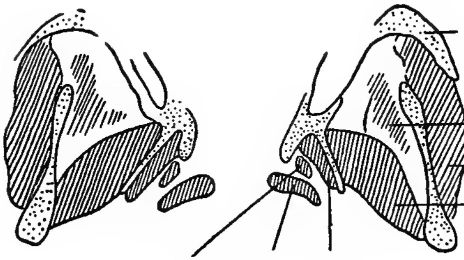


FIGURE 2. — Portion of horizontal section of head about an inch below the condyles of the lower jaw. The outward direction of the external pterygoids is well shown; also the close relation of the levatores and tensores palati with the internal pterygoids.

flows sluggishly through it, while there is a complete, or all but complete, stagnation of the lymph current; if a lymphatic trunk of a limb at rest be cut no lymph escapes from it. Rhythmic muscle contractions, however, stimulate the flow both of blood and lymph (*a*), in the contracting muscles themselves and (*b*) in the neighbouring parts. (*a*) Not only are the muscle arteries dilated during rhythmic contractions, but the blood is vigorously squirted out of the muscle veins, so that much more blood flows through a muscle during its rhythmic contraction than during rest. The flow of lymph is even more markedly stimulated,—this fluid, which, while the muscle is at rest, is stagnant or all but so, being during contraction driven actively along the lymphatic trunks. (*b*) How greatly rhythmic muscle contractions influence the circulation of fluids in the neighbouring parts is shown by the flushing of the skin and the swelling of the soft parts generally of a limb which is being exercised. We thus see how profoundly the exercise of the masticatory muscles — and among these we must not forget to include the tongue — influences not only their own nutrition but that of the important structures adjacent to them — that is to say, of the jaw-bones, salivary glands, buccal mucous membrane, soft palate, faucial tonsils, pharynx, and naso-pharynx, as well as of the nasal cavities and their accessory sinuses. All these parts are during mastication copiously flushed with blood and lymph, from which it is evident that efficient mastication must stimulate their nutrition and favour their proper development. Hence, in one who has from childhood upwards been accustomed to masticate efficiently, we generally find these parts well developed, the jaws large and shapely, the teeth regular and straight, the tongue and salivary glands large, the nasal and naso-pharyngeal passages spacious, and the mucous membrane of the buccal and adjoining cavities healthy.

Influence of mastication on the jaw-bones.— It is well known that the size of a bone is largely determined by the degree to which the muscles attached to it are exercised. That the jaws do not grow to their normal size, if not adequately exercised during their period of growth, is strikingly shown by the overcrowding of the teeth, which takes place in those brought up on soft foods, and this even though there be no contraction of the jaws resulting from mouth-breathing. The dependence of the size of the jaws upon the degree to which they are exercised is also shown by the smallness of the modern jaw, as compared with that of primitive peoples, a difference which, as we shall see, is in part congenital and in part due to the comparative disuse of the former. Mastication influences not only the size but also the shape of the jaws (*a*), through its influence on the size of the tongue, which by pressing against the teeth tends, as Sim Wallace has shown, to expand the jaws; (*b*) by the pressure of opposing teeth against one another, which has a similar effect; and (*c*) by the outward pull of the pterygoids, which tends to widen the maxilla posteriorly and to broaden the posterior nares.

Influence of mastication on the teeth.—The teeth being developed within the jaw-bones and remaining, even after eruption, in close anatomical and physiological association with them, must necessarily share in their nutritive tendencies. If these bones are efficiently exercised during the formation of the teeth—and my remarks apply especially to the permanent set—the tooth-germs will be abundantly flushed with blood, while the ample growth of the jaws themselves will provide the germs with plenty of room in which to grow and to develop, and the more perfect their growth and development the more resistant should we expect them to be to the ravages of caries. Who can contemplate the jaw-bones of a six-years-old child, dissected so as to display all the imbedded teeth, without being assured of the effect of mastication upon dental development? Fifty-two teeth meet the view: the whole region from the orbital rims to the inferior border of the mandible is literally paved with them, and I can hardly doubt that they collectively weigh more than the bone in which they are imbedded. Surely no one can examine such a dissection without being convinced of the urgent necessity, if the teeth are to grow and to develop normally, of giving the child's jaws from infancy onwards plenty of work to do.

The ample development of the jaws, which efficient mastication brings about, has a further beneficial effect as regards the teeth, in that it enables them to take up their proper places in the alveolar ridges, thus securing all the advantages of a good "bite." These I now proceed to consider. The teeth during mastication, and especially when the bite is good and the food of a kind necessitating vigorous and sustained mastication, are made to move in their sockets both vertically and horizontally; the effect of this is to stimulate the circulation in the tooth-pulp, the alveolar periosteum (and hence also in the cementum and alveolar walls which are supplied by it), and the circumjacent mucous membrane of the gum. All this makes for the health of the teeth; not only does it promote the nutrition of the tooth itself and of its bony socket, thus maintaining a firm dental setting, but it also tends to secure a healthy environment for the exposed part of the tooth — that part, namely, wherein caries begins — by maintaining a healthy state of the surrounding and, indeed, of the entire buccal mucous membrane, as well as of the various secretions which bathe the mouth. Wherefore it is not surprising to find that those who masticate efficiently suffer much less from dental caries and its complications (such as abscess at the root) and disease of the periodontal membrane (*e.g.*, pyorrhœa alveolaris and loosening of the teeth) than those who are accustomed to bolt their food.

A few words as to the influence of mastication in wearing down the teeth. In those races which masticate vigorously the teeth in quite early adult life show signs of wearing away, while in later life it is quite common for the biting surfaces to be worn flat; sometimes the crown of the molars is worn away so that its surface shelves downwards and inwards and not infrequently it is concave, having a scooped-out appearance; often the dentine is exposed in this way; and yet among many hundreds of skulls examined I do not remember to have seen one single case where caries has started on the biting surface thus worn down.

I had always attributed this wearing down of the teeth to the friction of coarse food against them. Primitive races eat coarse vegetable food, which frequently contains grit, and this doubtless helps to grind the teeth down, but they may be markedly ground down even in those living on soft food, and in such cases the grinding away can obviously only be due to the friction of opposing teeth against one another. I, indeed, believe this to be the essential cause of the phenomenon, both in civilised races living on soft food and in primitive races whose coarse food necessitates prolonged and vigorous mastication and a corresponding amount of attrition between the biting surfaces of opposing teeth. In order that this attrition may occur two things are requisite: the upper and lower teeth must be well opposed — there must be a good bite — and mastication must be vigorous and of the right kind. Mere vertical pressure of the teeth against one another will not wear away the opposing surfaces; there must be friction of these surfaces against one another — a transverse and sagittal movement of the lower teeth against the upper by means of the pterygoids. Mainly to this do I attribute the marked wearing down of the teeth observed in primitive peoples, and I am gratified to know that so competent an authority on dental pathology as Sim Wallace is a convert to this view.

That all the teeth may be worn down just as we observe in primitive people, even in those who have lived all their lives on the ordinary fare of the moderns, is proved by a case I have under observation. It is that of a man in his fiftieth year, who was brought up in Belgium but who has resided in London for the last thirty years. When he came to my out-patient room I was not a little surprised to find that all his teeth were sound — a very unusual occurrence, I need hardly say, among the London poor at his age. In seeking for an explanation I elicited the fact that he was unable to swallow his food without chewing it very thoroughly, and on giving him a moderate-sized piece of bread, with the request that he should chew it in the ordinary way, I found that he subjected it to one hundred and twenty separate bites before swallowing it, and in the steady, deliberate way he went to work and in his extensive lateral movements of the mandible he reminded one for all the world of a cow chewing its cud. The temporals and masseters of this man are enormous, and the like is no doubt true of the pterygoids; he has well-developed nasal passages, has never suffered from nasal obstruction, while his buccal mucous membrane is unusually healthy for one of his years and circumstances. May we not attribute this healthy state of the mouth, teeth, and nose to the good effects upon them of efficient chewing? Here is a man who has lived for thirty years in London on the same kind of food as the average poor Londoner, but instead of finding his mouth full of carious, tartar-coated teeth, and spongy, receding, pus-exuding gums, we find thirty-two sound teeth firmly set in healthy gums and all but devoid of tartar.

A word as to the wearing down of the teeth in the anthropoid apes. In this respect the gorilla differs markedly from the orang and the chimpanzee. In all the skulls of these latter which I have examined the teeth show signs of wearing away, while I have found the teeth of the gorilla, with the exception of the tusk-like canines, but little worn. From this we should expect the latter animal to be mainly carnivorous, and the orang and chimpanzee to be largely herbivorous.

SECTION II. From *London Lancet*, July 18, 1903

CHANGES WHICH THE JAWS AND TEETH OF MAN HAVE UNDERGONE DURING MAN'S EVOLUTION FROM HIS ANTHROPOID ANCESTORS

During man's progress upwards from the anthropoid his diet has undergone a progressive change, and a parallel adaptation has taken place in his jaws and teeth. Dietetically considered, we may divide his evolutionary career into the following epochs[1]: (1) the anthropoid stage; (2) the pre-cooking human stage; (3) the cooking pre-agricultural stage; (4) the early agricultural stage; and (5) the late agricultural stage.

1. *The anthropoid stage.* — The diet of man's anthropoid ancestors was probably much the same as is that of existing anthropoid apes; it consisted, namely, of raw vegetable and animal food, necessitating a vigorous use of the maxillary apparatus. This latter, we may assume, was of the type belonging to the anthropoids — *i. e.*, the jaws were massive and markedly prognathic; the denture was the same as it is in existing man, but the teeth were larger, especially the upper canines, which served as weapons of offence and defence; the third molars (the wisdom teeth) were as large as the other molars and were provided with three fangs, and there was an ample portion of alveolar ridge behind them; there was no chin. No doubt the massiveness and the marked prognathism, which characterised the jaws at this stage, served other ends than that of mastication; it is obvious that projecting jaws and teeth are much more effec-

[1] This subject I am obliged to deal with very briefly, and am compelled to omit the reasons for my conclusions.

tual for seizing and lacerating prey than are the orthognathic jaws of modern man.

2. *The pre-cooking human stage* extends from the time man's ancestors first assumed the human form till they learned to apply fire in the preparation of their food. During all this period the jaws and teeth were probably used as much, or almost as much, for mastication as during the anthropoid stage; raw animal food had to be torn from the bones, the latter had to be crunched, while the bulk of the raw vegetable food needed then no less than it needs now prolonged and vigorous mastication in order to liberate the starch and other nutritive ingredients from their undigestible cellulose envelopes.[1] Nevertheless, the jaws and teeth underwent considerable change during this period, for not only were they with every advance in intelligence called less and less into requisition for purposes of offence and defence, but the jaws, at least, became materially modified in correlation with the expanding cranial cavity and in connection with the assumption of the erect posture. It is, I think, rather for these reasons than in consequence of alterations in the nature of the food that the masticatory apparatus now gradually

[1] Recent observations go to show that man possesses no power of digesting cellulose, though this substance is to a limited extent capable of solution by the agency of bacteria in the lower portions of his alimentary canal.

lost its more bestial aspect and assumed an essentially human type, becoming towards the close of the period much the same as may be observed among the most primitive peoples now living.

3. *The pre-agricultural cooking period.* — The characters of the maxillary apparatus belonging to this period are still available for study, the aboriginal Australians, the Bushmen, Negritos, and many Esquimaux not having yet emerged from it. So far as mastication is concerned, cooking influences vegetable far more than animal food, for it not only softens it but by rupturing the undigestible cellulose chambers and liberating their contents relieves mastication of one of its essential functions. Wherefore, with the advent of cooking, man's jaws and teeth began to get smaller, and they have continued to diminish in size up to the present time. No great diminution, however, took place at first, inasmuch as the diet still continued to be largely animal (and prior to the use of knives and forks such food had to be torn by the teeth), while the coarse vegetable food of this date, even when cooked, still needed laborious mastication. The chief differences between the maxillary apparatus of this early cooking age as compared with that of the present day are as follows: the jaws of the earlier period — *e. g.*, in the abo-

riginal Australian — are more massive, and their sagittal diameter is greater, giving rise to decided prognathism, the teeth for the most part are larger and stronger, the third molars being nearly, if not quite, as big as the other molars, and provided with three fangs, while there is a considerable portion of alveolar ridge behind them. The third molars, however, show a decided tendency to be smaller than the rest, and the alveolar ridge behind them is less marked than in the previous period, features, I doubt not, attributable to the influence of cooking in diminishing mastication. Dental caries is rare and is chiefly met with in the third molars.

4. *The early agricultural age.* — All the existing primitive races which have attained to the cultivation of the soil may be regarded as belonging to this period. Previously to it man was mainly carnivorous, owing to the comparatively limited quantity of vegetable food available, so long as the supply was left to nature alone; but when by cultivation this supply was increased and, at the same time, rendered more constant and certain, he gradually became less carnivorous and more vegetarian in his diet. The result of agriculture, however, is not only to increase the supply of vegetable food, but to diminish its fibrous, cellulosic ingredients, and thus to render it more easily masticated. Hence

at this stage we find the maxillary apparatus becoming smaller than in the previous period, although the difference as shown — *e.g.*, by the examinations of the skulls of the African negroes and the Melanesians — is less pronounced than we might perhaps have anticipated; prognathism is not so decided, the jaws are smaller, also the teeth, especially the third molars, which now for the first time show a tendency to be furnished with two instead of three fangs, while the alveolar ridge behind them is distinctly shorter than in the preceding period. Dental caries, hitherto rare, now becomes more frequent.

5. *The late agricultural period.* — A mid-agricultural period might be described, but I shall take no account of it here, but pass on to a consideration of the late agricultural period — that, namely, in which we ourselves live. The chief characteristic of the food of this period is its softness. Cooked animal food requires, indeed, more mastication than raw, but the vegetable food of to-day, owing to the combined effects of improved agriculture, and skilful milling and cooking, is so soft as to excite comparatively little mastication. The present may, in fact, be described as the *age of pap*. Hence the jaws and teeth are now called upon to perform far less work than in any earlier stage of our evolution, and there has taken place in consequence

a great diminution in their size, more especially in the size of the jaws, so that there is now often no room for the teeth to take up their normal positions, and there is generally a complete absence of alveolar ridge behind the last molars. The latter are, moreover, apt to be very small or even absent, while dental caries is alarmingly frequent.

It will thus be seen that from the period of the anthropoids to the present time, a progressive change in the size and shape of the jaws and teeth has been taking place, a change which is to be explained by (1) the cessation of the need for using them for offensive and defensive purposes; (2) the growing capacity of the cranium and the assumption of the erect position; (3) the progressive alteration in man's diet; and probably also (4) considerations of beauty. The first three factors have operated through natural selection, the last through sexual selection, which has come into play, I would suggest, chiefly within recent times. Probably the most pronounced change which has taken place in the jaws during the agricultural periods has been the suppression of prognathism which, in the woman especially, is very unsightly, and tends to diminish the likelihood of marriage.

Instances of the Vigorous Use to which the Jaws and Teeth are put among Existing Primitive Peoples

A study of existing primitive peoples brings forcibly home to the mind how laboriously the jaws and teeth of our primitive ancestors were used. I have already shown how in pre-agricultural and early agricultural times the nature of the food compelled a sustained and vigorous exercise of these structures, and I wish here only to refer to a few specific and peculiar instances of laborious mastication exercised by primitive races now or recently living.[1] Among some of these mastication has been promoted almost to the position of an industrial art.

The chewing of very tough substances in order to extract therefrom liquid or nourishment.—The recently extinct Tasmanians included among their articles of diet a species of sea-weed which, even when cooked, was so tough as to require long-sustained mastication in order to extract its nutrient elements. The Indians of North California chew kelp, which is "as tough as white leather" (*i. e.*, leather dressed with alum). "A young fellow with good teeth will masticate

[1] I am under great obligation to Miss Eva Dunn, who has collected valuable information for me on this and kindred subjects.

a piece of it a whole day." Again Featherman[1] tells how when the Bushmen are short of food in the winter they steep an old dried gnu-skin in water and, having rubbed off the hair, boil it, and proceed to gnaw the tough morsel until their very jaws ache. The Modoc Indians are said to munch the raw kais root all day long.[2] Among the Esquimaux it is a universal custom to chew the raw skin of the whale, the porpoise, and the seal for the blubber it contains, and the skin being as tough as india-rubber, it requires, as may be imagined, a good deal of chewing. The Lower Californians also chew deer-skin and ox-skin (Bayert). The more southern Esquimaux, according to Nansen, preserve the stalks of *angelica* by steeping them in a mixture of chewed blubber and saliva. Finally, I may refer to the habit of chewing the sugar-cane, a practice which is prevalent among the natives in all countries where the cane grows, and affords, it need scarcely be said, abundant exercise for the jaws and teeth.

Mastication in the preparation of beverages.— I find that among widely separated aboriginal peoples chewing is resorted to in the preparation of beverages, both intoxicating and non-intoxicating. The Gran Chaco Indians make an in-

[1] Social History of the Races of Mankind, 1881.

[2] S. Powers: Tribes of California, 1877.

toxicating drink by chewing the algarroba bean and then spitting into a receptacle. In other parts of South America berries are chewed with the same object. In some of the Pacific Islands boys and girls with good teeth are selected to chew a root (kava), from which they then prepare a drink. In New Guinea drinks are similarly prepared from roots. Boiled cassava root is chewed by the Indians of Nicaragua for the same purpose. In British Guiana the natives make a drink by adding chewed maize and saliva to sweet potato, maize, and sugar-cane. The Indians in Honduras, after steeping cassava cake or carbonised bread in hot water, chew a portion and mix it with the rest.

Mastication in the industries. — Even among moderns teeth are used for many purposes other than mastication — *e. g.*, for holding pins and needles and for severing cotton; also in some industries — *e. g.*, among diamond workers — where it is the custom for girls to hold the diamond between their front teeth, which in consequence get much worn away, as I have myself seen. It is only among primitive peoples, however, that the jaws and teeth actually play the part of implements for use in the arts. The Australian women make lines, nets, and bags by chewing various kinds of fibre, a process which wears down their teeth considerably and may cause them to be tender.[1] The Esquimaux are still more dependent upon the use of their teeth as implements, especially in the preparation of skins for their clothing, boats, and lines. The teeth are used to hold the skins, while the latter are being scraped, the mouth constituting, in fact, "a third hand;" and the front teeth of Esquimaux women are often by this means worn away to the merest stumps.[2] The garments of the Esquimaux, even to the boots, are made up of skins which have been laboriously chewed for this purpose by the women "inch by inch," till they acquire a beautiful softness and flexibility, and are often, indeed, chewed again after having been dried. And we are told that the women have no objection to the task, while the children are eager to help in it on account of the blubber the skin contains; also, that in bad times the men do not object to join in the work. The lines for harpooning are prepared in a similar way from the skin of the bearded seal, and in very large quantities.[3] When we think of the quantity of skins needed for these lines, for their dress, including boots and gloves, and for their boats

[1] E. M. Curr: The Australian Races, 1886–7. Taplin: The Narrinyeri; an account of Tribes of South Australian Aborigines, 1879.

[2] J. F. Nansen: Eskimo Life, 1893.

[3] Dr. Kane: Arctic Exploration, 1854.

(although for the latter some skins are used without having first undergone chewing), it is clear that enormous quantities must be chewed. The Esquimaux men also use their teeth considerably in other work — *e. g.*, in lashing the sledges together.[1] The Indians of North California use their teeth for stripping the bark from the fresh shoots employed in making their wickerwork utensils, and they also employ their teeth in making strings, cords, and nets.

THE INSTINCT TO MASTICATE

Seeing that the maxillary apparatus of man has for long ages past been put to vigorous use, it is not surprising that the need to exercise it should express itself as a powerful instinct. This instinct manifests itself in many and curious ways, some of which I will now consider. During the early months of life the natural function of feeding at the breast provides the infant's jaws, tongue, and lips with all the needful exercise. This bottle-feeding fails to do, and we frequently find bottle-fed children seeking to satisfy the natural instinct by sucking their thumb, fingers, or any convenient object to hand. The teeth are a provision for biting hard foods, but even before they actually appear we find the child seeking to exercise his toothless

[1] E. Astrup: With Peary near the Pole, 1898.

gums on any hard substance he can lay hold of, and there can be no doubt that exercise of this kind tends to facilitate the eruption of the teeth, a truth, indeed, recognised universally, whether by the primitive mother who strings the tooth of some wild animal round the neck of her infant, or the up-to-date parent who provides her child with a bejewelled ivory or coral bauble. When the teeth have erupted, the masticatory instinct finds among primitive peoples abundant satisfaction in the chewing of the coarse, hard foods which constitute their dietary; but among us moderns, subsisting as we do mainly on soft foods, affording but little exercise for the masticatory apparatus, it does not find its proper expression, and thus tends to die out. Nevertheless, it dies a hard death, and long continues to assert itself; witness the tendency of children to bite their pencils and pen-holders; I have known a child to gnaw through a bone pen-holder, much in the same way as a carnivorous animal gnaws at a bone.

This instinct to chew for chewing's sake manifests itself all over the world. In our own country not only do children bite pencils and pen-holders, but they will chew small pieces of india-rubber for hours together. The practice of gum-chewing, so common among our American cousins, evidently comes down from far-off times, for the primitive Australians chew several kinds of gum, attributing to them nutrient qualities,[1] and the Patagonians are said to keep their teeth white and clean by chewing *matri*, a gum which exudes from the incense bush, and is carefully collected by the women and children.[2]

A widespread custom in the East is betel-chewing, which is met with in India, Malay, Melanesia, and Polynesia, and even among the primitive Veddahs of Ceylon. This article is composed of the pungent leaf of the betel plant, the areca nut and lime rolled together, and when chewed yields a reddish juice which stains the mouth and teeth. The Veddahs, failing to get the genuine article, manufacture a quid from the leaves of an aromatic plant, the barks of one or two kinds of tree, and calcined small shells.[3] The compound must possess some strange attraction, for otherwise such pains would not be taken to secure it. What is the attraction? Doubtless betel has stimulating properties, and it must, moreover, be remembered that the mere mechanical act of mastication stimulates the circulation, a fact which helps to

[1] Sir George Grey: Journal of Two Expeditions in North-West and Western Australia, 1841.

[2] Muster: With the Patagonians, 1869.

[3] Bailey: Transactions of the Ethnological Society, 1862.

explain the tendency for man, all the world over, to chew non-nutrient substances. Tobacco-chewing is common in many parts of the world, and here, again, the effect for the time is stimulating. Pitcherie is extensively chewed among the aboriginal Australians; it consists of twigs of about the thickness of rye-grass stems, which are first chewed into a mass, then mixed with the ash of gum trees, and made into a paste, which is chewed for its stimulating and narcotic effects.[1]

I may allude in passing to the grinding of the teeth, which takes place during sleep in disturbed states of the nervous system. It is a true masticatory act, in which the normal lateral movement of the mandible is well marked, and it may thus be regarded as a perverted manifestation of the masticatory instinct.

THE CAUSATION OF INEFFICIENT MASTICATION

The effects for good upon the organism of efficient mastication being profound and far-reaching, it follows that inefficient mastication must lead to many evils. What these are we have now to consider; but first it will be well to inquire into the causes of the defective mastication which prevails among moderns.

1. *Softness of food.* — By far the most impor-

[1] E. M. Curr: The Australian Race, 1886–87.

tant of these lies in the nature of the food taken. The food of to-day — of the late agricultural age period, as I have termed it — is for the most part soft and pappy, of a kind which does not compel thorough mastication; so much so, indeed, that, as I have already said, we may speak of this as the age of pap. This feature is especially noticeable in the case of children's diet: under the modern system children are kept on a liquid, or semi-liquid, diet, not merely during the first months, but during the first years of life, and at the seventh or eighth month all kinds of artificial saccharide foods in liquid or semi-liquid form are poured into the child's stomach; thereafter he is fed on such viands as mashed potatoes and gravy, rusks soaked in milk, milk puddings, bread dipped in bacon fat, pounded mutton, thin bread-and-butter, and the like; and we are told that this is the kind of diet best suited to the young human, from the time of weaning to the end of the second year! The same pernicious methods are adopted subsequently. "Perhaps the great majority of children after they have got their complete set of temporary teeth have," writes Dr. Sim Wallace,[1] "a dietary such as the following. Breakfast: bread-and-milk or porridge, milk, tea,

[1] The Causes and Prevention of Decay in Teeth, pp. 88, 89. London, 1902.

coffee, or cocoa, bread-and-butter, perhaps an egg. Dinner: potatoes and gravy, or meat, milk pudding. Tea: milk or tea with bread-and-butter, jam, cakes. Supper: bread or biscuit and milk." Now food of this kind does not invite mastication, and it finds its way into the stomach all too readily. Hence the instinct to masticate has little opportunity of exercise and, not being properly exercised, tends, as I have said, to die out. Small wonder that the child nourished on such pappy food acquires the habit of bolting it, and learns to reject hard, coarse foods in favour of the softer kinds; everything nowadays must be tender, pultaceous, or "short." Given a choice between a food compelling little or no mastication and one necessitating prolonged mastication — as between, say, fresh Vienna bread and an Abernethy biscuit — and in nineteen cases out of twenty the one which gives the least trouble in eating will be chosen. To such absurd lengths has this harmful custom been pushed that even bread crust is avoided by many. Witness the fashion of eating bread-and-butter with a minimum of crust; order bread-and-butter at any place of refreshment, and the last thing you will be served with is a plateful of crusts of bread. Many establishments, indeed, make a regular practice of giving away their crusts as unsaleable. Thus, the rectangular loaves used for bread-and-butter in the "Aërated bread-shops" are cut transversely into slices, each loaf thus yielding two end crusts which are put into baskets for the poor, only the soft crumby pieces being reserved for the customers, to be, in due course, no doubt washed down by copious libations of tea and coffee.

When we trace the diet of the modern from childhood upwards we find the same story: it tends to remain soft and pappy to the end. Animal food, especially as it comes to the tables of the well-to-do, necessitates very little mastication. It is the coarser varieties of vegetable food alone which call out the full functional activity of the masticatory apparatus, but the vegetable food of to-day is rarely of a kind to do this; cooked vegetables, such as potatoes, greens, peas, and beans, can be, and generally are, swallowed after little or no preliminary mastication, and our flour is so carefully deprived of its fibrous portions and so cunningly dealt with in the bakehouse and kitchen in the making of bread, cakes, and pastry which shall eat light and short that these articles get very little chewing; while such vegetable products as rice, vermicelli, tapioca, and macaroni are, as served at table, so soft that they slip down into the stomach almost as readily as simple milk.

Let any one run through his dietary of any one day, and he will realise how very little work his masticatory apparatus is called upon to perform. It will read something like the following. Breakfast: porridge and milk, eggs, bacon, bread, and marmalade. Lunch: fish, tender meat, boiled vegetables, bread, some "sweet," and cheese. Tea: bread, butter, and cake. Dinner: much the same as lunch. What opportunity, I ask, does such a bill-of-fare afford for the development of teeth and jaws, and for the proper functional activity of the salivary glands?

2. *Defective masticatory apparatus.*—Another potent cause of inefficient mastication is some defect in the masticatory apparatus, and defects of this kind are very common in those who have not been accustomed to masticate thoroughly in early life. Foremost among these are irregularities of the teeth leading to faulty "bite" and caries of the teeth which causes them to be tender or to break away, if it does not lead to their actual extraction. Mastication cannot be thorough where the bite is defective, for this not only leads to imperfect opposition of the upper and lower teeth, but renders the lower ones incapable of that ample lateral movement against the upper which is needful to normal mastication.

3. *Idiosyncrasy.* — Some are temperamentally more disposed to hurry over their meals than others. The katabolic, restless, nervous individual is more apt to swallow his food hastily than is his more deliberate and phlegmatic brother. Individual differences in this respect are even observed among the lower animals. Thus, one of a pair of horses of about the same age and build is nervous and excitable and inclined to bolt its food, while its companion of more stolid temperament is a thorough and efficient masticator. The former shows comparatively little wearing down of the teeth, and often suffers from indigestion, a large portion of corn grains passing through his digestive canal intact; in the latter the teeth are well worn, indigestion never occurs, and but very few grains pass through the digestive tract unchanged. It may be objected here that we cannot help temperament, and to a large extent this is true; but much can be done towards modifying it, and it is something to know where dangers, temperamental dangers, among others, lie.

4. *Circumstances of life.* — Again, in this hurrying, strenuous age people are much less deliberate than in the easy, slow-going days of long ago. A meal is too often regarded as something to be got through quickly, as taking

up time which might be devoted to something more profitable. Especially is this true of breakfast and lunch; it is no uncommon thing for a business man to hurry through his breakfast in a few minutes, preparatory to rushing off to his train, and his lunch as likely as not is as hastily swallowed in his office or at a bar. Tradesmen are apt to take their meals in mere snatches; apprentices, shop girls, and other "hands" are often not allowed sufficient time for their meals; while, to come to the professions, we all know how the busy medical man, for instance, is often obliged to take a hurried snack in the short intervals between seeing his patients. No wonder that thus circumstanced people acquire the habit of bolting their food. A meal should be regarded as an end, and an important end, in itself. It should be taken at leisure, body and mind being, for the time being, given up to it, and to agreeable social intercourse. If this rule were always observed a most important source of inefficient mastication would be removed.

SECTION III. From *London Lancet*, July 25, 1903

EVILS RESULTING FROM INEFFICIENT MASTICATION

Too much food is eaten. — Inefficient mastication conduces to excessive eating. Now it is obvious that soft foods, and these constitute the bulk of our modern dietary, pass much more readily into the stomach than coarse, hard foods which compel a certain amount of preliminary mastication, and for this reason the former predispose to excessive eating: hence a danger at all periods of life, not only in grown-ups but in children, even infants; brought up as the latter are, mainly on liquid and pappy foods, many of them consume not only far more than is needful, but far more than is healthful, their stomachs being literally deluged with nutriment.

When the food is of a kind necessitating abundant mastication it is much less likely to be taken in excess, for the longer the time spent in mastication the less will the individual be tempted to consume; even in the case of soft food, less will probably be eaten if it be thoroughly masticated and insalivated than if it be bolted. Thorough mastication, however, not only tends to diminish the amount of food consumed on account of the time and labour which it entails; it actually reduces the amount needful to constitute a sufficiency, for the more perfectly the food is chewed the more perfectly is it digested and the more economically is it disposed of in the system; the less, moreover, is the tendency to that morbid craving for food which is so frequent an accompaniment of defective digestion. It is certain that appetite and the needs of the system are sooner satisfied when food is well masticated and digested than when it is swallowed whole.

A mass of unmasticated food may lodge in the throat and cause fatal suffocation. — This may seem to be a very exceptional kind of evil, but I am informed by one whose experience makes him an authority on the ways of the British soldier that it is by no means uncommon for soldiers in barracks to die from this cause. Usually it is when they are under the influence of alcohol that fatal results occur, post-mortem examination disclosing large undigested masses of food in the stomach. A like experience is also frequently met with in the case of men killed by accident.

The presence of masses of imperfectly masticated food in the stomach may cause disturbance either mechanically or by reason of their imperviousness to the gastric juices. — We have already seen that the digestibility of a food is largely determined by its consistence, and that many articles of diet, such as cheese, hard-boiled egg, cocoa-nut, lobster, and new bread, which have the reputation of being very indigestible, can, if finely comminuted by chewing or otherwise, be rendered quite digestible. Such articles are indigestible essentially by reason of their compactness; the compact lumps, but little pervious to the gastric juice, tend to undergo abnormal chemical change in the stomach, and may in this way cause violent local irritation, even to the extent of setting up acute gastritis; or they may paralyse the nerves of the stomach and check gastric secretion and movement, and thus remain *in loco* wholly undigested for hours or even days; or, again, more distant nervous effects may be produced, such as frontal headache, which may be felt almost immediately after ingestion of the peccant substance, being of reflex rather than toxic origin, and presumably in some cases, at least, due to the mere mechanical irritation of the stomach. The passage of imperfectly digested food into the bowel may still further aggravate matters. It does not seem improbable that the habitual bolting of food, by the prolonged local irritation to which it gives rise, may predispose to cancer of the stomach: Napoleon was a notorious fast eater and it is well known that he died from this disease.

While, however, the bolting of food readily sets up disturbance in some, it must be conceded that in many it seems to cause little or no inconvenience; especially is this the case in the young with vigorous muscular stomachs capable of triturating the food, and thus doing duty for the teeth. The human stomach is, indeed, a long-suffering organ, and wonderfully tolerant of ill-treatment, sometimes almost rivalling in its hardiness the gizzard of the bird. Nor is this surprising when we reflect that it is, in the ordinary course of nature, constantly exposed to the entrance of noxious substances. In this respect it stands in marked contrast to the intestines, for not only are highly irritant substances often vomited rather than passed onwards, but in ordinary circumstances the gastric contents are not allowed to pass the pylorus, until they have been duly prepared by the stomach; the pylorus, in fact, stands guard over the entrance to the bowel and is jealous of anything passing it which is likely to injure that canal.

And just as the pylorus protects the bowel so, in exceptional cases, may the œsophagus protect the stomach, regurgitating, after the fashion of the ruminants, insufficiently masticated bits of food, in order that they may be re-masticated. I have myself met with cases in point. Sometimes, in cases of this kind, the œsophagus may be dilated into a sort of proventriculus, which is capable of temporarily lodging a large quantity of food. Such a proventriculus is said to have developed in an apprentice who, not being allowed sufficient time for his dinner, rapidly bolted it, to regurgitate it after working hours and to chew the cud at leisure. Whether in these cases the food is ever returned from the stomach itself I am unable to say.

While the stomach is the organ especially liable to be injured by the swallowing of lumps of unmasticated food, the bowel may also suffer, especially the cæcum and vermiform appendix. And here we come to one of the most serious indictments against the bolting of food; though man has doubtless always suffered from appendicitis, there can be little doubt that this malady is more common now than it used to be; and there is equally little doubt, in my own mind at least, that the cause of its greater frequency is related to his food. I do not propose to discuss here in detail how food is capable of causing appendicitis, but will merely refer to one of the ways in which it may do so. I had already come to the conclusion that the habit of bolting food is a potent cause, when I read Sir Frederick Treves's Cavendish Lecture in which he makes that contention. Sir Frederick Treves points out that in this rushing age people, especially business men, are apt to hurry over their meals and to take them at irregular times and often while standing at a bar; even when there is more leisure, food is rarely masticated nowadays in the same thorough way that it was in the old time, when it was of a coarser nature: hence solid lumps, especially in the case of such articles as pine-apple, preserved ginger, nuts, tough meat, and lobster, are apt to pass beyond the pylorus and, escaping intestinal digestion, to lodge in the cæcum and precipitate an attack of appendicitis, the most common predisposing cause of which is a loaded cæcum, often preceded by constipation. Sir Frederick Treves contends that this distended state of the cæcum encourages catarrh of the appendix by dragging upon it and blocking its orifice, as well as by twisting it and thus interfering with its blood-supply.[1]

An excess of starch is apt to pass into the stomach. — We have just seen that inefficient mastication tends to promote over-eating, and what has been said on this head applies to all kinds of food, starchy foods among others. It leads, however, to a further evil as regards these latter; not only does it tend unduly to increase the quantity of them consumed, but it too often causes the stomach and intestines to become flooded with starch in a wholly undigested form. I cannot too frequently repeat that in ancient times, especially in the pre-cooking age, laborious

[1] Gilbert Barling also traces the relationship between appendicitis and diet. "In a considerable number of cases," he writes, "the attack of appendicitis can be directly attributed to unsuitable food — pork, mackerel, over-ripe or under-ripe fruit, uncooked vegetables" (Brit. Med. Jour., vol. i., 1903, p. 61).

mastication was needed in the case of all starchy foods, partly because they were coarse and fibrous, but chiefly because the starch and other nutritive ingredients had, in order to become available for nutrition, to be liberated from their undigestible cellulose envelopes. In these days of prepared, soft, starchy foods, however, mastication is very little required for these purposes, but in other respects it is as needful as ever, indeed more needful, if the large quantities of starch which are now consumed are to be insalivated effectually. The laborious and sustained mastication to which primitive man was compelled to subject *his limited supplies of uncooked starchy food, went far to effect complete digestion of the starch within the mouth*, for raw starch is freely digested by the saliva,[1] and hence in his case *very little passed into the stomach in a wholly undigested form.* How different is the case with us moderns. Since the opening of the era of agriculture and cooking, man has enormously multiplied his supplies of saccharide, and he now consumes large quantities of starch which has been freed from its cellulose framework by cooking, milling, grinding, and the like, and reduced

[1] My friend, Dr. Thompson. undertook, at my suggestion, some experiments to test the digestibility of raw starch within the mouth; he found that raw potato yields abundant sugar when subjected to long-continued mastication.

to a soft or pappy form, such as milk puddings, porridge, boiled potatoes, and new bread, all of which can be swallowed with little or no preliminary chewing; and when food can be swallowed easily, without mastication, few will take the trouble to masticate it. In these circumstances the starch does not undergo adequate salivary digestion, and a large quantity passes wholly undigested into, and out of, the stomach, not beginning to be digested until it reaches the bowel. Small wonder that the latter should rebel again this invasion and that flatulence, pain, and other dyspeptic evils should result.

It is especially in young children that these evils are observed. Too often the stomach of the child, semi-carnivorous, remember, by its ancestry, is literally deluged with pure starch. At the seventh or eighth month, or even earlier, for many of the patent infant foods contain it, this substance is poured into the stomach without being afforded any opportunity of undergoing salivary digestion; and for a long time after infancy large quantities are given in the liquid or pultaceous form, such as rusks soaked in milk, puddings, and mashed potatoes. This practice of deluging the digestive organs with starch, besides leading to the more immediate troubles connected with flatulent dyspepsia, gives rise to abundant formation of toxins which, by irritating the alimentary mucous membrane, set up gastro-intestinal catarrh; this, again, intensifies the dyspepsia already existing and causes a still further production of toxins, so that the motions become intensely fœtid. These poisons being absorbed into the blood the tissues become saturated with them and the nutrition of the entire organism is disturbed, the faulty metabolism manifesting itself by a diminished resistance to pathogenic agencies, by a tendency on the part of the tissues to inflame (as shown by a liability in children thus fed to bronchitis, rhinitis, naso-pharyngitis, and tonsillitis), by their proneness to tuberculosis, and finally by a disposition to rickets, which I little doubt is essentially of toxæmic origin.

Besides the above-mentioned troubles an excess of starch in the stomach may set up hyperchlorhydria — *i. e.*, that form of dyspepsia in which there is excessive secretion of hydrochloric acid. This affection occurs during the most vigorous years of life and is apparently due to excessive activity on the part of the gastric glands. The excess of acid does not give rise to any symptoms so long as there is any unsatisfied proteid in the stomach to unite with it, but directly all the proteid is satisfied and free acid is present in the stomach, pain, heartburn, and distention are apt to be felt; hence these symptoms are generally removed temporarily by a meal, the food ingested seizing upon the free acid, and tend to recur in the course of an hour or two. Other symptoms are mental and bodily lassitude and great mental depression, while, if the condition is long-continued, gastric catarrh and dilatation ensue. Eructation of the acrid mass, its removal with a tube, or its dilution or neutralisation by an alkali, causes relief of the symptoms. Now Dr. William Russell, who has recently studied this form of dyspepsia, has shown, and the fact is most significant from our present point of view, that in it starch is the last constituent to leave the stomach; that when this organ has so far emptied itself as to contain but one or two ounces of very acrid material the residue consists chiefly of finely divided undigested starch, which continues to stimulate the gastric secretion; "and, there being no more proteid with which to combine, the secretion accumulates and leads to hyperacidity."[1] Inasmuch, then, as inefficient mastication leads to an excess of starch in the stomach, we see how it may predispose to hyperchlorhydria and we shall presently see that there is yet another reason why it should do so.

It will be gathered from the foregoing that thorough mastication is the most effective way

[1] *The Lancet*, March 21st, 1903, p. 806.

of securing efficient starch digestion. This simple fact has been most strangely overlooked. Thus "van Valzah considers that not a little of the difficulty of the digestion of starches and cereals can be overcome by more thorough cooking. Patients who cannot eat potatoes after ordinary cooking are [he urges] often able to digest them very readily if they are doubly cooked before being served. Cereals, as a rule, should [he contends] be allowed to simmer all night and then be thoroughly cooked for a half hour in the morning before being eaten."[1] This is an admirable illustration of the modern tendency to cheat the mouth of its proper work. A much more rational way of facilitating starch digestion in those who experience a difficulty in this respect is by efficient mastication.

Evils resulting from an insufficient quantity of alkali in the stomach.—I doubt if it is adequately realised what a large amount of alkaline saliva passes into the stomach as the result of prolonged mastication. Its presence there serves the useful purpose of prolonging the period of starch digestion within the stomach, while it further aids gastric digestion not only by exciting the secretion of gastric juice, but also by its influence on the reaction of the gastric contents; it can scarcely be doubted that the effect is on

[1] Brit. Med. Jour., Epitome, vol. i., 1903, p. 45.

the whole one favourable to digestion in general. We have just seen that defective mastication may predispose to hyperchlorhydria by allowing an excess of pure starch to pass into the stomach, and I suggest that it may further operate in the same direction by cheating the stomach of its due supply of alkaline saliva. Now the saliva in this affection is apt, as was pointed out by Sir William Roberts, to be superalkaline, and for this reason he recommended his acid-dyspeptics to excite the flow of it by chewing gum-mastic with the object of neutralising the gastric hyperacidity. That relief can thus be obtained there can be no doubt; but it is surely more rational to get the patient to stimulate his salivary glands by masticating actual food, by which we secure the additional advantages accruing from its complete insalivation and comminution as well as from the reflex gastric effects. Actuated by these considerations, I have long been in the habit of recommending hyperchlorhydriacs to subject their food to prolonged mastication, this being, in my belief, the most rational and effective way of breaking the stomach of its vicious habit. In extreme cases we must insist that each morsel of food should be chewed at least one hundred times and not permit any relaxation of this severe discipline, until the stomach has been schooled into healthier ways.

Evils in connection with the jaws and their appendages and the adjacent structures: the nasal passages, naso-pharynx, and faucial tonsils. — In those who do not masticate properly in early life these parts fail to develop as they should, and they are on this account alone predisposed to disease; their resistance to disease is still further lowered by the fact of their blood and lymph flow not being adequately stimulated by the vigorous exercise of the masticatory muscles. Now we have seen that the great cause of defective mastication in children is the softness of the food given them and that the feeding of them upon an excess of soft food, especially the starchy kind, disturbs digestion, induces toxæmia, and in this way evokes a catarrhal tendency. In children thus fed we have therefore several conditions which make for disease in the parts under consideration — defective development, sluggish circulation, and toxic saturation. Is it any wonder that the modern child should be liable to disease in these regions, that he should so frequently suffer from rhinitis, naso-pharyngitis, tonsillitis, and from hypertrophy of the pharyngeal tonsil ("adenoids") and of the faucial tonsils?

It is in this way that I would explain the frequency of adenoids among the children of civilised communities. I claim, in fact, that this disease is largely dietetic in origin. I submit that a child whose nasal apparatus and naso-pharynx are well-grown and habitually bathed by a stream of pure blood and lymph, periodically accelerated by an ample and vigorous use of the masticatory muscles, is unlikely to contract adenoids. On the other hand, I contend that a child in whom these parts are ill-developed and bathed by an habitually sluggish stream of tainted blood and lymph — one, *i.e.*, that is not only poisoned, but rarely, if ever, hurried along its lazy course by due exercise of the muscles of mastication — I submit that such a child runs great risk of contracting the disease. The influence in setting up adenoids of toxic saturation with its resulting catarrhal tendency is shown by the frequency with which this affection follows upon the rhinitis and naso-pharyngitis of measles and diphtheria, and in order to realise how greatly the circulation of blood and lymph in the walls of the naso-pharynx must be influenced by mastication, one has but to remember how very closely the pterygoids are related to this region; in exploring it for adenoids they can, indeed, often be felt to stand out prominently.[1]

[1] A further aid to the circulation in the naso-pharynx is afforded by the lusty use of the voice. It is natural for the young human to cry and to shout, and unless this instinct is allowed full play the child is apt to suffer in health. I cannot but think that the modern child is too much repressed in this respect, and that he is not afforded, especially in towns, proper

This, then, is my explanation of the truly fearful prevalence of adenoids among the moderns. It is essentially a disease of pap-fed peoples. A child may, with the one exception that he is fed on a pappy, super-saccharide diet, be brought up under ideal health conditions. He may live in the heart of a dry, open country, far from the darkness, dust, and tainted atmosphere of the town, sleep with the windows open all night, live out of doors all day, be fed on the most nourishing (too nourishing, it may be) food, be clothed after the most approved methods, and yet, in spite of all this, we may find his naso-pharynx packed with adenoids. This disease is, in fact, scarcely less prevalent in the country than in the towns, scarcely less common among the rich than among the poor. Yet in primitive communities it is practically unknown. And what, I would ask, is the one condition in the material environment of my supposititious child differing from that of the primitive child? What but the factor of diet? Therefore, I say, the prevalence of adenoids among moderns must be the result of the modern system of feeding children, and the defective mastication which goes along with it.

That the foregoing is a grave indictment

opportunity of venting his vocal energy in out-door play. May we not have here a contributory factor in the causation of adenoids?

against that system, it need scarcely be said. For adenoid disease is fraught with many evils, among them mental hebetude, blocking of the Eustachian tubes, and manifold other auditory troubles, gastro-intestinal disturbances from the passage into the stomach of unhealthy discharges, and, most serious of all, nasal obstruction and consequent mouth-breathing. So serious are the evils connected with this latter habit that they demand more than a passing reference. Pronounced adenoid disease is always associated with mouth-breathing, and there can be no doubt that in the majority of these cases, the nasal obstruction is not in the nasal passages primarily, but is due to a blockage of the posterior nares by the adenoid growths, for it generally happens that nasal breathing is rapidly re-established after their removal, though in a certain proportion of cases the obstruction still persists, and has to be dealt with by treatment directed to the nasal passages themselves. Some have, indeed, contended that a primary nasal obstruction is one important factor in the induction of adenoids, leading as it does to a dry-cupping of the naso-pharynx during inspiration and to a consequent congestion of its lining membrane. I am quite ready to allow that this mechanism may play some part in causation, and such an assumption is in entire harmony with my main contention that adenoid disease is of dietetic origin, for nasal obstruction in children, other than that caused by adenoids, is mainly due to defective development of the nasal passages coupled with inflammation of their lining membrane, both of which conditions may, as we have seen, be essentially the outcome of defective diet.

Coming now to the evils resulting from mouth-breathing, we have first to remember that normally the air is inhaled through the nose, and is thus warmed, moistened, and filtered before being allowed to pass into the lungs; but in the mouth-breather the air, which may be dry, cold, and dust-laden, passes at once unprepared through the mouth into the lungs, impinging in its passage against the pharynx, thus drying and mechanically irritating the mouth, pharynx, larynx, and bronchial tubes, all of which are thereby predisposed to disease. In this way laryngitis and bronchitis, nay, even phthisis, may be induced. Dental caries is also predisposed to by the habit of breathing through the mouth. Mouth-breathing further interferes with the proper development of the cranial bones, but especially of the maxilla, giving rise to what may be termed the "mouth-breather's jaw," so characteristic is it. I do not propose to discuss here the mechanism by which this deformity is produced, interesting though the question is; suffice it to say that nasal breathing is essential to the normal development of the jaws. The deformity in question, though it involves the maxilla chiefly, affects also the mandible from the fact of its being, to a large extent, moulded on the maxilla; in typical cases the maxilla is small and its alveolar ridge does not attain its normal length, but is compressed laterally towards the sagittal plane, giving rise to the false appearance of a "high arch" and often thrusting the anterior portion of the ridge forwards; the teeth, the growth of which is not so much interfered with as that of the imbedding bone, are thus prevented from taking up their proper positions and show irregularity, sometimes extreme. Dental irregularity may also, as we shall see, result from inadequate use of the jaws in mastication, but not to the extent which is frequently observed in the mouth-breather's jaws, and therefore pronounced dental irregularity always shows that there has been protracted nasal obstruction, and this in the vast majority of cases implies the existence of adenoids, past or present; I say in the "vast majority," for in a few rare cases long-continued nasal obstruction in children originates primarily in the nose and may lead to the typical mouth-breather's jaw, with the resulting dental irregularity.

The tongue. — If the tongue is not properly exercised in childhood and youth, we find it imperfectly developed; hence in inefficient masticators it is generally small. It must not be forgotten in this connection that this organ is considerably exercised when the infant is at the breast, from which the milk is obtained, not by suction, but by a vigorous tugging and squeezing of the nipple (in which the tongue takes considerable part), whereby the gland is reflexly excited to secrete. When, on the other hand, the child feeds at the bottle he obtains his milk by actual suction, and generally through an orifice of such ample dimensions as to allow the bottle to be rapidly emptied with comparatively little exercise of the lips and tongue. In short, the breast-fed infant has to do some work for his living, and that of a sort calculated to promote the health of the jaws and their appendages, while the bottle-fed child can glut himself by doing very little more than opening his mouth; wherefore we find the tongue and adjacent parts less developed in the latter than in the former. It may be thought to be a matter of indifference whether the tongue develops to its normal proportions or remains small, but such is by no means the case, for, as Dr. J. Sim Wallace has shown, the pressure of this structure against the teeth promotes the normal development of the jaws, especially of the mandible, and when it is small they are apt to be so too.

The salivary glands. — Just as mastication increases the functional activity of the salivary glands and buccal glands and favours their normal development, so, contrariwise, inefficient mastication during early life fails to call forth their normal functional activity and to secure their adequate development. Thus we find that a child who has been brought up on hard, starchy foods, necessitating abundant mastication has much larger and more active salivary glands than one who has been fed on soft foods which slip down into the stomach before they have had the chance of being properly masticated, and it is needless to say that the more efficient these glands are the more likely is digestion to be carried out satisfactorily.

The jaw-bones. — If the jaws are not adequately exercised in youth by mastication they fail to grow to their normal size and shape, and there is apt in consequence to be overcrowding of the teeth. The main defect of the jaws in such cases is their smallness; they do not present that pronounced lateral compression and anterior protrusion which characterise the mouth-breather's jaw, nor such extreme dental irregularity, the most common being overlapping of the incisors, displacement of the canines, and difficulties in regard to the eruption of the wisdom teeth from shortness of the alveolar ridge. I have already referred to the progressive shortening in the post-molar ridge, which has been taking place during man's evolution from the anthropoid in correspondence with the alteration in his diet.

We thus see that defective use of the jaws leads to irregularity of the teeth (1) directly and (2) indirectly through the induction of adenoids. This irregularity is not only unsightly but leads to certain evils which thus primarily owe their origin, in large measure at least, to defective mastication. What, then, are these evils? In the first place, dental irregularity predisposes to dental caries by favouring the lodgement of food between the teeth; in the next place, it leads to defective "bite." Now when the bite is defective adequate mastication is impossible, for not only is it impossible in these circumstances to oppose the teeth properly, but also, owing to their interlocking, to accomplish that free lateral movement of the lower teeth against the upper, which belongs to normal mastication. I do not say that defective bite is the sole cause of this imperfect lateral movement; it may, indeed, be observed in most moderns brought up on soft pappy food, whether the bite be good or not. Normal mastication is, in fact, becoming a lost art; the average modern masticates mainly by a vertical compression of the lower teeth against the upper, and in only a small degree by a lateral frictional movement which, it is needless to say, is the more effective method for grinding purposes; and it is, I doubt not, chiefly for this reason that the teeth of modern man are so much less worn down than those of primitive peoples.

The teeth. — Imperfect use of the teeth leads to many ills. When adequately exercised and made to execute for one or two hours every day a lively dance in their sockets, during which the circulation of blood and lymph in the tooth-pulp, periodontal membrane, and surrounding tissue of the gum is vigorously stimulated, and the cavity of the mouth is bathed in a copious flow of salivary and other buccal secretions, we have conditions which make alike for the health of the buccal mucous membrane, of the teeth, and of the periodontal membrane and alveoli; but when the circulation is not duly stimulated in this way the teeth do not develop properly, while the secretions of the mouth are apt to be scanty and unhealthy, both of which conditions predispose to caries. How far dental caries is due to inherent dental weakness and how far to faulty conditions outside the teeth we need not stop to inquire; Dr. Wallace attributes little influence to the former factor, contending that caries depends essentially upon faulty dental environment; and one can scarcely doubt that the state of the gums and of the oral secretions profoundly influences the growth of bacteria in the mouth, upon the acid yielded by which organisms the corrosion of the dental enamel essentially depends. Faulty conditions of the oral secretions likewise favour the deposit of tartar.

Another result of imperfect use of the teeth is undue thinness of the alveolar walls and periodontal membrane, in consequence of which the teeth are not so firmly held in their sockets as they should be. This is, I believe, one of the reasons why they are prone to fall out prematurely among the moderns: we know that the teeth tend to drop out in old people owing to a senile atrophy of the alveolar walls; the Haversian canals get smaller and may, indeed, disappear entirely, and it stands to reason that this atrophy must be hastened by inefficient exercise of the teeth. So far as I am able to gather from an examination of skulls in museums, the teeth are rarely shed among primitive peoples before extreme old age, while among moderns they frequently fall out long ere this is attained.

A still worse evil attaching to insufficient use of the teeth is pyorrhœa alveolaris or Riggs's disease, which, in conjunction with the deposit of tartar, is the great cause of the premature loosening and shedding of the teeth observed among latter-day civilised peoples. This affection consists of a purulent inflammation of the periodontal membrane, owing to the invasion of it by pyogenic cocci, so that pus wells up on pressing the gum against the teeth. Now, when by a vigorous use of the teeth the buccal cavity is kept well flushed with healthy secretions, the growth of micro-organisms within this chamber is kept down, and when, by the same means, the vitality of the periodontal membrane and adjacent tissues of the gum is periodically stimulated, these tissues offer stout resistance to the invasion of pathogenic organisms; but when, contrariwise, the teeth are little used, the secretions of the mouth are in consequence defective both as to quality and quantity, and the growth of organisms in the buccal cavity is promoted; and when, further, the circulation in the periodontal membrane and adjacent soft tissues is not adequately stimulated by vigorous mastication, their vitality is poor and they offer but a feeble resistance to parasitic invasion. We can thus, I think, safely infer that inefficient mastication is a potent cause of pyorrhœa alveolaris; and the chief cause of inefficient mastication being the eating of soft foods, we must also conclude that the latter practice is chiefly responsible for the disease in question; such foods further predispose to this affection in that they are apt to lodge between the teeth and by undergoing decomposition there to favour the growth of micro-organisms within the mouth. The condition of the teeth and gums among the civilised poor is, alas, little calculated to make us proud of our boasted civilisation — the spongy pus-exuding gums, the lengthening, loose, tartar-covered, carious teeth, and the putrescent breath constitute a damning indictment against our modern system of living on a soft, pappy diet, and not giving the teeth the work for which they are designed. I never examine such a mouth without being impressed with, and I may add oppressed by, this fact.

I am not, of course, contending that pyorrhœa alveolaris only occurs in those who masticate inefficiently; whatever causes an unhealthy condition of the gums and saliva predisposes to it, but it is surely much less common in those who masticate well than in those who masticate ill. Confirmatory of this statement is the fact that it is more frequent in those with irregular teeth than in those with a good bite, who are thus able to put their teeth to more effective use. This affection is very common among the carnivora of menageries as well as among dogs and cats; indeed, one seldom fails to find it in dogs over four years of age, and in old dogs it is generally rampant. Doubtless in all these cases the general conditions of life play some part in the causation of the disease, but I do not think that we can eliminate from it the factor of defective use of the jaws and teeth, for it is certain that dogs and cats are fed largely on pappy foods and are often insufficiently supplied with bones.

The causation of dental caries. — Dr. Wallace, in his philosophical work on "The Cause and Prevention of Decay in Teeth," contends that the cause of the prevalence of dental caries is that the natural food-stuffs are, to a large extent, ridded of their accompanying fibrous parts and consumed in a form which renders them liable to lodge and to undergo acid fermentation in the mouth; while from the same cause and the induced conditions the micro-organisms of the mouth lodge and multiply and augment the rapidity and intensity of the acid fermentation. I am perfectly at one with Dr. Wallace in believing that the removal of the fibrous portions of food is the main cause of the prevalence of caries among moderns, and I can hardly doubt that foods so prepared tend to promote caries in the way indicated, but I venture to think that they do this even more by failing to call forth the normal degree of mastication. I cannot but think that if these same soft foods were as laboriously masticated as they would need to be if they retained their fibrous ingredients, dental caries would be much less common than it actually is. I have endeavoured to show how very different the local conditions are in the efficient from what they are in the inefficient masticator — how in the former the jaws and teeth are wont to be well developed, the bite to be good, and the secretions which bathe the teeth to be of a kind calculated to promote their health; and how in the latter an entirely opposite set of conditions is wont to prevail. That it is possible to maintain a fine set of healthy teeth till past middle life on ordinary civilised diet, provided the food be habitually subjected to efficient mastication, is shown in the case of the man already referred to, and by numerous other cases which I have observed.

Since the application of cooking to food there has been a progressive lessening in the work of the jaws and teeth and, parallel with this, a diminution in their size and an incursion of dental caries. Among the anthropoids in their natural state caries is practically unknown, and I think we may conclude that the same was true of man before he learnt to cook. In the pre-agricultural races, such as the aboriginal Australians, the effect of cooking the food is shown in the lessening in the size of the wisdom teeth and of the post-wisdom alveolar ridge; dental caries, though rare among these people, does occur, and especially in the wisdom teeth.[1] In the early agricultural period, owing to the increasing softness of the vegetable food, the jaws and teeth show a tendency to be smaller than in the previous periods; the wisdom teeth are decidedly smaller and more prone to caries, while caries of the other teeth is by no means rare. In the late agricultural period the jaws and teeth often show very decided defects of development, while dental caries is, as we know but too well, rampant.

What has been said concerning the relative prevalence of caries in different diet epochs applies to many other diseases of the teeth; thus, along with the increase of caries, there has been a parallel increase in the prevalence of pyorrhœa alveolaris.

[1] Among the Australian skulls I have examined in museums caries of the wisdom teeth — *i.e.*, in those very teeth which, as shown by their atrophy, are least used — is by no means uncommon (though it is possible that some of the skulls belong to natives who have embraced the dietetic customs of the white man). I submit that this fact may fairly be used as an argument in favour of the view that inefficient use of the teeth predisposes them to caries by interfering with their re-

Concluding Remarks

I have now set forth some of the evils resulting from inefficient mastication. They are many and serious. The immediate evils, such as over-eating, indigestion, adenoids, dental caries, and pyorrhœa alveolaris, are bad enough, but when we consider the secondary evils to which these primary ones give rise, — and I have only mentioned a few of them, — we must come to the conclusion that an appalling amount of misery and suffering may be saved by the simple expedient of inculcating the habit of efficient mastication. How this end can best be accomplished will be considered in the next section.

Section IV. From *London Lancet*, August 8, 1903

Means of Insuring Adequate Mastication

In order to secure the full advantages accruing from the use of the jaws and their appendages, it is, above all, necessary for them to be adequately exercised during the period of development. If this is done, not only will the tendency to dental caries, adenoids, indiges-

sisting power, though it must be acknowledged that the position of the wisdom teeth places them at a disadvantage, owing to the tendency of food to accumulate about them, especially in undeveloped jaws in which they have not adequate room.

tion, and other evils be greatly diminished, but the masticatory instinct will establish itself as a permanent force, so that the individual will tend for the rest of his life to subject even soft foods to thorough mastication. The tongue, the lips, and the jaws of the newly born child find their natural exercise at the mother's breast, and we should, therefore, do our utmost to get the mother to suckle her child, the bottle affording neither the same kind nor the same amount of exercise. If, unhappily, we fail in this, we must see that the teat of the feeding-bottle is so constructed as to compel the child to earn his meal by, at any rate, some exercise. This kind of exercise promotes the growth of the tongue and thus of the jaws, especially of the mandible. Directly the infant shows a disposition to bite hard things the instinct should be gratified. We may observe a tendency in this direction as early as the third or fourth month, and it becomes more and more pronounced when, the time for the eruption of the teeth approaching, the gums begin to swell up and to get tender, and saliva begins to flow from the mouth; it is now, more than ever, necessary to provide the child with hard substances on which to exercise the jaws and the gums, and a great deal of the trouble of teething is due to the failure to recognise this fact. What, then, are we to employ for this purpose? I am convinced that it is a mistake to rely solely, or even mainly, upon baubles of ivory, coral, and the like, useful though these may be in their way; it is far better to give the child something which is not only hard but nutrient and pleasant to the taste, something which will at one and the same time exercise the maxillary apparatus, excite the gustatory organs, and provide a certain amount of nutriment. To this end we may, as the teething time approaches, give a chop or chicken bone, from which most of the meat has been removed; by powdering the bone with white sugar or salt we may increase its attractiveness. From such bones a good deal of nutriment can be extracted, and this of a kind which is most acceptable to the infant stomach, for it must be remembered that the young human is in the main carnivorous. Indeed, since milk is a purely animal diet, all the mammals must be regarded as essentially carnivorous during the period of suckling, while man, as already observed, from the time he emerged from the anthropoid until he learned to cook his food, was throughout life mainly an animal feeder. Therefore we should not hesitate to allow the teething infant animal food in the form suggested. Chicken and chop bones, yielding as they do before the pressure on the gums, are, moreover, just of the right degree of consistence for the purpose in view, while they afford abundant exercise for the tongue; ivory, coral, and the like are, on the other hand, too hard and unyielding, and lack, moreover, the attractiveness belonging to sapidity.

By thus providing the maxillary apparatus with suitable exercise we shall do much to facilitate the eruption of the teeth and to favour the growth of the jaws and their appendages, including the salivary glands, and so to prepare the mouth for the reception of vegetable food. This should, of course, not be given till the teeth appear. The order in which these make their appearance gives some indication as to the order in which vegetable food should be administered to the child. The first teeth to penetrate the gums are the lower incisors which appear from the seventh to the eighth month; then follow the upper incisors from the seventh to the tenth month. These teeth enable the child to *bite*, but not, be it observed, to *masticate*, for which function the molars are necessary. Now the first molars do not appear till the twelfth or fourteenth month; the second molars not till between the fourteenth and the twentieth month; and it seems to me certain that our primitive ancestors could not have obtained starch in any quantity until they reached this age; at the best, pre-cooking man was but scantily supplied with starch, and such slender supply as he had could only be rendered accessible to the digestive juices by vigorous mastication, which broke up the indigestible cellulose framework in which all vegetable starch is contained; hence, until the young human cut his molars, he had little opportunity of securing any starch. These considerations strongly suggest the desirability of giving but small quantities of starch before the twelfth month, and though the facts, that ptyaline appears in the saliva about the time the first incisors are cut, and that pancreatic juice develops its amylolytic ferment at the same time, show that the digestive organs are ready for the reception of some starch at the seventh or eighth month, yet I believe the quantity should be strictly limited. I am ready to admit that the modern child may have, indeed probably has, a greater power of digesting starch than his remote pre-agricultural ancestor; but even so, I am convinced that we should be on our guard not to over-gorge infants with this substance. Only a small quantity should be given before the twelfth month, and it should be gradually increased up to the twentieth month.

I have said that the pre-agricultural infant was unable to secure starch in any quantity by means of his incisors. These teeth enabled him, however, to obtain some soluble nutriment from fruits, and Dr. Sim Wallace has suggested that the early eruption of the lower incisors is for the purpose of enabling the infant to pierce the outer covering of fruits so as to permit him to extract the soluble contents by suction; and, accordingly, when these teeth are cut we may allow the child to bite at such vegetable substances as apples, oranges, and sugar-cane. The latter is a useful article of diet for children, for it provides soluble saccharide in a diluted form, and it is advisable that the child should receive his cane sugar well diluted, for it must be remembered that before the agricultural period man's supply of pure sugar was limited to wild honey which, consisting as it does almost entirely of mono-saccharide (grape sugar and fruit sugar), is very easily disposed of by the digestive organs. Nowadays, the less digestible cane sugar (which is a di-saccharide) is very largely consumed in the undiluted state, in which it is apt to set up disturbance. When, however, it is obtained by chewing the sugar-cane, it is diluted both by the water in the cane and by the saliva, and I should like to see children obtain most of their cane sugar in this way.

The consideration of the conditions obtaining for pre-agricultural man not only strongly suggests that the young human of to-day should be given starch in very moderate quantities up to the twelfth month, but it points an even more important lesson — viz., that this substance should be given not, as is the custom, as liquid or pap, but in a form compelling vigorous mastication, for it is certain that early man, from the time he emerged from the ape till he discovered how to cook his vegetable food, obtained practically all his starch in such a form; it cannot too often be repeated that uncooked starch in the natural state, locked up as it is in chambers of indigestible cellulose, has no nutritive value; these chambers need first to be broken up by prolonged and energetic chewing, and in this way much or most of the starch is converted in the mouth into dextrines and maltose, very little passing into the stomach in the crude state to set up disturbance in that organ and later in the bowel. If it is given as liquid or pap it will pass down as starch into the stomach, while if it is administered in a form which obliges the child to chew it properly, not only will the jaws, the teeth, and the gums obtain the exercise which they crave, and without which they cannot develop normally, but the starch will be so thoroughly insalivated that much of it will be converted within the mouth into maltose. How foolish to upset the child's digestive system by deluging it with liquid starch, and then to endeavour to correct matters by giving the malt extract which the child can and should himself manufacture within the laboratory of his buccal cavity.

Clearly, then, the child should make his first acquaintance with starch, not in the form of a liquid or pappy patent food, but in a solid and somewhat tough form. The best means of achieving this end is occupying my attention, and I hope soon to publish the results of my investigation. Meanwhile, I would point out that hard, well-baked crusts constitute a convenient form in which to administer starch to children. A piece of crust may be put in the oven and re-baked; this not only hardens it but helps to convert the starch into dextrine, which is a stage on the road to maltose. If the crust be then cut into a suitable shape and spread with bacon fat or fresh butter, it constitutes a most agreeable morsel. Later, we may give hard plain biscuits. The same principle should be acted upon during later childhood and youth: we should always give, as far as possible, the starch in a form compelling abundant mastication. Loaves should be shaped so as to give a maximum of crust and a minimum of crumb, and should be baked hard. Such loaves are quite as nutritious as the ordinary ones, and much more digestible, containing as they do an abundance of dextrine and not a little maltose, and compelling efficient mastication, especially if eaten, as they should be, without any fluid. A lady who has the catering for a large number of girls gives the bread in this way, and she tells me that there is keen competition for the most crusty portions.

I do not say that starch in the liquid and pappy form should find no place whatever in man's dietary at the present day, for this would imply the prohibition of porridge, boiled potatoes, milk puddings, and the like. We cannot put back the hand of time and return to the food of our primitive ancestors; nor is it desirable that we should; but we can, at least, arrange matters so that a large proportion of the starch we consume shall be in a form inviting mastication, such as crusts, stale bread, stale cake, biscuits, and so forth. The less children eat of pastry, or, indeed, of any luxurious foods, the better; if brought up on a healthy dietary and under healthy conditions generally, they will relish their simple fare more than the choicest dishes of the epicure. I do not, I say, object to the child consuming a certain proportion of starch in the liquid or pultaceous form, for if, by bringing him up on a rational dietary, his instinct to masticate be afforded due opportunity to develop he will be likely to subject even soft vegetable food to something like adequate mastication; this will tend to mitigate the evils associated with such food, not only by facilitating the digestion of starch, but by flushing the mouth and promoting the health of the teeth and buccal mucous membrane.

The question how far children should be allowed to crack nuts may here be considered. If the child has been brought up on pappy food, and has in consequence brittle and ill-developed teeth, the cracking of hard nuts will be likely to injure them, and this is *a fortiori* true if any of the teeth are carious or "filled." And not only nuts but hard food of any kind, such as ship's biscuits, may in these circumstances injure the teeth, as many of those who went through the recent South African campaign can testify. But if, on the other hand, the child has from the beginning been fed on coarse, hard foods, so that the teeth have been allowed to grow dense and strong, no harm is likely to ensue from cracking such nuts as filberts and Spanish nuts. If a squirrel or a monkey weighing a few pounds can do so with impunity, surely the young human should be able to also. The cracking should, however, be done by the molars, while such hard nuts as Brazils had best not be tackled at all.

Animal food does not need the same amount of mastication as vegetable food, since it is not digested in the mouth, though some contend that the mixture of proteid with alkaline saliva facilitates its subsequent peptonisation. Cooked animal food is, however, all the better for some mastication, owing to the coagulation of the proteids, and, in order to insure the efficient mastication of meat, fish, and poultry, Dr. Sim Wallace recommends that they should be given in large pieces cut thin. "Flat pieces about one inch square generally *necessitate* a certain amount of mastication. It is difficult to swallow large flat pieces of meat without mastication, but when finely minced little or no mastication is called forth." The younger the child the more underdone should the meat be.

Examination of the Mouth and Adjacent Parts

If a child be brought up on the lines indicated and under healthy conditions generally, it is tolerably certain that the maxillary apparatus will develop normally, that the teeth will be strong and well opposed, and show little tendency to disease; but, inasmuch as the methods advocated are but seldom put into practice, disorders of the teeth, more especially caries and irregularities, are common, and hence with a view to promote more efficient mastication it is always advisable to examine our patient's teeth.

Each individual tooth should be inspected in a good light for the presence of caries, and careful note should be taken of the "bite," a normal bite implying not only a proper opposition of the two rows of teeth but the capacity of the lower ones to move freely across the upper; mere vertical movement of the mandible does not constitute efficient mastication. In this connection it must not be forgotten that an unopposed molar is useless for purposes of mastication, and it is by no means rare to find in a mouth several sound unopposed molars which are for this reason absolutely functionless. Nay, more than this, it may happen that teeth, perfectly sound ones, too, far from helping, may actually interfere with mastication; thus, among the poor, we sometimes find all the teeth gone save the upper canines and the lower incisors, and the teeth and gums being alike unable to come into contact, nothing worthy of the name of mastication is possible; it would be far better to be without any teeth whatever, for the toothless gums would then be permitted to come into contact along their entire extent, under which condition they gradually harden and come to be quite efficient grinding agents.

Next the gums, the alveoli, and the roots of the teeth must be examined, especially for the presence of erosion, tartar, and pyorrhœa alveolaris, this latter condition being evidenced by the welling-up of pus upon pressing the gums against the sides of the teeth.

If our examination of the mouth discloses anything likely to interfere with mastication the aid of the dentist should at once be sought, but every physician should be so far acquainted with disorders of the teeth as to be able to say, in the majority of cases, at all events, when this is necessary. I am convinced that far more illness than is generally supposed is attributable to dental defects, and this even among the more leisured classes. With regard to pyorrhœa alveolaris, it has to be remembered that it not only does harm by causing loosening, lengthening, and shedding of the teeth, and thus interfering with mastication, but also by contaminating the stomach and the blood and thus upsetting the digestion and causing constitutional diseases, such as anæmia and arthritis; and inasmuch as poisonous discharges from the nose, the nasopharynx, the pharynx, and the tonsils may act in a similar way, these parts also should be inspected in connection with the examination of the teeth. In the dust-laden atmosphere of towns they are very liable to disease, and even when healthy are necessarily dirtied; some go so far as to advise all town dwellers daily to wash out the nasal passages and to gargle the throat; but, whatever may be thought of this, it is certain that under existing diëtetic conditions special means are needed in order to keep the mouth and teeth clean. When man fed on raw food this was not necessary, the food itself and the copious flow of saliva, induced by prolonged mastication, effectually cleansing these parts; but, under present conditions, food tends to remain within the mouth, especially between the teeth and in their crevices, and therefore special means are needed to remove it. This is done by "cleaning the teeth" and by rinsing the mouth.

The tooth-brush. — Probably the ideal method of cleaning the teeth is that adopted by many primitive and not a few semi-civilised peoples — viz., rubbing them with a twig of wood which has been teased out at one end so as to form a sort of brush by means of which the teeth can be burnished and food dislodged from them. The modern tooth-brush requires to be used with great caution, as it is capable of doing much harm, not only by removing the mucoid film, which, according to Dr. Wallace, protects the teeth from corroding agencies,[1] but probably

[1] This film can be felt by the tongue as a somewhat rough covering, which gives place to a smooth surface after the use of the tooth-brush.

also by injuring the edge of the gum and the neck of the teeth, and thus setting up the condition known as "erosion." Certain it is that some of the best sets of teeth I have encountered have been wholly unacquainted with the tooth-brush. In any case the brush should be employed with great care; it should be soft, and should always be drawn away from the gums both on the inner and outer aspect of the teeth towards the biting surface, as well as across the latter, never transversely across the outer surfaces, as so frequently is done. The object of these procedures is to dislodge any particles of food that may have collected between the teeth or in their crevices. For this purpose the tooth-pick may also be employed judiciously. In order to render the enamel of the teeth white it is better to rub each tooth carefully with some soft material, such as chamois leather, rather than to scrub them with a brush. Tooth-powders should not be used as a matter of routine, but only occasionally and for appearance rather than for cleanliness, and should consist of some simple non-irritant material. Antiseptic powders and washes are to be scrupulously avoided, for it is neither desirable nor possible to render the buccal cavity aseptic; myriads of bacteria flourish within it, many of which play a useful part as scavengers. The time of all others for cleaning the teeth is just before going to bed, so that the food shall not be allowed to decompose in the mouth during the night. There will then be no need to use the tooth-brush in the morning.

Rinsing the mouth. — The mouth should be rinsed out as a matter of routine after each meal and on rising, and care should be taken to do this before the early cup of tea, so as not to contaminate the stomach with the buccal secretions which have accumulated during the night. Inasmuch as raw vegetable food has a cleansing effect on the teeth, it is often a wise plan, especially in the case of children, to finish a meal with some kind of fruit, such as an apple or an orange. It hardly seems necessary to insist upon the necessity for keeping all artificial dentures thoroughly clean.

PROFESSOR PAWLOW'S DEMONSTRATIONS OF PSYCHIC INFLUENCE IN DIGESTION

[In presenting a theory of human alimentation involving mental or nervous as well as mechanical and chemical factors which influence it for good, it is not often that an author is able to enlist the assistance of a complete battery of scientific confirmation to fortify his own crude observations taken direct from personal experience in the study of natural requirements.

Professor Pawlow, with his marvellously skilful investigation of the workings of the digestive secretions, and Dr. Cannon of the Harvard Medical School, by aid of persistent and patient X-ray studies, explain how it is that earned appetite and thorough mouth-treatment of food are preliminary necessities of easy digestion, and that disturbance or shock of any sort during the process stop digestive proceedings and endanger health. They show also that when the mouth is used to do *all that it can do* in the work of digestion all the rest is easily accomplished by the NATURAL AUTOMATIC PROCESSES within the body.

They both show that we have, each of us, a certain responsibility in the matter of right digestion and healthy nutrition, and that all this personal responsibility is located in the head, in the mind, and in the mouth, and that while the alimentation is proceeding it is a sacred duty to do our part *right*, according to the intelligence that these most valuable demonstrations teach.

Professor Pawlow has allowed publication of his lectures in Russian and German, and recently Professor W. H. Thompson of the Physiological Department of Trinity College, Dublin, has made an English translation which is issued by Charles Griffin & Company of London and J. B. Lippincott of Philadelphia.

The A.B.-Z. of Our Own Nutrition

The author has to express special gratitude to Professor Pawlow, Professor Thompson, Messrs Griffin and Lippincott for permission to reprint herein some entire lectures and extracts that bear especially on the practical understanding of our subject.

Professor Pawlow is one of the Board of Scientific Assessors mentioned in the REPORT of a PLAN for an INTERNATIONAL INQUIRY into the subject of HUMAN NUTRITION.

In one of the lectures, not here reprinted, Professor Pawlow gives merited recognition of the early statements of the French physiologist Bloodlot relative to psychic influence on the digestive secretions made some half century ago, but discredited by physiologists since that time, owing to insufficiency of evidence brought forward in support of the statements.

Professor Pawlow's acknowledgment is so gracefully rendered that it is here given as a model of scientific courtesy.

"I have depicted the work of the gastric glands as we have seen it in our experiments, and as it has developed under our hands. Is the picture a new one? In its details, yes; but not in its fundamental features. However singular it may appear, the sketch of this picture was more than fifty years ago outlined by physiology. May this constitute another reason for our science relinquishing its characteristic shyness of new things and for its conversion to our interpretation of the phenomena under consideration!

"The talented author of the *Traité Analytique de la Digestion* — Blondlot — spoke in plain words of the importance of taking food, and of the specific excitability of the gastric mucous membrane. The facts adduced in the working up of his theory were naturally insufficient, but we must not forget that the first experiments on dogs with artificial gastric fistulæ had only just been performed. It is truly incomprehensible that the researches of Blondlot and his views upon the secretion of gastric juice have experienced during the past fifty years no completion, no additions, but, on the contrary, have passed out of sight, thanks to the faulty experiments and erroneous representations of later authors. Only in the works of a few writers — and those mostly French — has Blondlot's theory survived. Of other investigators we must give mention to Heidenhain, who has enriched the physiology of absorption in general, but more especially, in connection with the secretory work of the stomach, has discovered many important facts and has given birth to many fruitful ideas. From him proceed the subdivision of the secretory process according to periods and exciting agencies, as well as the suggestion that it would be important to investigate the individual food-stuffs in relation to the work of the stomach. Heidenhain's results are contained in his well-known article on the secretion of the cardiac glands of the stomach, published in the year 1879 in PFLÜGER'S ARCHIVES. The work of Blondlot and the additions of Heidenhain comprise almost everything of importance which was accomplished by physiology in fifty years concerning the conditions and mechanism of the secretory work of the stomach during digestion. Full of moment, however, for our subject was the obvious error that mechanical stimulation constituted an effective excitant of the gastric glands, and this error was in its turn a result of faulty methods." — HORACE FLETCHER.]

LECTURE IV

GENERAL SCHEME OF AN INNERVATION MECHANISM — THE WORK OF THE NERVOUS APPARATUS OF THE SALIVARY GLANDS — APPETITE, THE FIRST AND MOST POTENT EXCITER OF THE GASTRIC SECRETION

Constituent parts of a complete innervation mechanism — The special duty of the peripheral terminations of afferent nerves — The specific qualities of nerve cells — Analogy between the innervation mechanism of the salivary glands and that of the deeper-lying glands of digestion — The exciting agencies of the nervous mechanism of the salivary glands; their particular properties — Differences between the exciting agencies of the different salivary glands — Discussion of the sham feeding experiment — Mechanical and chemical stimulation of the cavity of the mouth has no effect on the gastric glands — The experiment of Bidder and

Schmidt relative to psychic excitation of the gastric secretion — Conditions for success in this experiment — The passionate longing for food — the appetite — alone brings on the secretory effect in the sham feeding experiment.

GENTLEMEN, — As you have learned in the last lecture, and also in part have seen by direct experiment, the nervous system can influence the work of our glands in the most diverse ways. The vagus nerve, already burdened with many duties, has, in addition, proved itself to be an undoubted exciter of the gastric glands and of the pancreas. But we must also assign to the sympathetic nerve a similar *rôle*. This is a matter which cannot be doubted, so far as the pancreas is concerned, and is highly probable as regards the stomach. We also saw good reason for believing that these two nerves contained two different classes of fibres, secretory and trophic, a condition which had already been proved to exist by Heidenhain for the nerves of the salivary glands. As a hypothesis we might even have proceeded a step farther and have divided Heidenhain's trophic nerves into separate classes of secretory fibres. Lastly, we advanced important experimental evidence to show the existence of special inhibitory fibres to the glands, and these fibres also run in the vagus, the list of whose functions seems almost interminable.

We obtained these results by division and artificial excitation of the nerves which run to the glands. But when, how, and by what means these nerves are thrown into activity during the normal course of physiological events remains a question.

In order to avoid repetition, and at the same time impart the utmost clearness to our representation, it may be useful to bring before your minds at once the plan of innervation of a given organ, all the more since this scheme is seldom completely followed out or adequately described in physiological text-books. Consequently, it is not borne in mind with sufficient precision by the majority of medical men.

A complete innervation mechanism consists of the peripheral endings of the centripetal (afferent) nerves, the centripetal nerves themselves, the nerve cells (a group of nerve cells connected with each other is termed a "nerve centre"), the centrifugal (efferent) nerves, and, lastly, their peripheral terminations. Physiology now accepts it as a settled fact, that nerve fibres serve only as *conductors* of nervous impulses, which come in from contiguous links of the nervous chain. Only the peripheral endings of nerves and the nerve cells themselves have the power of transforming the external stimulus[1]

[1] By the term "external stimulus" I mean here without distinction every outward agency of nature, as well as every

into a nervous impulse. In other words, in the intact organism these alone constitute the normal receiving apparatus of the nervous system. Whether the peripheral ends of centrifugal (efferent) nerves are likewise able to function as normal sites for the application of external stimuli has still to be answered. Consequently, when any external agency excites the peripheral terminations — the receiving stations — of centripetal nerves in this or that organ, the effect of the stimulus will be conveyed through the centripetal nerves, as through a receiving wire, to the central station — the nerve cells. Here it becomes changed into a definite impulse and now comes back along the centrifugal nerves— the outgoing wires.

The utmost importance is to be attached to the fact that only the peripheral endings of centripetal (afferent) nerves, in contrast to nerve fibres themselves, respond to *specific* stimuli; that is to say, are able to transform definite kinds of external stimuli into nervous impulses. The function of the end organs with which they are connected is therefore of a purposive nature; in other words, these organs are only called into play by certain definite conditions, and impart

agency which has its seat within the organism. The word "external" applies here to everything with the single exception of the nervous system itself.

the idea of being aware of their purpose, of being conscious of their duty. We have long known that the peripheral endings of sensory nerves are possessed of a high degree of speciality, and cannot therefore have any doubt regarding the specific nature of the end organs of other centripetal nerves. This is a sore point in present-day physiology. But, notwithstanding our knowledge of the separate parts of the animal body, we shall only be able to form a true conception of the motive agencies of the whole complicated machine, when we have established the specific excitability of the end apparatus of every centripetal nerve, and have discovered all the mechanical, chemical, and other factors which throw this or that end apparatus into an active condition. I always look upon it as a period of scientific inadequacy so long as the effects of the most diverse external agencies upon any normal physiological process are admitted to be indistinguishable. As the work of the digestive canal is now represented in the majority of text-books, and consequently presented to the mind of the physician, it bears the impress of this period. To impart to the physician a more correct conception of this matter was my chief object in giving these lectures. I hope, indeed, to furnish you with evidence sufficiently convincing, that the alimentary canal is endowed not with mere general excitability; that is to say, does not respond to every conceivable form of agency, but only to special conditions which are different for the different portions of its length. Just as men and animals in the world are only able to maintain their existence and constantly adapt themselves to changing circumstances by aid of the peripheral endings of their sensory nerves, so every organ, indeed every cell of every organ, can only maintain its place in the animal microcosm, and adapt itself to the activity of innumerable associates, as well as to the general life of the whole, by virtue of the fact that the peripheral end apparatus of its centripetal nerves possesses a specific excitability.

The same applies to the nerve cells: obviously they are endowed with specific sensibility. Irrespective of the excitations which are communicated to them from centripetal nerves, they respond, as originators of nervous impulses, only or at least mainly to definite forms of mechanical, chemical, or other stimuli arising in the organism. This follows not alone from a number of physiological facts but also from various pharmacological data. Thus we learn that various drugs excite or annul the activity of definite portions of the nervous system, at least in the earlier phases of their effects. This specific excitability of nerve cells, just as much as the same property of peripheral end organs, lies at the bottom of the purposive action of these organs.

Hence, our next duty is to endeavour to discover the normal exciting conditions of the centripetal nerves belonging to the glands which we had under consideration in our last lecture, or, more correctly, to find out the conditions which excite the centres, as well as the peripheral endings of the different nerves, which form parts of the nervous apparatus of these glands. We have, therefore, for each phase of the work of secretion, to find out that portion of the nervous mechanism which is for the time being under excitation, and to discover the primary agency by which this condition is elicited. This would include an exact analysis of the stimulating influence which mastication and food exert upon the nervous mechanism of these glands. We shall also be able more fully to comprehend the inner mechanism underlying the facts which formed the subject of the second lecture. This, of course, is an ideal programme which we can only follow out as far as the present state of physiology permits. It may now be instructive, and, for our further conclusions, advantageous, to glance shortly at the nervous control of the salivary glands.

The salivary glands, whose innervation has long ago been investigated, have generally been accepted as types of the deeper-lying digestive glands, and when it became necessary to form a conception of the mode of activity of the latter, medical science resorted to a bold analogy and thought of the nervous apparatus of the salivary glands. But the attempts of investigators to apply rigidly to others the scheme of innervation which holds good for the salivary glands, have done considerable harm to the usefulness of the analogy and have prevented our arriving at a correct idea of the plan of innervation of the abdominal glands. We have already had an example of this nature before us. In the salivary glands we have no clearly marked indications of nervous inhibition, and this circumstance has decidely retarded the due development of our knowledge of the nervous control of the abdominal glands. Authors naturally expected to see a simple and prompt stimulation-effect from the same conditions of experiment which sufficed for the salivary glands, and the failure of this gave them, as they thought, the right to deny the existence of any extrinsic nervous influence upon the abdominal glands. The error is now obvious; the abdominal glands behave in some ways different from the salivary glands, and for their successful investigation, other conditions of experiment are necessary than those which held good for the former. In the working of the abdominal glands nervous inhibitory processes play a large part, but they are almost wholly absent in the case of the salivary glands. This is an additional warning that one must never push the conclusions drawn from analogy too far, but must constantly bear in mind that the life-functions of all organs are extremely complicated, and that the work of even the most apparently similar organs should be submitted to separate and careful observation. To me it appears that the unjustified analogy drawn between the abdominal and salivary glands has to be credited with another important misapprehension. And precisely for this reason I think it desirable to bring under consideration, if only in brief fashion, the conditions of work of the salivary glands, especially since Dr. Glinski has instituted in the laboratory some easily performed experiments which bear upon the matter.

The experiences of daily life teach us from the outset, that the activity of the salivary glands begins even before the introduction of food into the mouth. With an empty stomach, the sight of food or even the thought of it is sufficient to set the salivary glands at once into activity; indeed, the well-known expression, "to make one's mouth water," is based upon this fact. Hence a psychic event, the eager longing for food, must be accepted as an undoubted excitant of the nervous centre for the salivary glands. On the other hand, the same every-day experience, as well as numerous experiments upon animals, teach us that a number of substances, when brought into contact with the mucous membrane of the mouth, are likewise able to call forth a secretion of saliva. One even acquires the impression that everything brought into the mouth may reflexly influence these glands, the only difference being a gradual shading off in the effect, dependent upon the strength of the stimulation which the substance introduced is able to exert, and it appears to me that it is precisely this impression which has driven the idea into the background, that the peripheral end apparatus of the centripetal nerves of the digestive canal are specifically excitable. The facts were here correctly observed, but their indications erroneously interpreted.

The great multiplicity of excitants of salivary secretion, has without doubt, some connection with the complicated physiological functions of the saliva. This is the first fluid encountered by everything which enters the alimentary canal. It must, therefore, in a sense play the part of host to every substance taken in — moisten the dry, dissolve the soluble, envelop the hard and bulky with mucus in order to facilitate its passage down the narrow œsophagus; and submit certain forms of food material, such as starch, to a process of chemical elaboration. Nor is its duty by any means ended here. The saliva is secreted in the first compartment of the alimentary canal, which is at the same time the sorting-room of the organism. Much of what enters the mouth may prove in the testing process to be useless, or even noxious, and must either have its deleterious properties neutralised or be completely rejected. The saliva is secreted in the first instance to obviate injurious effects in some way; thus, for example, a strong acid is to a certain degree neutralised, while other corroding substances may be simply diluted, and by mere reduction of concentration have their harmfulness diminished.

In the second place, when the injurious substances have to be wholly removed, the saliva plays the *rôle* of a washing-out fluid; otherwise the material, by clinging to the mucous membrane of the mouth, might in longer or shorter time gain entry into the blood and there develop its noxious influence. This last function of the fluid is hardly taken into account at all in physiology, and yet it is evident that the saliva, as a cleansing fluid, must have a wide importance.

If you only think of how often we are impelled to expectorate, that is, to wash out the mouth with saliva after something unpleasant, this will be clear. Such a view finds additional support when we reflect that a feeling of disgust produces almost as strong a flow of saliva as the sight of a tasty meal. In both cases the secretion performs the office of forerunner: in the first it prepares for the washing out of the mouth, in the second for the requisite elaboration of the food. Think how often, when something disagreeable enters the mouth, with what rapidity the saliva is poured out, even after the unpleasant substance has been for a considerable time removed, and not a trace more is apparent to the sense of taste. Indeed, long afterwards one has only to recall the circumstances to mind in order to bring on anew the secretion of saliva. Apparently the psychic excitation of the nerves of salivary secretion also ushers in the act of vomiting, which, as is well known, can be called forth by mental influence. Further, the function of the saliva just mentioned is probably the true physiological explanation of the feeling of disgust which many persons experience at the sight of the secretion itself.

Hence I hold that substances which obtain entry to the mouth set up a secretion of saliva only because we have here the seat of a definite physiological sense, and not because the peripheral terminations of the buccal nerves are devoid of specific excitability, and capable of being thrown into action by every desired form of stimulus. In other words, the specific excitability of the peripheral endings of the salivary nerves is very comprehensive and widely extended. This is no picture of the imagination, for it can be supported by facts. To say nothing of the testimony of earlier authors, that the salivary glands have each particular exciting agencies to which they specially respond, we can demonstrate the following facts from the material collected in our laboratory.

Dr. Glinski isolated the orifices of the salivary glands in dogs with portions of the adjoining mucous membrane, brought them out of the oral cavity, and caused them to heal into the edges of the skin wounds. In his first animal the ducts of the submaxillary gland were thus led outwards. By means of a Mendeljeff's clip, the wide end of a conical funnel of waterproof material was attached to the skin surrounding the orifice. To the narrow end a small test-tube, which served to collect the saliva, was attached by a wire. I now offer such an animal a piece of flesh, and, as you see, the tube fills up at once with saliva. I stop tempting the dog, hang on a new test-tube, and give it a few pieces of flesh to eat; once more a strong secretion of saliva results. A new tube is now attached to the funnel, the dog's mouth is opened, and a pinch of fine sand thrown in; again there is a flow of saliva. Once more a new test-tube; and now I apply to the buccal mucous membrane, the plume of a feather dipped in acid solution, with the result that I obtain a strong flow of saliva. One may employ a number of substances in this way, when a similar effect is always produced. You see, in this, such a comprehensive excitability of the innervation apparatus of the salivary glands that you might readily interpret it as meaning the power of response to all and sundry forms of stimulation. We now proceed, however, to another dog, whose parotid duct has in a similar manner been diverted outwards. The saliva is collected in the same way. We tempt the dog with a piece of flesh, but to our astonishment no saliva flows, and yet the animal is most eager for the savoury meal offered. Now we give it some raw flesh to eat; again the secretion of saliva is as good as absent; only when I come near can I detect one or two drops of saliva running down the sides of the tube. Probably you will say there is something wrong, either with the method or with the glands of the animal. But wait a little. I now give the dog finely powdered dry flesh, and obtain at once an abundant secretion. Should any one happen to think that the variation in the result is dependent, not on a different specific activity of the glands, but on individual differences in the dogs, I respond that Dr. Glinski has had an animal with double parotid and submaxillary fistulæ, and was able to observe on one and the same dog, a like behaviour on the part of the glands to that which we have just seen in two different individuals. An analogous experiment with bread was also carried out by Dr. Glinski. The eating of fresh moist bread produced no secretion worth mentioning, while dry bread, on the other hand, caused the saliva to flow in large quantities. The results of this experiment permit us to draw extremely instructive conclusions. In the first place, the several salivary glands are, as a matter of fact, very sharply differentiated in the conditions necessary for their activity — that is to say, in respect to the agencies which excite their nervous mechanisms. Secondly, the innervation apparatus of the parotid manifests a very sharp selective power in the choice, so to speak, of an adequate stimulus. The mechanical effect of large pieces of flesh is naturally much greater than that of the finely powdered material, and yet it was precisely to the latter that the glands responded. The stimulus is, therefore, not due to the mechanical, but to some other property of the food. This other property is obviously the dryness of the material. Our example illustrates how that which we may term "purposiveness" comes into play in the working of our glands and also how erroneous is the opinion that the mechanical stimulus is all potent. Indeed, previous authors have already pointed out that dry substances cause a specially free secretion of saliva, and yet physiological opinion throughout the length and breadth of the land, as expressed in text-books, has chosen to recognise a *universal* instead of a *specific* excitability. Dr. Wulfson, who is at present carrying on the investigation of salivary secretion in our laboratory, has added a very interesting observation to the results of Dr. Glinski already related. The parotid gland, which is hardly, if at all, excited when one offers fresh meat to the animal, responds with a very active secretion, when dry food (bread or powdered meat) is offered. This phenomenon is all the more surprising since the desire of the animal for eating is much more strongly excited by flesh than by dry bread. I am quite convinced that an exact study of the exciting agencies of the three salivary glands will furnish a number of new data bearing upon the question in hand.

The second reagent which is poured out on the raw material in the digestive canal is the gastric juice. How, in the normal course of events, is the work of the gastric glands, which prepare this juice, called into play? With the first, and manifestly important factor, which has a relation thereto, you are already acquainted, and, indeed, have already seen. I refer to the production of gastric juice in the empty stomach, as a result merely of the swallowing of food in the so-called sham feeding of an œsophagotomised dog. When one takes into consideration the absolute independence of this factor, and the intensity of the effect, which makes itself evident in the secretion of a large quantity of juice of high digestive power, the exciting agency which brings about such secretion must be recognised as one of the most important and effective processes in gastric digestion. But in what does it consist? At first sight it appears — and when I previously drew your attention to the fact I expressed the opinion — that there is here a simple reflex effect from the cavity of the mouth upon the secretory nerves of the stomach, similar to the reflex excitation, *e.g.*, of the parotid gland, by finely powdered flesh thrown into the mouth. Now, however, I assert quite emphatically that this is not the case. We have, it is true, in the activity of the salivary glands an analogous phenomenon to indicate — not, however, that of which we have just spoken. We might apply every conceivable form of stimulus which could possibly come into play in the act of eating, and yet would not obtain the slightest indication of secretory activity in the stomach. In this dog with a gastric fistula, and with also a divided œsophagus, I will try such an experiment, using the most effective chemical stimulus to the buccal mucous membrane, viz., acid solution.

The secretion of saliva begins at once, as you see; the acid is, therefore, effective. From the stomach, however, in spite of continued excitation, no secretion results, although the acid, mixed with the saliva, is swallowed and flows out again from the upper segment of the œsophagus — that is to say, passes along precisely the same path that the food takes in sham feeding.

We could experiment in the same way with a number of other substances: saline, bitters, pepper (strong local excitation), mustard, and so on, and always with the same results; a free secretion of saliva, but perfect quiescence of the gastric glands. We may even, with the same object, employ the soluble constituents of flesh in the form of a decoction, and likewise observe, in most cases at least, no sign of activity on the part of the gastric glands.

With the chemical we may also combine a

mechanical stimulus. We can, for example, wipe out the mouth with a sponge soaked in the solution to be experimented with, but always with the same negative result. We may finally give such pieces of sponge, or even smooth stones of considerable size, to the dog to swallow, passing them back behind the anterior pillars of the fauces and allowing them to fall out again, from the upper portion of œsophagus. It may be added that a well-taught dog puts up with all these procedures without the slightest protest. You see that all the manipulations in this case are carried out with bare hands and without instrumental aid. One can easily train a dog to swallow stones which are placed in the anterior part of the buccal cavity. It simply makes a few chewing movements and swallows them down. The dog on which the acid experiment has just been made serves also for the swallowing of the stones. The attendant now places some pebbles in the front part of the mouth, when the animal rolls them round, as if chewing and gnawing them, and then swallows them. The stones fall out, as you see, from the œsophagus, and drop with an audible sound upon the table. This play with the stones has now lasted fifteen or twenty minutes (in the laboratory we have often kept it up for hours), and yet not a drop of gastric juice is to be seen.

In order to prove that the dog is perfectly healthy and normal, we lay aside the stones and proceed to our old experiment of sham feeding. As you see, the first drop of gastric juice makes its appearance precisely at the end of five minutes, and after a further five minutes we have collected more than 15 c.c. of the fluid; consequently there can be no doubt that in this dog both gastric glands and nerves are uninjured and function in normal manner. At one time we even had a dog which voluntarily took the stones out of one's hand and swallowed them; the sagacious creature had seen our object in previous experiments and learned to perform it of its own accord! But in this case also the result was negative.

Clearly, therefore, neither chemical nor mechanical stimulation of the buccal mucous membrane is capable of reflexly exciting the nerves of the stomach. Further, it is obvious that the excitation of these nerves in sham feeding is not the result of a stimulation coincidently produced; that is to say, the excitement of the chewing and swallowing centres does not imply simultaneous action of the secretory centre of the gastric glands. In what, then, does this influence consist which is intrinsic to the sham feeding, but which we have not been able to reproduce in our analytical investigation? There is only one thing to think of, namely, the eager desire for food, and the feeling of satisfaction and contentment derived from its enjoyment.

It has, indeed, been known for forty years, thanks to the experiments of Bidder and Schmidt, that at times, the offering of food to a hungry dog, in other words, the excitement of a keen desire for it, is sufficient to cause a flow of gastric juice from the empty stomach. We shall presently have occasion to observe the force of this physiological factor. Here I bring before you another dog, likewise having a gastric fistula with divided œsophagus. The stomach has been washed out half an hour ago, and since then not a drop of gastric juice has escaped. We begin to get ready a meal of flesh and sausage before the animal as if we meant to feed it. We take the pieces of flesh from one place, chop them up, and lay them in another, passing them in front of the dog's nose, and so on. The animal, as you see, manifests the liveliest interest in our proceedings, stretches and distends itself, endeavours to get out of its cage and come to the food, chatters its teeth together, swallows saliva, and so on. Precisely five minutes after we began to tease the animal in this way the first drops of gastric juice appear in the fistula. The secretion grows ever stronger and stronger, till it flows in a considerable stream. After the lapse of a few minutes we can count the number of cubic centimetres by tens. The meaning of this experiment is so clear as to require no explanation; the passionate longing for food, and this alone, has called forth under our eyes a most intense activity of the gastric glands. If the experiment be frequently repeated, one can easily observe that the keener and more eager the desire on the part of the dog for the food, the more certain and intense is the secretory effect. In extreme cases there is even a quantitative relationship between this effect and that of the sham feeding.

Here is an experiment of Professor Ssanozki, in which the secretory effect of the mere tempting of the animal with the sight of food is compared with that of sham feeding. A few threads of alkaline mucus had just escaped from the stomach, and then the excitation of the dog with flesh was begun. After six minutes the secretion commenced and continued as follows:

Duration of the flow.	Quantity of the juice.
8 minutes	10 c.c.
4 "	10 "
4 "	10 "
10 "	10 "
10 "	10 "
8 "	10 "
8 "	10 "
19 "	10 "
19 "	3 "

Then followed a sham feeding for six minutes.

Duration of the flow.	Quantity of the juice.
17 minutes	10 c.c.
9 "	10 "
8 "	10 "

It is clear that in this case the tempting, instead of being less effective than the sham feeding, on the contrary excelled it.

Consequently, the observation of Bidder and Schmidt was perfectly correct. It cannot, however, be said that it received general recognition in physiology, or that it was sufficiently appreciated. There are authors who could never convince themselves of its reality, and in many physiological text-books it is not once mentioned. By way of explanation, we shall now consider how this matter must be dealt with by those who wish to observe the effect. It is only under certain conditions that it can be seen. Firstly, the animal must be healthy and vigorous; it must have a perfectly uninjured gastric mucous membrane; and this, from the description in the case of many authors who obtained a negative result, was not the case. Secondly, the success of the experiment, as stated above, is dependent upon the intensity of the desire for eating, and this, again, is dependent upon how freely and how long beforehand the dog had eaten, and also upon what it is tempted with, whether with a dish that excites its desire or leaves its interest unawakened. It is known that dogs have very different tastes, just as men have. Thirdly, one may find among the dogs positively careless, indifferent creatures, incapable of being perturbed in this way by anything which has not actually reached their mouths, and patiently waiting till the food is given them. Hence for success in the experiment, eager, impressionable, and excitable animals are necessary. Fourthly, one has to reckon with the sense and cunning of the dog, a factor which is not lightly to be disregarded. Often the animals perceive at once that they are only being teased with the food, become annoyed thereat, and turn away offended at what is being done before them. We must, therefore, so arrange matters as if the animals were not going to be disappointed but fed in reality. If attention be paid to these conditions the experiment of " psychic excitation of the gastric secretion," as we usually term it, will be found to be as reliable as the experiment of sham feeding. When one is occupied for a length of time with the study of the gastric secretion under different conditions, one becomes convinced of what a dangerous source of error this psychic excitability may become in the different experiments. We must constantly fight, so to speak, against this factor, keep it ever in view, and guard against it. If the dog has not eaten for a long time, every movement, — the going out of the room, the appearance of the attendant who ordinarily feeds the animal — in a word, every little triviality may give rise to excitation of the gastric glands. The minutest attention is necessary in order to avoid such sources of error, and we should not be far wrong if we said that much which has been ascribed in former investigations to the effect of this or that agency was in reality a result of unobserved psychic influence. Consequently, in order to verify our own conclusions concerning the effects of this or that condition, we have performed many of our experiments on sleeping animals, having beforehand convinced ourselves by frequent repetition that sleep exercises no restraining influence on the working of the gastric glands.

When we recall to mind the failure of our attempts to obtain a secretion of gastric juice by any stimulation whatever of the buccal mucous membrane, and at the same time see how constant and intense the action of this psychic impression is, we are forced to the inevitable conclusion that in our sham feeding experiment the whole secretory effect is due to the psychic stimulus, that is to say, to the keen desire on the part of the animal for food and the satisfaction of enjoying it.

In view of the importance of the act of eating, which even now is apparent, but which will become still more obvious when the succeeding periods of secretion are investigated, we have spared neither time nor trouble to arrive at a correct explanation of the mechanism of this factor. We have, therefore, taken in hand a number of modifications of the sham feeding experiment, and these investigations have confirmed the opinion at which we had arrived. If, for instance, the dog has been prepared by a long fast of two to three days, a very intense secretion of gastric juice will always be obtained by the sham feeding experiment, no matter what may be given it to eat, whether boiled or raw flesh, bread or coagulated egg-white, etc. The dog, however, which has not fasted, that is to say has been fed fifteen to twenty hours before, will pick and choose amongst the different foods, eating one with great greed, tolerating another, and refusing altogether a third, and, corresponding therewith, the amount and quality of the gastric juice will manifest wide variations. The more eagerly the dog eats the more juice will be secreted and the greater the digestive power which it possesses. The majority of dogs prefer flesh to bread, and correspondingly less juice will be produced by sham feeding with bread than with flesh. Sometimes, however, we find dogs which will devour bread with greater appetite than flesh. In these cases one obtains more and stronger juice in sham feeding with bread than with flesh. Here is a case in point: a dog is given boiled meat which has been cut into pieces of definite size, and the pieces follow each other at regular intervals of time. The animal eats, but soon, from its behaviour, you see that it develops no particular greed for the meal, and this observation is confirmed by the fact that after fifteen to twenty minutes it ceases taking the flesh. The secretion of juice has meanwhile either not begun at all, or only after a longer interval than five minutes, and remains scanty to the end. Now wait till the secretion has stopped and give the same dog raw flesh, either forthwith or next day, in pieces of the same size and at the same rate as before. The raw meat tastes excellently to the dog; it eats for hours at a time; the secretion of gastric juice begins precisely after five minutes and is very active. With another dog which prefers boiled to raw meat exactly the reverse occurs. Broth, soup, milk — towards which dogs are usually more indifferent than towards solid food — often produce in sham feeding either no secretion at all or only very little, although broth, for instance has essentially the same taste as flesh.

It is therefore clear that in sham feeding the psychic effect may readily become an absolute and independent factor. All the conditions which we enumerated above, and which are necessary for the successful production of the psychic effect, hold good in combined form for the sham feeding experiment. The dog eats with greed before one's eyes; the food which it receives is pleasant; it not only imagines food but actually eats it, and has therefore no reason to feel offended, for naturally the idea does not occur to any of the dogs that all their trouble is in vain.

Consequently, in the sham feeding experiment, by the act of eating, the excitation of the nerves of the gastric glands depends upon a psychical factor which has here grown into a physiological one, that is to say, is just as much a matter of course, and appears quite as regularly under given conditions as any other physiological result. Regarded from the purely physiological side, the process may be said to be a complicated reflex act. Its complexity arises from this, that the ultimate object is attained by the joint working of many separate organic functions. The material to be digested — the food — is only found outside the organism in the surrounding world. It is acquired not alone by the exercise of muscular force, but also by the intervention of higher functions, such as judgment, will, desire. Hence the simultaneous excitation of the different sense organs, of sight, of hearing, of smell and taste, is the first and strongest impulse towards the activity of the gastric glands. This especially applies to the two latter senses, since they are only excited when the food has already entered the organism, or at least has arrived very near it. It is by the establishment of this passionate desire for eating that unerring and untiring nature has linked the seeking and finding of food with the commencement of the work of digestion. That this factor, which we have now carefully analysed, stands in closest connection with an every-day phenomenon of human life, namely, appetite, may easily be predicated. This agency, which is so important to life and so full of mystery to science, becomes here at length incorporated into flesh and blood, transformed from a subjective sensation into a concrete factor of the physiological laboratory.

We are therefore justified in saying that the appetite is the first and mightiest exciter of the secretory nerves of the stomach, a factor which embodies in itself a something capable of impelling the empty stomach of the dog in the sham feeding experiment to secrete large quantities of the strongest juice. A good appetite in eating is equivalent from the outset to a vigorous secretion of the strongest juice; where there is no appetite this juice is also absent. To restore appetite to a man means to secure him a large stock of gastric juice wherewith to begin the digestion of the meal.

LECTURE V

PERIOD OF OCCURRENCE AND IMPORTANCE OF THE PSYCHIC OR APPETITE JUICE IN THE SECRETORY WORK OF THE STOMACH — THE INEFFICIENCY OF MECHANICAL STIMULATION OF THE NERVOUS APPARATUS OF THE GASTRIC GLANDS

The psychic secretion is the normal commencement, in the majority of cases, of secretory activity on the part of the gastric glands. If the meal be subdivided and administered at intervals, the psychic juice appears each time — Demonstration of "appetite juice" in a dog with an isolated gastric *cul-de-sac*. The work of the gastric glands if appetite juice be avoided by introducing food through a gastric fistula unperceived by the animal — Digestion of flesh by the stomach with and without sham feeding — Duration of the secretory influence of sham feeding — After the cessation of the psychic effect, how is the secretory work of the stomach maintained? — Experiments to prove the ineffectiveness of mechanical stimulation: excitation of the mucous membrane by means of a glass rod, a feather, a puff of sand, and by rhythmic dilatation of an india-rubber ball — Contact between the food and the stomach-wall may indirectly call the activity of the glands into play by awakening or increasing the desire for food.

GENTLEMEN, — On the last occasion we made ourselves acquainted with the first normal impulse which, in the natural course of events, calls into activity the innervation apparatus of the gastric glands. This impulse is a mental one, and consists in a passionate longing for food, that which in every-day life, and in the practice of the physician, is called "appetite," and which everybody, both medical and lay, endeavours carefully to promote. We may now venture to say explicitly, APPETITE IS JUICE, a fact which at once displays the pre-eminent importance of the sensation. Medical science endeavours to assist the debilitated stomach by introducing the active constituent of gastric juice — pepsin — from without, or by prescribing other remedies believed to promote its secretion. It is, however, of interest to follow our experimental investigation still farther. What position is to be assigned to the "psychic" or "appetite-juice"[1] in the course of normal gastric digestion? Is any definite *rôle* to be attributed to it? What course does gastric digestion take when it is absent? Fortunately to all these important questions satisfactory answers are forthcoming by experiment. We have only to regret that these answers come so late.

Let us recall to memory how the secretion of gastric juice proceeded after feeding with flesh or bread in the case of our dog with the

[1] One may be permitted to use this expression for the sake of brevity.

isolated miniature stomach. The following are the quantities and digestive capabilities of the first two hourly portions of juice after the administration of 200 grams of flesh or bread (experiments by Dr. Chigin):

Hour.	Flesh.		Bread.	
	Quantity of juice.	Digestive power.	Quantity of juice.	Digestive power.
1st	12.4 c.c.	5.43 mm.	13.4 c.c.	5.37 mm.
2nd	13.5 "	3.63 "	7.4 "	6.50 "

You see at once that the secretion of the first hour is identical in the two cases both as regards quantity and digestive power, and only in the second is the secretory work differentiated according to the nature of the food. How are we to explain the secretion which takes place at the commencement? Is it not the same which we have already seen in the sham feeding experiments? Is not this first onrush of the stream of secretion the preliminary psychic juice? Unquestionably, gentlemen, this is the case, and we may convince ourselves of the fact in the most diverse ways. Above all, the following is clear: whatever occurs in the so-called sham feeding cannot wholly be absent in the case of normal feeding, since the former is nothing else than the isolated commencement of normal digestion. This justifiable inference is fully confirmed, if the secretion of the first hours after the administration of flesh and bread be compared with that after simple sham feeding. In the case of feeding with flesh and bread, the identically similar and high digestive power of the first hourly portions is striking, and this power coincides with what we have met in sham feeding. Further, if the quantity of juice from the miniature stomach during the first hour be compared with that produced by the non-resected part of the organ, — to do which we must multiply it by ten, since the resected *cul-de-sac* is approximately one-tenth of the whole organ, — it is here again found that the quantity approximately corresponds to the mean values obtained by sham feeding. Finally, the depression in digestive power or quantity of juice (with flesh, decrease of digestive power; with bread, decline in the quantity of juice), which sets in soon after the taking of food, indicates that the two conditions are connected with the ingestion of food — *i. e.*, with a transitory factor which soon passes away and gives place to other conditions. Our explanation becomes still more convincing when we take into consideration the effects of other foods. If you give the dog, for example, something else to eat which does not interest it to the same degree as flesh or bread, you will find the initial increase in quantity and strength of juice does not appear. Offer the animal milk, for example, which in sham feeding, especially if it does not last long, calls forth, as a rule, no secretion, or at all events only very little, and the rapid flow of the commencement — the already-mentioned initial rise — absolutely fails to appear. You have already seen the figures which deal with this matter; I think it necessary, however, to bring them forward again in order that you may be better able to compare them with the secretion after flesh and bread.

The dog was given 600 c.c. of milk (experiment by Dr. Chigin).

Hour.	Quantity of juice.	Digestive power.
1st	4.2 c.c.	3.57 mm.
2nd	12.4 "	2.63 "

We have now begun the analytical examination of the variations of our secretory curve. But owing to the importance of the matter we did not confine ourselves to conclusions which might be drawn from earlier investigations. We turned to new forms of experiment for further proof.

Thus we divided the ordinary ration of flesh given to our dogs — 400 grams — into four equal parts, which were administered at intervals of an hour and a half. (Experiments by Privat docent Kotljar and Dr. Lobassoff.) Each time after the dog received its 100 grams of flesh we were able to detect a rise both in the quantity and in the digestive power of the juice. The following table shows the figures in question:

Half-hour periods.	Quantity of juice.	Digestive power.	Remarks.
1st	3.1 c.c.	5.13 mm.	100 grms. flesh given.
2nd	5.0 "	4.63 "	
3rd	4.7 "	4.50 "	
4th	5.4 "	4.88 "	100 grms. " "
5th	5.5 "	3.38 "	
6th	4.7 "	2.75 "	
7th	6.0 "	3.75 "	100 grms. " "
8th	5.4 "	2.50 "	
9th	5.9 "	2.50 "	
10th	5.4 "	3.88 "	100 grms. " "
11th	5.3 "	3.0 "	
12th	4.2 "	2.5 "	

In the curve which follows, only the variations of digestive power are represented.

It is clear that the increase, both of digestive power and of juice volume, is connected with the act of taking in food.

It appeared of interest definitely to determine the volume and properties of the secretion called forth by the act of eating in the dog with the isolated stomach. We endeavoured, therefore, at the beginning, to imitate the conditions of sham feeding as they occurred in the case of the dog with divided œsophagus. In addition to the fistular orifice leading into the isolated miniature stomach, another was opened into the main portion of the organ. If we now fed the dog in the ordinary way with small pieces of flesh, these were received back again at the orifice of the latter fistula, covered with saliva. Precisely as in sham feeding, after five minutes the juice began to flow simultaneously, from both the large and small stomachs. The secretion ran a corresponding course in the two cavities and ceased at the same length of time in both after the administration of food was stopped. Here is an instance taken from such an experiment performed by Dr. Lobassoff.

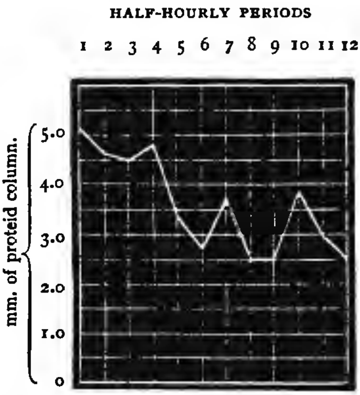


FIGURE 1.—Curve of digestive power constructed from the foregoing table.

In five minutes the dog had eaten eighty pieces of flesh (weighing 172 grams), all of which soon afterwards dropped out at the fistula. The secretion began in both stomachs after the lapse of seven minutes from the commencement of the feeding, and proceeded as follows:

<table>
<tr><th rowspan="2">Hour.</th><th colspan="2">Miniature stomach.</th><th colspan="2">Main stomach.</th></tr>
<tr><th>Quantity of juice.</th><th>Digestive power.</th><th>Quantity of juice.</th><th>Digestive power.</th></tr>
<tr><td>1</td><td>7.7 c.c.</td><td></td><td>83.2 c.c.</td><td>5.35 mm.</td></tr>
<tr><td>2</td><td>4.5 "</td><td rowspan="2">6.25 mm.</td><td>58.1 "</td><td rowspan="2">In consequence of a mixture with bile (10–15 c.c.) the digestive power was greatly reduced.</td></tr>
<tr><td>2½</td><td>0.6 "</td><td>8.5 "</td></tr>
</table>

The secretion from both cavities also came to an end at the same time.

This experiment proves to us, first, that the main and miniature stomachs work in perfectly parallel manner with each other. The beginning, the end, and the intermediate variations of the secretion correspond in both cases. Secondly, the digestive power of the secretion coincides in both, and is the same which was observed in the so-called sham feeding. It has here remained at the same height till the cessation of the secretion, without falling to the lower value which we observed from the beginning of the second hour onwards, after normal flesh feeding.

This was also confirmed later, when we performed an œsophagotomy on the dog, and carried out sham feeding in typical form. Here follows one of these experiments taken from Dr. Lobassoff's article.

The first drop of juice appeared from both cavities during the sixth minute after commencing the feeding, which was kept up for half an hour. The further course of the secretion was as follows:

Hour.	Miniature stomach.		Main stomach.	
	Quantity of juice.	Digestive power.	Quantity of juice.	Digestive power.
1st	7.6 c.c.	5.88 mm.	68.25 c.c.	5.5 mm.
2nd	4.7 "	5.75 "	41.5 "	5.5 "
3rd	1.1 "	5.5 "	14.0 "	5.38 "
	13.5 (total)	5.75 (mean)	123.75 (total)	5.5 (mean)

The secretion came to an end in both stomachs at the same time.

The above is represented in curves in Figs. 2 and 3, the scale on which that for the main stomach is drawn being ten times less than that for the small. As you see, the progress of secretion is identical in both.

The existence of a fistula leading into the large stomach affords us also the possibility of performing an experiment upon our dog which is exactly the converse of the sham feeding experiment, and which constitutes a real *experimentum crucis*. While in sham feeding, we had only, so to speak, the beginning of digestion before us, we are now able in our cross experiment to start at the continuation of this beginning. For this purpose it is only necessary to bring the food into the stomach through the fistula, without attracting the dog's attention. Since in this experiment it is above all necessary

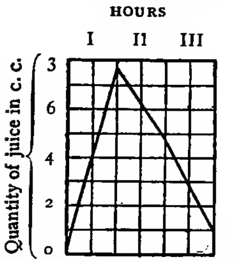


FIGURE 2. — Curve of secretion from the miniature stomach.

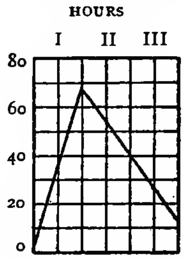


FIGURE 3. — The same from the main stomach reduced ten times.

not to excite the dog's appetite, it is best to carry out the procedure on the sleeping animal. I may add at once, however, that the same result can be obtained on the waking animal, only the process must be performed unnoticed, and the animal's attention must be diverted from thoughts of food.

The results of this experiment are striking, and do not in any way resemble the secretion after normal feeding. Some kinds of food, for instance bread and coagulated white of the hen's egg, when directly introduced into the stomach, do not yield a single drop of juice during the first hour or more afterwards. This holds good both for the small and large stomachs. When a glass rod is introduced into the food contained in the organ it remains dry. Flesh, if introduced at this stage, is able to excite a secretion, but the appearance of the juice is considerably retarded. It begins from fifteen to forty-five minutes after the feeding, instead of from six to ten, is under normal circumstances extremely scanty during the first hour (3 c.c. to 5 c.c. instead of 12 c.c. to 15 c.c.), and possesses a very low digestive power.

Here is an experiment by Dr. Lobassoff:

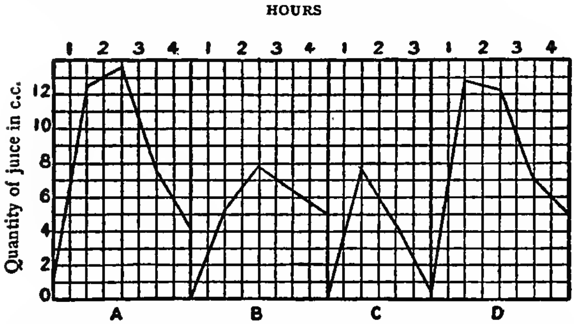
400 grms. of flesh were brought into the stomach.

Hour.	Quantity of juice.	Digestive power.
1st	3.7 c.c.	2.0 mm.
2nd	10.6 "	1.63 "
3rd	9.2 "	1.5 "
4th	7.0 "	1.88 "
5th	5.6 "	2.25 "
6th	6.6 "	2.63 "
7th	7.5 "	1.88 "
8th	5.3 "	2.0 "
9th	3.0 "	5.0 "
10th	0.2 "	— "

The secretion began twenty-five minutes after introducing the food. I now ask you to compare the following tables:

Hour.	Fed with 200 grms. of flesh (Chigin).		Flesh (150 grms.) brought into stomach (Lobassoff).		Sham feeding (Lobassoff).		Total quantity of juice in two experiments.
	Quantity of juice.	Digestive power.	Quantity of juice.	Digestive power.	Quantity of juice.	Digestive power.	
1st	12.4 c.c.	5.43 mm.	5.0 c.c.	2.5 mm.	7.7 c.c.	6.4 mm.	12.7 c.c.
2nd	13.5 "	3.63 "	7.8 "	2.75 "	4.5 "	5.3 "	12.3 "
3rd	7.5 "	3.5 "	6.4 "	3.75 "	0.6 "	5.75 "	7.0 "
4th	4.2 "	3.12 "	5.0 "	3.75 "	— "	— "	5.0 "

The progress of juice secretion in the above is also represented in the following curves:



FIGURES 4-7.—A. Ordinary curve of gastric secretion (200 grms. flesh). B. Curve from direct introduction of food (150 grms. flesh). C. Sham feeding with same. D. Summation of B and C.

As you see, the curve which represents the results of the direct introduction of flesh ascends much more slowly and does not attain anything like the height of that caused by normal feeding with the same food. But if the quantities obtained by direct introduction of the flesh be added to those of sham feeding, the resulting curve is almost identical with the normal.

In like manner the digestive power of the secretion in the foregoing experiments can be dealt with, and with the same result. It is a good instance of how a secretion curve can be synthetically constructed from its constituent factors.

Finally, I am able to demonstrate to you the following instructive experiment. In the presence of some of my listeners, whom I had invited to attend an hour before the lecture, I carried out the following procedures on two dogs, both of which had ordinary gastric fistulæ and were, besides, œsophagotomised. Into the stomach of one, while its attention was distracted by patting and speaking kindly to it in order to avoid arousing any thoughts of feeding, a definite number of pieces of flesh were introduced through the fistula. The morsels were threaded on a string, the free end of which was fastened to the fistular cannula by inserting a cork. The dog was then brought into a separate room and left to itself. A like number of pieces was introduced into the stomach of the other dog in the same way, but during the process a vigorous sham feeding was kept up, the animal being afterwards left alone. Each dog received 100 grams of flesh. Since then an hour and a half have elapsed, and now we may draw the pieces of flesh out by means of the thread and weigh them. The loss of weight, and consequently the amount of flesh digested, is very different in the two cases. In that of the dog without sham feeding the loss of weight amounts to merely 6 grams, while the flesh withdrawn from the stomach of the other dog weighs only 70 grams, that is to say, was reduced by 30 grams. This, therefore, represents the digestive value of the passage of food through the mouth, the value of an eager desire for food, the value of an appetite.

I give also a series of figures obtained by Dr. Lobassoff in analogous experiments. Into the dog's stomach 25 pieces of flesh (100 grams) were brought. The flesh remained two hours in the cavity. Without sham feeding 6.5 per cent, with eight minutes' sham feeding 31.6 per cent, of the quantity was digested.

Again: the flesh remained an hour and a half in the stomach; without sham feeding 5.6 per cent, with five minutes' sham feeding 15 per cent, was digested.

Once more: the flesh remained five hours in the stomach; without sham feeding 58 per cent, with sham feeding 85 per cent, was digested, the balance of undigested food being 42 per cent in the one case and 15 per cent in the other.

I must, however, add that from the nature of this experiment it is not well adapted for class demonstration, and may often fail. On the one hand, it is not at all easy to conceal the introduction of the flesh from the dog; on the other, the unusual and distracting surroundings of the animal often causes a short period of sham feeding to have less effect than would otherwise pertain. In order to avoid such failures it is better before an audience to carry out this experiment only on dogs accustomed to appear in the lecture theatre, and of whose temperament the experimenter is well assured.

I hope you have now been convinced of the great importance which is to be attached to the passage of food through the mouth and œsophagus, or, in other words — and this, according to our former experiences, means the same thing — to the eager desire for food. Without this longing, without the assistance of appetite, many forms of food-stuffs which gain entry to the stomach remain wholly devoid of gastric juice. Others, it is true, excite a secretion, but the juice poured out is scanty and weak.

It is only later, when we have still more fully recognised the conditions upon which the secretory work of the gastric glands depends, that we shall be able to grasp the meaning of these facts in a more comprehensive manner. For instance, why does bread brought unnoticed into the stomach of the dog cause no secretion for hours, while flesh tolerably soon (after twenty to forty minutes) provokes this act? This will be explained in the next lecture; now, however, we must consider other questions.

How long does the after-effect, the echo of the first impulse to the secretory nerves of the stomach, continue to last? How long does appetite juice continue to flow after the normal act of eating, which, especially in the case of animals, is not of long duration? We have already determined many times, not only on our dog with the isolated stomach, but also on other animals, how long the after-effect of sham feeding is continued.

Here, for example, is an experiment from the article of Professor Ssanozki which deals with the point. The dog had a gastric fistula and also an opening leading into the œsophagus. After a sham feeding of five minutes the secretion began, and was continued as follows:

Time in minutes.	Quantity.	Digestive power.
10	25.5 c.c.	8.1 mm.
10	20.0 "	8.0 "
10	13.5 "	6.8 "
10	11.0 "	7.5 "
10	8.5 "	8.1 "
10	6.5 "	9.0 "
20	13.5 "	7.4 "
20	11.0 "	7.2 "
20	7.0 "	7.2 "
20	11.5 "	6.8 "
20	11.0 "	6.5 "
30	6.5 "	7.6 "
20	5.5 "	7.2 "

The effect, therefore, even after a short period of sham feeding, stretches over a length of time. Naturally the same holds good for the taking of food in the normal way. One must, however, bear in mind that in sham feeding, with all the force and reality of a hunger sensation not satisfied, the eager desire for food, the effective agency, becomes more and more accentuated, and therefore the secretory influence is prolonged and more powerful. In normal feeding, however, the quelling of the longing, the feeling of satisfaction which, as is well known, sets in long before the termination of the digestive period from the mere filling and distension of the stomach, must diminish the desire for food, and, consequently, bring the secretory effect to an end.

It is, therefore, improbable that the whole secretory process in the stomach, which, in the case of certain kinds and quantities of food, lasts from ten to twelve hours, is dependent on the factors which we have up to the present investigated. This is all the more obvious since a sham feeding of five minutes, even under the most favourable circumstances, does not call forth a secretion for longer than three to four hours. We must, therefore, seek for other exciting agencies of the innervation apparatus of the gastric glands.

Why and wherefore is the secretion instituted by psychic influence maintained? What would first occur to all your minds is naturally the immediate influence which the food exerts upon the walls of the stomach. And this is true, but it does not happen in the simple, direct fashion current in the minds of many physiologists and physicians. When I said that bread or boiled white of egg, introduced directly into the stomach, may not for hours produce a trace of secretion, probably many of my hearers may have asked themselves with natural astonishment, "How, then, is the effect of the forced feeding of phthisical and insane patients, and the artificial feeding of those with gastric fistulæ (performed on account of stricture of the œsophagus) to be explained?" I will introduce my answer by a very unexpected pronouncement relative to the assertion that mechanical stimulation of the stomach wall by food constitutes a reliable and effective means of calling forth the secretory work of the glands. This assertion, which is so categorically set forth in many text-books of physiology, and which consequently has gained hold of the mind of the physician, is nothing else than a sad misconception degenerated into a stubborn prejudice. My own statement, repeated in many published articles, and at the meetings of various medical societies, that this dictum is only a picture of the imagination, has met, for the most part, either with an unbelieving shake of the head or else with a direct avowal that "it cannot be so." I regret exceedingly that these steadfast unbelievers are not here, so that we might together bring the matter before the tribunal of fact, to the demonstration of which we will now proceed. To this matter I attribute very great importance. It is on this ground, according to my opinion, that the whole battle must be fought out between the generally accepted view that every agency is capable of exciting the gastric mucous membrane and the theory that it is only excitable by specific and selected stimuli. If once the defenders of the old opinion are driven from their position and obliged to admit the inefficiency of mechanical stimulation, there would be nothing further left for them than to build up new theories and search out old facts concerning gland work which have hitherto been rigidly kept in the shade. We may take it that it is mainly because people were so seized with the belief in the direct and simple mechanical explanation that Bidder and Schmidt's experiment of the excitation of gastric secretion by mental effect has been so little taken into consideration, notwithstanding that it appeared so thoroughly reliable and convincing.

I will now repeat the experiment of mechanical stimulation of the gastric mucous membrane before you in the well-known, traditional, and classic manner. Here is a dog with a gastric fistula on which a cervical œsophagotomy has in addition been performed. I open the fistula; as you see, nothing flows out of the stomach; it was washed out clean with water an hour ago. We take the celebrated feather and also a tolerably strong glass rod. Folds of blotting-paper saturated with red and blue tincture of litmus are placed at hand. I now ask my assistant to continuously move the feather and glass rod, alternately, in all possible directions in the stomach, changing from one to the other every five minutes. On removal from the stomach each is carefully dried with red and blue blotting-paper. You have all seen, gentlemen, that this procedure has now been kept up for half an hour. From the fistular orifice not even a single drop has escaped, and, moreover, the drops of moisture on all the pieces of red blotting-paper I have been able to hand to you have assumed a distinct blue tinge, caused by the moisture of the alkaline mucous membrane. The blue pieces, however, have merely been made wet without altering their colour. Consequently, with the most thorough mechanical stimulation of the whole cavity of the stomach, we have not been able to find a single spot possessing a noticeable acid reaction. Where, then, are the streams of pure gastric juice of which we read in text-books! What objection can be raised against the conclusiveness of this experiment? In my opinion only one: that we are dealing with a dog out of health, whose gastric glands from some possible cause are unable to react normally. This single objection can be set aside before your eyes. After failing with the mechanical stimulation, we proceed forthwith to the sham feeding of the same animal. The dog takes the food offered it with keen appetite, and you see that, exactly five minutes after beginning the feeding, the first drops of juice appear from the stomach, followed by others faster and faster. I catch a couple of drops on the blue litmus paper, and you see that they produce bright red specks on the blue sheet. After thirty minutes' sham feeding we have collected 150 c.c. of juice, which, without filtering, looks as clear and transparent as water.

We cannot, therefore, possibly doubt that, when the proper stimulus is used, the gastric glands react to it in a perfectly normal fashion, furnishing a healthy gastric juice. From this it irrefutably follows that only one explanation is to be found for the negative result in the first half of our experiment, viz., that the mucous membrane of the stomach, so far as secretory activity goes, is perfectly indifferent to mechanical excitation. And yet this mechanical stimulus is demonstrated as an exciting agency in the physiological lecture theatre. I venture to think that this lecture experiment from now onwards will quit the field, and give place to the one I have just shown you. This apparently simple experiment of mechanical stimulation can, however, only be successfully performed when certain very obvious rules are followed. These, however, physiologists have not observed, probably on account of a preconceived belief in the effectiveness of the mechanical stimulus. These rules are two. First, it is necessary that the stomach should be clean, and that nothing shall gain entry to it from without. Such conditions were not formerly fulfilled. It is true the stomach was emptied by removing the stopper from the fistular cannula, but it was not washed out till an acid reaction was no longer given, and consequently preformed gastric juice was left behind between the folds of the mucous membrane. At the same time saliva from the cavity of the mouth could gain entry, which quickly became acidified in the incompletely emptied and imperfectly washed-out organ. It is, therefore, not surprising that the glass tube, by setting up contractions of the stomach, was the means of expressing small quantities of acid fluid from the fistula-tube. (The relationship between mechanical stimulation and the motor functions of the stomach is not to be confounded with what we are here speaking of.) That matters are as I state, and that the facts correspond to the explanation is proved by this; namely, that nobody till now has obtained genuinely pure gastric juice of an acidity amounting to 0.5 or 0.6 per cent. It is only necessary to call to mind that Heidenhain, when determining the acidity of the juice first obtained from the resected stomach, was placed in no little doubt as to whether his results (0.5 to 0.6) were correct, and his assistant at the time (Gscheidlen) was set to verify the correctness of his standard solutions. The acidity of the "purest" juice known at that time was scarcely 0.3 per cent. As a further proof that none of the older observers ever really obtained a secretion from mechanical stimulation pure and simple, we may adduce the fact that none of them made mention of the constant and precise period of five minutes' latency. To overlook this was not possible if a genuine excitation of the glands had been obtained.

Of no less importance is the second condition when we wish to perform the experiment of mechanical stimulation in the correct way. It is very necessary that the gastric glands be not already in activity at the beginning of the experiment, and also that during the experiment no impulse comes into play, which of itself, apart from mechanical excitation, could excite the glands to secretion. Nor have we any proof that observers formerly waited for hours before commencing the experiment and convinced themselves that the gastric glands had ceased working. On the contrary, we have not the slightest evidence to indicate that the authors had attempted to guard against accidental psychical stimulation of the glands — a matter which we have seen is of considerable difficulty. And some dogs are so easily excited in this way that it is almost impossible to bring their glands to rest, or at least it is necessary to wait for hours. The experimenter must strain his whole attention to preserve such an experiment free from objection. It is only necessary that some food be near the dog, or that the hands of the attendant who has prepared the food should smell of it, or that some other similar circumstance should come into play, and the glass tube, quite undeservedly, will be made answerable for the excitation of the gastric glands. As you have just seen, both of our conditions have been fulfilled on the dog before you, and the result of the experiment stands in irreconcilable contradiction to those of the laboratory and lecture experiment of former times.

The importance of the experiment, which I have already dwelt upon, justifies me in making still further demands upon your attention in order to show you two modifications of it. Nobody has as yet said, with regard to mechanical stimulation, that in order to obtain results the mechanical agency must simultaneously come into contact with numerous points of the inner surface of the stomach. But in order to meet this possible objection I will now show you two new modifications. Again a similar dog is used, that is to say, one on which both gastrotomy and œsophagotomy have been performed. The stomach has been washed out clean and is at present in a state of complete rest. Into the fistula I bring a thick glass tube containing a number of small openings (2 to 3 mm. diameter) at its rounded end. The other end of the tube is connected with a glass ball containing tolerably coarse sand. Leading into the ball is a second tube, with which an india-rubber pump can be connected and a blast of sand blown through. By rhythmic compression of the india-rubber ball I inject sand with considerable force into the stomach, and this play is kept up for ten to fifteen minutes; nevertheless, we see no trace of gastric juice. The sand falls out again between the side of the cannula and the glass tube, and it is either dry or scarcely moistened, but in no case is it able to turn blue litmus red. And yet we are here dealing with a strong and widely diffused stimulus. Look for a moment at the performance of the bellows outside the stomach. From every opening of the tube — numbering considerably more than ten — a strong stream of sand is ejected. If you hold your hand against it, you feel quite distinctly that the grains of sand strike with considerable force. And now, when our experiment is ended, we may convince ourselves by sham feeding, in easy and unquestionable fashion, that the innervation of the dog's stomach is perfectly normal.

Yet another experiment on a similar dog. Into its empty and resting stomach an india-rubber ball is introduced. This is distended with air by means of a syringe till it is as large as a child's head and maintained in this condition for a time, afterwards being allowed to collapse. The procedure is kept up for ten to fifteen minutes. During this time not a single drop of juice has appeared from the stomach. The surface of the ball taken out of the organ is everywhere alkaline. And here also subsequent sham feeding shows that the dog is in a suitable condition for the experiment. I must add that in making this observation the dog must not be too hungry, that is to say, must have been fed within ten to twelve hours before, otherwise a psychic excitation of the secretion can readily be induced.

If one dispassionately regards this question, and if any of our methods for the study of gastric secretion are reliable, one must be convinced step by step in the laboratory of the uselessness of mechanical stimulation. In the case of dogs with an ordinary gastric fistula, and failing some special reason, not a drop of gastric juice ever escapes from the stomach other than during the digestive period. How could this be the case if the mechanical stimulus were effective, since the inner rim of the fistula-tube is continuously in contact with the gastric mucous membrane? The same holds good for the dog with resected stomach. During the experiment a glass or india-rubber tube is brought sufficiently far into the *cul-de-sac* to catch the juice, and yet not a drop flows through the tube, nor does its inner surface ever become acid, so long as true secretory conditions are absent. Moreover, the tube has tolerably often to be taken out and set right.

In the ordinary gastric fistula in dogs, when the operation has lasted a long time — over a year — folds of mucous membrane are often formed in the neighbourhood of its inner orifice which completely close the tube. In these cases a long, thick, perforated metal tube has to be passed in deeply, and yet the manipulation of itself never calls forth a secretion. Further, it is a daily occurrence to find in the stomach of the dog thick rolls of hair, and yet their presence in no way hinders the arrest of the secretion, which occurs when digestion has ceased. Such an occurrence would have been specially obvious in our dog with the isolated stomach, since it was bedded with sawdust in order to guard against maceration of the wound by juice trickling out. Very often we found enormous quantities of sawdust in the stomach, as much as half a pound weight; obviously the dog had licked the wound from adherent sawdust, which it then swallowed, together with that sticking to its nose. And yet these particles of sawdust of themselves, which certainly acted as mechanical stimuli, never caused a secretion. It appears to me that this long series of facts ought to suffice to carry the supposition to its grave that by direct mechanical stimulation one is able to set the neuro-secretory apparatus of the stomach into activity.

And yet the feather and the glass tube continue the even tenor of their ways to this moment and function in some text-books, yea, even in articles which specially treat of gastric secretion as exciters of the gastric glands. There are, it is true, a few physiologists who hold mechanical stimulation, in relation to gastric secretion, not to be very effective, and give it a subordinate position in the series of exciting agencies, but as yet I know of no other physiologist who has wholly denied its influence, and who has not held it possible to obtain at least some juice by it.

To conclude this lecture, we will take into consideration a question connected with the matter we have just discussed. Since the contact of food with the gastric mucous membrane has no direct influence on the secretion, is its entry into the stomach devoid of all connection with the secretory process?

It can hardly be doubted that, under normal conditions, the stomach is the seat of certain definite sensations, that is to say, its surface has a certain degree of tactile sensibility. This sensation is, as a rule, very weak, and the majority of people become accustomed to pay no heed to it in the normal course of digestion. They obtain their sensations of general well-being, and especially of satisfaction from the enjoyment of food, without taking cognisance of the factors contributing to them. The feeling of general hunger, however, is referred solely to the stomach.

On the other hand, all of us have met with men who could describe exactly, and with gusto, how they were able to follow a special tit-bit, or a mouthful of a favourite wine, the whole way through the œsophagus down to the stomach, especially when the latter happened to be empty. Naturally the gourmand, who directs his attention continuously to the act of eating, can in the end distinctly perceive sensations, and even call them up to the consciousness, which in other people are normally masked by other sensations and impressions. We may therefore take it that the satisfaction derived from eating is caused not only by stimulation of the mouth and throat, but also by impulses awakened by the passage of the food along the deeper portions of the œsophagus and by its entry into the stomach. In other words, food which merely passes through the mouth and throat produces less enjoyment and excites, therefore, a less feeling of appetite than the food which passes the whole way into the stomach. The appetite, the eager craving after food, is, indeed, a very complex sensation, and often not merely the need of the organism for food material is necessary for its excitement, but also a condition of thorough well-being, together with a normal healthy feeling in all parts of the digestive tract. For this reason it is easy to understand how patients who have diseased sensations in these organs, and who have no feeling of appetite, no desire for food, remember the sensations, whether consciously or unconsciously, even when they are no longer present. Cases are known to neuro-pathologists where people with gastric anæsthesia suffered from this loss of appetite. Such patients are no longer conscious of having stomachs, and dislike the idea of eating because the food, as they express it, appears to fall into a strange empty sack. In this way one can also conceive how the appetite becomes lost in cases of long-continued obstruction of the alimentary tube. The patients forget their stomachs, and in such instances direct introduction of food into the organ, after an operation, may suddenly bring back the appetite.

As a further illustration, I may be permitted to give an instance from my own personal experience. After an illness with which a transient but high fever was associated, although otherwise fully recovered, I had lost all desire for food. There was something curious in this complete indifference towards eating. Perfectly well, I only differed from others in that I could with ease abstain from all food. Fearing that I should collapse, I resolved on the second or third day to endeavour to create an appetite by swallowing a mouthful of wine. I felt it quite distinctly pass along the œsophagus into the stomach, and literally at that moment perceived the onset of a strong appetite. This observation teaches that the tactile sensation of the stomach at the moment of entry of food is capable of awakening or increasing the appetite. It is known that withholding food from the organism, or in other words the creation of a necessity for food, does not lead immediately, nor in all cases, to the production of an appetite, to a passionate craving for food. How often does it happen that the ordinary hour for a meal has struck, and yet, owing to some keenly interesting occupation, not the least desire for food is felt? It is known to everybody, indeed it has become a proverb, that real appetite first sets in with eating. If this be true, the initial impulse towards awakening an appetite may originate in the stomach and not in the buccal cavity. When we spoke above of the desire for food being the excitant of the secretory nerves of the stomach, we naturally meant the passionate and conscious longing for food, that which is called "appetite," and not the latent need of the organism for nourishment, the lack of nutrition, which has not yet been transformed into a concrete passionate desire. A good example which enables us to differentiate between these two factors is furnished by our dogs with sham feeding. The necessity for food exists in such cases even before the experiment; the juice, however, only begins to flow as soon as this need has taken the form of a passionate longing. It is therefore quite possible that in the case of some dogs, and at a certain stage of hunger, the touching of the gastric mucous membrane with any object at hand, its mechanical excitation, its distension by the food mass, may give the impulse which excites the appetite, and when the appetite is awakened the juice flows. This is possibly a third reason why, in the old experiment, the mechanical stimulus came to be considered effective. Viewed from this point it may, to a certain degree, lead to a reconciliation between my assertion concerning the inefficiency of the mechanical stimulus and the generally prevailing belief. I further also admit that mechanical excitation will at times call into play the work of the gastric glands, not however directly by means of a simple physiological reflex, but indirectly, after it has first awakened and enlivened the idea of food in the dog's consciousness, and thereby called forth the passionate desire. I hope that the foregoing will in no way lead to a confusion of ideas in your minds, but will assist you to an exact and concrete analysis of the previous simple explanation of the facts. This representation, which bears more or less of a hypothetical character, could, of course, be submitted to experimental proof. For such it is only necessary to compare the influence which sham feeding exercises in an œsophagotomised dog with that in one having a simple gastric fistula.

LECTURE VIII

PHYSIOLOGICAL ACTION AND THE TEACHING OF INSTINCT: EXPERIENCES OF THE PHYSICIAN

It would be desirable, in the interests of medicine, that the methods described in these lectures should be employed in experimental investigations into the pathology and therapeutics of the digestive canal on the lines laid down — The fact that the beginning of the secretory work in the stomach depends upon a psychic effect harmonises with the experiences of every-day life, namely, that food should be eaten with attention and relish — To restore the appetite has from all ages been the endeavour of the physician — The indifference of the present-day physician towards appetite — Probable causes of this — Curative remedies based upon a restoration of appetite — The therapeutic effects of bitters depend upon the excitation of appetite — The usages of the mid-day meal are in agreement with physiological requirements — Physiological reasons for certain instinctive customs and empirical regulations—Importance of an acid reaction of the food — Dietetics of fat and its therapeutic application — The peculiar position of milk among food-stuffs is based on physiological reasons — Explanation of the curative effects of sodium bicarbonate and sodium chloride — The causes of individual differences in the work of the digestive glands — Participation of the inhibitory nerves of secretion in the production of pathological effects.

GENTLEMEN, — To-day we shall endeavour to bring the previously communicated results of our laboratory investigations into reconciliation with the customs observed in the ingestion of food, and with the regulations prescribed by the physician in disorders of the digestive apparatus. To bring our knowledge to full fruition, and so secure for it the most useful application, the same methods should be applied from the same standpoint to the experimental investigation of the pathology and therapeutics of the alimentary canal. Nor should we be likely to encounter insuperable difficulties. Thanks to the advances of bacteriology, many of the pathological processes can now be experimentally produced in the laboratory. Moreover, we would, in a sense, have to deal with external ailments, since our present methods enable us to obtain access to any desired part of the inner surface of the digestive canal. In such pathological animals the functional diseases of the apparatus could be studied in a precise and detailed manner; that is to say, the alterations of secretory activity, the properties of the fluids, and the conditions under which they appear could be examined. On such animals therapeutic remedies could also be tested, the whole process of healing and the final result experimentally observed, while the conditions of secretory activity during every phase of the healing process could be investigated. It can hardly be doubted that scientific, that is to say ideal, medicine, can only take its proper position as a science when, in addition to an Experimental Physiology and Pathology, there has also been built up an Experimental Therapeutics. A proof that this is possible is furnished by the recent vigorous strides made by the science of bacteriology.

I have already described one of such pathological therapeutic experiments; namely, on the dog whose vagi nerves were divided in the neck. Other similar cases I can also call to mind. Our dog with the two stomachs suffered at one time from a slight and transitory gastric catarrh. It was then very interesting to observe that the pathological process (which we were usually able to wholly guard against) spread from the large to the small stomach. It manifested itself here in an almost continuous slimy secretion of very slight acidity, but of strong digestive power. At the beginning of the ailment, indeed before it became fully established, the psychic stimulation was remarkably effective (that is to say, still furnished juice in appropriate quantity), while local excitants almost completely failed. One may conceive that the deeper layers of the mucous membrane with the gastric glands were still healthy, and thus easily thrown into activity by central impulses, whilst the surface of the membrane with the end apparatus of the centripetal nerves was already distinctly damaged. I mention these, which I may call impressions rather than precise observations, because I wish to point out what a fruitful field awaits the investigator who wishes to study, with the aid of our present methods, the pathological conditions of the digestive organs and their treatment. Such an investigation is all the more desirable because clinical study of the same subject (notwithstanding the zeal devoted to it during the last ten years and the results derived therefrom) has to contend with serious difficulties. We must not forget that the sound or stomach-tube, the chief clinical instrument, is more uncomfortable than the ordinary form of gastric fistula which was previously practised on animals, and yet the physiology of the stomach, even with the aid of the latter, made no material progress for many long years. Nor is this difficult to understand. The investigator obtained through the fistula a mixture of substances from which it was difficult, or even at times impossible, to decide anything.

Hence the exact scientific study of therapeutic questions in this region still belongs to the future. But this does not exclude the probability that the newer acquirements of physiology may fruitfully influence the work of the physician. But physiology naturally can make no pretence to guide the field of medicine, since the knowledge at its disposal is incomplete and is much more restricted than that of the broad world of clinical reality. As a recompense for this, however, physiological knowledge is often able to explain the causation of an illness and the meaning of empirical curative methods. To employ a remedy the mode of action of which is not clear is quite a different thing from knowing precisely what we are doing. In the latter case the treatment of the diseased organ will be more effective because it will be better adapted to the special needs of the case. It is thus that medicine, being daily enriched by new physiological facts, will at length grow into what it ideally must become; namely, the art of repairing the damaged machinery of the human body, based upon *exact* knowledge, or, in other words, applied physiology.

We may now return to our subject. If it be at all admitted that human instinct is the outcome of an every-day experience, which has led to the unconscious adoption of the most favourable conditions for life, it is particularly so with regard to the phenomena of digestion. The expression that physiology merely confirms the precepts of instinct is justified here more than anywhere else. It appears to me also that, in relation to the foregoing facts, instinct has often made out a brilliant case when brought before the tribunal of physiology. Perhaps the old and empirical requirement, that food should be eaten with interest and enjoyment, is the most imperatively emphasised and strengthened of all. In every land the act of eating is connected with certain customs designed to distract from the business of daily life. A suitable time of day is chosen, a company of relatives, acquaintances, or comrades assemble. Certain preparations are carried out (in England a change of raiment is usually effected, and often a blessing is asked upon the meal by the oldest of the family). In the case of the well-to-do a special room for meals is set apart, musical and other guests are invited to while away the time at meals — in a word, everything is directed to take away the thoughts from the cares of daily life, and to concentrate them on the repast. From this point of view it is also plain why heated discussions and serious readings are held to be unsuitable during meal-times. Probably this also explains the use of alcoholic beverages at meals, for alcohol, even in the lighter phases of its action, induces a mild narcosis, which contributes towards distraction from the pressing burden of the daily work. Naturally this highly developed hygiene of eating is only found in the intelligent and well-to-do classes, first, because here the mental activity is more strained and the various questions of life more burning; and secondly, because here also the food is served in greater quantity than is required for the wants of the organism. In the case of the poorer classes, where mental activity is less highly developed, the greater amount of muscular activity and the constant lack of more than sufficient nourishment insure a strong and lively desire for food in a normal manner, without recourse to any special regulations or customs. The same conditions explain why the preparation of food is so choice in the case of the upper classes and so simple in that of the lower. Further, all the accessories of the meal, which are foretastes of the actual repast, are obviously designed to awaken the curiosity and interest, and to augment the desire for food. How often do we see that a person who begins his customary meal with indifference afterwards enjoys it with obvious pleasure when his taste has been awakened by something piquant or, as we say, appetising. It was here only necessary to give an impulse to the organs of taste, that is, to excite them, in order that their activity might be later maintained by less powerful excitants. For a person who feels hungry such extra inducements are, of course, not necessary. The quelling of hunger in his case affords of itself sufficient enjoyment. It is not, therefore, without reason that it is often said that "Hunger is the best sauce." This dictum, however, is only right up to a certain point, for some degree of appetising taste is desired by everybody, even by animals. Thus, a dog which has not fasted for more than some hours will not eat everything with equal pleasure which dogs usually eat, but will seek out the food which it relishes best. Hence the presence of a certain kind of spice is a general requirement, although naturally individual tastes differ.

This short discussion as to how different people behave with regard to the act of eating is of itself testimony that care should ever be taken to keep alive the attention and interest for food and to promote enjoyment of the repast — that is to say, that care should be taken of the appetite. Every one knows that a normal, useful food is a food eaten with appetite, with perceptible enjoyment. Every other form of eating, eating to order or from conviction, soon becomes worse than useless, and the instinct strives against it. One of the most frequent requests addressed to the physician is to restore the appetite. Medical men of all times and of every land have held it to be a pressing duty, after overcoming the fundamental illnesses of their patients, to pay special attention to the restoration of the appetite. I believe that in this they are not only animated by an endeavour to free their patients from troublesome symptoms, but also by the conviction that the return of appetite of itself will favour the restitution of normal digestive conditions. It may be said that to the same extent to which the patient wishes back his appetite the physician has effectively employed measures to restore it. Hence we have not a few remedies which are specially named "gastric tonics," and whose action is to promote appetite. Unfortunately medical science has latterly deviated from this, the correct treatment of the appetite, and that which corresponds to the real conditions. If one reads current text-books on disorders of digestion, it is remarkable how little attention is paid to appetite as a symptom or to its special therapy. Only in a few of them is its importance indicated, and then merely in short, parenthetic phrases. On the other hand, one may meet statements in which the physician is recommended to adopt no special means for counteracting so unimportant a subjective symptom as a bad appetite! After what I have said and demonstrated to you in these lectures, one can only designate such views as gross misconceptions. If anywhere, it is precisely here that symptomatic treatment is essential. When the physician finds it necessary, in disorders of digestion, to promote secretory activity by different remedies, this object can most certainly and completely be achieved by endeavouring to restore the appetite. We have already seen that no other excitant of gastric secretion, so far as quantity and quality of the juice are concerned, can compare with the passionate craving for food.

To a certain degree we can understand — and this contributes to an explanation of matters — how medical science of our time has come to regard so lightly the loss of appetite as a special object for treatment. Now, however, the experimental method has penetrated more and more into medical science, with the result that many pathological factors and therapeutic agents are judged of according to whether they hold good in the laboratory or not — that is to say, they are valued only in so far as they can be verified by laboratory experiments. Naturally we do not doubt that a movement in this direction indicates a great advance, but even here, as with every undertaking of mankind, things do not proceed without mistakes and exaggerations. We must not consider an event to be a mere picture of the imagination because it is not realisable under given experimental conditions. We often do not know all the essential conditions for the production of the phenomenon in question, nor are we yet able to grasp the connection between all the separate functions of life as fully as may be desired. Thus in the clinical treatment and pathology of digestion assistance was sought for in the laboratory, but nothing was there met with which had a relation to appetite, and consequently this factor was overlooked in medical practice. As stated above, the psychic gastric juice obtained only cursory mention in physiology, and this not even by all authors; and when it was noticed it was related more as a curiosity. Great importance was, on the other hand, assigned to the mechanical stimulus, the efficiency of which, now that our knowledge is more complete, has been shown to be purely imaginary. Each of the contending factors has at length been assigned its proper place, and if clinical medicine maintains her worthy desire of following out the experimental investigation of her problems, she must in actual practice accord to appetite its old claim for consideration and treatment.

But notwithstanding the indifference of physicians to appetite in itself, many therapeutic measures are based on the promotion of it.

And in this the truth of empiricism makes itself irresistibly felt. When the patient is enjoined to eat sparingly, or when he is restrained from eating at all till the physician expressly permits, or again, when he is (for instance, during convalescence) removed from his ordinary surroundings and sent to an establishment where the whole life, and particularly the eating, is regulated according to physiological needs — in all these cases the physician seeks to awaken appetite, and relies upon it as a factor in the cure. In the first case, where the food is prescribed in small portions, in addition to preventing the overfilling of a weak stomach, the oft-recurrence of appetite juice, which is so rich in quantity and so strong in digestive power, is of great importance. I ask you here to call to mind one of our experiments in which food was given in small portions to a dog, and thus led to a secretion of much stronger juice than if the whole ration had been eaten at once. This was an exact experimental reproduction of the customary treatment of a weak stomach. And such a regulation of diet is all the more necessary, since, in the commonest disorders of the stomach, only the surface layers of the mucous membrane are affected. It may, consequently, happen that the sensory surface of the stomach, which should take up the stimulus of the chemical excitant, is not able to fulfil its duty, and the period of chemical secretion, which ordinarily lasts for a long time, is for the most part disturbed, or even wholly absent. A strong psychic excitation, a keen feeling of appetite, may evoke the secretory impulse in the central nervous system and send it unhindered to the glands which lie in the deeper as yet unaffected layers of the mucous membrane.

An instance of this, taken from the pathological material of the laboratory, I have already related at the beginning of this lecture. It is obvious in these cases that the indication is to promote digestion by exciting a flow of appetite juice, and not to rely upon that excited by chemical stimuli. From this point of view the meaning of removing a patient, the subject of chronic weakness of the stómach, from his customary surroundings is also plain. Take, for instance, a mentally overstrained individual, or a responsible official; how often does it happen that he cannot for a moment distract his thoughts from his daily work. He eats without noticing it, or eats and carries on his work at the same time. This often happens, particularly in the case of people who live in the midst of the incessant turmoil of great cities. The systematic inattention to the act of eating prepares the way for digestive disturbances in the near future, with all their consequences. There is no appetite juice, no "igniting juice," or, at most, very little. The secretory activity comes slowly into play; the food remains much longer in the digestive canal than is necessary, or passes, for want of sufficient digestive juices, into a state of decomposition which irritates the mucous membrane of the alimentary canal and brings it into a condition of disease. No medicinal treatment can help such a patient while he remains surrounded by his old conditions. The fundamental cause of his illness still continues in progress. There is only one course to pursue; namely, to take him completely away, to free him from his occupation, to interrupt the interminable train of thought, and to substitute for a time, as his only object in life, the care of his health, and a regard for what he eats. This is attained by sending the patient to travel, or by placing him in a hydropathic establishment. It is the duty of the physician to regulate not only the life of individual patients according to such rules, but also to have a care that in wider circles of the community a due conception of the importance of eating should be disseminated. This is particularly so with the Russian physician. It is precisely in the so-called intelligent classes of Russians that a proper conception of life generally is often found wanting, and where an absolutely unphysiological indifference towards eating often exists. More methodical nations, like the English, have made a species of cult of the art of eating. It is, of course, degrading to indulge excessively and exclusively in culinary enjoyments, but, on the other hand, a lofty contempt for eating is also reprehensible. As so often is the case, the best course here also lies between the two extremes.

With the establishment of mental effect upon the secretion of juice the influence of condiments enters upon a new phase. The conclusion had already been empirically arrived at that it was not alone sufficient for the food to be composed exclusively of nutrient substances, but that it should also be tasty. Now, however, we know why this is so. For this reason the physician, who has often to express an opinion upon the suitability of the dietaries of different persons, or even of whole communities, should constantly bear in mind the question of psychic secretion; that is to say, he should inquire after and learn how the food has been eaten, whether with or without enjoyment. But how often do the people who have charge of the commissariat pay attention solely to the nutritive value of the food, or place a higher value on everything else than taste? We must, further, in the interest of the public weal, direct attention especially to the feeding of children. If this or that inclination of the taste ultimately determines the relation of grown-up individuals towards food, a matter with which the commencing phase of digestion is closely linked, it would seem undesirable to habituate children solely to a nicety and uniformity of gustatory sensations. Such might effect their capabilities of adapting themselves to other conditions in after life.

The question of the therapeutic influence of the so-called bitters, it appears to me, bears the closest connection with that of appetite. After a long period of high repute these substances have been almost expelled from the list of pharmaceutic remedies. When tested in the laboratory, they were unable to justify their old and valued reputation; when directly introduced into the stomach, many of them were unable to produce a flow of gastric juice. Consequently, in the eyes of the clinician, they became greatly discredited, so that many were quite ready to discard their use altogether. Obviously, the simple conclusion was drawn that a weak digestion could only be assisted by a remedy which directly excites secretory activity. In this, however, it was forgotten that the conditions of the experiment possibly had not corresponded with the actual state of affairs. The whole question of the therapeutic importance of the bitters, however, acquires a different significance when we link it with another question, such, for instance, as how do bitters affect the appetite? It is the universal opinion of the earlier and later physicians that bitters increase the appetite, and if this be so everything is said. They are, in consequence, real secretory stimulants, since the appetite, as has many times been repeated in these lectures, is the strongest of all stimuli to the digestive glands. It is, however, not by any means strange that this had not previously been observed in the laboratory. The substances were either introduced directly into the stomachs of normal dogs or else injected into the circulation. But their action is chiefly bound up with their effect upon the gustatory nerves, and it was not, therefore, without some reason that this large group of remedies, consisting of substances of the most varied chemical composition, were grouped together mainly on account of a certain bitter taste common to them all. A person who suffers from digestive disturbance has, moreover, a blunted taste, a certain degree of gustatory indifference. The ordinary foods, which are agreeable to other people, and also to himself when in health, now appear tasteless. They not only arouse no desire for eating, but may even cause a feeling of dislike; there is no sense of taste, or at best a perverse one. It is necessary, therefore, that the gustatory apparatus should receive a strong stimulus in order to restore a normal sensation. As experience teaches, this object is most quickly attained by exciting sharp, unpleasant, gustatory impressions, which by contrast awaken the idea of pleasant ones. In either case there is no longer indifference, and this is the foundation upon which an appetite for this or that kind of food may be awakened, and here a general physiological law is illustrated. The light appears brighter after darkness, a sound louder after silence, the enjoyment of blithesome health more intense after illness, and so on. This explanation of the appetising effects of bitters proceeding from the mouth does not exclude the possibility of some such similar influence coming also from the stomach. As has been already stated in the fifth lecture, there is some reason for believing that certain impulses from the cavity of the stomach are likewise necessary for the excitation of appetite. It is possible that bitters not only act directly on the gustatory nerves in the mouth, but that they also act on the mucous membrane of the stomach in such a way that sensations are generated which contribute to the passionate craving for food. As a matter of fact, it has been confirmed by many clinicians that after the administration of bitters some such special sensations do arise in the stomach. The effect of these remedies consists, therefore, not merely in the generation of a simple reflex, but in the production of a certain psychic effect, which indirectly excites a physiological secretory activity. The same probably applies to other substances, such as condiments. In any case, whether our explanation corresponds to the actuality or not, the question of the therapeutic effect of bitters is settled in the affirmative the moment we acknowledge that these substances awaken appetite. The problem, therefore, of an experimental investigation of bitters consists in establishing the fact that they have an effect upon the appetite. The question is a difficult one, and has not hitherto been attempted in the laboratory. It is not sufficient to hand over clinical observations to the laboratory as experimental proofs. One must have, in addition, the assurance that the investigation has been correctly carried out; that is to say, that it dealt exactly with the point under consideration. It is interesting to observe that the connection between appetite and gastric juice is by many physicians, and in many text-books of medicine, exactly reversed. Thus it is represented that some medicinal remedy calls forth a secretion of gastric juice, and this, by its presence in the stomach, awakens an appetite. Here we have to deal with a false explanation of a true fact, and that because it was not recognised that a psychic effect could by any possibility be a powerful excitant of secretory nerves. The customs of the chief meal of the day also correspond with our physiological results. After this or that *hors d'œuvre*, perhaps also with a liqueur of brandy (especially customary in Russia), both of which are designed to awaken the appetite, the repast proper begins, and, in the majority of cases, with something hot, consisting mostly of meat broth (*bouillon*, different soups, and so on). After this comes the really nourishing food — meat of different kinds served in various ways, or, in the case of poorer people, stews made with vegetables, and therefore rich in carbohydrate material. This sequence of foods, from the standpoint of physiology, is quite rational. Meat broth, as we have already seen, is an important chemical excitant of gastric secretion. An attempt is therefore made in two ways to secure a free secretion of gastric juice to act on the chief food; first, in the excitement of the appetite juice by the *hors d'œuvre*, and secondly, in the promotion of the flow by the action of the meat broth. It is in this way that human instinct has made provisions for the digestion of the chief meal. A good meat broth can only be afforded by well-to-do people, and consequently with the poorer classes a less expensive, and, indeed, also a less effective, chemical excitant is used for awakening the early secretion. For example, *kwas*[1] serves in this way with the Russian population, while in Germany, where the price of meat is high, different kinds of soups are used, consisting of water mixed with flour, bread, etc. It is further to be borne in mind that the quantity of the digestive juices in general stands in close connection with the content of water in the organism. This has been shown by the experiments of Dr. Walther for the pancreatic juice, and by my own for the gastric juice. If this sequence of foods, therefore, holds good for healthy people, it must be even more strictly adhered to in pathological conditions. Thus, when a person has no appetite, or only a weak one, he has no psychic juice or only very little; consequently, the meal must in every case be begun with a strong chemical excitant — for example, with a solution of the extractives of flesh.

[1] *Kwas* is a favourite Russian drink, prepared from water, bread or meal, with malt and yeast. It contains a considerable quantity of lactic acid, some acetic acid, and other products of fermentation.

Otherwise solid foods, particularly if they do not consist of meat, would remain long in the stomach without any digestion whatever. It is, therefore, in every way desirable to prescribe meat juice, strong broth, or meat extract to people who have no appetite. The same applies also to forced feeding, for instance, of the insane. It is true that the method of introduction in this case necessarily secures the presence of a chemical excitant, since the food can only be introduced in a fluid form. In any case the addition of meat extract would be very useful. If one arranged the ordinary fluid foods in descending order, according to the influence of the chemical excitants, the following would be the series: first, the preparations of the flesh, such as meat juice and the like; secondly, milk; thirdly, water.

The usual termination of the repast is also, from the physiological standpoint, easy to be understood. The chief meal is generally ended with something sweet, and everybody knows that sweets are pleasant. The meaning of this is easy to guess. The repast, begun with pleasure, consequent on the pressing need for food, must also, notwithstanding the stilling of hunger, be terminated with an agreeable sensation. At the same time the digestive canal must not be burdened with work at this stage; it is only the gustatory nerves which should be agreeably excited. After thus dealing in general with the usual arrangement of our meals, we may now speak of some special points.

Above all comes the acid reaction of the food. It is apparent that acidity enjoys a special preference in the human taste. We use quite a number of acid substances. Thus, for example, one of the commonest seasoning substances is vinegar, which figures in a number of sauces and such like. Further, many kinds of wine have a somewhat acid taste. In Russia, *kwas*, especially in the acid form, is consumed in great quantities. Moreover, acid fruits and green vegetables are used as food, and they are either of themselves acid, or made so in the preparation. In medicine this instinct is likewise often made use of, and acid solutions, especially of hydrochloric and phosphoric acids, are prescribed in digestive disturbances. Finally, Nature itself constantly endeavours to prepare lactic acid in the stomach in addition to the hydrochloric acid. The former arises from the food introduced, and is consequently always present. These facts are all physiologically comprehensible when we know that an acid reaction is not only necessary for an efficient action of the peptic ferment, but is at the same time the strongest excitant of the pancreatic gland. It is even conceivable that in certain cases the whole digestion may depend upon the stimulating properties of acids, since the pancreatic juice exerts a ferment action upon all the constituents of the food. In this way acids may either assist digestion in the stomach where too little gastric juice is present, or bring about vicarious digestion by the pancreas where it is wholly absent. It is easy, therefore, to understand why the Russian peasant enjoys his *kwas* with bread. The enormous quantity of starch which he consumes, either as bread or porridge, demands a greater activity upon the part of the pancreatic gland, and this is directly brought about by the acid. Further, in certain affections of the stomach, associated with loss of appetite, we make use of acids, both from instinct as well as medical direction, the explanation being that they excite an increased activity of the pancreatic gland, and thus supplement the weak action of the stomach. It appears to me that a knowledge of the special relations of acids to the pancreas ought to be very useful in medicine, since it brings the gland—a digestive organ at once so powerful and so difficult of access—under the control of the physician. We could, for instance, intentionally discard digestion in the stomach, and thus transfer it to the bowel, by prescribing substances which do not excite the gastric glands. On the other hand, by lessening the acidity of the gastric juice we could reduce the activity of the pancreas, and these are matters which might be made use of in various special diseases, or even in some general disturbances of the digestive apparatus.

No less instructive is a comparison of the results of our experiments upon fat, with the demands of instinct and also with the precepts of dietetics and therapeutics. Everybody knows that fatty foods are heavy, that is, difficult of digestion, and in the case of weak stomachs they are usually avoided. We are now in a position to understand this physiologically. The existence of fat in large quantities in the chyme restrains in its own interest the further secretion of gastric juice, and thus impedes the digestion of proteid substances; consequently, a combination of fat and proteid-holding foods is particularly difficult to digest, and can only be borne by those who have good stomachs and keen appetites. The combination of bread and butter is less difficult, as might *a priori* be inferred from its wide employment. Bread requires for itself, especially when calculated per unit, but little gastric juice and but little acid, while the fat which excites the pancreatic gland insures a rich production of ferment both for itself and also for the starch and proteid of bread. Fat alone does not count by any means as a heavy food, as may be seen from the fact that large quantities of lard are consumed in certain districts of Russia with impunity. This also is comprehensible, since the inhibitory influence of the fat in this case does not prevent the digestion of any other food-stuff, and is conducive to the assimilation of the fat itself. There is no struggle in this case between the several food constituents, and therefore no one of them suffers. In harmony also with daily experience the physician, in cases of weakness of the stomach, totally excludes fatty food and recommends meat of a fat-free kind; for example, game, etc. In pathological cases, however, where an excessive activity of the gastric glands is manifested, fatty food, or fat as emulsion, is prescribed. And here medicine has empirically brought to its aid the restraining action of fat, which we have so strikingly seen in our experiments.

Amongst all the articles of human food, milk takes a special position, and this is unanimously recognised, both in daily experience and in the practice of medicine. By everybody milk is considered a light food, and is given in cases of weak digestion as well as in a whole series of severe illnesses; for example, in heart and kidney affections. The extreme importance of this substance, a food prepared by Nature itself, we can now well understand. There are three properties of milk which secure it an exceptional position. As we already know, in comparison with nitrogenous equivalents of other foods, the weakest gastric juice and the smallest quantity of pancreatic fluid are poured out on milk; consequently, the secretory activity requisite for its assimilation is much less than with any other food-stuff. In addition, milk possesses a further important property. Thus, when it is introduced unobserved into the stomach of an animal it causes a secretion both in the stomach and also one from the pancreas; consequently, it appears to be an independent chemical excitant of the digestive canal; and in this action it is remarkable that we perceive no essential difference in the effect when the milk is brought unnoticed into the stomach from that which occurs when it is given to the animal to lap. Although flesh is a better chemical excitant, it is by no means a matter of indifference how it gets into the stomach. It must, therefore, be accepted that milk excites not only a really effective, but at the same time a very economic, secretion, and also that the appetite is unable to stimulate this secretion into a more active or abundant flow. The secret of the relation of milk to the secretion of the digestive juices can, unfortunately, at present be submitted to no further analysis or investigation. We are at liberty, however, to suppose that the fat on the one hand is of importance for the inhibition of the gastric glands, and the alkalinity on the other for the restraint of the pancreas. Thus the gastric glands and the pancreas, notwithstanding the presence of excitants, are maintained by milk at a certain but not too high degree of activity, a matter which is in every way desirable in consideration of the easy digestibility of its constituents. Finally, the third characteristic which is observed to belong to milk, and which is probably only an expression of the first, consists in the following. When one administers to an animal equivalent quantities of nitrogen, in the one case as milk, in the other as bread, and afterwards estimates the hourly output of nitrogen in the urine, it results that the increase during the first seven to ten hours after the milk (compared with the excretion beforehand) amounts only to from 12 per cent to 15 per cent of the nitrogen taken in, while after bread it amounts to 50 per cent. If the hourly rate of absorption and the extent to which milk and bread are respectively used up be taken into consideration, it has to be admitted that these augmentations of urinary nitrogen which appear soon after feeding must be expressions of the functional activity of the digestive canal itself, and that this activity in the case of bread is three or four times greater than in the case of milk (*Experiments of Prof. Rjasanzew*); consequently, in the case of milk a much larger fraction of its nitrogen is free to be used up by the organism at large (irrespective of the organs of digestion) than in that of any other kind of food. In other words, the price which the organism pays for the nitrogen of milk, in the form of work on the part of its digestive apparatus, is much less than that for other foods. How admirably, therefore, the food prepared by Nature distinguishes itself when compared with all others!

The facts just related bring forward a new aspect from which the relative nutritive values of different foods may be judged. The older criteria must frankly make room for the new or else be displaced by them. Experiments upon the utilisation of food-stuffs, in which what remains undigested is determined as well as what is absorbed into the body fluids, cannot alone be trusted to solve the question in a satisfactory manner. Suppose, for instance, that in the digestion of a given food the alimentary canal has been given a certain work to perform; if it be in health the work will be accomplished in the best possible manner — that is to say, with complete abstraction of everything nutrient. You will thus learn how much nutrient material was contained in the food, but the question of its digestibility remains as obscure as before. In your experiment you do not know how great an effort it has cost the alimentary canal to extract all the nourishment from the food. Nor can artificial digestion experiments settle the question of digestibility, for experiments in which food is normally partaken of are quite different from those in the test-tube, where we have to deal with only one juice, and not with the interaction of different juices and different food constituents. That one must here, as a matter of fact, make a distinction is clear from the observation of Dr. Walther in our laboratory. Fibrin, which is regarded by all as the most easily digested proteid, proved, when compared with a nitrogen equivalent of milk, to be a much stronger excitant of the pancreas, although milk contains, in addition to nitrogenous substances, a good deal of other non-nitrogenous material. The digestibility and nutritive value of foods must obviously be decided by an estimation of the real work which they entail upon the digestive apparatus, both in regard to the quantity and quality of the juices poured out on a given amount of nutrient material. The energy used up in gland metabolism must be deducted from that of food taken in. The remainder will then indicate the value of the food to the organism; that is to say, will give the amount available for use by all the other organs exclusive of the digestive apparatus. From this point of view those materials must be taken as less nourishing and less digestible which are in large part used up to make good the expenditure entailed by their digestion on the part of the alimentary canal; that is to say, those food-stuffs are less useful whose nutritive value little more than covers the cost of their digestion; consequently, it is of great practical importance to compare from this aspect the same foods differently prepared — for example, boiled and roast meat, hard and soft boiled eggs, boiled and unboiled milk, etc.

A discussion of some further medical questions may here be taken up. The first concerns the therapeutic use of the neutral and alkaline salts of sodium. In clinical, pharmacological, and physiological text-books it is stated now, as ever, that these salts promote a flow of gastric juice. We may look in vain, however, for any experimental foundation to support this doctrine. The experiments brought forward cannot be regarded as conclusive. When Blondlot sprinkled sodium bicarbonate upon flesh, or Braun and Grützner introduced sodium chloride solutions directly into the blood, they began with methods either false in themselves or far removed from normal conditions. In this case, however, the gaps in the experiment were happily made good by the clinician, for the experiment appeared to be confirmatory of clinical experience. That sodium salts (the chloride and bicarbonate) are useful in disorders of the digestive apparatus there can be no doubt. How do they act, however? It appears to me that here, as in some other cases, medical science has fallen into error. When we know that an effect takes place it does not by any means imply that we know the mechanism by which it occurs; and although medicine is broad enough and comprehensive enough to make free use of empiricism in practice, yet it often thinks in narrow grooves when it turns to the explanation of facts. It frequently tries to explain complicated healing processes in the simplest way, on supposed physiological data. And this is true in the present case, which affords an example of prevalent medical reasoning; the alkalies work favourably in digestive disturbances — therefore they are succagogues. Naturally the stomach, under the influence of alkalies, sometimes begins to secrete a greater quantity of juice. This means, however, that it has recovered from a disordered state and has returned to normal conditions. Consequently, the effect is due to the fact of recovery, and not to a direct influence of the alkalies. This latter, however, must be specially proved. The assistance afforded by the alkalies to the organism might be capable of another explanation; for example, that which is ordinarily given. In this case, however, I venture to offer a reason for the effects of sodium chloride, and of the alkaline salts of sodium, which is exactly the opposite of that generally accepted. We were unable to convince ourselves of any succagogue influence on the part of these salts. Indeed, both on the stomach and pancreas they proved in our hands to have an inhibitory effect. In addition to the experiments which I previously brought forward concerning the relation of alkalies to gastric and pancreatic juice, I may relate the following observation. A dog which fortunately had survived the performance, one after the other, of a gastric fistula, a pancreatic fistula, and an œsophagotomy, received daily during the course of several weeks an addition of soda to its food. The animal enjoyed good health and had an excellent appetite. When the first sham feeding experiment was carried out, the relatively small effect of this otherwise very active juice-exciting procedure at once struck us. At the same time we observed that the pieces of flesh which fell from the upper end of the œsophagus, contrary to the ordinary rule, were hardly at all insalivated. In this dog, therefore, a greatly lowered activity of several digestive glands — viz., of the gastric, pancreatic, and salivary glands — simultaneously existed. With regard to the salivary glands the circumstance was naturally submitted to closer investigation. I believe that the inhibitory influence of the alkalies on the digestive glands, which was here proved experimentally, may furnish a basis for the following representation of their mode of action in producing healing effects. Catarrhal affections of the stomach are characterised by an incessant or very protracted secretion of slimy, weakly acid gastric juice. Further, in many cases the affection begins with a hypersecretion, that is an abnormal excitability, of the secretory apparatus which makes itself evident in a superfluous and useless flow. The same must be conceived to happen in disorders of the pancreatic gland; at least such a condition sets in after operations performed for physiological purposes. It is, further, justifiable to suppose that, when an affection is once set up by this or that cause, it may later maintain itself independently; for continuous activity has undoubtedly a harmful influence on the glands. The due nourishment, and the restoration of organs after activity, proceeds best during rest. In the normal course of events, after a period of active work follows a pause, during which the latent work of restoration is accomplished. When, therefore, a remedy effectively restrains the excessive work of a diseased organ, it may in this way contribute to the removal of the pathological condition, and thus to a restoration of the normal state. In this consists, in my opinion, the healing effects of the alkalies. One might draw a parallel between the action of these substances in digestive disturbances and that of digitalis in compensatory disturbances of the heart. An uncompensated heart beats rapidly, and thereby only aggravates its condition. Its time of rest, that is of recovery, of restitution of the organ, is shortened. A vicious cycle is set up. The weak action of the heart lowers blood pressure ; the lowering of this leads (from known physiological causes) to an increase in the number of beats; the quickening leads to weakening of the organ. Without doubt the digitalis aids by breaking through this vicious cycle, in that it greatly slows the pulse, and thereby gives new power to the heart. With our explanation of the action of the alkalies harmonises the further circumstance that, with the use of the salts in question, a strict diet is generally prescribed, which means that a certain amount of rest is secured for the digestive glands. It is interesting that in clinical investigations with the stomach-tube, after a period when the alkalies were looked upon as succagogues, a new phase has also set in, mention being now more frequently made of a restraining effect.

The cause of the erroneous belief that alkalies promote a flow of juice obviously lies in this, that people omitted to compare the effects of the saline solutions with those of like quantities of water (*Dr. Chigin*).

The second point which we may consider is the following. The chief difficulty of the physician who wishes to regulate the diet of patients when they suffer from digestive disturbances consists in the fact that idiosyncrasy plays a very important *rôle*. In one and the same illness, different patients react to the same diet in wholly different ways. That which is agreeable to one, and is well borne and useful, may be rank poison to another. Consequently, the golden rule in dietetics is to give no directions with regard to food till one has made inquiries concerning the inclinations and habits of the patient. What does all this indicate? Till now physiology had no experimental answer to the question. But our facts, it appears to me, contribute to a clearing up of the situation. Every food determines a certain amount of digestive work, and when a given dietary is long continued, definite and fixed types of glands are set up which can only slowly and with difficulty be altered. In consequence, digestive disturbances are often instituted if a change be suddenly made from one dietetic *régime* to another, especially from a sparse to a rich diet; such, for instance, as happens after the long Russian fasts. These disturbances are expresssions of the temporary insufficiency of the digestive glands to meet the new demands made upon them.

Finally, it may be of some use to relate the following here. There are often cases of sudden and unaccountable digestive disturbances. From the standpoint of modern physiology they might be explained by an activity of the secreto-inhibitory nervous system, which from some cause or other has been excessively and abnormally stimulated. In any case this system is now a factor of which the physician has to take due account.

SWALLOWING AND MOVEMENTS OF THE STOMACH AND INTESTINES

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[Note. — In the beginning of 1896 Dr. Professor Henry Pickering Bowditch, one of our Board of Scientific Assessors in the Nutrition Case suggested the use of the Röntgen ray as a means of learning more than was then known about the mechanism of swallowing. There was much difference of opinion among research physiologists about this important function, and the question was far from settled. Magendie published a theory of deglutition, in Paris, in 1836, which was practically accepted until 1876, when Dr. Professor Angelo Mosso, of the University of Turin, Turin, Italy, established the theory of sole peristaltic assistance in swallowing. Again in 1880 Dr. Professor Kronecker, of Berne, Switzerland, in connection with Dr. Falk, and later in connection with Dr. Meltzer, of New York, produced evidence to prove a more complicated process in deglutition than that of peristalsis alone. But even Kronecker and Meltzer found, as they went on, evidence to modify their earlier beliefs, and hence the subject was not cleared up to a point of general agreement.

The suggestion made by Dr. Bowditch was taken up in the Harvard Physiological Laboratory and formed the beginning of a series of studies of the mechanical factors in digestion. The reports of these studies, presented by Dr. W. B. Cannon and collaborators, in the *American Journal of Physiology*, in the volumes of 1898 and 1903, are so understandable, even to the layman ignorant of physiological nomenclature, that we are prompted to give them, almost entire, leaving out only the technical description of the methods employed, which are only interesting to research students who have access to the *Journal*.

It will be noted that three of the professors of physiology mentioned in connection with this preliminary study of the nutrition problem — Bowditch, Mosso, and Kronecker — are members of our presently organised Board. — HORACE FLETCHER.]

THE MOVEMENTS OF THE FOOD IN THE ŒSOPHAGUS

BY W. B. CANNON AND A. MOSER

From the Laboratory of Physiology in the Harvard Medical School
Extracts from *American Journal of Physiology*, 1898

The movements of deglutition, in common with many other physiological processes, were explained by the older physiologists on anatomical grounds. Thus, Magendie divided the act into three parts, corresponding to the anatomical regions of the mouth, pharynx, and œsophagus. The muscles of each of these divisions were considered the active agents in propelling the food onward. The function of moving the mass to the pharynx was variously ascribed to the tongue itself, to the mylohyoid muscles, and to gravity. For the second part, the movement through the pharynx, there was more unanimity of opinion, since the constrictors, especially the middle and lower, were evidently concerned.

Direct observations on the movement of swallowed masses in the œsophagus were first made by Mosso. The œsophagus of a dog was laid bare, and a transverse incision made through it, or a piece of it excised. A small wooden ball was placed in the canal below the excised part, and the animal was then stimulated to swallow. One or two seconds after the contraction of the pharyngeal muscles a peristaltic wave began to traverse the œsophagus. This wave did not stop at the point of excision, but in due time reappeared below, and carried the ball to the stomach. Thus the act was shown to be controlled by the central nervous system. Peristalsis was so plainly the motive power that the action was never doubted. Yet this belief was soon to be questioned.

In 1880 Falk and Kronecker studied the movements in the mouth and pharynx, and advanced the theory that deglutition was accomplished by the rapid contraction of the muscles of the mouth. During the act of swallowing the air-tight buccal cavity shows a manometric pressure of twenty centimetres of water. The same pressure was demonstrated to be present also in the œsophagus, but not in the stomach. This pressure was considered sufficient to force food through the œsophagus before the peristaltic wave traversed it. Another argument for rapid descent was found in the fact that cold water can be felt in the epigastric region almost immediately after being swallowed. Further, when strong acids pass through the gullet, they corrode but small parts of it, and not the entire mucous membrane, as would be the case were the acid carried to the stomach by peristalsis.

Over a year and a half ago it was suggested by Prof. H. P. Bowditch that if some substance opaque to the Röntgen rays were swallowed, it could be seen in its passage to the stomach, and the nature of its movement thus determined. Anæsthesia could be dispensed with, — a desirable condition, since observers had found that it interfered greatly with the deglutition reflex. It would be unnecessary to open either the abdominal or the pleural cavity. The reflex stimulus of food, moreover, would be better than electrical stimulation of the superior laryngeal nerve. In short, the animal would swallow normal food under practically normal conditions. At Dr. Bowditch's suggestion and with his valuable assistance — which we gratefully acknowledge — we made the following series of experiments.

To render the swallowed mass opaque, subnitrate of bismuth was used. The salt is tasteless, practically inert, and can be fed in large quantities without harm. In order that observations could be made by more than one person, all experiments were conducted in a dark room. On the side of the animal opposite the Crookes tube was placed an open fluorescent screen, on which the different tissues of the animal were outlined with varying degrees of light and shade. Among these shadows the swallowed mass appeared as a darker object, and thus its motion could be studied.

For the first experiments the goose was selected. The head and neck were held stationary by a tall pasteboard collar, which allowed free movement of the head without constriction of the neck. The fluorescent screen was placed against this collar at a uniform distance of thirty centimetres from the tube. When a bolus of corn-meal mush mixed with bismuth was placed in the pharynx, it descended slowly and regularly, and occupied about twelve seconds in passing over a distance of fifteen centimetres. The screen was marked at intervals of two centimetres with cross lines, by means of which the relative rate in different parts of the œsophagus could be studied. A vibrator marking tenths of a second was interrupted whenever the bolus crossed a line. An average of over one hundred such observations showed that the rate became slightly slower as the bolus proceeded.

In order to test liquids, molasses was mixed with bismuth to such a consistency as to drop easily from a glass rod. When this was fed with a pipette, it passed slowly and regularly down the œsophagus, clearly by peristalsis. The rate was about the same as for solid food. In both these experiments the addition of water would sometimes cause irregularities in the descent. Microscopic sections from four different parts of the œsophagus of the goose showed no histological difference.

In the experiments on the cat, the animal was placed on its back and left side on a holder. The extremities were secured by straps. The head was held between two upright rods, connected above by a thong; this allowed free movement of the head, without resistance to the passage of food. Shreds of meat dipped in bismuth were ordinarily masticated and swallowed without difficulty. For soft solids, bread and milk were used, so fluid as to be easily drawn up into a pipette. The insolubility of the bismuth salt rendered the study of liquids more difficult. Strong solutions of potassic iodide and other salts, and suspension of bismuth, in acacia and molasses were tried; but a simple mixture of milk and bismuth, shaken in a test tube and immediately drawn up into a pipette, was found most practicable.

Inasmuch as the movement of these different foods varied in different parts of the œsophagus, it will be convenient to divide the latter into three sections. The first or cervical portion extends from the pharynx to the thorax; the second or thoracic, from here to the lower half of the heart; and the third comprises the rest of the canal. The relative length of these three parts is about in the ratio of 9:8:6.

The beginning of deglutition was noted by one observer by a finger on the larynx; the same observer called out when the bolus arrived at the thorax, heart, and stomach respectively, while the other observer noted the time. The movement of solids will first be considered. The descent the entire way was by peristalsis, but the rapidity varied. The duration of the movement in the cervical portion was two and a half seconds, and in the thoracic region a little less than two seconds. At the lower end of the heart there was sometimes a slight pause. In the lower section, from the heart to the stomach, the movement was decidedly different; the rate was always very slow. The distance was less than one-third of the entire canal, yet the time consumed in this part ranged from six to seven seconds, or three-fifths of the entire time of descent. The character of the movement here was also peculiar. Whereas in the upper sections the passage was uniform and regular, with a slight acceleration in the thoracic region, here it was apparently irregular, for the bolus descended about one centimetre with each inspiratory movement of the diaphragm, and remained stationary or descended very slightly during expiration. Thus a series of hitches seemed to carry the bolus to the cardia. A probable explanation of this peculiar movement is that the stomach and lower œsophagus were pulled down with each descent of the diaphragm. This would make the movement appear irregular, although it was really a slow peristalsis. It may be well to remark here that this movement was invariably observed in the cat with every kind of food.

Semi-solids, namely, a mush of bread and milk, descended in the same way as solids; but the rate was slightly faster in the upper œsophagus, for the bolus took about a second less to reach the cardiac level. From here the rate was the same as with solids.

For liquids, one and a half to two seconds sufficed for the descent to the midheart region. Here there often occurred a long pause, from a few seconds to a minute or more. Then the œsophagus apparently contracted above the liquid, which slowly passed on to the stomach, as already described. Sometimes it seemed as if a swallowing movement, evidenced by a rise of the larynx, started the peristaltic wave. Again, several swallows would succeed one another before the liquid passed on. A few times the bismuth and milk seemed strung out along the œsophagus; some more liquid descending would gather this up, and the whole mass, assuming an ovoid form, would move into the stomach.

Thus in the cat the total time for deglutition varies from nine to twelve seconds. The lowest section presents no change ascribable to a difference in consistency, while in the upper sections the rate does slightly increase with the more liquid character of the food.

In experiments on the dog, bismuth enclosed in capsules or wrapped in shreds of meat was fed as the solid. The general phenomena were as follows: With the rise of the larynx there was a quick, propulsive movement of the bolus, which descended rapidly for a few centimetres, sometimes as far as the clavicle. From this point the rapidity was diminished, yet no pause was observed; the bolus simply moved more slowly. This rate was then continued to the stomach without a slackening of speed in the diaphragmatic region, as was observed in the cat. Semi-solids moved in the same way as solids. The total time of descent from larynx to stomach was from four to five seconds.

Liquids gave even a more decided squirt in the beginning of the movement. To render the œsophagus as lax and free as possible, the head of the dog was released from the upright rods and held by the hands after the food was placed in the mouth. Sometimes the liquid descended rather rapidly as far as the heart, at other times no further than the clavicle; then without a pause it passed on slowly and regularly, reaching the stomach in about the same time as solids and semi-solids.

Thus in the dog and cat but little variation was seen in the swallowing of liquids and solids. The liquids pass somewhat faster in the upper œsophagus. But in some animals the difference of rate with foods of varying consistency is much more marked. In the horse, for instance, mere observation shows a decided variation in the rate of movement in the œsophagus. Liquids shoot along the gullet, while solids move clearly by peristalsis. To determine the rate of solids, one hand was placed on the larynx of a horse to note the beginning of swallowing, and the other hand near the shoulders, where the bolus could be easily felt in its passage. The time consumed by the bolus in passing over a certain distance was measured by a stop watch. The rate obtained for solids, such as hay or grain, was from thirty-five to forty centimetres a second.

For semi-solids, a mixture of bran and water was made, thin enough to run easily between the fingers. Each bolus was watched by a separate observer with a separate watch. The average rate obtained was the same as for solids.

Liquids in the horse pass with a rapidity too great to be affected by peristalsis. Another force must be sought. Among the various muscles supposed to be effectual in moving food into the pharynx, the mylohyoids were shown by Meltzer to be essential. The styloglossi were cut by him without much interference with deglutition, but section of the mylohyoid nerves rendered the act impossible. The activity of these muscles in the horse during swallowing is easily perceived by the hand. Their energetic contraction is a sufficient explanation of the rapid passage of water through the œsophagus. The motion here is more than five times as rapid as that of solids and semi-solids.

Meltzer's experiment to measure the rate of liquids in man by passing a stomach tube containing litmus paper was repeated by us with some modifications. Congo red paper was used, since it is more sensitive than litmus; it also furnishes a means of differentiating between mineral and organic acids, as the discolouration produced on Congo red by mineral acids is removed by ether. It was thus possible to distinguish between the discolouration produced by gastric regurgitation and that produced by the swallowed liquid. For the swallowed liquid, one-half per cent lactic acid was found most satisfactory, as the colour produced by it on Congo red test paper is almost instantly discharged in ether. By this method the paper was found discoloured within half a second after the rise of the larynx, certainly too short a period for a peristaltic wave to carry the liquid to the neighbourhood of the cardia.

The X-ray method lends itself less successfully to the study of deglutition in man than in the other animals we have studied. The thickness of the thorax, the distance of the œsophagus from the surface, and the relation to dense tissues render the observation of a swallowed mass difficult, especially when the mass is in rather rapid motion. The few observations which we have to report were made on a seven-year-old girl, placed in the sitting posture. Gelatine capsules containing bismuth were used for solids, and were traced to a point below the heart. The motion was very regular, and apparently due to peristalsis, for the bolus descended without a hitch or irregularity of any kind. Sometimes the capsule became fixed in the upper œsophagus, at about the level of the second rib. Repeated swallows of water would fail to dislodge it. An interesting point was noted here. With each attempt at swallowing, the capsule would rise slightly, as if the œsophagus was pulled up with the rise of the larynx; then the capsule would descend to its former position.

Semi-solids — a mush of bread and milk — could be seen about as far as solids; that is, to just below the heart. The motion of the mushy bolus was the same as with solids, except that the rapidity was perhaps slightly greater.

It should be noted here that with the human subject, as well as with the horse, our results for semi-solids differ from those derived by Meltzer's method; for according to his statements semi-solids, like liquids, are squirted down the œsophagus, and are not propelled by peristalsis, as has been the case in our observations.

Liquids — bismuth and water — were seen only in the neck and upper thorax. Here there was a decided squirt. With the rise of the larynx the liquid was seen to pass rapidly through the pharynx and well down into the thoracic œsophagus before it was lost to observation. The rate, however, by estimation was less than that of liquids in the horse.

There remains to be considered Meltzer's latest investigation, in which he endeavoured to ascertain whether liquids remain above the cardia till the arrival of the peristalsis, or ooze down before. An experimental answer was secured by Meltzer by the following method. The abdominal and gastric walls of an anæsthetised dog were incised, and a tube (vaginal speculum) introduced. Through this the entrance of food into the stomach could be observed directly. In repeated experiments no liquid was seen to pass through the cardia before the arrival of the peristaltic wave. An incision through the diaphragm near its anterior origin showed that the swallowed liquid was not squirted as far as a point an inch above the diaphragm. To observe the œsophagus nearer its beginning, the upper three ribs were resected on the left side. Thus the swallowed liquid was seen to shoot along the œsophagus before any peristalsis reached this point. The resection of the fifth rib exposed the œsophagus half-way between the bifurcation of the trachea and the diaphragm. Here a bulging was sometimes observed immediately after the beginning of the act, and the swallowed mass remained there until a peristaltic wave carried it down. If the mass swallowed was small, or was projected with moderate force, it might not even reach as far as the bifurcation. From these experiments Meltzer concluded that in animals, as in man, liquid food is not carried down the œsophagus by peristalsis, but is thrown rapidly into a deep part of the canal. The depth reached depends on the quantity swallowed, the force used, and the tonicity of the lower part of the œsophagus.

The difference between these methods of Meltzer and those employed in our experiments has already been mentioned; and merely his results, which were obtained with liquids alone, need be considered here. According to our observations on the dog, there was no distinct pause at any part of the canal. The movement simply became slower, and continued at this rate until the stomach was reached. Neither was the rate through the diaphragmatic part of the œsophagus slower than through the thoracic. The quick propulsive movement noticed in the dog was observed with solids and semi-solids as well as with liquids, but the liquids descended further down the canal before the movement changed to the slower peristalsis. While this difference was evident to the eye, the total time consumed by liquids in passing from pharynx to stomach was not enough shorter than the time for solids and semi-solids to be determined by our measurements.

SUMMARY.

The phenomena of œsophageal deglutition as determined by our experiments may then be described as follows: —

There is a difference in swallowing according to the animal and the food which is used.

In fowls the rate is slow and the movement always peristaltic, without regard to consistency. A squirt-movement with liquids is manifestly impossible, as the parts forming the mouth are too hard and rigid. With this diminution of propulsive power in the mouth there is observed a greater reliance on the force of gravity. The head is raised each time after the mouth is filled, and the fluid by its own weight trickles into the œsophagus, through which it is carried by peristalsis.

In the cat the movement is always peristaltic, and slightly faster than in fowls. A bolus takes from nine to twelve seconds in reaching the stomach. Liquids move somewhat more rapidly than semi-solids in the upper œsophagus. In the lower or diaphragmatic part the rate is very much slower than above, and is the same for liquids as for solids.

In the dog the total time for the descent of a bolus is from four to five seconds. The food is always propelled rapidly in the upper œsophagus, and moves more slowly below. This rapid movement is frequently continued further with liquid food. No distinct pause was observed when the movement of the bolus changed from the rapid to the slower rate.

In man and the horse liquids are propelled deep into the œsophagus at a rate of several feet a second by the rapid contraction of the mylohyoid muscles. Solids and semi-solids are slowly carried through the entire œsophagus by peristalsis alone.

THE MOVEMENTS OF THE STOMACH STUDIED BY MEANS OF THE RÖNTGEN RAYS

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Since the stomach gives no obvious external sign of its workings, investigators of gastric movements have hitherto been obliged to confine their studies to pathological subjects or to animals subjected to serious operative interference. Observations made under these necessarily abnormal conditions have yielded a literature which is full of conflicting statements and uncertain results. The only sure conclusion to be drawn from this material is that when the stomach receives food obscure peristaltic contractions are set going, which in some way churn the food to a liquid chyme and force it into the intestines. How imperfectly this describes the real workings of the stomach will appear from the following account of the actions of the organ studied by a new method. The mixing of a small quantity of subnitrate of bismuth with the food allows not only the contractions of the gastric wall, but also the movements of the gastric contents to be seen with the Röntgen rays in the uninjured animal during normal digestion. An unsuspected nicety of mechanical action and a surprising sensitiveness to nervous conditions have thereby been disclosed.

Introductory Literature

The early writings on the subject of gastric movements are characterised by general inferences from physical laws and from the anatomical structure of the stomach. According to Galen the stomach had four functions: to draw the food from the mouth (*facultas attractrix*), to retain the food (*facultas retentrix*) during the process of chemical digestion (*facultas alteratrix*), and, finally, to pass the changed material onward (*facultas expultrix*). In later writings the *facultas attractrix* failed to appear as one of the functions of the stomach. Fallopius, in the sixteenth century, changed the notion of the *facultas retentrix* by suggesting that the pylorus alone performed this office, and that the muscles of the gastric wall could help only by remaining quiet. Thus the *facultas alteratrix* and the *facultas expultrix* are left as true gastric functions. It is with the latter activity and its effects that this paper is concerned.

The ideas of the early writers concerning the pylorus and cardia are of interest. The cardia, they were agreed, is closed during normal digestion in order to keep the food from re-entering the œsophagus. The pylorus they looked upon as the ruler of the actions of the stomach. Such names as pylorus (keeper of the gate), janitor justus, and rector, which the first investigators gave to the sphincter, indicate their theories of its functions. The passage of chyme into the duodenum, the keeping of undigested food in the stomach, the act of vomiting, were all dependent, they believed, on the "will" of the pylorus.

No substantial advance was made beyond these hypotheses until the beginning of the eighteenth century, when Wepfer and Schwartz applied the experimental method to the study of the gastric movements and laid the foundation of a more accurate knowledge. Wepfer vivisected wolves, dogs, and cats, and observed constrictions following stimulation of the stomach. He remarked a general contraction of the pyloric part in vomiting and noted peristaltic and antiperistaltic movements passing over the organ. About the middle of the stomach he frequently saw a deep constriction. The investigations of Schwartz are more valuable in that his search was for the normal action of the muscular coats. The movements, as he observed them, were generally only slight. They began either at the pylorus and passed to the left, half-way to the cardia, or started at the fundus and went to the pylorus. The contractions and relaxations, following one another, formed larger or smaller depressions and elevations, *i. e.*, more or less definite waves.

Near the middle of the last century Haller, after confirming the results obtained by Schwartz and Wepfer, summarised his knowledge of the motor functions of the stomach as follows. In general, contraction alternates with relaxation, so that the stomach is, now here, now there, made narrower by longitudinal or transverse depressions; then in these same places relaxation and bulging occur. So long as both apertures are closed the food is driven hither and thither by the shifting movements. It first takes a definite direction when the cardia or the pylorus opens. If the cardia opens, there is an antiperistalsis followed by regurgitation and vomiting. If, on the contrary, the pylorus relaxes, a contraction, starting at the œsophagus, pushes the contents of the stomach into the duodenum. The pylorus allows the passage of fluids, but if it be stimulated by over distention or by hard pieces of food, it closes tightly.

Such was the knowledge of gastric movements in Haller's time. A comparison of his descriptions with those in any standard work on physiology published ten or fifteen years ago will show that, despite very many researches, little advance had been made. Examinations of animals and men with gastric fistulas, studies of the stomach through the atrophied abdominal wall, and vivisection have yielded numerous results; but these have not been harmonious, and have led to much controversy. Prominent in this mass of material as a valuable contribution are Beaumont's careful observations through the gastric fistula of Alexis St. Martin. Beaumont's work has recently been confirmed by Hofmeister and Schütz, who, with Rossbach, Hirsch, Openchowski, and others, have presented during the last twelve years much new and interesting information. Since, however, it will conduce to clearness to set forth the results of these investigations in connection with my own work, their consideration will be deferred until later.

It will then appear that these later investigations, like the earlier researches, disagree as to the details of the stomach movements. Such differences in results are the proper outcome of the abnormal conditions under which the studies have been conducted. Obviously, in order to see the natural movements of the stomach, the organ should be observed in its natural state, and not after it has been disturbed by removal from the abdomen, or by the adhesions and losses of substance incident to gastric fistulas.

As a means of watching the gastric motor activities under normal circumstances, Dr. H. P. Bowditch, in the autumn of 1896, suggested the use of the Röntgen rays. The present paper is the result of the work thus far completed. The kind assistance and stimulating counsel of Dr. Bowditch throughout the investigation are gratefully acknowledged.

The Anatomy of the Stomach and its Relations to the Shadow

It must be constantly borne in mind that the shadows described in this research are cast by the gastric contents, not by the stomach itself. Therefore the movements of the organ are not seen directly, but are indicated by their effect on the contained food. Variations in the length and breadth of the stomach can be inferred from changes in the outline of the shadow, but variations in the front-to-back diameter of the organ must be judged from changes in the intensity of the shadow.

The form of the active stomach soon after food has been taken is shown in outline in Figure 1. Since the several parts of the stomach are to be mentioned frequently, it will be well to recall them here in their relations to the outline. The larger, cardiac part of the organ lies to the left of a line through *w x*. Into it the œsophagus opens through the cardiac sphincter, or cardia, at *c*. The pyloric part, which includes all of the stomach situated at the right of a line *w x*, is closed by the pylorus at *p*. This part has two divisions: the antrum at the right of the line *y z*, and the preantral part of the pyloric

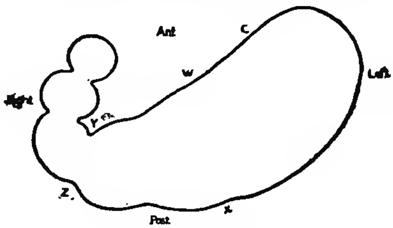


FIGURE I.

portion, or middle region of the stomach, between the lines *w x* and *y z*. The lesser curvature corresponds approximately to the anterior border of the shadow *c w p*; the greater curvature to the more extensive sweep, *c p*, along the posterior border.

The wall of the cat's stomach consists of three coats, but as this paper deals only with the functions of the muscular coat, that alone will be described. The gastric muscular fibres are disposed in three sets: an outer longitudinal layer, a middle circular layer, and a set of inner oblique fibres. The longitudinal fibres continue those of the œsophagus, and, radiating over the cardiac end, become more marked along the curvatures than on the front and back surfaces. Over the antrum they lie in a thick, uniform layer. The circular fibres form a complete investment, and are arranged in rings at right angles to the curved axis of the stomach. Towards the pyloric end they become denser and stronger, and at the pylorus form a thick bundle, the pyloric sphincter. Separating the antrum from the rest of the stomach, at *y z*, is a special thickening of the circular fibres, called by the early writers the "transverse band," and described by Hofmeister and Schütz as the "sphincter antri pylorici." The oblique fibres start from the left of the cardiac orifice and pass as two strong bands along the anterior part of the dorsal and ventral surfaces, giving off fine fasciculi to the circular musculature; towards the antrum they gradually disappear.

The musculature of the stomach consists of smooth muscle fibres, the chief physiological characteristics of which are slowness of contraction, rhythmic alternation of contraction and relaxation, and a very great tonicity, or power of prolonged contraction. The action of these muscles in the process of gastric digestion is now to be considered.

The Normal Movements of the Stomach

Since the time of Haller the chief contributors to the knowledge of the mechanics of the stomach have been Beaumont, Hofmeister and Schütz, and Rossbach.

Beaumont's famous investigations on Alexis St. Martin are recorded in almost all general works on physiology. Through a gastric fistula he introduced a thermometer-tube and observed how it was affected by the motions of the stomach. His conclusions are as follows: "The circular or transverse muscles contract progressively from left to right. When the impulse arrives at the *transverse band*, this is excited to a more forcible contraction, and closing upon the alimentary matter and fluids contained in the pyloric end, prevents their regurgitation. The muscles of the pyloric end, now contracting upon the contents detained there, separate and expel some portion of the chyme. . . . After the contractile impulse is carried to the pyloric extremity, the circular band and all the transverse muscles become relaxed, and a contraction commences in a reversed direction, from right to left, and carries the contents again to the splenic extremity to undergo similar revolutions."

In close accord with Beaumont's description of the activitives of the human stomach are the records of the investigations on the stomach of dogs by Hofmeister and Schütz. They removed the stomach from the body and placed it in a moist chamber, kept at body-heat and covered with glass. Under such conditions the organ remained active for from sixty to ninety minutes. A typical movement is described by these observers as composed of two phases. In the first phase a constriction of the circular fibres, deeper on the greater curvature, starts a few centimetres from the cardia and passes towards the pylorus. As the constriction proceeds it increases in strength until a maximum is reached about two centimetres in front of the antrum. This annular contraction, called by Hofmeister and Schütz the "preantral constriction," closes the first phase. Immediately thereafter the strong sphincter antri pylorici, or transverse band, contracts. Now, while the preantral constriction is relaxing, the sphincter antri pylorici tightens still more, and the antrum is shut off from the rest of the stomach. As soon as this has occurred a general contraction of the muscles of the antrum follows. Relaxation begins at the sphincter antri pylorici and progresses slowly towards the pylorus; it is sometimes accompanied by an antiperistaltic movement.

Although Rossbach also used dogs, his results vary considerably from those of Hofmeister and Schütz. This discrepancy is possibly accounted for by a difference in method, for Rossbach left the stomach in the body. The dogs were treated with morphia and curare, and the abdomen was then widely opened, so that the movements could be clearly seen. When the stomach was full Rossbach saw deep constrictions begin near the middle and pass in waves to the pylorus. At first these movements were weak; later, however, they became more vigorous. The fundus remained in tonic contraction about its contents and took no part in the peristalsis.

Before attempting to explain the difference in the records of these observers I shall give an account of what may be seen in a cat by use of bismuth subnitrate and the Röntgen rays.

1. *Movements of the pyloric part.* — Within five minutes after a cat has finished a meal of bread, there is visible near the duodenal end of the antrum a slight annular contraction which moves peristaltically to the pylorus; this is followed by several waves recurring at regular intervals. Two or three minutes after the first movement is seen very slight constrictions ap-

pear near the middle of the stomach, and pressing deeper into the greater curvature, course slowly towards the pyloric end. As new regions enter into constriction, the fibres just previously contracted become relaxed, so that there is a true moving wave, with a trough between two crests. When a wave swings round the bend in the pyloric part the indentation made by it deepens; and as digestion goes on the antrum elongates and the constrictions running over it grow stronger, but until the stomach is nearly empty they do not entirely divide the cavity. After the antrum has lengthened, a wave takes about thirty-six seconds to move from the middle of the stomach to the pylorus. At all periods of digestion the waves recur at intervals of almost exactly ten seconds. So regular is this rhythm that many times I have been able to determine within two or three seconds when a minute had elapsed simply by counting six similar phases of the undulations as they passed a given point. It results from this rhythm that when one wave is just beginning several others are already running in order before it. Between the rings of constriction the stomach is bulged out, as shown in the various outlines in Figures 2, 3, 4, and 5. The number of waves during a single period of digestion is larger than might possibly at first be supposed. In a cat that finished eating fifteen grams of bread at 10.52 A.M., the waves were running regularly at 11.00 o'clock. The stomach was not free from food until 6.12 P.M. During that time the cat was fastened to the holder at intervals of half an hour, and the waves were always observed following one another in slow and monotonous succession. At the rate of three hundred and sixty an hour, approximately two thousand six hundred waves passed over the antrum during that single digestive period.

From the above review it will be manifest that my observations of the movements of the pyloric part agree closely with those of Rossbach, but differ considerably from the harmonious results of the work of Beaumont, and Hofmeister and Schütz. Beaumont's methods, however, may be justly criticised on the ground that the thermometer-tube which he held in the stomach was wholly unlike food and very liable to bring about unwonted contractions in so sensitive an organ as the stomach. Further, the movements observed by Hofmeister and Schütz, as Ewald has pointed out, may easily have resulted from the abnormal stimulus due to lack of blood — a potent cause of peristalsis. And it will be shown later that the accounts given by these investigators describe very well the actions of the stomach when stimulated by an unusual irritant. In this connection it may be added that since the publication of the preliminary notice of my work, Roux and Balthazard, using the Röntgen rays, have published the results of observations on the stomachs of the dog and man similar to those thus far described in this paper.

The fact that my observations and those of Roux and Balthazard were conducted under normal conditions, and that the conditions of Rossbach's experiments were more nearly normal than those of the other observers mentioned, warrants the conclusion that the pyloric part has a more important function than that of merely expelling the contents of the stomach into the intestines. After summarising the description given by Hofmeister and Schütz, Ewald, for *a priori* reasons, declares: "I cannot accept this view. The plain fact that the pyloric portion secretes a strongly digesting fluid containing pepsin and hydrochloric acid proves it to be an important part for the peptonising function of the stomach." The account of the remarkable manner in which the pyloric portion performs this function must be deferred until the movements of other parts of the stomach have been considered.

2. *Movements of the pyloric sphincter.*—Rossbach mars his otherwise careful work by de-

claring that the pylorus is tightly closed during the whole digestive period of from four to eight hours, and that then the sphincter relaxes and the peristaltic waves empty the stomach. That this is not the normal action of the sphincter has been shown by several observers. Hirsch watched dogs with duodenal fistulas and saw food come from the stomach at intervals of one-fourth of a minute to several minutes. Roux and Balthazard maintain that in dogs food enters the duodenum at the completion of each wave of constriction. Observations on the cat, however, do not support their view, but agree rather with the statement of Hirsch.

In cats fed with bread mixed with subnitrate of bismuth, ten or fifteen minutes elapse after the first constriction in the antrum before any food can be seen in the duodenum. When food does appear it is spurted through the pylorus and shoots along the intestine for two or three centimetres. Not every constriction-wave forces food from the antrum. On one occasion, about an hour after the movements began, three consecutive waves were seen, each of which squirted food into the duodenum. The pylorus remained closed against the next eight waves, opened for the ninth, but closed once more against the tenth and eleventh. For each of the four succeeding waves the sphincter relaxed, but blocked the food brought by three constrictions that followed; and in this irregular way the food continued passing from the stomach. Near the end of gastric digestion, when the constrictions are very deep, it may be that the pylorus opens for every wave.

When a hard bit of food reaches the pylorus, the sphincter closes tightly and remains closed longer than when the food is soft. This action of the sphincter was shown by giving with the regular food of the cat a dry, hard pellet of equal parts of starch paste and bismuth subnitrate about the size of a pea. The food itself contained merely enough bismuth to throw a dim shadow, near the centre of which the pellet could be clearly seen as a dark object. The continual passing of the contraction-waves finally brought the little ball to the pylorus. When it arrived there, five grams of bismuth subnitrate were introduced into the stomach through a tube in the œsophagus. This was done in order that the food passing into the intestines after the ball came to the pylorus might be distinguished from that which had gone on before. By kneading the stomach the bismuth was distributed, as shown by the uniformly black shadow. The pellet could still be seen near the end of the antrum when the constrictions passed over it. Now, although the waves continued to run regularly, the very black food did not gather in the intestines in sufficient amount to be recognised until forty-two minutes after it had been introduced. And when, finally, the food did show itself in the intestines, its shadow contrasted strongly with that of the food which had already passed on. The slowness of the expulsion is not to be regarded as wholly due to the hard mass. No doubt the kneading of the stomach mixed the contents of different parts of the organ and brought to the pylorus food not yet sufficiently digested to be passed by that selective sphincter. But this does not explain the whole delay. Food similar to that given here, except that it contained no hard particles, has usually been seen as small masses in the intestines within fifteen minutes after being swallowed. A part of the delay was evidently, therefore, caused by the hard pellet. Further evidence on this point was secured when, on one occasion, the sphincter was seen to open only seven times in twenty minutes following the arrival of a hard particle of food at the pylorus. The conclusion may therefore be drawn that hard morsels keep the pylorus closed and hinder the passage of the food into the duodenum.

3. *Activity of the cardiac portion.* — The part played by the fundus apparently has not hitherto been properly appreciated. It has been

regarded as the place for peptic digestion, or as a passive reservoir for food; but it is in fact a most interestingly active reservoir.

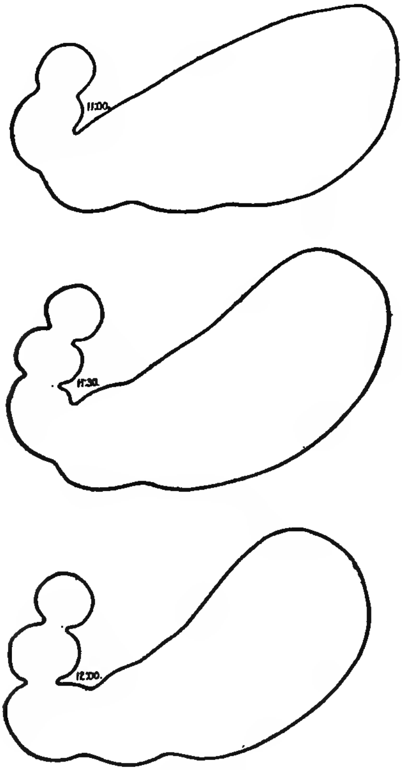


FIGURE 2.

The action of the cardiac portion will be best understood by comparing the appearances the

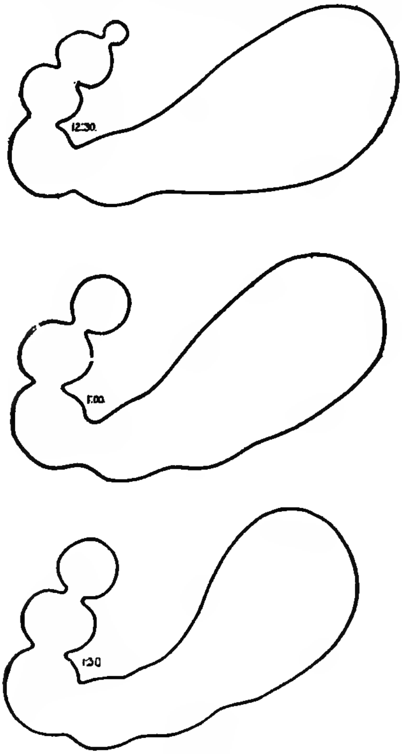


FIGURE 3.

stomach presents at various stages in a digestive period. In order to show these stages I carefully made a set of three tracings of the outlines of the stomach as soon as possible after a cat had finished eating, and another set of three

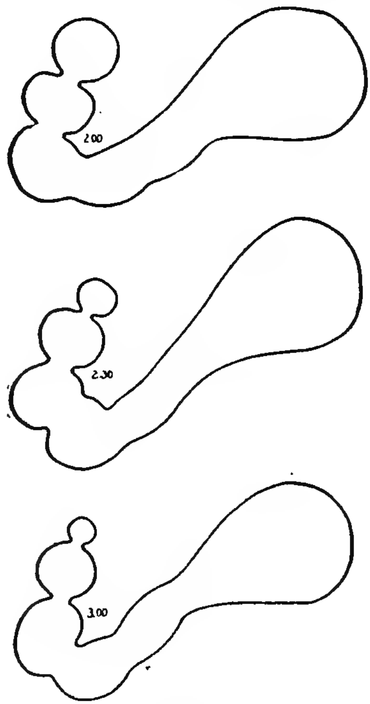


FIGURE 4.

every half hour thereafter, until the contents had disappeared (Figs. 2, 3, 4, and 5). These tracings were made by placing white tissue paper over the fluorescent screen, and drawing with a thick lead pencil, easily seen, as much of the boundary

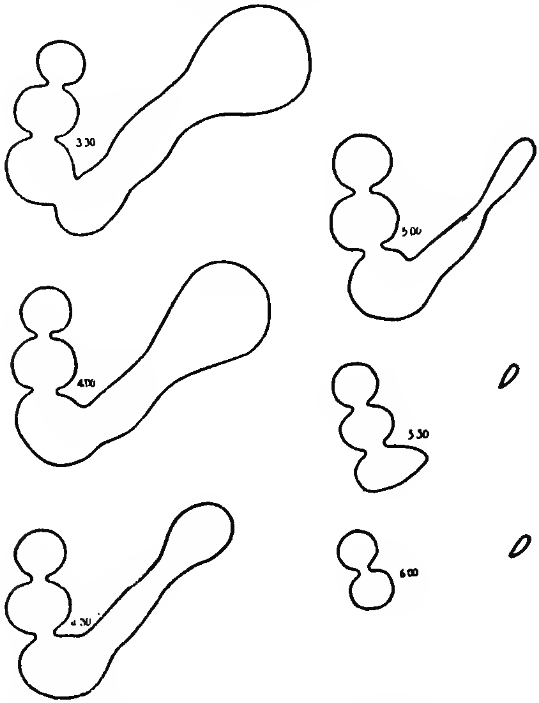


FIGURE 5.—Figures 2, 3, 4, and 5 present outlines of the shadow of the contents of the stomach cast on a fluorescent screen by the Röntgen rays. The drawings were made by tracing the outline of the shadow on tissue paper laid upon the fluorescent surface, and are about one-half the actual size. They show the change in the appearance of the stomach at intervals for half an hour, from the time of eating until the stomach is nearly empty.

of the stomach as I could at the end of each expiration. Between the times for making the drawings the cat was allowed to rest quietly on a mat, but care was taken to lay her in the same position on the holder for every drawing. The drawings of each set were afterwards fastened over one another, so that the lines coincided as closely as possible. Another piece of tissue paper was then put over these, and all four sheets were laid on an illuminated pane of glass. It was thus easy to get a composite tracing which, considering the movement imparted to the stomach by respiration, and the dimness of the shadows in the later stages of digestion, probably represents more exactly than any single drawing the outline of the stomach for each successive period.

A comparison of these drawings shows that as digestion proceeds the antrum appears gradually to elongate and acquire a greater capacity, and that the constrictions make deeper indentations in it. But when the fundus has lost most of its contents, the longitudinal and circular fibres of the antrum contract to make it again shorter and smaller. Its change of form, however, compared with the rest of the stomach, is slight.

The first region to decrease markedly in size is the preantral part of the pyloric portion. The peristaltic undulations, caused by the circular fibres, start at the beginning of this portion, and gradually, by their rhythmic recurrence, press some of the contents into the antrum. As the process continues, the smooth muscle fibres with their remarkable tonicity contract closely about the food that remains, so that the middle region comes to have the shape of a tube (Figs. 3 and 4 — 1.30 P.M. to 2.30 P.M.), with the rounded fundus at onc end and the active antrum at the other. Along the tube very shallow constrictions may be seen following one another to the pylorus.

At this juncture the longitudinal fibres which cover the fundus like radiating fingers, and the circular and oblique fibres reaching in all directions about this spherical region, begin to contract. Thus the contents of the fundus are squeezed into the tubular portion. This process, accompanied by a slight shortening of the tube, goes on until the shadow cast by the fundus is almost wholly obliterated (Fig. 5 — 5.30 P.M.).

The waves of constriction moving along the tubular portion press the food onward as fast as they receive it from the contracting fundus, and when the fundus is at last emptied they sweep the contents of the tube into the antrum (Fig. 5 — 5.00 P.M. to 6.00 P.M.). Here the operation is continued by the deeper constrictions till, finally (in this instance at 6.12 P.M.), with the exception of a slight trace of food in the fundus, nothing is to be seen in the stomach at all.

The food in the fundus may possibly be slightly affected by the to-and-fro movements of the diaphragm in respiration. With normal breathing the upper border of the cardiac portion swings through about one centimetre; with dyspnœa, or deep breathing, through one and a half or two centimetres. Since the lower border does not move so much, the contents are gently pressed, and then released from pressure, at each respiration. The pyloric portion is moved very little by the diaphragm, the oscillation being less than a half centimetre.

Moritz has pointed out the value of an organ like the stomach for holding the bulk of the food and serving it out a little at a time, so that the intestines may not become congested during their digestive and absorptive processes. All of the advantages supposed to be thus secured to the intestines may be claimed also for the stomach itself. For the preceding description indicates, and experiments to be described later prove, that the stomach is composed of two physiologically distinct portions: the busy antrum, over which during digestion constriction-waves are running in continuous rhythm; and the cardiac part, which is an active reservoir, pressing out its contents a little at a time as the antral mechanism is ready to receive them.

The Movements of the Stomach in Vomiting

The appearance of the stomach during vomiting has been studied particularly by Openchowski. He says that when an emetic is given there follows a quivering of the stomach-wall, which, beginning near the pylorus, shows itself later in the antral and middle regions of the stomach. The quivering afterwards passes into a contraction, most strongly marked in the antral part, since the peristaltic waves running down to the antrum from above are continually growing deeper. At the same time the fundus expands spherically. The increased contraction in the pyloric part drives the contents towards the more dilated portion, and thence they are forced into the œsophagus by abdominal pressure.

The same phenomena occur when a cat is given apomorphine hypodermatically. First the upper circular muscles relax and become so flaccid that the slightest movement of the abdomen changes the form of the fundus. Then there are apparently irregular twitchings of the fundus wall. Soon a deep constriction starts about three centimetres below the cardia and, growing in strength, moves towards the pylorus. When it reaches the transverse band the constriction tightens and holds fast, while a wave of contraction sweeps over the antrum. Another similar constriction follows. In the interval the transverse band relaxes slightly, but tightens again when the second wave reaches it. Perhaps a dozen such waves pass; then a firm contraction at the beginning of the antrum completely divides the gastric cavity into two parts. This same division of the stomach into two parts at the transverse band is to be seen when mustard is given. Now, although the waves are still running over the antrum, the whole preantral part of the stomach is fully relaxed. A flattening of the diaphragm and a quick jerk of the abdominal muscles, accompanied by the opening of the cardia, now force the contents of the fundus into the œsophagus. As the spasmodic contractions of the abdominal muscles are repeated, the gastric wall again tightens around the contained food. Antiperistalsis I have seen only once; then, while the cat was retching, a constriction started at the pylorus and ran back, over the antrum, completely obliterating the antral cavity.

It will be recalled that the principal difference between the movements of the stomach and their effects as described by Beaumont, and Hofmeister and Schütz on the one hand, and Rossbach, Roux and Balthazard, and myself on the other hand, is that the former observed constrictions completely dividing the stomach at the transverse band, and the antrum then squeezing its contents into the intestines; whereas the latter have seen the constrictions moving forward as narrowing rings, but not separating the gastric cavity into two parts.

With the exception of peristalsis in the antrum, the gastric movements at the beginning of emesis are almost exactly the same as those Beaumont, and Hofmeister and Schütz, declare to be the normal contractions of the stomach. Their observations were made, however, when the organ was subjected to unnatural stimulation. In the excised stomach, observed by Hofmeister and Schütz, not only were all nervous connections severed, but likewise all flow of blood to the organ was entirely stopped, and the cutting off of the blood supply is regarded as one of the most powerful predisposing causes of peristaltic action. The thermometer-tube used by Beaumont was an irritant to the stomach, as he himself admits. "If the bulb of the thermometer," he writes, "be suffered to be drawn down to the pyloric extremity, and retained there for a short time, or if the experiments be repeated too frequently, it causes severe distress and a sensation like cramp, or spasm, which ceases on withdrawing the tube, but leaves a sense of soreness and tenderness at the pit of the stomach." Moritz also noticed that a rubber sound introduced into the human stomach proved to be a source of irritation. It seems reasonable to suppose, therefore, that these observers did not see the normal movements, but the actions resulting from abnormal irritation.

The Effect of the Movements of the Stomach on the Food

In my first observations on the active stomach a bulging of the stomach-wall was to be seen in front of the passing waves. But as food did not immediately appear in the intestine, and as, after the pylorus relaxed, the gastric contents did not diminish rapidly enough to allow the supposition that all of the food squeezed forward by the waves was immediately forced through the pylorus, it was assumed that a part, at least, of the food under pressure was forced back towards the cardia through the constriction-ring. This inference was stated in the preliminary notice of my work. Roux and Balthazard also observed the passage of the undulations over the pyloric part, but state merely that the function of the constrictions is the propulsion of food into the intestine, without mentioning what must be regarded as a very important function; namely, the mixing effect of the waves.

Most writers have agreed that the result of the active and passive movements of the stomach is to force the contents hither and thither, thus mixing them and the gastric juice together. Two observers, Beaumont and Brinton, have attempted to explain the manner of the mixing. Beaumont, after noting how the thermometer-tube, used by him to indicate the gastric motions, was affected, describes the circulation of the food as follows: "The bolus as it enters the cardia turns to the left, passes the aperture, descends into the splenic extremity, and follows the great curvature towards the pyloric end. It then returns, in the course of the small curvature, makes its appearance again at the aperture, in its descent into the great curvature, to perform similar revolutions." Brinton bases his theory of the circulation of the food on an analogy between the movement of a constriction over the stomach and the passage of a septum with a central perforation along the interior of a cylinder full of liquid. The result in both cases, he declares, must be a peripheral current of advance, and a central current of return. Thus in the stomach there would be peripheral currents from the cardia along the walls of the stomach to the pylorus, where they would unite and run as an axial current back to the cardia.

Certain *a priori* objections may be urged against each of these conclusions. In the first place Beaumont's observations were made on a subject having a gastric fistula, and the adhesions between the stomach and the abdominal wall would prevent the fundus from acting quite normally in relation to its contents. Beaumont's conclusions, furthermore, are based on the movements of a thermometer-tube introduced through the fistula, and on the recognition of particles of food which he had seen before as they passed the fistulous opening: the first method, as has been shown, made the conditions in the stomach more abnormal than they were previously; the second gave uncertain knowledge of the course of the food when out of the observer's sight. Brinton's hypothesis states the probable movements of fluid contents acted on by a passing constriction. But it may be objected that the conditions assumed by him do not exist in all parts of the stomach. For not only is there no peristalsis visible in the fundus, but with the usual food the fundus contents are not liquid. Moreover, the constrictions at the beginning of the pyloric portion are very slight and move slowly. The food in front of them is, accordingly, not under much greater pressure than the food behind them. The axial current which might result, therefore, could not be strong enough to go far into the cardiac portion.

It is easily possible to test experimentally the validity of these two theories by watching the action of pieces of food which throw a black shadow in a dimly outlined stomach. For this purpose little paste pellets of bismuth subnitrate, with starch enough to keep the form, were given with the customary meal. These pellets, it was found, did not break up in the stomach during the gastric digestion of soft bread. Several times I have been fortunate in getting two of the little balls in the axis of the stomach and about a centimetre apart. As the constriction-wave approached them, both moved forward, but not so rapidly as the wave. Now when the constriction overtook the first ball, the ball moved backward through the constricted ring, in the direction of least resistance. The wave then overtook the second ball, and it also passed backward to join its fellow. At the approach of the next wave they were both pushed forward once more, only to be again forced backward, one at a time, through the narrow orifice. As the waves recurred in their persistent rhythm, the balls were seen to be making progress — an oscillating progress — towards the pylorus;

for they went forward each time a little farther than they retreated. This to-and-fro movement of the pellets was much more marked in the antrum, where the waves were deep, than in the middle region. On different occasions from nine to twelve minutes have elapsed while the balls were passing from where the waves first affected them to the pylorus; which means that on the way they were moved back and forth by more than a half hundred constrictions.

If the pylorus does not relax, it is evident that a wave approaching it pushes the food into a blind, elastic pouch, the only exit from which is through the advancing constricted ring. The constrictions are deeper near the end of the antrum, and the rings are small; consequently, the food is squirted back through them with considerable violence. As has been noted, the pylorus opens less frequently for a while after a solid piece of food comes to it. In such a case the slow driving waves squeeze the hard morsel and the soft food about it up to the sphincter, only to have the whole mass shoot back, sometimes half-way along the antrum. Over and over again the process is repeated till the sphincter at last opens and allows the more fluid parts to pass. Hofmeister and Schütz, and Moritz have disclaimed any selective action of the pylorus, and declare that solids are driven from the pylorus to the fundus by antiperistalsis. The action of the pylorus which I have seen, however, is more like that described by the earlier investigators; for during digestion there was no antiperistalsis, and the sphincter, separating the fluids from the solids, caused the solids to remain and undergo a tireless rubbing. Frequently, when several of these balls have been given at the same time, they have all been seen in the antrum after the stomach was otherwise empty. Here they remain to be softened in time by the juices, or to be forced through the pylorus later, for solids do pass into the intestine. Thus when the teeth neglect their work the stomach attempts to perform their function; the relative inefficiency of the gastric method of grinding and its interference with the normal gastric activities point an obvious hygienic moral.

During the process of digestion the food in the cardiac portion gives no sign of currents. Balls which lie in the fundus immediately after the food is ingested keep their relative positions until the cardiac portion begins to contract, and then move very slowly towards the antrum. Moreover, the food in the fundus of a cat has the same mushy appearance when examined after gastric peristalsis had been active for an hour and a half that it had when ingested. The contents of the antrum, on the other hand, look quite different and have the consistency of thick soup. The inactivity of the food in the fundus can also be proved by feeding first five grams of bread and bismuth, then five grams without bismuth, and finally five grams again with bismuth in it. The stomach contents are thus arranged in two dark layers along the curvatures, with a light layer between. Tracings made on tissue paper show that ten minutes after peristalsis commenced the stratification had entirely disappeared in the pyloric part, but that an hour and twenty minutes thereafter the layers were still clearly visible in the cardiac region.

The value of the circulation of the food, as described by Beaumont and Brinton, lay in the supposition that the contents of the stomach were thus brought near to the secreting gastric wall, and that the gastric juice could thus more readily exert its action. Although my observations do not support their theories of mixing currents running throughout the stomach, they still show that the pyloric portion is an admirable device for bringing all of the food under the influence of the glandular secretions of that region. For, when a constriction occurs, the secreting surface enclosed by the ring is brought close around the food lying within the ring in the axis of the stomach. As this constriction passes on, fresh areas of glandular tissue are continuously pressed in around the narrow orifice. And also, as the constriction passes on, a thin stream of gastric contents is continuously forced back through the orifice, and thus past the mouths of the glands. The result of this ingenious mechanism is that every part of the secreting surface of the pyloric portion is brought near to every bit of food, before the latter leaves the stomach, a half hundred times or more, as evidence by the moving ball.

Salivary Digestion in the Stomach

The absence of movement in the fundus would seem to give the food during its stay there little opportunity to become mixed with the gastric juices, and thus to undergo peptic digestion. The truth of this supposition can easily be proved experimentally by feeding a slightly alkaline meal, and later testing the chemical reaction of the contents of various parts of the stomach. A cat which had been without food for fifteen hours was given eighteen grams of mushy bread made slightly alkaline with sodium carbonate. One hour and a half after the cat had finished eating she was killed, and the stomach laid bare by opening the abdomen. A very small hole was then made through the wall in the fundus region, and another similar hole was made into the antrum. By means of a glass pipette food was extracted first from the periphery of the fundus; this food was slightly acid. The cleaned pipette was then introduced two and a half centimetres into the fundus contents, and the food thus extracted gave the original alkaline reaction. Specimens of the liquid contents of the antral and middle regions, taken from various depths, were all strongly acid. A dog killed an hour and three-quarters after eating showed similiar differences between the reactions of the food in the fundus and the food in the pyloric portion. So, as a matter of fact, the food does not become acid at a uniform rate in all parts of the stomach, as would be the case if Beaumont's and Brinton's theories of mixing currents were true. Moreover, if the facts accorded with their notions, the saliva, which ceases to act in the presence of more than 0.003 per cent free hydrochloric acid, and is destroyed when the percentage of acid proteids is large, would manifestly have its service as a ferment limited to the relatively short time during which the stomach contents, in the process of thorough mixing, were reaching that degree of acidity. There is, however, no movement of food in the fundus, and the alkaline food received from the œsophagus remains alkaline in this region for a considerable period. The nutriment, therefore, if well chewed and thus mixed with saliva, can undergo salivary digestion in the fundus for a considerable period without interference by the acid gastric juice.[1]

From all these observations the conclusion must be that the fundus acts as a reservoir for the food, in which the digestion of sugars and starches may take place; and that the pyloric portion with its simple but marvellous peristaltic mechanism, by a single process, triturates the food, brings it near to the active glands, stirs it thoroughly with their secretions, and expels the products into the intestines.

The Inhibition of Stomach Movements during Emotion

Early in the research a marked unlikeness was noticed in the action of the stomachs of male and female cats. The peristalsis seen with only a few exceptions in female cats failed to appear in most of the males, although both had received exactly the same treatment. Along with this difference was a very striking difference in behaviour

[1] An investigation by Cannon and Day (*American Journal of Physiology*, 1903) has confirmed this conclusion. An hour after starchy food mixed with saliva was ingested a unit volume of the food in the cardiac end of the stomach contained almost twice the amount of sugar found in a unit volume of the food in the pyloric end.

when bound to the holder; the females would lie quiet, mewing occasionally, but purring as soon as they were gently stroked. The màles, on the contrary, would fly into a violent rage, struggle to be loose from their fastenings, bite at everything near their heads, cry loudly, and resist all attempts to quiet them. On account of this difference only female cats were used for some time, and the significance at first attributed to the action of the males was almost forgotten when the following incident recalled it and suggested that the excitement caused the suspension of the stomach movements. On October 23, 1897, a male cat was fed at 12.00, but was not placed on the holder till ninety minutes later. The waves were passing at the rate of six a minute. The cat fell into a rage and the waves suddenly stopped.

A few days later an observation on a female with kittens explained the absence of gastric movements in the males. While the peristaltic undulations were coursing regularly over the cat's stomach, she suddenly changed from her peaceful sleepiness, began to breathe quickly, and struggled to get loose. As soon as the change took place, the movements in the stomach entirely disappeared; the pẙloric portion relaxed and presented a smooth, rounded outline. I continued observing, and stroked the cat reassuringly. In a moment she became quiet and began to purr. As soon as this happened the movements commenced again in the stomach; first a few constrictions were visible near the end of the antrum, then a few near the sharp bend in the lesser curvature, and finally the waves were running normally from their habitual starting-place. By holding the cat's mouth closed between the thumb and last three fingers, and covering her nostrils with the index finger, she could be kept from breathing. At the first sign of discomfort the fingers were removed. This experiment was repeated a great many times on different cats, and invariably the evidence of distress was accompanied by a total suspension of the motor activities of the stomach and a relaxation of the antral fibres.

No amount of kneading or compression of the abdomen with the fingers, short of making the cat angry, would cause the waves to stop; so that the cat's movements, in themselves, were not the source of the inhibition. And since expressions of strong feeling on the part of the animal always accompanied cessation of the constriction-waves, the inhibition was probably due to nervous influence. It has long been common knowledge that violent emotions interfere with the digestive process, but that the gastric motor activities should manifest such extreme sensitiveness to nervous conditions is surprising.

SUMMARY

1. By mixing a harmless powder, subnitrate of bismuth, with the food, the movements of the stomach can be seen by means of the Röntgen rays.

2. The stomach consists of two physiologically distinct parts: the pyloric part and the fundus. Over the pyloric part, while food is present, constriction-waves are seen continually coursing towards the pylorus; the fundus is an active reservoir for the food and squeezes out its contents gradually into the pyloric part.

3. The stomach is emptied by the formation, between the fundus and the antrum, of a tube along which constrictions pass. The contents of the fundus are pressed into the tube and the tube and antrum slowly cleared of food by the waves of constriction.

4. The food in the pyloric portion is first pushed forward by the running wave, and then by pressure of the stomach-wall is returned through the ring of constriction; thus the food is thoroughly mixed with gastric juice, and is forced by an oscillating progress to the pylorus.

5. The food in the fundus is not moved by peristalsis, and consequently it is not mixed with

the gastric juice; salivary digestion can therefore be carried on in this region for a considerable period without being stopped by the acid gastric juice.

6. The pylorus does not open at the approach of every wave, but only at irregular intervals. The arrival of a hard morsel causes the sphincter to open less frequently than normally, thus materially interfering with the passage of the already liquefied food.

7. Solid food remains in the antrum to be rubbed by the constrictions until triturated, or to be softened by the gastric juice, or later it may be forced into the intestine in the solid state.

8. The constriction-waves have, therefore, three functions: the mixing, trituration, and expulsion of the food.

9. At the beginning of vomiting, the gastric cavity is separated into two parts by a constriction at the entrance to the antrum; the cardiac portion is relaxed, and the spasmodic contractions of the abdominal muscles force the food through the opened cardia into the œsophagus.

10. The stomach movements are inhibited whenever the cat shows signs of anxiety, rage, or distress.

THE MOVEMENTS OF THE INTESTINES STUDIED BY MEANS OF THE RÖNTGEN RAYS [1]

By W. B. Cannon

From the Laboratory of Physiology in the Harvard Medical School
Extracts from *American Journal of Physiology*, 1902

Introduction

The investigation of intestinal movements has been beset by the same difficulties that characterised the investigation of the gastric mechanism. Pathological subjects or animals subjected to the disturbing action of drugs and anæsthetics and of serious operations have been the only sources of our knowledge. A considerable difference of opinion as to the nature of the normal movements in the intestines has resulted from observations made under these necessary abnormal conditions. The slowly advancing peristaltic wave and the *Pendelbewegung*, or swaying movement, described by Ludwig, have been regarded as true physiological processes. Concerning antiperistalsis and

[1] The results of this investigation were reported to the Boston Society of Medical Sciences, November 19, 1901.

the swiftly running vermicular contraction, observers are not so nearly in agreement. The activity of the large intestine has been described as simply peristalsis of a slower rate than that seen in the small intestine.

The best known of the intestinal movements is the normal peristaltic wave. This wave is slow, having a rate of about two centimetres per minute, is regular, and by most observers is said to move always in one direction. The progress of the contraction, as suggested by Nothnagel's experiments, and as clearly stated by Mall and by Bayliss and Starling, is dependent upon a local reflex. According to Mall, when an object stimulates the mucosa there occurs above the point of stimulation a constriction which forces the object downward; and as it moves downward new regions immediately above the mass are by this reflex brought into constriction, and thus the wave and its stimulus advance together. "At the same time," Mall states, "a sucking force, due to active dilatation below the body, may have a tendency to drag it down." In what manner an active dilatation of the intestinal wall may occur so as to produce a "sucking force" he does not make wholly clear. Bayliss and Starling, in describing normal peristalsis in the intestine, state that the contractions above the bolus increase until there is a strong tonic constriction. This passes the bolus onward, and as it advances the ring of constriction follows it. While the bolus is passing down, the gut above it is traversed by waves running as far as the constricted ring. These observers state the law of intestinal peristalsis thus: "Local stimulation of the gut produces excitation above and inhibition below the excited spot."

The pendulum movements are characterised by a gentle swaying motion of the coils, and are accompanied by rhythmical contractions of the intestinal wall. They continue with undiminished force after paralysis of the local nervous mechanism by nicotine or cocaine; they have been called, therefore, myogenic or myodromic contractions. Observers have described them variously as shortenings and narrowings of the gut, rhythmically repeated at nearly the same intestinal circumference; as alternating to-and-fro movements of the long axis without changes in the lumen; as local or extensive periodic contractions and relaxations mainly of the circular musculature; and as waves involving both muscular coats of the intestine, and travelling normally from above downward at a rapid rate (2 to 5 cm. per second). They have been seen in the dog, and in the rabbit and cat. In the cat Bayliss and Starling noticed that when the lumen of the gut was distended by a rubber balloon, there appeared rhythmical contractions, which nearly always were most marked at about the middle of the balloon; *i. e.*, the region of greatest tension. This form of constriction, which, as my observation shows, is an indication of the manner in which the rhythmical contraction acts in the cat's intestine, Bayliss and Starling seem to have regarded with slight attention, since it did not accord with the law of peristalsis.

The swift vermicular wave may pass the whole length of the intestine in about a minute. It is often seen just after death, as well as in pathological states such as intestinal anæmia or hyperæmia, and when the bowel contains gases and organic acids from decomposing food. Starling is inclined to regard this type of intestinal activity as an exaggeration of the rhythmic type; Mall, on the other hand, places it in a class by itself, and declares that its service is to rid the intestine rapidly of irritating substances. Nothnagel, who designates this form of movement with the term *Rollbewegung*, thinks it is transitional between a physiological and a pathological activity.

The existence of antiperistalsis has been so much questioned that it will be considered in a special section of this paper, where my observations may be conveniently introduced.

The common understanding of the manner in which food passes through the intestinal canal is that the chyme ejected from the stomach is pressed downward by a peristalsis, which passes slowly over a part or all of the small intestine. The peristaltic waves of the colon are supposed to constitute an independent group, similar to those of the small intestine, but weaker and slower. Movements of the food other than the uninterrupted advance have been mentioned by some observers. Starling states that the effect of the pendulum movement is to mix the contents of the intestine and bring them into intimate contact with the mucous membrane. Grützner writes that he has been brought "by strange and peculiar observations" to believe that the fluid contents of the small intestine move irregularly forward, then forward and back, then perhaps remain quiet for some time, only to pass backward for a long distance, and finally to move forward steadily to the end. In this manner the food is mixed and brought into contact with the absorbing walls. The to-and-fro shiftings of the food Grützner ascribed to advancing and retrograde contractions of the intestinal musculature, and he argued that even circular constrictions must force the liquid contents away in both directions. To support his contention, Grützner introduced mercury into the intestine and observed it with the Röntgen rays. After noting a backward and forward movement of the mercury he dismissed the method, saying, "Many a flash must come from the Röntgen tube before the *normal* movement of the intestinal contents is made entirely clear by this method."

The following account is a summary of many repeated observations on different animals, and is a contribution to a clear understanding of the normal movements of the intestines and their contents.

The Movements of the Small Intestine

When the food has been distributed through the intestine so as to present the appearance shown in Figure 1, a noticeable feature in most or all of the loops is the total absence of movement. If the animal remains quiet, however, only a few moments elapse before peculiar motions appear in one or another of the loops, or perhaps in several, and last for some time. These motions consist in a sudden division of one of the long, narrow masses of food into many little segments of nearly equal size; then these segments are again suddenly divided and the neighbouring halves unite to make new segments, and so on, in a manner to be more fully described. I have called this process the rhythmic segmentation of the intestinal contents. Further observation reveals peristalsis here and there, and under certain circumstances the typical swaying movements may be seen. All these phenomena are now to be considered in detail.

FIGURE 1. — Appearance of food in the intestines 5¾ hours after eating. This and other radiographs reduced two-thirds.

Rhythmic segmentation of the intestinal contents. — This is by far the most common and the most interesting mechanical process to be seen in the small intestine. The nature of the process may best be understood by referring to the diagram in Figure 2. A string-like mass of food is seen lying quietly in one of the intestinal loops (line 1, Fig. 2). Suddenly an undefined activity appears in the mass, and a moment later constrictions at regular intervals along its length cut it into little ovoid pieces. The solid string is thus quickly transformed, by a simultaneous sectioning, into a series of uniform segments. A moment later each of these segments is divided into two particles, and immediately after the division neighbouring particles (as *a* and *b*, line 2, Fig. 2) rush together, often with the rapidity of flying shuttles, and merge to form new segments (as *c*, line 3, Fig. 2). The next moment these new segments are divided, and neighbouring particles unite to make a third series, and so on. At the time of the second segmentation (line 3,

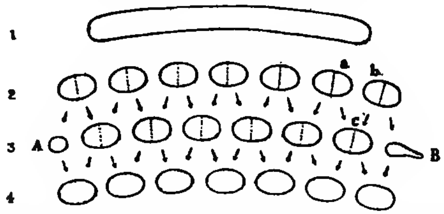


FIGURE 2.—Diagram representing the process of rhythmic segmentation. Lines 1, 2, 3, 4 indicate the sequence of appearances in the loop. The dotted lines mark the regions of division. The arrows show the relation of the particles to the segments they subsequently form.

Fig. 2) the end particles are left small. Observation shows that these small pieces are not redivided. The end piece at A simply varies in size with each division; at one moment it is left small, at the next moment it is full size from the addition of a part of the nearest segment, and a moment later is the small bit left after another division. The end piece at B (probably the rear of the mass) shoots away when the end mass is divided, and is swept back at each reunion to make the large end mass again, only to be shot away and swept onward with each recurrence of the constrictions. Thus the process of repeated segmentation continues, with the little particles flitting towards each other and the larger segments shifting to and fro, commonly for more than half an hour without cessation. From the beginning to the end of a period of segmentation the food is seen to have changed its position in the abdomen to only a slight extent; whether this change is a passing of the food along the loop, or a movement of the loop itself, it is impossible to tell from the shadows on the screen. The change of position, however, is much less conspicuous than the lively division and redivision which the mass suffers so many times from the busy, shifting constrictions.

From this typical form of rhythmic segmentation there are several variations. Sometimes, and especially when the mass of food is thick, the constrictions do not make complete divisions and are so far apart that the intermediate portions are relatively large. Moreover, the constrictions do not take place in the middle of each portion, but near one end; thus each portion is constricted, not into halves, but into thirds. If a little pointer is placed at the middle of a segment, when the segments are completely divided into halves, in a few seconds the pointer will be in the middle of the clear space between two segments; but in a few seconds more the first phase will return and the pointer will again be indicating a segment, — two operations intervene between similar phases. When, however, the portions are constricted into thirds, the indicator shows it, since three operations intervene between similar phases. The manner of these changes is made clearer by reference to the diagram in Figure 3. That each portion is constricted into three pieces is proved also by watching the gradual reduction of the portion at the left end of line 1 through lines 2 and 3, and also in the gradual formation of a full-sized portion at the right end of lines 2, 3, and 4. When food undergoing this process is watched, it appears to be affected by a series of constrictions, each of which starts at one end of the mass and marches through to the other end, leaving its impress at short intervals along the length. The progression of the dotted lines from right to left in *a*, *b*, *c*, and *d*, etc., Fig. 3, gives a notion of these advancing constrictions.

Another variation of the segmentation is shown in Figure 4. In this type there are evidently divisions and subdivisions, *i. e.*, one more operation between the appearance and the reappearance of the same phase than is present in the simple division of the small segments in a long string of food (Fig. 2). This form of segmentation is fairly typical for the constrictions seen in food advancing through the intestine. Sometimes the divisions occur in the middle of a long string of food and leave the ends wholly unaffected.

A remarkable feature in the segmentation of the food is the rapidity with which the changes take place. The simplest way of estimating the rate of division is to count, not the number of times the partition of the food recurs in the same place, but the number of different sets of segments observed in a given period. Thus in Figure 4 the appearances of lines 1, 2, 3, 4, etc., would be counted, and not merely lines 1, 4, etc. Repeated observations on different animals have shown that the most common rate of division in long, thin chains of food varies between twenty-eight and thirty times in a minute; *i. e.*, there is a change from one set of

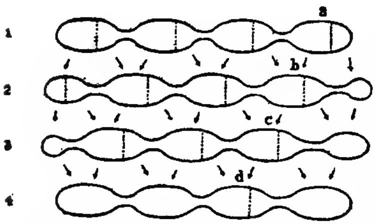


FIGURE 3. — Diagram showing the relations of the portions when they are constricted into three pieces. The dotted lines indicate regions of constriction; the arrows indicate the relationship of the pieces to the portions they subsequently form.

segments to another set every two seconds, and a return of the same phase every four seconds. In some cases the rate is as low as twenty-three times per minute. The larger masses seem to be associated with a slower segmentation; the operations indicated in Figure 3, for example, occurred from eighteen to twenty-one times in a minute, so that the same phase reappeared only once in eight or nine seconds. The segmentation frequently continues for more than half an hour; in one instance it was seen to persist with only three short periods of inactivity for two hours and twenty-two minutes. At the rate of thirty segmentations per minute it is clear that a slender string of food may commonly undergo division into small particles more than a thousand times while scarcely changing its position in the intestine.

I have seen once, in a cat only lightly etherised, the exterior of an intestine which was dividing the food as above described. An hour and a half after a meal of salmon the anæsthetic was given, the abdomen opened, and the flaps raised so as to form walls. Warm salt solution was then poured into the abdominal cavity, and the floating coils left covered with the transparent omentum. The gastric peristaltic waves were running regularly; on the intestine there were visible at various places during the period of observation regions of constriction which had the appearance shown in Figure 3, except that the rings were relatively nearer together. New rings of constriction took place on the same side of all the bulging parts at the margin of the constricted portion (*cf.* dotted lines, Fig. 3). As new rings occurred the old relaxed, but apparently with tardiness, for the contents gurgled as if forced through the narrowed lumen. The constrictions recurred irregularly and at much longer intervals than in the normal animal. The contracted rings were pale and bloodless.

The effect of the process of rhythmic segmentation proves it an admirable mechanism. The food over and over again is brought into closest contact with the intestinal walls by the swift kneading movement of the muscles. Thereby not only is the undigested food intimately mixed with the digestive juices, but the digested food is thoroughly exposed to the organs of absorption. Mall has shown that contraction of the intestinal wall has the effect of pumping the blood from the submucous venous plexus into the radicles of the superior mesenteric vein, and thus materially aids the intestinal circulation. Moreover, lacteals loaded with fat will in a few moments become empty unless the intestine is slit lengthwise, so that the muscles cannot exert compression. The rhythmic constrictions, therefore, both propel the blood in the portal circulation and act like a heart in promoting the flow of lymph in the lacteals. This single movement with its several results is an excellent example of bodily economy; the repeated constrictions, as already shown, thoroughly churn the food and digestive fluids together, and also plunge the absorbing mucosa into the very midst of the food masses: but not only are the processes of digestion and absorption favoured by these movements; they also, by compression of the veins and lacteals of the intestinal wall, serve to deport through blood and lymph channels the digested and absorbed material.

Peristalsis.[1] — The phenomena of peristalsis and segmentation are usually combined in some manner while the food passes through the small intestine. Peristalsis is observed normally in two forms: as a slow advancing of the food for a short distance in a coil, and as a rapid movement sweeping the food without pause through several turns of the gut. The latter form is

[1] Without the possibility of seeing the relations of a movement to the ends of the intestine, it cannot be stated absolutely whether the movement is peristaltic or antiperistaltic. Such relations can be seen on the fluorescent screen only near the stomach and near the ileocæcal valve. The evidence that advancing peristalsis is the normal movement is so overwhelming that I have assumed that when food is moving in loops not visibly related to fixed points it is moving forward.

frequently seen when the food is carried on from the duodenum; and it may readily be produced in other parts of the small intestine by giving an enema of soapsuds.

When a mass of food has been subjected for some time to the segmenting activity of the intestine, the separate segments, instead of being again divided, may suddenly begin to move slowly along the loop in which they lie. That this movement is not a swinging of the coil as a whole, but a peristaltic advance of separate rings of its circular musculature, is made probable by the fact that the succeeding segments follow along the same path their predecessors have taken. The advance of the little pieces may continue for seven or eight centimetres, when finally the front piece stops or meets other food. Then all the succeeding pieces are swept one by one into the accumulating mass, which at last lies stretched along the intestine, a solid string manifesting no sign of commotion.

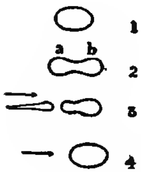


FIGURE 4.—Diagram showing combined peristalsis and segmentation.

Another form of slow peristalsis is frequently observed when the food is pushed forward, not in small divisions, but as a large lump. The relatively long string of food is first crowded into an ovoid form as the forward movement begins, and as it is collecting thus, it seems at the last to be suddenly formed into a more rounded ball, as if the mass were pulled or pushed together at the two ends. The next moment it is indented in the middle by a circular constriction (as shown in Fig. 4, line 2), which spreads it in both directions along the loop. The trailing portion (*a*) is next cut in two, and the severed part sometimes flies back over its course about a centimetre. Now the whole mass is swept together again and slightly forward as shown in line 4, Fig. 4, and the segmenting process is repeated. At stage 3, Fig. 4, a constriction sometimes appears around the middle of the advanced portion (*b*). Thus, with many halts and interruptions, the food slowly advances.

A slight variation of the movement just described is observed when the amount of food is greater and extends farther along the intestine. Under such circumstances, as the mass moves forward, constrictions appear just in front of the rear end, which separate it from the main body, and cause it to shoot backward sometimes through the distance of a centimetre. The main body meanwhile is not disturbed. No sooner has the rear section been shot away than it is swept forward again into union with the rest of the food, and the whole mass then advances until another interfering constriction repeats the process.

Rhythmic segmentation and the pendulum movement. — There is little doubt that the segmentation of the food which I have seen is due to an activity of the intestinal musculature similar to that which causes the so-called pendulum movement. This activity, as already noted, is rhythmic, and, although accounts differ, analytical methods prove that it involves both the longitudinal and the circular layers of muscle. Observations of the effect of the rhythmic contractions upon the food show that the action of the circular fibres is most prominent. It is probable, however, that the longitudinal fibres also play an important part in the process of segmentation. Examination of Figure 2 makes clear that in line 2 the regions of constriction appear between the regions of constriction in line 3; before *c* can be formed, therefore, the constriction between *a* and *b* must relax. Contraction of the longitudinal fibres between two segments would help to enlarge the constricted lumen of the gut. It seems probable that, as the constrictions on either side of *c* occur, the longitudinal fibres between them contract; almost simultaneously the constriction between *a* and *b* relaxes, and the two particles are thus brought swiftly together. A similar process naturally would take place for each of the shifting segments. Thus the function of the longitudinal muscles would be to contract between new rings of constriction and thereby aid in relaxing the former ring between them. During my one observation of the segmenting process, as seen on the surface of the intestine, I could not be sure that the distance between neighbouring segments was shortened as the constriction relaxed; that activity of the longitudinal fibres is present, however, is indicated by observations of Raiser on the intestines of the rabbit and the cat. Raiser observed the outer surface of the coils, and describes the normal movement as an alternate contraction and relaxation of single divisions of the longitudinal fibres; he notes that these short divisions shift. But whether they shift in alternation with the shifting circular constrictions, as seems probable, is an interesting point not yet determined.

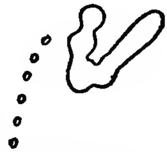


FIGURE 5. — Tracing showing segmentation of chyme in the duodenum. This and other tracings reduced two-thirds.

Bayliss and Starling state that the swaying pendulum movements are essentially due to peristaltic waves recurring in the same place and running rapidly downward. This form of the movements I have seen only once. At this time about 90 c.c. of soapy water had been injected. This procedure has the effect of exaggerating in every particular the movements of the small intestine. In this instance a broad constriction appeared about the middle of a long string of food and persisted there while it spread down the gut. As the contraction spread, the gut swayed slowly to and fro before it. Then there was a relaxation, followed by a recurrence of the constriction in the same place, a spreading of the contraction, and a swinging of the loop just as before. This phenomenon was repeated again and again, till finally the string was divided and the forward piece pushed through a tortuous course to the colon.

The course of the food in the small intestine. —Chyme is not forced from the stomach by every wave that passes over the antrum, but only at intervals. When the pylorus relaxes, the food, moved towards the pylorus under considerable pressure, is squirted along the duodenum for two centimetres or more. Careful watching of this food shows that usually it lies for some time in the curve of the duodenum until additions have been made to it from the stomach, and a long, thin string of food is formed. While it is resting in this place it is exposed to the outpouring of the bile and pancreatic juices. All at once the string becomes segmented (see Fig. 5) and the process of rhythmic segmentation continues several minutes, thoroughly mixing the intestinal digestive juices with the chyme. In this region the alternate positions of the segments are sometimes far apart, and the to-and-fro movements of the particles may be a relatively extensive and very energetic swinging. Finally the little segments unite into a single mass, or form in groups, and begin to move forward. The peristalsis here, as already mentioned, is much more rapid than the normal peristalsis elsewhere in the small intestine. The masses, once started, go flying along, turning curves, whisking hither and thither in the loops, moving swiftly and continuously forward. After passing on in this rapid manner for some distance the food is collected in thicker and longer strings, resembling the strings seen characteristically in the other loops. Towards the end of digestion the small masses shot out from the stomach, after a few segmentations, may move on in the rapid course without being accumulated in a larger mass until the swift movement ceases.

During the first stages of digestion in the cat's small intestine the food usually lies chiefly on the right side of the abdomen; during the last stages the loops on the left side contain the greater amount of food. In these loops the food remains sometimes for an hour or more with no sign of movement. All at once a mass begins to show irregular depressions and elevations along its length, and then suddenly it is divided, at first partially, later completely, into many little equal parts, and these repeatedly undergo division and reunion, division and reunion, over and over again, in the manner described above as rhythmic segmentation. After a varying length of time the activity wanes and the little segments are carried forward individually and later brought together, or join and move on as a single body, or they may reunite and lie quietly for some time without further change. Thus by a combined process of kneading and peristaltic advance the food is brought to the ileocæcal valve to enter the large intestine. Records from ten different animals show that salmon does not appear in the small intestine until an hour or an hour and a half after the food is eaten. Inasmuch as five or six hours elapse after eating before this food begins to be seen in the colon, it is evident that the chyme takes four to five hours to pass the length of the small intestine. It is interesting to note that the operations are considerably shortened if the meal has consisted of bread and milk.

The Competence of the Ileocæcal Valve

The ileocæcal valve in the cat is situated three or four centimetres from the blind end of the cæcum. Its position is usually marked in shadows of the food in the colon by a slight indentation, towards which masses about to enter the colon are ordinarily directed from a point somewhat distant in the small intestine (see Fig. 6).

Regarding the competence of the ileocæcal valve many observations have been made. Grützner has reviewed the evidence bearing on the question and concludes that the valve is not competent, least of all for liquids. He declares that as soon as liquids or thin fluid masses appear in the upper part of the colon they pass in many instances into the small intestine the moment that the pressure on the colon side rises slightly. If the colon contains a solid or a thick, mushy mass, the passage towards the small intestine is scarcely possible, because every increase of pressure in the large intestine must force the two lips of the valve together and close it.

The importance of the competence of the ileocæcal valve under normal conditions cannot be appreciated until the function of the first part of the colon is considered. In order that this part of the intestinal mechanism may perform its service, the competence of the valve for the food which enters the colon from the ileum should be perfect. As a matter of fact, such is the case. Not only does the activity of the colon prove this statement, but the failure of every attempt to drive the food in the colon back through the valve into the ileum confirms the proof. Again and again I have tried, by manipulation through the abdominal wall, to press the normal contents of the colon downward with sufficient force to cause them to return to the small intestine, but without success. The valve held perfectly.

THE MOVEMENTS OF THE LARGE INTESTINE

When the large intestine is full, palpation through the abdominal wall demonstrates that the material in the lower descending colon and in the sigmoid flexure is usually composed of hard, incompressible lumps, while that in the ascending and transverse colon and the cæcum is soft, permitting the walls of the gut to be easily pushed together. The condition of the contents in these two regions seems to indicate a rough division of the large intestine into two parts, and the mechanical activities of these two parts verify the differentiation. In the descending colon the material is very slowly advanced by rings of tonic constrictions (see Fig. 7); in the ascending and transverse colon and in the cæcum by far the most common movement is an antiperistalsis.

Antiperistalsis in the colon.—The colon of cats which have been without food for a day usually contains enough gas to make the position of the gut distinguishable with the fluorescent screen (see Fig. 1). The first food to enter the colon from the small intestine is carried by antiperistaltic waves into the cæcum (Fig. 1), and all new food as it enters is also affected by these waves. Thus the contents of the colon, instead of being driven immediately toward the rectum by slow peristalsis, as is the general opinion, are first repeatedly pushed toward the cæcum by an antiperistaltic action.

These antiperistaltic waves follow one after another like the peristaltic waves of the stomach (see Figs. 5, 6, and 10). They begin either on the more advanced portion of the food in the colon (when only a small amount is present), or at the nearest tonic constriction, which is usually at the turn between the transverse and descending colon (Figs. 7 and 8.) The waves rarely run continuously for a long time. When the colon is full, it is usually quiet. The first sign of activity is an irregular undulation of the walls, then very faint constrictions passing along the gut towards the cæcum. These constrictions may first appear only on the ascending colon. As they continue coursing over the intestine they become deeper and deeper, until there is a marked bulging between successive constrictions. When the waves have thus become more prominent, they are seen to start near the end of the transverse colon and pass without interruption to the end of the cæcum. After these deepest waves have been running for a few minutes the indentations grow gradually less marked, until at last they are so faint as to be hardly discernible. The final waves are sometimes to be observed only at the end of the transverse colon.

Such a period of antiperistalsis lasts from two to eight minutes, with an average duration of four or five minutes. The periods recur at varying lengths of time; in one instance a period began at 1.38 P.M. and was repeated at 2.06, 2.34, 2.55, 3.15, and at 3.36, when the observation ceased; in another instance a period began at 2.43 P.M., and was repeated at 2.57 and at intervals of from ten to fifteen minutes thereafter while the animal was being watched. The waves have nearly the same rate of recurrence as those in the stomach; about five and a half waves pass a given point in a minute, *i. e.*, eleven waves in two minutes. This rate has proved fairly constant in different cats and at different stages in the process of digestion; in one case, however, the waves passed at the rate of nine in two minutes.

The stimulating effect of rectal injections on the movements of the small intestine has already been noted. Enemata have also pronounced stimulating action on the antiperistalsis of the colon. Usually the almost immediate result of a rectal injection of warm water is the appearance of deep antiperistaltic waves, which often continue running for a long period. In one case, after an injection of 50 c.c. of warm water, the waves followed one another with monotonous regularity during an observation lasting an hour and twenty minutes. The manner in which this antiperistaltic mechanism affects nutrient enemata introduced into the bowel will be discussed in the section devoted to the question of antiperistalsis.

These constrictions passing backward over the colon do not force the normal contents back through the valve into the small intestine again. I have seen hundreds of such constrictions, and only twice have there been exceptions to this rule, — once under normal conditions, when a small mass slipped back into the ileum, and at another time when a large amount of water had been introduced into the colon. The importance of the competence of the ileocæcal valve is now apparent; indeed, antiperistalsis in the colon gives new meaning and value to the location of a valve at the opening of the ileum.

For, inasmuch as the valve is normally competent, the constrictions repeatedly coursing towards it force the food before them into a blind sac. The effect on the food must be the same as the effect seen in the stomach when the pylorus remains closed before the advancing waves. The food is pressed forward by the approach of each constriction; but since it cannot go onward in the blind sac, and is, moreover, subjected to increasing pressure as the constriction comes nearer, it is forced into the only way of escape, *i. e.*, away from the cæcum through the advancing constricted ring. About twenty-five waves affect every particle of food in the colon in this manner during each normal period of antiperistalsis. The result must be again a thorough mixing of the contents and a bringing of these contents into close contact with the absorbing wall — a process which has already been variously repeated many times in the stomach and in the small intestine.

Two other movements have been observed in the ascending colon, but they are rare appearances. The first of these was a serial sectioning of the contents noticed in an animal given castor oil with the food. A constriction separated a small segment in the cæcum; another constriction then cut off a segment just above the first, and with the disappearance of the first constriction the two separated segments united. A third segmentation took place above the second, and the changes occurred again. Thus the whole mass was sectioned from one end to the other; and no sooner was that finished than the process began again and was repeated several times. A slight modification of this movement was observed in a colon containing very little food. The mass was pressed and partially segmented in the manner characteristic of the small intestine, and was thus again and again spread along the ascending colon, and each time swept back into a rounded form by antiperistalsis. The second of the two movements mentioned above consisted in a gentle kneading of the contents. This was caused by broad constrictions appearing, relaxing, appearing, relaxing, over and over again, in the same place. When several of these regions were active at the same time, they gave the food in the colon the appearance of a restless undulatory mass. Once a constriction occurred and remained permanently in one place, while the bulging parts on either side of it pulsated alternately, at the rate of about eighteen times in a minute, with the regularity of the heart-beat. Although these phenomena are somewhat striking, they are not usual, and are in no way so important as the antiperistalsis.

The changes when food enters the colon. — The passage of food through the ileocæcal valve seems to stimulate the colon to activity. As food is nearing the ileocæcal valve the large intestine is usually quiet and relaxed (Fig. 6, 4.00), though occasionally indefinite movements are to be observed; and sometimes just before the food reaches the end of the ileum the circular fibres of the colon in the region of the valve contract strongly, so that a deep indentation is present there. The indentation may persist several minutes; it disappears as the muscles relax just previous to the entrance of the food. The food is moved slowly along the ileum and is pushed through the valve into the colon. The moment it has entered a strong contraction takes place all along the cæcum and the beginning of the ascending colon, pressing some of the food onward, and a moment later deep antiperistaltic waves (Fig. 6, 4.03) sweep down from the transverse colon and continue running until the cæcum is again normally full, *i. e.*, for two or three minutes.

The appearance of tonic constrictions. — It has already been noted that as the food accumulates in the ascending colon it is at first confined to this region by antiperistaltic waves. With further accessions, however, the contents naturally must be pressed more and more into the transverse and descending colon. In the early stages of this accumulation, while the food lies chiefly in the ascending colon, the only activity of the muscular walls is the antiperistalsis. As the contents extend along the intestine a deep constriction appears near the advancing end and nearly separates a globular mass from the main body of the food (Fig. 6). The contents of the large intestine progress farther and farther from the cæcum; meanwhile new tonic constrictions appear which separate the contents into a series of globular masses. And as the number of these divisions increases they take a position farther from the cæcum, so that they are present chiefly in the descending colon (Fig. 7). Raiser has recorded a similar appearance in the terminal portion of the rabbit's colon, in which deep circular constrictions separate the scybalous masses. He maintains that these masses are pushed onward by the constrictions. Comparing tracings made at rather long intervals (forty-five minutes), I found that the rings disappear

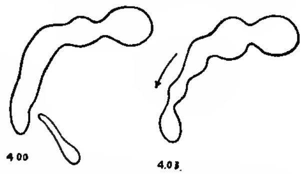


FIGURE 6. — Tracings showing changes when food enters the colon and also the first tonic constriction. 4.00, the colon relaxed as food approaches in the ileum. 4.03, the colon contracted and traversed by antiperistaltic waves after the food has entered.

from the transverse colon, and then are present with the waste material in the descending colon. Thus in the cat also these rings, which seem with short observation to be remaining in one position, are in reality moving slowly away from the cæcum, pushing the hardening contents before them. The contents at this stage are no longer fluid, and consequently they must offer considerable resistance to a force pushing them through the colon. It is an advantage to have this pultaceous substance propelled in divisions rather than in a uniformly cylindrical mass, since the fibres along the length of the mass are thereby rendered effective. Such are the functions of the persistent rings; they form the waste matter into globular masses at the end of the transverse colon and slowly push these masses onward.

FIGURE 7.— Radiograph showing the region of tonic constrictions (descending colon) and the region of antiperistalsis (transverse and ascending colon).

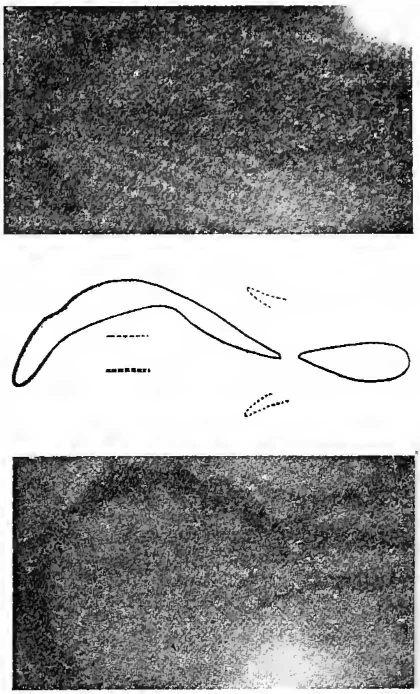
In the transverse colon, which is free from the slowly moving rings, the antiperistaltic waves have full sway. In the region of the tonic rings an infrequent or even a slowly periodic relaxation and contraction are often to be observed. These changes seem to take place in all the rings at about the same time. Once I saw antiperistaltic waves running over the uppermost of four segments, but since the rings on either side of the segment held tightly, the waves had merely the effect of churning the material of the segment and did not move it onward. Inasmuch as the material in these segments at first is soft, so that the segments are easily compressible, while the fæcal masses which are the final result are relatively hard and dry, it follows that even within the confines of these persistent rings some absorption is taking place.

Defecation

The process of clearing the colon is a process of repeated reduction of the amount of material present. Figure 8 (3.11) is a radiograph showing the food in the colon at 3.11 P.M. About 3.25, with a slow, sweeping movement, the gut swung around so that the ascending colon was lying in the position of the last half of the transverse colon, and the transverse colon had taken the position of the descending part (Fig. 8, 3.25). At the same time the tonic constrictions disappeared and were replaced by a strong, broad contraction of the circular muscle, tapering the contents off on either side in two cones. The region of strongest contraction was apparently drawn downward with the rest of the gut by a shortening of the descending colon. As the intestine swung around, more material was forced into the rectum, and when the swinging of the intestine stopped, the constriction which divided the lumen passed slowly downward, and with the aid of the muscles surrounding the abdominal cavity, pushed the separated mass out of the canal.[1] After the terminal mass had thus been pushed out, the colon with the remainder of its contents returned to nearly its former position (Fig. 8, 3.46). About two hours afterward this remnant had been spread throughout the length of the large intestine by means of the slowly moving rings. Figure 7 is a radiograph of the same colon pictured in Figure 8; the radiograph was taken at 11.50 A.M., and at 12.15 P.M. the material in the lower descending colon was forced out in the manner above described. Within three hours the remaining portion had been spread into the evacuated region, as shown in Figure 8, 3.11. The manner in which the material is spread from the region of the antiperistaltic waves into the region of the slowly advancing rings presents a problem. During normal living new food constantly ar-

[1] In this case the fæces were soft.

riving in the colon must force the old contents forward just as the later parts of a meal force forward the earlier parts; there is no doubt,



3.11 3.25 3.46

FIGURE 8. — Two radiographs and a tracing showing the changes taking place in defecation. 3.11, material in the colon. 3.25, colon carried downward and terminal mass separated. 3.46, after defecation, when the colon returns to former position. Defecation occurred at 3.27.

however, that most of the contents of the cæcum and the ascending colon may be passed onward even during starvation. The emptying of these regions, according to my observations, is never complete; for after considerable time has elapsed and the large intestine is cleared and dilated with gas, some substance is still to be detected in the cæcum and clinging to the walls of the ascending colon. The only activities manifested here are the antiperistaltic waves and the strong tonic contraction of the whole circular musculature shown in Figure 6. It is clear that the latter activity would serve to press into the transverse colon a considerable portion of the contents of the ascending colon, and the remnant seen clinging to the walls would be the part not thus pressed forward.

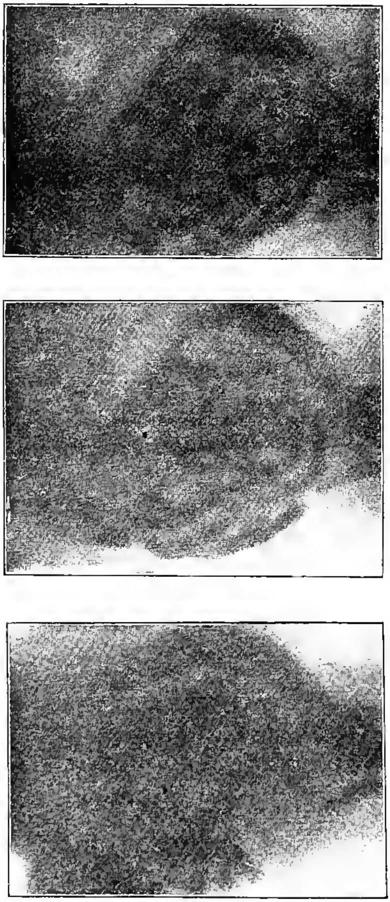
Twice I have seen appearances which might account for the emptying of the first portion of the large intestine in a more thorough manner than that above described. At one time, without apparent stimulation, strong tonic contraction occurred along the entire length of the ascending colon, which forced the contents almost wholly into the transverse portion. This action seemed merely an exaggerated form of that observable after food passes the ileocæcal valve (see Fig. 6). At another time, after a mass of food had passed through the ileocæcal valve, after the ascending colon had contracted generally and the antiperistaltic waves had coursed over it in the usual manner, a deep constriction appeared at the valve and ran upward without relaxation nearly the length of the ascending colon, pushing the contents before it. For an instant the wave paused; then the constriction relaxed and the food returned towards the cæcum. These observations indicate that either a general contraction of the wall of the large intestine or a true peristalsis may be effective in pressing waste matter from the region where antiperistalsis is the usual activity into the region where the slowly advancing rings may carry it on to evacuation (see Fig. 7).

The Question of Antiperistalsis

In 1894 Grützner published an observation and made an assumption about which there has since been much controversy. He maintained that when normal salt solution, holding in suspension hair, powdered charcoal, or starch grains, is injected into the rectum, it is carried upward into the small intestine and may even enter the stomach. These experiments have been repeated by several observers. Some have confirmed Grützner's results; others have failed, after using most careful methods, to find any evidence of the passage of the injected material back to the stomach, and they have declared that the apparent success was due to carelessly allowing the food of the animal to become contaminated with the test materials, so that these were introduced into the stomach by way of the mouth. That antiperistalsis does not occur in the small intestine seems to be proved by Mall's experiment of reversing a portion, sewing it in place, and then finding that the food does not pass the reversed region, but collects at the upper end. Sabbatani and Fasola reversed stretches of small intestine of varying length, and found that the reversed portions allowed fluids to pass, but that the persistence of the physiological direction of movement caused an accumulation of undigested food in the region of the upper suture. However a portion of the intestine lay in relation to the rest, it always manifested the normal peristalsis. Many other observers working directly on the intestine confirm this testimony and state that the progress of the constriction-rings is always downward, and that antiperistalsis is not physiological. In 1898, however, Grützner took his stand again in favour of a backward movement in the intestines, and in a somewhat metaphysical manner argued that peristalsis and antiperistalsis belong to each other just as relaxation of muscle is related to contraction. He assumed that as the contents are advanced by slow peristalsis, so are they returned by a similar movement in the opposite direction, and he mentions several pathological cases (fistula of intestine) to substantiate the assumption.

By means of the X-rays it is possible to see just what takes place when a fluid is injected into the rectum. For the purpose of determining how nutrient enemata are received and acted upon in the intestines, I have introduced thin, fluid masses in large and small amounts, and thick, mushy masses in large and small amounts, in different animals. The enemata consisted of 100 c.c. of milk, one egg, ten to fifteen grams of bismuth subnitrate, and two grams of starch to hold the bismuth powder in suspension. To make the thick enema all these were stirred together and boiled to a soft mush; to make the thin enema all the parts were boiled together except the egg, which was added after the boiled portion was cooled. The small amount injected was 25 c.c.; the large amount almost 90 c.c., about the capacity of the large intestine when removed from the body. The animals were given first a cleansing injection, and after this was effective the nutrient material was introduced. In order to make sure of the observation, a control radiograph was first taken to show no bismuth food present, and other radiographs taken at varying intervals after the injection to record the course the food was following.

These experiments show that when small



1.50 2.15 3.00

FIGURE 9. — Radiographs showing that after a large nutrient enema (about 90 c.c.) has been given the food is forced more and more from the large into the small intestine. The enema was introduced at about 1 40 P.M. At 3.00 segmentation was occurring in many loops.

amounts of nutrient fluid are introduced they lie first in the descending colon. In every instance antiperistaltic waves are set going by the injection, and the material is thereby carried to the cæcum. When large amounts are injected they stop for a moment in the region between the transverse and descending colon, as if a constriction existed there. Then a considerable amount of the fluid passes the point, and antiperistaltic waves carry it to the cæcum. In any case the repeated passing of the waves seems to have the effect of promoting absorption, for in the region where these waves continue running, the shadows become gradually more dim, and finally the bismuth appears to be only on the intestinal walls; in other regions, *e.g.* in the descending colon, the shadows retain their original intensity. Small injections have never in my experience been forced even in part into the small intestine; but with the larger amounts, whether fluid or mushy, the radiographs show many coils of the small intestine containing the bismuth food.

The passage of the injected material beyond the ileocæcal valve is probably due entirely to antiperistalsis in the colon, — a factor unknown to both Grützner and his opponents. The valve, which is thoroughly competent for food coming normally from the small intestine into the large, is curiously incompetent for a substance, even of the consistency of thick cream, introduced in large amount by rectum. When the valve first permits the food to enter the ileum, the fluid pours through and appears suddenly as a winding mass occupying several loops of the intestine (Fig. 9, 1.50, about ten minutes after the injection). The mass is continuous from the valve to the other end; antiperistalsis is therefore not visible in the small intestine under the circumstances of this experiment. The antiperistaltic waves of the colon, however, continue running; the transverse and ascending colon are thus almost emptied, and the small intestine more and more filled with food (Fig. 9, 2.15 and 3 00). After a short time the typical segmenting movements can be seen in the loops, busily separating the food into small masses, and over and over again dividing and redividing them.

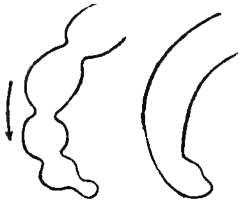
I have never seen food material pass back from the colon so far as the stomach; but once, about ten minutes after an injection of 100 c.c. of warm water, the cat retched and vomited a clear fluid resembling mixed water and mucus. In the fluid were two intestinal worms still alive.

The importance of the mechanism by which nutrient enemata are passed backward in the intestine is evident. In the colon the nutrient material is worked over by the antiperistaltic waves, intimately mixed with whatever digestive juices may be present, and exposed to the organs of absorption in that region. If the enemata are large, the digestive and absorptive processes are by no means confined to the colon, but may take place along extensive surfaces of the small intestine. I have repeatedly seen rhythmic segmentation active throughout many loops of the small intestine, thus exposing the injected food to the same mixing and absorbing processes as affect the nutriment which has come through the stomach in a normal manner.

The Effect of Emotions and Sleep

Observations on the stomach of the cat showed that the peristalsis is inhibited whenever the animal manifests signs of anxiety, rage, or distress. Since the extrinsic innervation of a large part of the intestinal tract is the same as that of the stomach, it is of interest to note the effect of emotional states on the movements of the intestines. Esselmont, in a study of the dog's intestine, noted constantly after signs of emotion a marked increase of activity lasting for only a few moments. Fubini also observed that fear occasioned more rapid peristalsis. There is no doubt that many emotional states are a strong stimulus to peristalsis, but it is equally true that other emotional states inhibit peristalsis. In the cat the same conditions which stop the movements of the stomach stop also the movements of the intestines.

The female cats used in these observations ordinarily lie quietly on the holder and make no demonstration. Sometimes, however, with only a little premonitory restlessness, the cat suddenly flies into a rage, lashing her tail from side to side, pulling and jerking with every limb, and biting at everything near her head. During such excitement, and for some moments after the animal becomes pacified again, the movements, both of the large and small intestine, entirely cease. Such violence of excitement is not necessary to cause the movements to stop; a cat which was restless and continually whining while confined to the holder showed no signs of intestinal movements during any period of observation (one period lasted more than an hour), although the changes in the distribution of the food observable from one period to the next proved that movements



11.35 11.37

FIGURE 10.—Tracings showing the effect of excitement on antiperistalsis in the colon.

were going on during the quiet intermissions. In another cat, uneasy and fretful for fifty minutes, no activity was seen; then she became quite for several minutes, and peristalsis of the small intestine appeared.

When the segmentation process in the small intestine is stopped by excitement the segments unite and the series of parts returns to the form of a solid string. The change occurring in the large intestine when the antiperistalsis is inhibited by excitement is shown in Figure 10. The tonic constrictions in the descending colon are apparently not affected by emotional states, for they do not seem to relax in the excitement which causes the movements to cease.

By holding the mouth and nostrils closed, or by pressing between the rami of the jaw, the breathing may be stopped. As soon as the cat shows distress from lack of breath every form of intestinal movement stops.

The statement is sometimes made in textbooks of physiology that the gastric and intestinal mechanisms cease to act during sleep. It is worthy of note that nearly all the animals curled up and slept during the time between observations; nevertheless, the progress of the food through the intestines continued. The statement is also made that at night, even without sleep, the intestines are almost entirely at rest;

that this is their normal time for repose. I have seen both large and small intestines actively at work, however, from half past nine until half past ten o'clock at night.

SUMMARY

1. Bismuth subnitrate, 10 to 33 per cent, mixed with the food renders the movement of the intestinal contents, and thereby the movements of the intestinal walls, visible on the fluorescent screen.

2. The activity most commonly seen in the small intestine is the simultaneous division of the food in a coil into small segments, and a rhythmic repetition of the segmentation each time applied to the new segments formed from parts of those just divided. In the cat this rhythmic segmentation may proceed at the rate of thirty divisions per minute. The effects of the constrictions causing the segmentation are the mixing of the food and the digestive juices, the bringing of the digested food into contact with the absorbing mechanisms, and the emptying of the venous and lymphatic radicles of their contents by compression of the intestinal wall.

3. Peristalsis is usually combined with segmentation. As the food is advancing, interfering constrictions often separate the rear end of the mass from the main body. The separation is

momentary, however; the rear end is swept into union with the main body again, and the whole mass is pushed onward until another constriction repeats the changes.

4. The ileocæcal valve is thoroughly competent for food entering the colon from the ileum.

5. The usual movement of the transverse and ascending colon and the cæcum is an antiperistalsis. This recurs in periods about every fifteen minutes, and each period lasts commonly about five minutes; the waves recur during a period at the rate usually of eleven waves in two minutes. This antiperistalsis gives new significance to the ileocæcal valve; for the food, now in a closed sac, is thoroughly churned and mixed by the constrictions running towards the cæcum, and again exposed to absorbing walls without any interference with the processes in the small intestine.

6. As soon as new food enters the large intestine a strong general contraction takes place along the cæcum and ascending colon, forcing some of the food onward; a moment later antiperistaltic waves begin to pass.

7. With the accumulation of material in the transverse colon, deep tonic constrictions appear one after another and carry the material into the descending colon, leaving the trans-

verse and ascending portions free for the antiperistaltic waves.

8. In emptying the large intestine the material in the lower descending colon is first carried out by combined peristalsis and pressure of abdominal muscles; the remainder of the material is then spread into the evacuated region, and this region is again cleared; the second remainder may be similarly affected. In normal life the new food arriving in the colon must force forward the old contents of the ascending and transverse colon.

9. The observations have revealed no evidence of antiperistalsis in the small intestine, but since the ileocæcal valve will allow nutrient material under pressure to pass backward, the antiperistalsis of the large intestine may force into the small intestine a considerable portion of a large nutrient enema. Segmentation in the small intestine affects such an enema precisely as it affects food which has passed normally through the stomach.

10. Signs of emotion, such as fear, distress, or rage, are accompanied by a total cessation of the movements of both large and small intestines. The movements continue in the cat both during sleep and at night.

THE BATTLE CREEK LABORATORIES

THE MAMMOTH SANITARIUM AND THE LARGE ADOPTED FAMILY OF DR. AND MRS. J. H. KELLOGG

[A report of one experiment has been selected from *Modern Medicine* relative to the work of the laboratories connected with the Battle Creek Sanitarium because it relates to the effect of cooking and mastication upon food in illustration of the statement of Dr. Campbell pertaining to these aids to digestion. Much more evidence could be had from the Sanitarium reports, but sufficient has already been given herewith from various authoritative sources to justify our claims of the great importance of mouth-treatment in human nutrition.

It may be said here, however, that the trial of thorough mouth-work as an aid to digestion, which has been in progress at the Sanitarium for more than a year, and which has finally been accepted and prescribed as the first requirement of the treatment of patients, is of the utmost significance. This is, by far, the largest sanitarium in the world, having some hundreds of physicians, nurses, and other attachés, and treating many thousands of patients annually. The "cure" is based upon natural methods of recuperation, and while all of the staff, both medical and surgical, are fully equipped diplomatists, and whereas the organisation has a legally and professionally accepted medical school of its own, so-called medicines are rarely used, and never except as antidotes to specific poisons. Nature is assisted by scientific means to do the curing, and now that an economic nutrition to relieve the exhausted system of the patient from all possible strain through ample mouth-treatment of food, as intended by the anatomical, dental, and chemical plan on which man is constructed, has been tried and accepted as a fundamental principle of the institution, it gives a practical indorsement of the claims set forth in "Glutton or Epicure," and in this present book, and declares that they are of greatest importance in securing health and efficiency.

The Battle Creek Sanitarium is a philanthropic and humanitarian institution operating under a perpetual charter which compels the use of all the profits gained to foster the spread of the humanitarian work. More than sixty branches of the parent institution have been established in or near large cities in different parts of the world, under the title of The American Medical Missionary Association, and each of these branches conducts a life-saving business on Good Samaritan principles. The organisation started its medical missionary work some thirty-seven years ago, with almost no capital and only one patient, in a small two-storey frame house, in the then small village of Battle Creek, Michigan. The incorporators were religious enthusiasts who believed that Christianity should be expressed in works as much as in faith, in curing the sick and healing the wounded, and thus preparing the unfortunate for the reception of moral and spiritual inspiration.

The best evidence that this scheme of procedure to attain the ultimate end was a good one is shown by the success of the institution in its growth from such small beginning to the immense proportions of the present time, with one of its buildings nearly a thousand feet in length and five storeys in height and numerous other buildings radiating from the main one and scattered about it in a finely wooded park. Fire came and destroyed the old building and all its contents, but yet it was soon rebuilt, and the concern goes on growing and growing, because the foundation principle of the institution is the beautiful Golden Rule, and the method of treatment employed is taken from the open book of Nature.

While the organisation was primarily based upon a special religious creedal enthusiasm, it has become so broadly altruistic as to suggest a return to original Christianity as defined in the Sermon on the Mount. In such Christian expression honest agnostics, born Buddhists, and the tolerant of all the different Christian creeds may join and say amen!

One of the splendid results of an economic nutrition, attained by following the natural requirements and impulses, is the curing of many diseases, among them several forms of constipation. The writer has a genuine admiration for the spirit that is the motive power of the Battle Creek Sanitarium and firm belief in the Christianity demonstrated in the work, especially in the private experiment of Dr. and Mrs. Kellogg, with their family of adopted waifs. Twenty-four children of unfortunate parents, waifs so unfortunate in their attractability as to be hopelessly neglected, have been gathered under this sheltering roof and are showing their mettle and gratitude by splendid behaviour and brilliant accomplishment in a manner that any proud parent might approve. To miss any opportunity to express gratitude to Dr. and Mrs. Kellogg for giving us such a splendid example of the true meaning of practical Christianity would be showing symptoms of the worst form of constipation; viz., constipation of appreciation and affection. — HORACE FLETCHER.]

EXPERIMENTAL INVESTIGATION OF THE INFLUENCE OF MASTICATION AND COOKING OF FOOD, ETC., IN THE LABORATORIES OF THE BATTLE CREEK, MICHIGAN, SANITARIUM, UNDER THE DIRECTION OF DR. J. H. KELLOGG

From *Modern Medicine*

The table clearly shows the effect of cooking and the effect of mastication upon the salivary digestion of food. Column 1 shows the results obtained after an ordinary test meal consisting of 1½ ounces of water biscuit to 8 ounces of water; column 2, 1½ ounces of water biscuit ground fine, mixed with water and swallowed without chewing; column 3, test meal consisting of 1½ ounces of raw wheat flour and 8 ounces of water; column 4, test meal consisting of 1½ ounces of unground pearled wheat with 8 ounces of water.

	Water biscuit, well chewed. 1	Water biscuit, not chewed. 2	Raw flour. 3	Raw wheat. 4
Total acidity (A)	0.142	0.140	0.204	0.136
Calculated acidity (A′) . .	0.156	0.132	0.186	0.128
Total chlorine (T) . . .	0.296	0.284	0.332	0.272
Free HCl (H)	0.050	0.028	0.056	0.052
Combined chlorine (C) . .	0.106	0.104	0.130	0.076
Fixed chlorides (F) . . .	0.114	0.152	0.146	0.144
Maltose (M)	1.088	0.272	0.000	0.000
Dextrine and soluble starch (D)	0.812	0.548	0.300	0.448
COEFFICIENTS				
Digestion of albumin (*a*) .	0.82	0.97	1.00	1.00
Digestion of starch (*b*) . .	0.71	0.42	0.00	0.00
Salivary activity (*c*) . . .	1.17	1.11	1.14	1.37
Fermentation (*x*)	5.00	11.00	6.00	6.00
Chlorine liberation (*m*) . .	0.80	0.70	0.85	0.71

Several points of interest are to be noted in the above table, the first and most conspicuous of which is the fact that the saliva did not act at all upon the raw flour and raw wheat, as shown by the total absence of maltose in the cases represented in columns 3 and 4. The small amount of dextrine and soluble starch shown was, perhaps, already present in the raw grain, but this point I have not investigated. It is clear, however, that no sugar was produced when raw starch was taken, whereas the amount of sugar produced after the ordinary test meal was more than 1 gram in each 100 c.c. of stomach fluid; in other words, the stomach fluid contained more than one per cent of sugar without taking into account the amount which had been absorbed.

The figures for maltose in column 2 represent a test meal in which little or no saliva was mixed with the test meal, the food being swallowed without chewing, indicating very slight action of the saliva, the amount of maltose found in the stomach fluid being but a trifle more than one-fourth the amount obtained after an ordinary test meal. The amount of soluble starch and dextrine was less than half the normal amount in the case of the raw flour, and but little more in the case of the raw wheat.

Another point of interest is the increased amount of lactic acid found in the test meal taken without chewing, represented in column 2. The coefficient of fermentation which represents the number of milligrams of lactic acid (as expressed in terms of HCl) found in 100 c.c. of stomach fluid was more than double that found after the same kind of test breakfast properly masticated, represented in column 1. The results of this experiment distinctly associate acid fermentation with imperfect mastication and imperfect salivary digestion.

Another fact noted in a comparative study of the results of the analysis of over 5000 stomach fluids, which very strongly confirms this idea, is that starch conversion is usually complete in cases of apepsia, while lactic acid is conspicuous by its absence. In nearly all cases of apepsia which I have encountered, numbering about forty cases in all, the most delicate tests for lactic acid have failed to show its presence except in the most minute quantities; in most cases it was entirely absent.

There are a number of other points of interest in the above table in addition to those which relate particularly to starch digestion. One of the most noteworthy of these is the fact that the digestion of albumen was not unfavourably influenced by the neglect to masticate the food, the coefficient of digestion, in fact, being raised from .82 to .97. This coefficient is a qualitative and not a quantitative index. The higher coefficient indicates a more perfect elaboration of proteids and a close approach to an absolutely perfect proteid digestion.

Another fact of perhaps even greater interest has relation to the digestion of albumen when the wheat was eaten raw, in the form of either flour or wheat. The coefficient of proteid digestion in both cases, as shown in columns 3 and 4, was 1.00, indicating perfect elaboration of the albuminoids. From this it appears that raw gluten, or the proteids of wheat, is digested more perfectly when taken in a raw state than when cooked, the very opposite of which we have seen to be true of starch. The digestion of raw starch may take place in the intestines, by the action of the pancreatic juice, but cannot take place in the stomach, for the reason that the saliva has not the power to penetrate the cellulose envelope of the starch granule, and hence cannot digest raw starch.

This fact coincides in a most interesting manner with the biological fact that man is by nature a frugivorous animal. In the process of ripening, the starch of fruits undergoes a hydration similar to that which takes place in cooking and in pancreatic digestion, whereby the insoluble starch is converted into soluble starch, dextrine, and sugar. This explains, also, why well-ripened fruit may be eaten raw with impunity, while unripe fruit and farinaceous food of all sorts require cooking. In his diet, man, like his nearest relative, the monkey, being naturally a frugivorous animal, may eat fruits in the state in which Nature has provided them; but when he introduces other natural products into his bill of fare, he must adopt artificial means for securing the preparation for digestion which Nature makes in the ripening process of fruits.

The coefficient of chlorine liberation (*m*) is very nearly uniform, indicating that the mastication of food and the cooking of food have little influence upon this digestive function.

The coefficient of salivary activity (*c*) was determined independently for each test breakfast. Its practical uniformity indicates that there was no essential change in the character or quality of the saliva to account for the differences shown by the totals in relation to the stomach digestion of starch.

DR. EDWARD HOOKER DEWEY AND THE "NO BREAKFAST PLAN"

The "No Breakfast Plan," evolved from the long experimental experience of Dr. Dewey, to secure much needed rest for the stomach and intestines, is described in a book bearing that title which can be had direct from the author by addressing him at his home, Meadville, Penn., U. S. A.

"No Breakfast" is, evidently, a misnomer, but means, in the present application, an appetite *earned* after arising from sleep. The writer, for instance, often begins work so early in the morning that by the time the ordinary breakfast is ready he has already done a fair day's work.

The writer has no reported details of the work of Dr. Dewey to add to this volume. In "Glutton or Epicure" full appreciation of this Esculapian Luther is expressed and extracts of his writings are reprinted. In fighting for more than forty years for the principle of less abuse of the tired body of man, Dr. Dewey has rendered a service that some time will be reckoned very great; and while there is no scientific report of the good doctor's work to call for introductory comment, it would be equally unhealthy to miss an opportunity to express gratitude for what he has done for us all.

PROFESSOR JAFFA AND THE FRUITARIANS

Professor Jaffa, too, of the University of California, has been doing most valuable service in testing the usefulness of fruits and nuts as human foods. He generously furnished the author with elaborate tables of his results, covering several years of observation, showing low nitrogen possibilities similar to those demonstrated by the writer and his colleagues at Cambridge and Yale. These have since been published, and relating to special kinds of foods, as they do, suggest a wide range of choice among the fruits of earth; but the collected evidence of this book shows that human nutrition is best served when the appetite, being kept at normal, is allowed to make selection from the whole range of nutritious products furnished by good Mother Nature.

DR. H. P. ARMSBY

In the Oct. 16th, 1903, number of *Science*, also, is an interesting article by Dr. H. P. Armsby on the heat values and muscular energy values of different food elements and their isodynamic replacement of each other under various conditions. — HORACE FLETCHER.]

Explanation of The A. B. C. Life Series

THE ESSENTIALS AND SEQUENCE IN LIFE

It would seem a considerable departure from the study of menticulture as advised in the author's book, "Menticulture," to jump at once to an investigation of the physiology and psychology of nutrition of the body and then over to the department of infant and child care and education as pursued in the *crêche* and in the kindergarden; but as a matter of fact, if study of the causation of human disabilities and misfortunes is attempted at all, the quest leads naturally into all the departments of human interest, and first into these primary departments.

The object of this statement is to link up the different publications of the writer into a chain of consistent suggestions intended to make life a more simple and agreeable problem than many of us too indifferent or otherwise inefficient and bad fellow-citizens make of it.

It is not an altogether unselfish effort on the part of the author of the A. B. C. Life Series to publish his findings. In the consideration of his own mental and physical happiness it is impossible to leave out environment, and all the units of humanity who inhabit the world are part of his and of each other's environment.

It would be rank presumption for any person, even though gifted with the means to circulate his suggestions as widely as possible, and armed with the power to compel the reading of his publications, to think that any suggestions of his could influence any considerable number of his fellow-citizens of the world, or even of his own immediate neighbourhood, to accept or follow his advice relative to the management of their lives and of their communal and national affairs; but while the general and complete good of humanity should be aimed at in all publications, one's immediate neighbours and friends come first, and the wave of influence spreads according to the effectiveness of the ideas suggested in doing good; that is, in altering the point of view and conduct of people so as to make them a better sympathetic environment.

For instance, the children of your neighbours are likely to be the playmates of your own children, and the children of degenerate parents in the slum district of your city will possibly be the fellow-citizen partners of your own family. Again, when it is known that right or wrong nutrition of the body is the most important agent in forming character, in establishing predisposition to temperance or intemperance of living, including the desire for intoxicating stimulants, it is revealed to one that right nutrition of the community as a whole is an important factor in his own environment, as is self-care in the case of his own nourishment.

The moment a student of every-day philosophy starts the study of problems from the A. B. C. beginning of things, and to shape his study according to an

A. B. C. sequence, each cause of inharmony is at once traced back to its first expression in himself and then to causes influenced by his environments.

If we find that the largest influences for good or bad originate with the right or wrong instruction of children during the home training or kindergarden period of their development, and that a dollar expended for education at that time is worth more for good than whole bancs of courts and whole armies of police to correct the effect of bad training and bad character later in life, it is quite logical to help promote the spread of the kindergarden or the kindergarden idea to include all of the children born into the world, and to furnish mothers and kindergarden teachers with knowledge relative to the right nutrition of their wards which they can themselves understand and can teach effectively to children.

If we also find that the influence of the kindergarden upon the parents of the infants is more potent than any other which can be brought to bear upon them, we see clearly that the way to secure the widest reform in the most thorough manner is to concentrate attention upon the kindergarden phase of education, advocate its extension to include even the last one of the children, beginning with the most needy first, and extending the care outward from the centre of worst neglect to finally reach the whole.

Experience in child saving so-called, and in child education on the kindergarden principle, has taught the cheapest and the most profitable way to insure an environment of good neighbours and profit-earning citizens; and investigation into the problem of human alimentation shows that a knowledge of the elements of an economic nutrition is the first essential of a family or school training; and also that this is most impressive when taught during the first ten years of life.

One cannot completely succeed in the study of menticulture from its A. B. C. beginning and in A. B. C. sequence without appreciation of the interrelation of the physical and the mental, the personal and the social, in attaining a complete mastery of the subject.

The author of the A. B. C. Life Series has pursued his study of the philosophy of life in experiences which have covered a great variety of occupations in many different parts of the world and among peoples of many different nations and races. His first book, " Menticulture," dealt with purging the mind and habits of sundry weaknesses and deterrents which have possession of people in general in some degree. He recognised the depressing effect of anger and worry and other phases of *fearthought*. In the book " Happiness," which followed next in order, *fearthought* was shown to be the unprofitable element of forethought. The influence of environment on each individual was revealed as an important factor of happiness, or the reverse, by means of an accidental encounter with a neglected waif in the busy streets of Chicago during a period of intense national excitement incident to the war with Spain, and this led to the publication of "That Last Waif; or, Social Quarantine." During the time that this last book was being written, attention to the importance of right nutrition was invited by personal disabilities, and the experiments described in "Glutton or Epicure; or, Economic Nutrition" were begun and have continued until now.

In the study of the latter, but most important factor in profitable living, circumstances have greatly favoured the author, as related in his latest book, "The A. B.–Z. of Our Own Nutrition."

The almost phenomenal circulation of "Menticulture" for a book of its kind, and a somewhat smaller interest in the books on nutrition and the appeal for better care of the waifs of society, showed that most persons wished, like the author, to find a short cut to happiness by means of indifference to environment, both internal and external, while habitually sinning against the physiological dietetic requirements of Nature. In smothering worry and guarding against anger the psychic assistance of digestion was stimulated and some better results were thereby obtained, but not the best attainable results.

Living is easy and life may be made constantly happy by beginning right; and the right beginning is none other than the careful feeding of the body. This done there is an enormous reserve of energy, a naturally optimistic train of thought, a charitable attitude towards everybody, and a loving appreciation of everything that God has made. Morbidity of temperament will disappear from an organism that is economically and rightly nourished, and death will cease to have any terrors for such; and as *fear* of death is the worst depressant known, many of the *worries* of existence take their everlasting flight from the atmosphere of the rightly nourished.

The wide interest now prevalent in the subjects treated in The A. B. C. Life Series is evidenced by the scientific, military, and lay activity in connection with the experiments at the Sheffield Scientific School of Yale University and elsewhere, as related in the "A. B.–Z. of Our Own Nutrition" and in "The New Glutton or Epicure" of the series.

The general application is more fully shown, however, by the indorsement of the great Battle Creek Sanitarium, which practically studies all phases of the subject, from health conservation and child saving to general missionary work in social reform.

HORACE FLETCHER.

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* While Napoleon was building his power and fame he was very careful and abstemious, but in later life succumbed to luxury and gluttony; Bismarck's rise and decline were similarly related to dietary influences. — H. F.

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