DOMESTIC ECONOMY

PART I THEORY

DOMESTIC ECONOMY

CAMBRIDGE UNIVERSITY PRESS
C. F. CLAY, MANAGER
London: FETTER LANE, E.C.
Edinburgh: 100 PRINCES STREET

New York: G. P. PUTNAM'S SONS
Bombay, Calcutta and Madras: MACMILLAN AND CO., LTD.
Toronto: J. M. DENT AND SONS, LTD.
Tokyo: THE MARUZEN-KABUSHIKI-KAISHA

DOMESTIC ECONOMY

A TEXT-BOOK FOR TEACHERS AND STUDENTS IN TRAINING

PART I

THEORY

BY
MARION GREENWOOD BIDDER
FORMERLY STAFF LECTURER OF NEWNHAM COLLEGE, AND LECTURER OF GIRTON COLLEGE, CAMBRIDGE

CAMBRIDGE:
AT THE UNIVERSITY PRESS
1916

First Edition 1901,
Revised 1911, 1916 (*in two parts*).

PREFATORY NOTE.

THIS book is intended for students in training to become Teachers of Domestic Science Subjects. It is an effort to combine scientific knowledge with practical experience, so that both may have their due proportion in the training of Teachers of Cookery, Laundry-work, Housewifery and other domestic arts. On the one hand we desire an accurate scientific treatment of such elementary science as is required in this training, on the other a practical knowledge of these subjects, and of the methods by which they can make their human appeal to those who wish to learn them.

It is a discredit that Teachers should expound theories which they hold unintelligently, or which are scientifically incorrect; it is not less essential that the art taught should be practised with skill, and with the beauty of complete success. A dominant question, therefore, for those responsible for the training of Teachers in Domestic Science is how to give their due proportion to theory and to practice in this training.

It is the experience of all of us that where the aptitude for science is strong, the skill in practice is not seldom weak, and vice versâ. But the Teacher is bound to reject such a divorce of *method* from the *knowledge* which alone makes it elastic and efficient. We hope that the book now published exhibits science and practice in their due relation to each other. Those who are interested in this education will recognise that the scientific portion of the book comes from the pen of a physiologist, whilst the practical portion is eminently imbued with the knowledge both of Domestic Economy as a practical art, and of the methods of teaching it.

Apart from the claims that the present work has to the favourable attention of those responsible for the direction of the organised teaching of Domestic Economy, the general public may be brought by the perusal of this volume to a larger knowledge of the importance of this education for their daughters, not only from a utilitarian point of view, but also as valuable training in powers of observation, in drawing out individual energies, and in other essential mental and moral qualities.

MARY E. PLAYNE,
President of the National Union for the Technical Education of Women in Domestic Science.

June 1901

CONTENTS.

PART I.

THEORY.

NOTE ON THERMOMETRIC SCALES.

The use of the Centigrade Thermometer is at present so wide-spread that the following equivalent temperatures should be ready in the mind of students of any science:

0° C.	= 32° F.	Freezing point of water.
15° C.	= 59° F.	"Ordinary temperature."
36°·9 C.	= 98°·4 F.	Temperature of the healthy human body.
40° C.	= 104° F.	Temperature of severe fever.
50° C.	= 122° F.	Destructive to almost all life except that of spores.
70° C.	= 158° F.	
100° C.	= 212° F.	Boiling point of water.

PART I.

CHAPTER I.

Introduction.

Domestic Economy may perhaps be translated into English as "*the ordering of a House which is a Home.*" It is a wide subject, and its limits are not very well defined. It may be urged with some justice that, in the ordering of a House which is a Home, the moral, intellectual, and social sides of life are of high importance and must be reckoned with; and yet, Domestic Economy, as generally understood, concerns itself with these quite indirectly; it deals, directly, almost wholly with the physical elements of man's life.

It is in this narrower sense that the words are interpreted in the chapters of this book: we speak of the food which man eats, of the air he breathes, the water he drinks, the clothes he wears; somewhat of the fabric in which he dwells. The third part of the book stands somewhat apart; it deals with the **Teaching** of Domestic Economy, and consists chiefly of *Notes of Lessons* actually given on the main divisions of the subject. In the second part of the book—the **Practical Section**—stress is laid upon the procedure which has been found good in these departments of Domestic Economy; in the first part of the book—the **Theoretical Section**—some attempt is made to show that the procedure is not solely empiric,—that there are certain established facts of the physical sciences with which it is in accord. So that while the second part will tell, as clearly as may be, **how** the house is to be ordered, the first part will endeavour to show **why** that ordering is good.

Thus:—the problems of *Ventilation* centre round the chemistry of air and the physiology of breathing, the right choice and *preparation of Food* are determined largely by the chemical characters of food-stuffs and the facts of human digestion; while the habits and life-history of disease-producing organisms offer strong reason for most stringent rules of Sanitation and personal cleanliness. It is true that the aesthetic instincts often guide the choice of clothing, and of the dwelling, but they are not unerring guides, and we wish to show that, setting them aside, sound reasons may be given for this or that practice in the ordering of a House which is a Home.

Now the great central group of facts which make these reasons valid is that group which belongs to the **Physiology of Man**; and there can be no doubt that all teachers of Domestic Economy should be students of Physiology, since it is that science which studies and endeavours to explain the physical phenomena of life. But no student of physiology is properly equipped for his study without at least a rudimentary knowledge of chemistry and physics. For these sciences deal with the properties and behaviour of the substances which make up the material universe, and of these substances living substance is one, although the most complex, the least stable, the hardest to examine; and its relations with other substances, and with its own constituents, are determined by physical laws.

The reader who wishes then to draw all that can be drawn from such discussion of the problems of Domestic Economy as is presented here, should come to its consideration armed with, at least, some slight knowledge of Physiology. The equipment cannot be provided in this book, but belongs to special treatises on that wide and ever-growing subject. But what we may try to do briefly in this introduction is to lay stress on one part of physiological teaching which is often neglected in the elementary text-books—or rather by the students of elementary text-books—and which is yet second in importance to none, whether for our purposes, or for the pure study of physiology. This is the teaching concerning the place of the **Nervous System** in man's life. Let us consider, a little, of what importance this is.

When we speak of *Living Substance*, we mean substance of complex chemical constitution which is unlike all other substances in the chemical activity it displays. It is continually breaking down and repairing its own mass, carrying on processes which, at least in part, can be imitated in no Laboratory. And any portion of living substance which has a separate, individual existence we call an Organism. Thus "organism" is the most general term for a living creature; it may be a man, a monkey, or a forest-tree; it may be almost without permanent structure, like the simple *Amoeba*, it may be so small that (like a *large* bacterium) upwards of a thousand million would be needed to fill an average cigarette. All these organisms have living substance as their foundation, and have separate lives; they build up this substance from food which is not living: they all have living creatures as offspring. But with this fundamental likeness, organisms exhibit also profound difference. We have just said that the *Amoeba* is almost without permanent structure, that is to say that if we were to break it up we should find the parts much alike except that containing the nucleus: any part of its exterior shrinks from the disturbance we call a stimulus; any part of its interior can pour forth digestive fluid; at any point a finger-like process or pseudopodium can be put out. But were an organism like a man to be shaped by aggregation of amoebae, with the properties of the simple amoeba unmodified, we can hardly imagine any gain in general activity, or indeed anything but hindrance as a consequence of the bulky multiplication. The body of man is an aggregation of units, but not of organisms; the units are minute portions of living matter which are for convenience termed *cells*, and they do not lead separate, individual lives, but are bound together into tissues (muscular, nervous, epithelial), and these are shaped into organs, such as the foot, the eye, the heart. The cells of any one tissue are like each other, and they do the same work, but they are unlike the cells of all other tissues and the work they do is different;—briefly, the body of man shows *physiological division of labour*. Thus:—*protective cells* (the external epithelia), cover the surfaces of the body: it is by the action of *muscular cells* that the body and its parts are moved: the cells of the alimentary canal form *digestive fluids*, and pour them on food that has been eaten: the cells of the kidney take from the body certain *waste matters* which are to be cast away. And as each tissue excels in one department of physiological work, there are others in which it is inactive: the epithelial cells do not contract; the digestive cells do not support (as do cartilage and bone); the kidney cells do not digest. Thus it becomes of the first importance that these tissues of varying activity should have a common bond. This bond exists and is two-fold: it is in the first place the bond of a common nutrition made possible by the **vascular system** (*heart, blood-vessels, lymph-vessels*); and in the second place it is a bond of government, the government of the **nervous system**. The blood, charged with oxygen in the vessels of the lungs, enriched by the products of digestion in the capillaries of the intestine, freed from waste matters in the vessels of the lungs, the skin, the kidneys, acts (with the lymph) at once as nurse and scavenger of the tissues; each tissue draws upon the blood and lymph for food materials; each yields to the blood and lymph its own waste.

The nervous system is, like all other tissues, fed by the blood and drained by the blood, but it may be called the **master tissue** of the body. By its special activity the activities of all the other tissues are controlled; there is no part of the body into which its ramifications do not spread; we could not find two regions which may not be brought into physiological relations by means of these ramifications. For the nervous tissue of the body is in part *peripheral*,—present in every organ and interpenetrating every tissue,—and in part it is *central*; there is a great central mass of nervous matter to which all the peripheral nervous matter leads or from which it radiates. To unravel the complexities of even one part of this orderly, nervous tangle may be the work of a life-time; here we cannot even give a brief description of the whole. We will leave aside all distinction of nerve-cells and nerve-fibres; we will lay no stress even on the relationships of brain, spinal bulb and spinal cord. We will only remember these important divisions of nervous matter: first, **central** nervous-tissue; second, tissue which bears messages or impulses *to the centre* and is called **afferent**; and third, tissue which, conversely, bears impulses *away from the centre*, and is called **efferent**. It is the office of the central tissue to receive afferent impulses, to discharge efferent impulses, to correlate the one with the other, and to check efferent impulses which might give rise to harmful action. In chapter VII. and chapter VIII. §§ 56, 60, we discuss some examples of the ordered action which is the result of this ceaseless activity of restraint and excitation, and all the events of healthy life furnish illustrations. From the closure of an eyelid to the hardest gymnastic exercises, there is no "voluntary" bodily movement which is not set up and guided by nervous impulse: there cannot be an important change of posture which is not accompanied by some adjustment of the blood-vessels of the body, some change of heart-beat, some widening or narrowing of arteries, and it is the **nervous system** which brings about these changes. And there is good evidence that it is nervous impulse which causes the gland-cells to build up their own substance, and, again, to pour out the secretions whereby digestion is effected, or waste matter is cast out from the body. On the other hand every sensation—not only of sight, sound or smell, but of heat, cold, touch, or pain—is inseparable from nervous impulse. Thus when we gasp at the touch of a cold shower-bath, or flush in the heat and movement of a ball-room; when the mouth "waters" at the sight of food, or some smell, or taste, sets up nausea or vomiting; then it is the central nervous tissue which, excited by afferent impulses reaching it from the periphery, discharges the efferent impulses which move the muscles of breathing, which widen the arterioles of the skin, which excite the secreting cells of the salivary glands, or the muscles of the abdomen and stomach-walls. And accompanying these nervous actions (which are fairly easy to observe) are others, more subtle, less obvious, but as important to the welfare of the body: among such are the efferent impulses which guide the nourishment—we may say the self-support—of the tissues, so that gland-cells, muscle-cells, and the like, remain healthy and vigorous. And among them too are those afferent impulses which stream from the periphery, to register, in the central nervous tissue, all muscular contraction. This is not the place, and not the moment, to discuss these subtleties of nervous action, but their existence should be remembered in considering the physical elements of the life of man. Man is not to be pictured mainly as an animal who breathes, who possesses certain digestive powers, certain glands capable of excreting waste matter, a system of blood-vessels by means of which nourishment is gleaned from the stomach, while waste is carried to the kidney. He is an organism full of delicate adjustments; an organism whose parts have constantly varying activities and needs; an organism which must meet changing strain and stress. The tissues cannot be "set" at one level of action; the muscles must contract slightly or strongly or must relax; the blood-vessels must widen or narrow here or there; the glands must pour out their secretions or depress this activity while others of their activities are heightened. And it is the work of the Nervous System to order and control these changes,—to adjust the impulses which stream to it from the periphery and the impulses which it sends out to the periphery so that the action of the whole shall be harmonious and helpful. There are no facts of man's life which should be rather borne in mind than these, in the ordering of a House which is a Home.

CHAPTER II.

Bacteria and Housewifery.

§ 1. It is probable that during the last thirty years no plant or animal has been so much before the attention of man, as certain forms which are perhaps the simplest, and certainly the most minute of all plants. These are the **Bacteria**; and we ought probably to include with them, as sharing some of the notice they have won, the *yeasts* and the *moulds*,—much larger indeed than the bacteria but still simple in structure.

In disease, in commerce, in domestic life, the power of these tiny creatures becomes recognized increasingly year by year, and to give a brief sketch of what they are, and what they do, is no unfitting introduction to the study of some of the main problems of **Domestic Economy.**

We are accustomed to divide the living beings in the world into *Plants* and *Animals*, and this broad distinction is based on differences which are very striking when we compare such an animal as the dog with such a plant as the geranium. There are differences of form, of habit-of-life, differences in many of the substances which are present, but above all, differences in the nature of food and in the mode of feeding. But further, plants and animals differ greatly among themselves; thus a dog is clearly very unlike a herring; both these differ widely from a black-beetle, this again from a snail, and all of these from a sea anemone. And among plants a geranium stands far apart from a fern, and a fern from the moss or lichen which clothes a wall. Indeed, as we pass from the highest or most complex plants to those which are very simple, we lose that distinction into *stem*, *leaf*, and *root* which we associate constantly with the field flowers and the forest trees. In the same way, examining a whole series of animals, each simpler than the last, we find some which lack not only the *nerves*, *muscles*, and *backbone* which we cannot separate from our ideas of a dog or a fish, but which want also a *mouth* and *stomach* as these words are commonly understood.

Among the simple creatures which stand at the end of each series we find forms which have the essential characteristics of plants and animals, and, yet again, forms which it is difficult to include in either category. The bacteria are usually placed among the *plants*,—among the smallest and simplest.

Now the most characteristic feature about the life of *green plants* is the great power possessed by them of building up the substances of which they are composed, from comparatively simple materials. This power is not possessed by animals which, being also composed of highly complex substances, feed either upon plants (as a sheep does) or upon other animals (as a cat does) or have such a mixed diet as that of most European men. It is true that the food thus taken in by animals needs important change before it actually nourishes the eater, such change as when the saliva forms soluble sugar from insoluble starch, as when the gastric juice turns the indiffusible proteins of lean meat into peptone, as when the secretion of the pancreas breaks the fat of butter into tiny particles and changes them chemically. Nevertheless, the lean meat, the starch, and the butter are in themselves complex bodies and, unless bodies of this description be available for food, an animal will starve. But green plants do not need proteins, fats, or carbohydrates as food[1]; in their substances all these bodies are present, but they are built up by the plant out of compounds so much less complex, that to animals they would be useless as food. This great building-up power belongs to plants of all kinds *provided that they hold the green colouring matter chlorophyll;* it is displayed by the oak, the geranium,

[1] A brief account of these bodies is given below, § 23.

and by the small and simple thread-like or one-celled plants which sometimes form the green scum on a stagnant pool. Now among animals there are certain forms which do not only need complex food, but need it prepared for absorption. They cannot digest, but live a degraded life, inseparable from some other animal which nourishes them. Of these we may take the Tape-worm as an example; they are known as parasites. Among plants too there are parasites; thus the Dodder, whose twining, red, stems are often seen on heaths, although it is nearly related to the Convolvulus and to Jacob's ladder, cannot live independently. It has no chlorophyll, and fastens itself upon and feeds upon other plants which are green and can therefore build up the substances which it and they require. In the groups of simple plants (those in which stem, leaf, and root cannot be distinguished) those forms which have no chlorophyll are known as Fungi. Simpler than even the simplest fungi in life history and in structure, the bacteria are allied to them in many ways. It is true that some forms possess a red colouring matter which in sunlight acts like the chlorophyll of plants in building up substances within the cell; and that others (possibly the most primitive of all living creatures) are able to use either nitrogen or sulphur, drawn from inorganic sources. But the bacteria are destitute of chlorophyll; the vast majority must have complex food to form their own substance, and they live either upon other living creatures, or upon substance which has been living in the recent past, or upon compounds which, although simpler than those which an animal needs, are much less simple than those which serve as the food of green plants. Indeed there is but little living or dead[1] matter upon which (unless it be too acid or too alkaline, too hot or too cold) bacteria of some sort will not thrive. What living creature, if killed, will not presently decay? And decay or putrefaction is a popular name for one form of bacterial change. Bacteria abound in every human intestine, not preying upon the living epithelium

[1] Dead is used here, not of inorganic bodies, but of substance which, having lived, now lives no longer.

of its walls indeed, but feeding abundantly upon the broken-down, digestive contents. Before the use of antiseptic dressings in surgery became usual, it was well established that a wound exposed to the air became the home and nursery of what we now know to be bacteria; indeed it would probably be difficult to find air, food, or water (unless these have received special treatment) in which they are not present. We may ask then "What are bacteria like? what is the importance of their widespread presence?"

§ 2. (*a*) In structure the bacteria are extremely simple. Each is a tiny mass of living matter—such a mass as Physiology teaches us to call a cell—having a protective, outside covering (or wall) of different and less complex composition. Some of these individuals have no power of independent movement, but are carried about passively by the movement of the surroundings in which they live; others move by means of outgrowths of their substance,—thread-like and exquisitely fine,—which have an action roughly comparable to that of the oars in a boat; others move by snake-like undulation of the whole body.

(*b*) In shape the bacteria are *threads*, *rods*, *spheres*, *dumb-bell-shaped*, or *comma-shaped*: in size they are so small that for satisfactory observation with the microscope they must be magnified 800 times or 1000 times linear. Some of the smaller spheres or *cocci* as they are called measure less than 1 *micromillimetre in diameter*[1]; what is perhaps the largest

[1] A micromillimetre is the one-thousandth part of a millimetre; a millimetre is ·039 inch. It is not easy to give to anyone ignorant of microscopic work a clear picture of the size of bacteria. Let us suppose that we take a small bacterium (a coccus) and a 'full-stop' in the text of this book and magnify them the same number of times. When we magnify the coccus so that it becomes the natural size of the full-stop, the full-stop, equally magnified, will appear a rounded patch of black, *covering the whole of two open pages of this book*. Many bacteria are larger than the cocci, as we have said, though still very minute; in life they are, for the most part, colourless and very bright (*highly refractive*), so that under a

bacterium known is $2\frac{1}{2}$ micromillimetres wide and 10 micromillimetres in length; thus, although small absolutely, it would hold 100 of the tiny cocci just described. But the rarity of this large size is indicated by the name *Bacillus megatherium* which is given to the bacterium in question.

Turning to our second question "What is the importance of the widespread presence of these minute creatures?" we may answer it somewhat as follows. The importance springs (*a*) from the rapidity and success with which bacteria multiply or reproduce themselves, (*b*) from their mode of nourishment and from the nature of the substances formed by them as they grow.

(*a*) *The reproduction of bacteria.*

It is clear that if we take a living being of many unlike parts,—for example a trout or a chicken—to split off or divide the whole individual or any part of it would not give rise to 2 new individuals, but would merely injure or maim. A young trout or a chicken is built up gradually as the work of organs of the parent specially set apart for that use, and all the complex parts of the perfect creature grow gradually from simple beginnings in the egg.

But on the other hand if we consider a bacterium such as the tiny *coccus* mentioned above, to split the coccus completely is to form 2 cocci, 2 *new individuals*. This form of multiplication is characteristic of bacteria and at times goes forward very quickly. Indeed it has been calculated that, taking for granted favourable conditions for this division, one bacterium, twice as large as a coccus (that is, the same breadth and twice the

good microscope they are shining threads or dots. For proper examination they must not only be highly magnified, but also stained with different and suitable colours, to bring out their characteristic shape, to distinguish their outside wall from its contents, and to show the presence or absence of *spores* (cp. below).

length), will increase at such a rate that, in two days' time, 2 *billions of bacteria* have sprung from it—enough to fill a ½ litre flask (nearly a pint). Fortunately for man and for the other inhabitants of the world, external conditions are often unfavourable; different bacteria destroy each other, and, when crowded, they are self-destructive, so that this possible increase is not attained. But the actual increase *is* very great, and this form of multiplication—by division or **fission** as it is technically called—brings enormous numbers of bacteria rapidly into existence from a single specimen.

For the second form of multiplication there is special preparatory change in the bacterium. Probably there is change in the little mass which forms the living part of the individual, certainly there is change in the surrounding envelope or wall. And the change is of such a nature that *the altered form is much more difficult to kill.* Among bacteria which have not undergone this special change there is great difference in the ease with which they can be killed. But we know, on the whole, that very great cold and more especially great heat do injure them beyond repair; that drying, shaking, the passage of electric currents, light, and, above all, sunlight are hurtful or fatal to them. When however they are changed in the fashion indicated above they can resist much more successfully these ordinarily harmful conditions. The changed bacteria are known as **spores**, and it has been shown that *some spores, dried for more than three years, can grow if moistened* again, and that a certain bacterium destroyed by a twenty minutes' exposure to boiling water *has spores which are not destroyed at the same temperature under* 3 *hours.* It is these two characters which give to spores their special power and danger when it is a question of destroying bacteria: heating and drying, which would cripple the fully grown forms, do not destroy the life of the spores. Added to this, the spores although varying in size are, for the most part, smaller than the bacteria to which they respectively belong, and, when dry, float readily,—or to be accurate sink very slowly—when by any means they are cast into the air[1].

It may be asked· "How is the vitality or life of spores shown?" It is shown by changes which may be (quite roughly) compared with the germination of a seed. As a seed which has been apparently unchanged through a long period of drought gives rise, when suitably moistened, warmed, and nourished, to a young plant, so the tiny spores, when suitably nourished, germinate, and from them arise bacteria with all their great and characteristic power of quick multiplication by fission.

(*b*) *The nourishment of bacteria and the nature of the substances formed by them in growth.*

The phrase "when suitably nourished" leads us to dwell for a time upon the second reason given for regarding bacteria as of high importance to the life of the world. And in this respect they are mighty for evil and for good.

§ 3. *The power for good* is often overlooked in popular thought and writing, but if we merely enumerate certain of the processes which are dependent on the activity of bacteria, we see it clearly.

In commerce the preparation of *flax* and *hemp* from the plants which produce them, the preparation of *skins* before tanning, the preparation of *tobacco leaves* before the tobacco we know is made,—these and others are processes in which bacterial activity is all important. Different forms are of course concerned in the different processes, but all bacteria have this in common, that they live upon liquid food and that they have most remarkable, though various, powers of breaking down complex matter outside themselves, in which action they obtain the nutritive liquid wherewithal to thrive and divide. At the same time they bring about other profound changes.

[1] A discussion of the conditions under which solid particles are found abundantly in the air is given below, § 10.

In **agriculture** we find bacteria active in all successful making of *hay*; and we find them enormously important in so altering the substances in soil that the crops grown can be well nourished. This activity is shown both in connection with the history of gaseous nitrogen and compounds of nitrogen in the soil and in connection with cast-off cellulose. Cellulose, as we know, is the non-nitrogenous substance of which the walls of plant cells are made and it is extremely difficult to dissolve: saliva, gastric juice, and pancreatic juice are alike without action—they can only pass through the cellulose envelope and attack the nitrogenous, starchy, or fatty, bodies lying within. Yet bacteria can dissolve it and even more resistent wood, and all the fallen leaves and twigs which "rot" upon the ground are being changed by the agency of these minute creatures into substances which, being set free into the air and the soil, are at the service of other plants and of animals.

In **domestic life** we find familiar examples of the activity of bacteria in changes which go on in milk, cheese, butter. In brewing, and in the formation of vinegar, they take active part, and it must not be forgotten that one of the yeasts (we shall speak later of these near neighbours of bacteria) is of daily use in bread-making. In fresh milk bacteria are always present, but usually they may be regarded as an evil[1]. In butter they abound, either carried on from the sour cream, or added deliberately after being separately cultivated: indeed butter is said to owe its delicate flavour to them. Cheese is always teeming with bacteria, and they have a most important share in changing the insipid "curd" to the highly flavoured, ripe cheese which we know.

Such bacteria may be regarded as working for good because on the one hand they bring about important changes

[1] It is now well-known that Metchnikoff regards lactic acid bacteria and the products of their action as of great value in checking putrefactive change in the large intestine. But, until our knowledge of this action is wider and more definite, the use of sour milk and its products should be directed by experts.

useful to man and because on the other hand they are not sources of disease when introduced into the human body; they belong to what are technically called the **non-pathogenic** bacteria.

But the power for evil of certain other forms can hardly be overestimated. These forms are the **pathogenic** (or disease-producing) bacteria: they are a minority when the whole group of the *Bacteria* is looked at from the point of view of numbers, but when we consider their effects it is hardly surprising that, to the popular imagination, they have thrown into the shade the beneficial action of some non-pathogenic forms. As one infectious disease after another has been carefully investigated in recent years, each has shown that bacteria are present in the blood and in various organs of the sufferer, and that the bacteria vary characteristically with the disease. *Diphtheria*, *scarlet fever*, *typhoid fever*, *cholera*, *wool-sorter's disease*, *consumption*, *tetanus* ("lockjaw"), *leprosy*, *small-pox*,—these are only some of the diseases in which bacteria are growing within the living body, poisoning its parts with the products of their activity, and lessening its vitality. And the issue of the struggle is recovery or death,—recovery if the bacteria and the substances which they form can be gradually destroyed by certain processes which each healthy body has at its command;—death if these processes fail (and we know how often this is the case), and the vitality of the diseased person is not only lessened but destroyed.

§ 4. Now the disease-producing bacteria concern us here, because it is within the power of a housekeeper to aid or check their spread in a house, or even their admission to it. This is seen clearly if we name some of the points of danger in the attack of these small enemies and some of the methods of defence which may be used.

A. *How may pathogenic bacteria enter or spread in a house?*

a. They may enter with someone who suffers from an infectious disease or with some article of furniture, dress, or ornament from an infected house.

They may spread from all excreta of the patient, from clothes soiled by him, rooms inhabited by him, utensils of food, or books used by him; from his skin and from his breath and the minute drops of water carried out with his breath.

b. They may enter with water and spread with the drinking of it. Water is a fruitful source of bacterial infection, and pollution of the water-supply of some towns has been associated with grave epidemics of typhoid fever, cholera, etc.

c. They may enter with milk and spread with its use. Tuberculous cows and goats are only too familiar as sources of diseased milk which may convey tuberculosis (consumption) to a child or to another animal, and milk, contaminated after it has left the cow, often carries *typhoid* bacteria, and has been known to carry the infection of *scarlet fever.*

d. They may enter with meat. Probably all meat which has been "hung" contains bacteria of some kind,—on its surface—or beneath the surface, if the interval since death has been long. But there is some meat, taken from unhealthy oxen or calves, in which a group of bacteria is present, members of which have been shown (with their products) to give rise to the marked and sometimes fatal symptoms which accompany meat-poisoning in man. "Unsound meat" is probably sometimes used carelessly or culpably in the making of meat pies, but the pathogenic bacteria may be present without giving rise to any suspicious change in the smell, colour or texture of the poisoned meat, and *then the danger is most insidious.*

e. They may be introduced by *domestic animals.* This is not a well-recognized source of infection, indeed it is perhaps too lightly regarded. The domestic reticence of cats is a safeguard in their case, but a dog is as indiscriminatingly enquiring abroad (even among refuse) as he is effusively affectionate at home. And these habits, which probably do make him a carrier of higher animal parasites, may well aid, sometimes, in the transference of pathogenic bacteria.

B. We turn then to ask *what methods of defence can be opposed to these subtle attacks?*

a. A general answer is found in naming some of the conditions which are hurtful to the life of bacteria. Foremost among these we must place the process of sterilization. To make a fluid, or solid, sterile is *to destroy all living creatures in it, and* **this is the great safeguard of the kitchen and the nursery.** Raised to a sufficiently high temperature in the dry, or wet, all food and drink is sterile. Now a high temperature is often hurtful to the nutritive matter in food, but sterilization may be brought about either by a short stay at a high temperature, or a longer stay at a lower temperature, or by repeated treatment with moderate heat (say 50° C.). Boiling is of course the rough, domestic form of sterilizing, though all forms of cooking, properly carried out, should rank with boiling. The effect of **cold** (as it can be applied in the kitchen) *is* **not** *to sterilize.* It does however check the development of bacteria and is therefore of great value.

b. Hardly less important than the use of sterilization is the use of substances known as **antiseptics.** *Corrosive sublimate, chloride of lime, sulphurous acid*, more lately *boracic acid*, and *formalin* have grown familiar terms. In different degrees they act harmfully, some when present in very minute amount. But it must be remembered that, injuring bacteria, they also injure all living things, so that while their use is wholly for good in the sick-room, they should never be used in the kitchen.

c. A most important aid to the destruction of bacteria is found in the **daylight,** and especially in **bright sunlight,** and it is of great interest that the pathogenic bacteria are, on the whole, most hurt by the sun. It has been found that when many thousands of a form of bacterium which is constantly present in the human intestine are added to water (100,000 bacteria to 1 c.c. of water), *no living specimens could be found after one hour's sunlight*, and equally marked destruction of the bacteria which belong to typhus, to anthrax, to asiatic cholera, has been observed. It may be argued that, since this clear cut destruction was demonstrated in layers of bacteria which could be readily penetrated by light, the conclusions cannot fairly be applied to the dim illumination of domestic life. But it is a fair deduction that unnecessary darkening of dwelling rooms is short-sighted in the extreme, and that the evils of "fading" carpets and curtains are not to be compared with the evils of fostering the growth of bacteria by shutting out the sunlight.

d. Lastly we must note that the human body, so disastrously fitted to be a home to pathogenic bacteria, may be made unsuitable for this purpose, or, in technical words, *immune*, or *partially immune.* The immunity conferred by inoculation and varying in completeness and in duration, is a thing, not of the kitchen, but of the surgery. But a partial immunity is inherent in the human body, and can be fostered or injured by those who order the daily life of man. It is probable that every inhabitant of a large town, at some time during the winter, has, in his mouth or lungs, some form of micro-organism which causes a "cold." The chemical changes of certain cells of his body form a natural guardian mechanism, and in vigorous health the infection gets no hold. But if the changes of these protective cells are depressed or hindered (if his "vitality" is lowered)—as by wet feet, long exposure, a railway journey in wet clothes,—the micro-organism is enabled to multiply, the defences of the man are broken down: he "takes cold[1]."

This brief statement is substantially an answer to the general question which went before it. Each point will be taken up in detail in the following pages, as that part of the subject is considered with which it is closely connected. And, if asked how briefly to arm a thoughtful housekeeper against

[1] Compare § 16.

the dangers of bacterial action, we can only say that, while no procedure will hedge about a household in complete security, she is well armed in observing,

1. *in the sick-room, rigid cleanliness with use of antiseptics;*
2. *in the larder, cleanliness with a temperature as low as may be;*
3. *in the kitchen, intelligent and above all* thorough *cooking;*
4. *throughout the dwelling-house, the admission of sunshine and fresh air.*

The extinction of non-pathogenic bacteria in the field and in commerce would be a measureless disaster, but in the kitchen their use is at an end, and they may be ruthlessly destroyed,—lest, by chance, side by side with them there grow the pathogenic forms[1].

§ 5. It may perhaps seem strange that in the foregoing paragraphs mere mention has been made of the *yeasts* and *moulds*. Like bacteria they are simple plants, though differing from bacteria and from each other in minute points of structure; like bacteria they exist on living or dead substance, breaking it down and changing it profoundly. But in the first

[1] In this brief account much that is important from a scientific aspect, has been omitted; the actions of bacteria in nitrification, in fixing free nitrogen, in breaking up and using carbonic acid in the absence of sunlight;—these are of the highest interest. It seemed well however to make a deliberate choice of such activities as mainly affect *domestic life*. It may be mentioned with regard to the familiar terms *micro-organism* and *microbe* that the latter is practically a popular equivalent for *bacterium*, while *micro-organisms* include not only bacteria, but yeasts and moulds, and certain very simple animals, microscopic members of the group *Protozoa*. The term *micro-organism* is indeed one which lays stress on the likeness among these minute forms (since all are living), rather than on the differences which make us group some with animals, some with plants (cp. p. 9); and it is to be noted that certain diseases carried from man to man by flies are due to Protozoa, almost as minute as bacteria.

place with rare exceptions they are non-pathogenic, in the second place they are less insidious in attack. Unsound meat, tuberculous milk, poisoned water do not necessarily show anything of their bacterial contents, but mouldy eatables are soon rejected in disgust. Briefly, we may say that, aiming at bacteria, the housewife kills moulds and yeasts as well.

CHAPTER III.

Air in relation to Life.

§ 6. We may look upon the atmosphere as a sea of air, bathing the earth. At the bottom of this air-sea (that is upon the surface of the earth) the pressure of the atmosphere is in equilibrium with a column of mercury 760 millimetres high; it is therefore under such a pressure that the majority of plants and animals live.

But the air which forms this sea is practically never still. Rising when it is warmed, and thus producing directly and indirectly currents of varying strength; constantly gaining moisture, and as constantly losing it; made foul and purified by different actions of living beings, the "open air" is like a chemical laboratory, the scene of varied and profound chemical change. It will be readily understood that profound changes taking place in any medium do not necessarily alter the final composition of that medium, provided that the different changes balance each other. And we find that the "open air," unless it is in close contact with such powerful pollution as that springing from thick-set chemical works, or from large masses of putrefying substance, has a constant composition. Taking account of water in the gaseous state (which is always present though in varying amount) we may accept the following analysis of air as typical:

"Nitrogen"	78·35 parts
Oxygen	20·77 parts
Moisture (water)	0·85 parts
Carbonic acid gas	0·03 parts
Air	100·00 parts

It must be remembered here that the "Nitrogen" does not represent one substance—one element. But the small percentage of argon or the other inert gases which have been described in air do not, so far as we know at present, touch the relation of air to life.

§ 7. We know from the teachings of Physiology that it is as a *source of oxygen* that air is all important to plants and animals, and it is in connection with this use that we must now consider it further.

There are however three points that may first be noticed.

(*a*) Firstly, certain living creatures, members of that group of organisms which we know as bacteria[1], can exist and reproduce themselves in *nutrient liquids which contain no oxygen.* Some of these forms are indifferent to the presence of oxygen and can thrive in its presence or absence, but to others the gas acts as a poison, they can only live in its absence. Bacteria, important as the work of recent years has shown them to be, alike from a commercial, a medical and an agricultural point of view, form only one sub-division of the great group of plants, and it is only certain forms among them which grow in the absence of oxygen. Nevertheless in considering the relation of the air to life, it must be remembered that *certain living creatures are entirely independent of it.*

(*b*) In the second place another group of bacteria have very remarkable relations with the nitrogen of the air. We know

[1] See above, chapter II.

that the element nitrogen is a necessary part of all proteins and that proteins are a necessary part of all living substance; but we also know (§ 1) that animals draw their nitrogen from the proteins of other animals or of plants, and that plants build them up from simple materials, such as nitrates found in the soil. But the group of bacteria of which we are now speaking, and they alone, can *use the free nitrogen of the air* and make it enter into chemical combination. They live in or upon the roots of certain plants—members of the order to which the pea, the lupin, the clover belong, and these plants are fed with the nitrogen "fixed" by the bacteria. These facts are of great practical importance to farmers, for crops thus fed by bacteria are much less dependent upon nitrogenous manuring than are oats, wheat, or potatoes, and may even leave the soil richer in this respect; they are also of the greatest scientific interest, since the behaviour of these bacteria to the inert nitrogen of the air is so unlike that of all other living things.

(*c*) In the third place the atmosphere must be regarded as a source of *carbonic acid to all living creatures which hold chlorophyll*—that is, all green plants and some few animals. Carbonic acid is a gas which is difficult to decompose, yet in the presence of sunlight, protoplasm holding chlorophyll can decompose it, and all the carbon that is found in living substance (and it is a very wide-spread element—found in proteins, in fatty matters, and in starchy matters) has once been present in the air in the form of carbonic acid gas. From this form it is taken by green plants and worked up to complex substances, and these substances become part of animals who live upon vegetable food, and thus, part of animals who are carnivorous.

§ 8. It is however in relation to the act of **breathing** that we wish to consider the air in detail, and looked at from this point of view it becomes a great storehouse whence oxygen is drawn and into which carbonic acid, watery vapours and other exhalations are poured. When air is cut off from an animal, then, as is well known, the animal dies. And short of this extreme state of things, changes in the surrounding air have most important effects on breathing.

I. *The pressure of the air which is breathed may be changed.*

Sometimes this special medical treatment is applied locally in the case of certain diseases of the chest; the patient is made to breathe air that is especially compressed, or especially rarefied. But with these cases we have no concern here; changes of pressure in the air during health are changes to which not only the lungs but the whole body is exposed.

Thus the pressure may be *increased* as it is in the closed chambers in which the builders of great bridges work. In the chambers or "caissons" which were formed in the building of the Forth Bridge, air was supplied at a pressure more than three times as great as the pressure of the atmosphere.

On the other hand the pressure may be *decreased.* As we rise above the surface of the earth the air is increasingly rarefied or "thin," and high in the Alps or Himalayas, or in high balloon or aeroplane ascents, the difference of pressure may be very great.

Now great changes in either direction may be brought about slowly with no ill effect. The workmen who build a bridge are placed in an "air lock" where the pressure is increased gradually, and they can then not only exist but work in the condensed air of the caisson. In the same way, passing through the air lock, they can come back to the earth unhurt. And men live and work in high Himalayan villages as easily as in London. But when the changes are extreme or sudden, injury, even death may follow; with *increased pressure,* slow and deep breathing, pain in the head, sometimes breakage of the drum of the ear: with *decreased pressure,* irritation of the skin, disturbance both of movement and feeling, sometimes unconsciousness and death. These are probably symptoms of an upset in the balance between the blood and the gases which it holds at the normal atmospheric pressure; this upset, carried everywhere because the blood in which it takes place travels everywhere, injures the delicate, nervous tissue which is so wide-spread, and thus brings about widespread injury. The mechanical effects of sudden decrease in pressure may be serious or fatal. In such cases, bubbles of gas are given off from the blood or lymph (as when the cork is taken out of a soda water bottle streams of bubbles break from the soda water) and, blocking the small blood vessels stop the circulation of the blood.

II. *The air breathed may be more or less loaded with moisture or may be exceptionally cold or warm.*

In the case of healthy persons changes of this nature, unless they are extreme, do not touch the breathing *directly*. They have of course very important action upon the skin with its blood vessels and sweat glands, and it is a well-known fact that extremes of heat and cold are more difficult to bear without injury if the air be loaded with moisture than if it be dry. We know that, be the surroundings hot or cold, the temperature of a healthy warm-blooded animal hardly varies; when however it is raised above the normal by some extreme external change or by disease, then the breathing is much more rapid. And what is unusual in man is usual in the dog; the panting or quick breathing of a heated dog is familiar to everyone—it probably brings about great loss of heat by evaporation from the windpipe, nose, and mouth, and thus is an aid in cooling the animal.

III. *The composition of the air breathed may be changed, not by the introduction of any new element or constituent, but by change in the gases usually present*, nitrogen, oxygen, carbonic acid.

We may put aside the question of change in nitrogen.

This does not occur under ordinary or even under unusual conditions of daily life, at least not in any degree which affects breathing. Nitrogen, indeed, is only important in respiration if it interferes with the proper inspiration of oxygen.

In like manner we may put aside the question of increase in the oxygen present. It may be increased considerably without distinct effect on breathing, and we do not meet with this increase under natural conditions.

But there are two possible changes which are all important in their effect on breathing—decrease in the amount of oxygen in the air and increase in the amount of carbonic acid. In careful experiments these two changes may be separated from each other, and each is found to be injurious and, if carried far enough, fatal; that is, a man may be killed by sufficiently reducing the oxygen in the air he breathes, and in a somewhat different way, by *greatly* increasing the carbonic acid present.

But practically the two changes come before us together, for the consumption of oxygen by all living creatures forms one side of the shield, while the other is the giving off of carbonic acid. The oxygen may be reduced considerably from the amount present in fresh air (20 vols. p.c.) without marked injury to breathing; it is the amount of carbonic acid present which is usually taken as the index of harmful change. This is not because of ill-effects proper to itself, but because under the conditions in which the carbonic acid of the air breathed is abundant, other subtle and injurious changes in the air have been brought about. Of these we shall speak later.

The **free air** is, as we have said above, remarkably uniform in its composition, indeed, taking Dr Angus Smith's figures, we may notice that there is hardly more carbonic acid in the street air of a crowded city than on a mountain top.

Percentage of carbonic acid in Air.

From the streets of London (mean)... ·0343 p.c. or 3·43 parts in 10,000.

From the top of Ben Nevis, „ ... ·0327 p.c. or 3·27 parts in 10,000.

This uniformity is, of course, due not only to the fact that activities of opposite character, tending to balance each other, go on in the air, but that owing to such agencies as rain and winds the air is in free movement[1]. Pure air is indeed attainable for all living creatures whose life is an out-of-doors life. But for the most part human life is in-doors, in limited spaces of air cut off more or less completely from the atmosphere. These are constantly fouled by waste matters poured into the air by every human being or other animal inhabiting them, from every burning candle, gas-jet or lamp. *Plants* also give off carbonic acid, but not in great amount, and in the sunlight they are sources of oxygen. *Domestic animals* are by no means negligible, but are important consumers of oxygen and producers of carbonic acid,—thus, in proportion to weight, a dog gives rise to two or three times as much carbonic acid as a man. But except in buildings specially devoted to them the numbers of domestic animals are small; the chief sources of impurity

[1] The proportion of carbonic acid varies somewhat in different towns, and it is, as might be expected, higher in foggy air. In considering those balancing activities which keep the composition of air constant it is interesting to note that as regards the amount of carbonic acid present, there is a tendency *to place too high* the combined influence of plant life in the sunshine (consumption of carbonic acid) and animal life (evolution of carbonic acid). There is good evidence that this influence sinks into insignificance compared with chemical reactions in which life is not directly concerned. Carbonic acid is still emitted from the earth in enormous quantities by volcanoes and springs, and it is only kept from loading the air by constant solution in the sea and rain, and by constant chemical combination. Thus, instead of existing freely as a gas, it is absorbed by water, and forms part of substances dissolved in fresh water or in the sea (such as carbonate of lime) which in the long-run help to form the solid substance of the earth. But as regards the renewal of oxygen in the atmosphere, *green plants are all-important.*

which we have to consider are found in man and in the different forms of burning.

§ 9. A man, when he is breathing quietly, sends out at every breath about 500 cc. (say 30 cubic inches) of air loaded with carbonic acid to the extent of 4 p.c.; a man working actively gives off much more. Now the air of a room should ideally contain the same percentage of carbonic acid as does the fresh air, namely 3·5 parts in 10,000. It is found that air containing more than this may, however, be breathed without injury or discomfort; but when the increase due to breathing is more than 2 parts in 10,000, that is to say when the whole carbonic acid present exceeds 5 (or at most, 10) parts in 10,000 (the excess over fresh air content springing from respiratory action) then the air becomes unwholesome.

We have taken 30 cubic inches as a measure of the amount of air taken in and sent out at each breath, but we know that this amount varies greatly even in healthy breathing. In the same way, the number of breaths taken in each minute, shows great variations from time to time, even in men of the same age. But we may take 15 as representing a fair average in quiet breathing, remembering however that departure is frequent both from this number and from 30 cubic inches as the volume of "tidal" air. Now if 15 breaths be taken in each minute, 900 will be taken in the course of the hour, and during this time 27,000 cubic inches or $15\frac{3}{5}$ cubic feet of air will be fouled with the products of breathing, carbonic acid being present to the extent of 4 p.c. But respiratory carbonic acid (as we have seen) must not exceed 2 parts in 10,000 if the air is to be thoroughly wholesome, that is to say the $15\frac{3}{5}$ cubic feet of expired air must be diluted 200 times. This will give about 3000 cubic feet of fresh air as the quantity with which a man should be supplied hourly under the given conditions, and about this quantity is contained in a room 17 feet square and 10 ft. 6 in. high. It is clear that to drive 3000 cubic feet of fresh air across one end of such a room, hourly, would not give the necessary supply to a man stationed at the other end; on the other hand it is clear that, could the products of breathing be removed as they are formed, wholesome air would be maintained with intimate admixture of considerably less than 3000 cubic feet of fresh air in the hour.

So far we have considered the necessities of a man who may be taken as an **average man**, resting, or at least not doing hard labour. It should be remembered that women and children need slightly less than this amount, while, for a man working hard, the hourly supply of fresh air should probably be doubled.

§ **10.** When we consider not only indoor life, but life in *artificial light*, new sources of impurity affect the air. Candles, lamps, and gaslights, are all consumers of oxygen, and the amount of carbonic acid they produce is large. It varies of course with the wax, paraffin, or gas respectively used; but it is probably not overstating the truth to say, that an ordinary **oil lamp** produces 3 times as much, and a batswing **gas burner** between 3 and 4 times as much carbonic acid in the course of an hour as does a man. But carbonic acid and water are the only important additions made by lamps and candles to the air in which they burn, and carbonic acid *per se* has been found unproductive of serious harm when present in much greater amount than that indicated as unwholesome in the preceding paragraph. The fouling of air due to gas, on the other hand, is partly due to products to which, in addition to carbonic acid, its burning gives rise. Looked at from this point of view, gas must be regarded as the least wholesome of illuminants, when it is burnt without precaution in inhabited buildings. And although air containing carbonic acid produced by any ordinary illuminant is far less harmful than that containing an equal amount produced by breathing—not, of course, because of difference in the carbonic acid but because of accompanying changes—yet the action of all forms of artificial light, except the electric light, must be reckoned with seriously in considering the healthful housing of man.

IV. *The composition of the air may be changed by the introduction of gases not usually present which have important effects on its relation to life.*

(*a*) *Carbon monoxide* (*also known as carbonic oxide, and to be distinguished carefully from carbon dioxide or carbonic acid*). This gas is found in the fumes from brick-kilns or lime-kilns, in the gases which come from blast furnaces, and from stoves in which coke or charcoal is burnt. It is also found at times in the air of coal-mines, and is present in coal gas. Indeed it forms about $\frac{1}{12}$ of coal gas as we ordinarily burn it; an escape of gas would thus set free a comparatively large amount of carbon monoxide into the air. Now it has been said more than once that the main value of air to living creatures consists in the fact that it is a source of oxygen, and we know that the substance which carries oxygen from the air throughout the body is, in man and in all the higher animals, *haemoglobin*—the colouring matter of the red corpuscles of the blood. Only by means of this haemoglobin united with oxygen (and then known as *oxyhaemoglobin*) can the body gain the element which is so essential to its well-being; and the most dangerous form of starvation is oxygen-starvation. Carbon monoxide is poisonous because it brings about oxygen starvation. Like oxygen it unites or combines with the red colouring matter of the blood, but more firmly than does oxygen. Thus if a solution of haemoglobin be exposed to air holding both oxygen and carbon monoxide, the union with the latter takes place more readily and more firmly than that with the former, *carbonic oxide haemoglobin* is carried by the circulating blood instead of *oxyhaemoglobin*, and the body dies for lack of oxygen. It dies indeed as if oxygen were absent; pure air loaded with carbon monoxide is of no more service for breathing than if it contained no oxygen at all.

It is probable that no year passes without the occurrence of deaths from carbon monoxide poisoning, but as domestic life is arranged at present in England (with its attendant fires and lighting) the danger is faced rather by men engaged in special work than by the dwellers in houses.

(*b*) *Sulphuretted hydrogen.* This is the ill-smelling gas which is given off from rotting eggs, and from the putrefactive breaking up of other nitrogenous substances; it is present for example in sewer gas. It is also found in, or readily formed from the waste of certain chemical works. Sulphuretted hydrogen is a powerful poison, but cannot be regarded as an insidious poison, for even in traces it is detected by its repulsive smell When present in the air in sufficiently great quantity, its poisoning action has some resemblance to that of carbon monoxide. It combines readily and firmly with oxygen, and can prevent the red colouring matter of the blood from combining with the oxygen which properly belongs to it. Thus, as in the case we have just considered, the body dies from oxygen-starvation. Sulphuretted hydrogen does not itself unite with any part of the blood but is simply dissolved, probably in the blood plasma, and thus it differs from carbon monoxide. The oxyhaemoglobin, deprived of its oxygen, is left uncombined with any gas; it becomes then the body which we know as *reduced haemoglobin*; and which, in health, is characteristic of venous rather than of arterial blood.

(*c*) *Nitrous oxide.* This is not a common impurity in air but is well-known as an anaesthetic in dentistry. Its physiological action forms an interesting contrast to those just considered for it does not in any way hinder the union of haemoglobin with oxygen. But, dissolved in the blood during its passage through the lungs, it is carried to all the capillaries of the body, bathing all the tissues and, among others, the central nervous system. And in small quantities the gas wakes up or *stimulates* certain of those cells of the nervous system so that the uncontrollable movements which have given to it the name of *laughing gas* are excited: in larger quantities it deadens the nervous tissue for a time, and thus, insensitiveness (anaesthesia) is produced.

V. *The composition of the air breathed may change according to the nature and amount of solid matter present.*

Other gaseous impurities are present in air in certain places and under special conditions, but those just named are of the highest general importance. But in studying the air in relation to life we have to deal with matter which like them is no integral part of the air, but which, unlike them, is solid matter.

The air, as we know, has mass and weight; and offers great resistance, e.g. to the rapid movement through it of an open umbrella. This resistance is not seen clearly when some rather large mass of heavy material such as a stone or a sovereign is thrown or falls to the ground. But whereas a stone can be thrown with the hand fifty yards, a handful of sand of the same weight (and sand is only stone broken small) cannot be sent more than a few feet. And when a sovereign is beaten out into gold leaf it is carried on the lightest breath of air, although gold is almost the heaviest substance known. This is because the total surface of the sand-fragments and of the gold leaf is enormously greater than that of the stone and of the sovereign respectively, and the air resists their passage much more. And it comes to pass that substance which is hundreds of times heavier than the air may, if it is in sufficiently fine particles, fall through the air so slowly as practically to float in it. Such particles are the **dust** of the air; and we may say that atmospheric dust is present abundantly for a height of one mile, or in places for many miles, from the surface of the earth. In the higher (and rarefied) layers of air these particles are exquisitely fine; near the surface of the earth they are coarser,—particles such as we see when a sunbeam falls into a darkened room. This dust of the air is always shifting, falling however slowly on the land and the sea and being constantly renewed, so that the dust of to-day is not the dust of a week ago. And the change of place of dust particles may be most striking: volcanic dust from an eruption of Vesuvius has fallen to the earth at Constantinople, and after the great eruption of the volcano Krakatoa it was calculated that the fine dust, thrown many miles into the air, must have travelled more than once round the globe before it fell.

§ 11. Now in domestic life we have to deal with **dust** which, as compared with that in the air of a mountain-top, is greatly increased in amount and is of more varied nature. But the particles which make it up fall into two great groups, separated by a distinction which, if it is rough, is convenient. There is in the first place *organic solid matter* in the air, and this may be popularly described as matter which is or has recently been part of living beings: in the second place there is *inorganic solid matter*, matter which has not immediate or recent connection with living beings, and is often popularly called mineral.

Inorganic particles in dust. Organic bodies, of which we have just given a rough definition, are, to the chemist, compounds in which the element carbon is present; for in everything that lives or has lived there is carbon—for example, in skin, in wool, in silk, in paper, in cork. But carbon, existing alone, is more properly included among the inorganic solid matters of the air, and it is probably the commonest impurity with which men come in contact. For soot—condensed and aggregated smoke—is carbon, and, at least in a country so smoky and so densely populated as is England, there can be few who do not daily breathe air in which soot is present. Some of the particles thus breathed are stopped in the complicated and twisted passages of the nose, some are stopped in the windpipe and bronchial tubes and cast out with the discharges (secretions) of these passages. But enough carbon, very finely divided, reaches the lung-tissue proper, to deepen its tint from the pinkish colour of the baby's lung to dirty or even blackish red in grown men, and this change is of course especially striking in the dwellers in cities.

Considered from a mechanical point of view, the presence of much foreign matter in the lungs is disadvantageous, but carbon is probably the least harmful solid substance taken in in breathing, for it is not a poison nor an acute irritant. But sometimes positive injury to the delicate lung tissue follows the breathing of fine mineral dust which fills the air when certain trades are carried on. Stonemasons and miners,—for example those who work in the gold mines with "dry bore"—suffer greatly from this sort of irritation, and the short lives of the "dry grinders" of Sheffield were notorious some years ago. Even with the improved arrangements for work, and the careful legislation of recent years, injury may be still great, and one well-known form of diseased lung is known as *stone-mason's lung.*

Organic particles in dust. These are sometimes actually living substance, and sometimes they may be called the *débris* of living beings; they form the greater part and certainly the most dangerous part of domestic dust. Almost all friction of solids (unless these are bathed with liquid) sets free into the air minute fragments which have been attached to, or have formed part of one or both of the solids thus rubbed. For example the thin surface-scales of skin (epidermal cells) are shed daily by all animals possessing them; tiny fragments of dried excreta, of hair, cotton, fur, and feathers are very widespread, and in the carrying-on of certain different trades the two last named are present in dangerous amount. The dust-like pollen of flowers is, at times, a noticeable element in dust, especially such comparatively light pollen as forms what has been called the "smoke" of the yews and pine trees, (the so-called *showers of sulphur*) or the odorous dust of the hay-field. And other products of simpler plant-life abound. We know that all jam, damp bread, jelly, and many other eatables *mould* if exposed to the air, especially in summer. The **moulds** which are so familiar as blue-green or white, dusty patches, are really simple plants, visible to the naked eye only when they are gathered into masses. The spores of these plants (see above § 2) are in all air, and when suitable material for their growth is exposed to the air, they grow, and give rise to moulds. Very nearly related to these are the particles popularly known as *disease germs*, which we have recognised as exceedingly simple plants, members of the group of **Bacteria** and properly known as *pathogenic bacteria*[1]. We have said that bacteria of many different kinds may be present in the air (either as spores or as bacteria themselves) and this especially when they are dry. This being so, they are taken in with the breath, the harmless and the harmful alike. Now there is perhaps no sheet of living matter more delicate than those membranous cells, which are all that separate the air in the lungs from the blood that courses through the lung-capillaries. Moreover the extent of this delicate tissue is great; it has been estimated that the surface of the human lungs spread flat would cover an area of 90 square metres; in other words, the lining cells would form a sac or bag able to line completely the floor, the ceiling and the walls of a room 14 feet square by 10 feet high. Delicate as these cells are, when they are whole and sound, even disease-producing bacteria may be inhaled without necessarily producing disease. But some weakness which has existed from birth, or some local injury due to cold, or the irritant effect of some inorganic particles breathed, or constant exposure to impure air, may produce spots of injury where the "germs" can find a home and food-material, and whence they, or poisons made by them, enter the general circulation; just as an open wound will always form good growing-ground for the bacteria of the air if it be exposed to them. We have seen above (§ 11) that consumption may follow the breathing of poisonous dust, and it was a common sequel to the work of dry grinding in past years,—not because steel dust could in itself give rise to consumption, but because, irritating the lungs, it weakened them, and made them especially susceptible to the *bacterium* proper to that disease.

The well-known *wool-sorter's disease*, again, is directly associated with poisonous dust: as the Alpaca wool is "sorted,"

[1] Cp. above § 3.

anthrax and its spores (which have been lurking in the fleece) are shaken into the air. But anthrax is the special *bacterium* which gives rise alike to the wool-sorter's disease and the splenic fever of cattle, and its constant presence in the air, breathed during each working day, enables it to get a hold on at least the majority of the men long occupied in the sorting-room, with disastrous, often fatal results.

CHAPTER IV

Ventilation.

§ 12. The foregoing considerations touching the ordinary constituents and the accidental and changing impurities of air are far from complete, but they may put us in a position to understand the problems with which we have to deal, in ventilation.

We are concerned with the maintenance of fairly healthy life under difficult conditions.

In the first place it is the life of men in *limited spaces of air*, and men are at once taking from the air the element which is all important to life and pouring out into it actively injurious waste matters.

In the second place it is largely *life in artificial light* (at least in the case of most town-dwellers); and almost all sources of artificial light have a vitiating action on the air.

But in the third place it is the life of persons dressed in clothes *which are for the most part imperfectly clean.* We know that glands of two kinds are constantly passing their secretions on to the surface of the human body,—the *sweat glands* and the *sebaceous glands*, the latter opening at the bases of the hairs. The sweat carries water, common salt, some complicated fatty (often odoriferous) compounds and some urea, which last we know as an important nitrogenous waste matter; the sebaceous secretion is mainly the changed and broken-down cells of the little glands which yield it, and is rich in fatty matters with some admixture of nitrogenous substance. Now the amount of these secretions varies greatly (there may be many litres in the course of twenty-four hours) but they are constantly formed; of sensible perspiration we are conscious when the temperature round us is high, especially in moist air, or the exertion is great,—but insensible perspiration is present at all other times. What is its fate? There is of course loss by evaporation, loss of water and of some of the more volatile constituents of the secretions, but a residuum must always be deposited upon the skin, or must soak into the clothes. Let us suppose that the skin is cleansed completely by bathing twice in the day; the clothes worn near it will in one day not be seriously polluted, and their exact condition will depend largely on the substance of which they are made. Thus the most pervious clothing naturally allows the most free escape of the water of the skin secretions and accompanying volatile matters, while relatively impervious clothing (such as linen and cotten) causes the deposition of liquid sweat which soaks the garments in contact with it[1]. The list of impervious clothing is headed by such articles as are "waterproof"; most persons are familiar with the discomforts of exertion taken while macintosh is worn, and the sensible discomfort is only the expression of hindrance to that free escape of matter which, in an unclothed man, would attend the vigorous action of a flushed skin. However carefully bathing is carried out, however carefully the materials of clothing be chosen, still it is evident that in the course of a few days, some complex organic matter,—re-inforced by dust particles from the

[1] See below, § 83.

air—must impregnate the garments worn near the skin. And when we remember that even daily bathing is not customary among the bulk of the inhabitants of England, that clothing is often carelessly chosen and impervious, that some articles of dress which are worn for weeks or months may be in daily contact with the skin (this is the case with some dress bodices of women) we realize vividly the power of clothes for evil.

Fourthly, we are considering the life of men *in furnished dwellings*. Here we have a source of impurity which is closely related to that last named. We know how the moisture given off from human beings condenses into drops on the wall of a crowded room. Something like this condensation is always going on in inhabited dwellings, on walls, ceiling, and furniture; furniture is, moreover, constantly touched by hands which may be unclean, but which, if they are clean, always bear the natural (and healthy) grease of the skin. We are familiar with the "close" smell and oppressiveness of the air in a heavily furnished room which has been shut up for some time without occupation; it is probably the traces of human life in the past now undergoing putrefactive or other chemical changes which give rise to unwholesome and offensive products. It has long been taught that air vitiated by breathing is especially poisonous because the watery vapour with which expired air is saturated bears from the lungs (and possibly from the alimentary canal) organic matter apt to putrefy. Later observations and experiments on this point give ground for believing that it is *not only from the breath itself* but from *want of cleanliness in the body or in the room inhabited*, that these odorous and harmful substances spring.

Lastly, we deal in many cases with the life of *unhealthy men*. Much sickness, especially infectious sickness, is of course gathered into the special dwellings which are arranged for its careful treatment. But in schools, in public meetings[1], in carelessly ordered homes, and in the crowded homes of the very poor, there must be sometimes conscious, sometimes unknowing, admixture of the breath and other waste matters of the **unhealthy** with those of the strong. Few things can be more dangerous than the *sputum* of a consumptive patient left to dry upon the floor and then rubbed to a light dust by passing feet, and there is probably hardly any infective matter which has had more widespread and disastrous action.

§ 13. Consideration of the actual **methods of ventilation** by which the difficulties named above are dealt with, belongs clearly to the practical side of domestic economy; there are however certain aims which must be before the practical worker even if they are not entirely capable of realization. In noticing these we may fitly speak at once of the gaseous impurities of air, and of dust, for as we have seen, even the free, country air is not dustless, while the dust of dwellings helps to form a serious problem in domestic life.

We may say truly, though with apparent contradiction, that the treatment of impurities of all sorts in the air should be *preventive* and *curative.*

As preventive treatment we may group the following :—

(*a*) *The fitting of interiors, and the choice of furniture.* A room abounding in cornices or mouldings with flat upper surfaces (especially in places which are difficult of access) is clearly fitted to gather dust. This is recognized so far that, in some hospitals, the flooring joins the walls at a curve

[1] In the pure air of a mountain sanatorium or in the arctic snows, no amount of exposure ever induces a "cold." On the other hand it is common knowledge that in a small unventilated room almost everyone is vanquished by the multitudinous infection from a person with a "bad cold."

from which dust can easily be cleaned, and the more frequent replacement of a right angle by a curve, or of flat surfaces by sloping or bevelled surfaces would be a distinct sanitary gain. The dangers of upholstered furniture are familiar; where the inhabitants of a dwelling are leisured and few in number careful treatment may practically abolish these dangers, but when great numbers of ill-cared-for human beings are gathered together there should be no furniture which cannot be subjected to severe and effectual cleansing.

(*b*) The choice of *means of lighting and heating* is of high importance where such choice can be made. It will be readily gathered from the foregoing pages that all illuminants, all fires, all stoves, are not alike, in detail, in their effect upon the air,—that they vary in heating action, in drying action, in their use of oxygen, and in the giving out of different injurious gases; it is clear that by the use or rejection of certain of these lighting and warming agents the fouling of the air may be hastened or checked.

(*c*) *The use of sunlight in rooms* can hardly be too much advocated as a check of putrefactive change. We have seen (§ 4 *c*) what a remarkably destructive effect the sunlight exerts on the great majority of bacteria, and it is probable that no room, bathed in sunlight, would ever show vigorous bacterial growth on its walls, on its furniture, or in its air. *Dove non va il sole, va il medico* (Where sunlight does not come, the doctor comes) is an old Italian proverb which recent researches only confirm, and no one who is intelligently concerned for domestic purity will shut out the sun.

(*d*) It is perhaps departing slightly from the point, to touch on the relation of sickness to these preventive measures: yet the necessity of isolating invalids who suffer from infectious disease and of the careful destruction of all their excreta can hardly be too often pressed home.

The lack of care in these matters may readily give disease-producing bacteria as an element of household dust; on the other hand, the risks of infection are greatly lessened if fresh air be freely admitted into the sick-room and the house of sickness. Open windows bring about constant movement and change of the air in the house, and thus, impurities are diluted and removed. And it is a matter of common experience that the fresh air is an active and valuable stimulant to the nerves of most invalids, and thus an important help to the body in its struggle with disease.

§ 14. By the neglect of these preventive measures however, or in spite of them, the fouling of air is an undeniable fact,—indeed the commonly accepted meaning of ventilation is that it is a process which removes, rather than prevents, impurity. And successful curative ventilation is such that certain ends are reached or approached. The chief of these ends may be stated as follows:

(*a*) The fresh air supplied is *mixed intimately* with the existing air of the room. We have pointed out (§ 9) that to drive great volumes of fresh air across one end of a room is not efficient ventilation, and unless free circulation or very thorough mixture in some form is assured, parts of the air of a room into which even a breeze is blowing may remain astonishingly foul.

(*b*) The fresh air is admitted *without the formation of a "cold draught."* It would of course be possible to bring about complete change of air by means of cold draughts properly arranged, but so many other disastrous results follow that such a scheme cannot be called successful. In the open air there is probably nothing which can be called a draught; in closed rooms, especially when the temperature is high, currents of cold air are especially felt by the human skin, and produce sudden discharge from eyes and nose closely resembling that of hay-fever, or the more lasting effects of cold or chill.

(*c*) The entrance of fresh air is accompanied by the *removal of the products of breathing and burning.* This is a great economy; it is the fouling rather than the exhaustion of air with which we have to do in breathing or in burning; if the impurities remain, a much larger volume of fresh air must be admitted to bring about proper dilution of them than if they are carried off wholly or in part. And this removal is of special importance when diseased persons are present,—as they may well be in schoolrooms or crowded halls.

§ 15. As in the case of preventive ventilation, so in the case of curative ventilation, the *dust of dwellings* must be reckoned with. All vigorous rubbing of dusty fittings and furniture adds new impurity to the air, and the gentle removal of dust by wiping can hardly be urged too strongly. Damp cloths, which hardly give the highest polish to furniture, are most valuable for this gentle removal, and in sweeping floors the value of damp particles, such as sawdust, tea-leaves, or (in America) finely torn paper, is generally recognized. These gather the dust mechanically, and so prevent it from rising into the air in clouds; and such patent preparations as florigen or the O-cedar mop polish have constituents which act in the same way. It would hardly be going too far to say that no furniture should be polished which is not first nearly dust-free. The aim of dusting of course is permanently to remove dust from the room where it is found; thus the frames of beds, and hollow heads to beds, bookcases, or wardrobes —if such be necessary—should be covered with some non-absorbent covering which may be removed at intervals and carried completely away with the dust which has settled upon it.

§ 16. In leaving this subject,—the relation to life of the air which is at once so important in purity and so easily made impure,—it is perhaps worth while to urge what great power (in the matter of personal health) lies in the hands of each individual. The more vigorous is the life,—that is the sum of all the chemical changes—in a living body, the more fitted is that body to withstand the ill effects of harmful surroundings. It has been said that there is a "margin of resistance to injury," and this is widest in health and is narrowed in the weakly. One great promoter of vigorous life is, of course, the vigorous action of the skin, and this is aided by careful cleansing and by frequent change of healthy clothing. But there is another activity—that of breathing—which is often grossly neglected. Many persons hardly ever take deep breaths from the chest; the possible lung capacity for each individual is hardly ever used to the full. This is a form of oxygen starvation, perhaps not directly suicidal, but enough to injure one of the main sources of life; there can be no doubt that the habit of taking deep breaths, especially in the fresh air, would give increased mechanical strength to the lungs and increased vigour to their delicate, lining cells. If, in addition to this, the habit of *breathing through the nose* become fixed, an additional safeguard is provided. The cold air is warmed and further moistened before it actually reaches the lungs, and, the complex nasal passages act as ground where dust particles, dead or living, are checked. And this checking is of the greatest importance, as mucin and the remnants of cells are constantly being sent to the exterior, and with them may be carried that foreign matter which, did it reach the actual substance of the lung, would irritate or poison.

CHAPTER V.

Water in relation to Life.

§ 17. We are here concerned with water considered in relation to life. And in this relationship we have to deal with it as a drink, as a means of bathing and cleansing the person, and as a means of cleansing clothes, household furniture, dwellings and the surroundings of man. As a *constituent of the air* we have already named it (§ 8), and as a *constituent of food* we shall deal with it in succeeding chapters. But it must not be forgotten that the presence of water in food has much to do with its use as a drink: if a rabbit be fed on lettuce or cabbage it need drink no water (in 100 parts by weight of lettuce, 96 are water), but water should be supplied with its dry food. In the same way we are conscious that the need for drinking arises much more strongly when we eat a sponge-cake than when we eat porridge with milk; in the one case water is a large constituent of the article of diet, in the other it is taken as an adjunct. Whether water be used much or little, however, its quality is of high importance; and though this is true especially of water used as a drink, it is true in a less degree of that used for cleansing purposes, although different characteristics are harmful or advantageous to the different uses.

§ 18. To say that the quality of water is of high importance is to say, by implication, that what is chemically one substance has important varieties. And this is true:

chemically pure water is never found in nature. It may be prepared by distillation, and, since the water of the air has arisen by evaporation, which is the first stage of distillation, we might perhaps expect it to be pure and constant in quality. But when this atmospheric water reaches the earth once more, as dew, or rain, it is pure no longer. We have seen (§ 6) that the air is a mixture of gases, and that immense numbers of fine particles, forming atmospheric dust, are suspended in it; now *water has very great solvent power*, and this solvent power is shown, both as it passes through the air, and, later, as it passes through the earth. It dissolves the atmospheric gases with certain other matters (varying with the region of the air concerned), and, further, it carries down in suspension some particles which are not dissolved, such as the carbon particles which may be seen in the rain-water collected in a smoky town. Thus rain, although probably the purest natural water (especially when it is gathered in the country, and at the end of a long wet period), has many and varied impurities; and dew[1], which must rank with the purer forms of rain, can hardly have more than a romantic use for drinking and for washing. The questions that are before us then are the following: *what is the nature of the impurities in water? what is their importance?* how far may they be disregarded in the use of water for what are commonly called domestic purposes?

A. *The characters of the impurities in natural waters.*

§ 19. In the first place, gases are present; we have said above that this is true even of rain-water, and we may add, further, that it is true of the waters of the sea, of springs, lakes and rivers, and wells. It is of course from oxygen dissolved in

[1] In the dew-ponds, which are of such interest and have been investigated of late years, we find large quantities of dew-water, but these ponds are too rare to be dwelt upon here.

water that the plants and animals which are "water breathers" draw the oxygen necessary for their healthy life. All water exposed to the air dissolves not only oxygen, but those gases which are normally present in the atmosphere, and others which are present frequently or rarely. Nitrogen (with argon) is the least soluble of the ordinary constituents of air; oxygen is twice, and carbonic acid about seventy times as soluble. Consequently, when water takes up gases from the air the proportions in which they exist are changed, and "dissolved air" has not the composition of the air of the atmosphere. We have seen in § 6 that 100 volumes of atmospheric air contain

"Nitrogen,"	78·35 volumes,
Oxygen,	20·77 volumes,
Carbonic acid,	·03 volumes.

If air of this composition be in contact with 100 volumes of water at ordinary temperature and pressure, the water will dissolve

"Nitrogen,"	1·4 volumes,
Oxygen,	·7 volumes,
Carbonic acid,	0·3 volumes[1],

so that in the *atmospheric air* there is 1 part of carbonic acid to 700 of oxygen and 2600 of "nitrogen," while the "*dissolved air*" in the water consists of 1 part of carbonic acid to little over 20 of oxygen and 40 of "nitrogen."

[1] These figures are given for 15° C. Except in the case of hydrogen, the amount of gas absorbed increases as the temperature becomes lower, and at freezing point 100 volumes of water will absorb from the air at atmospheric pressure

"Nitrogen,"	1·9 volumes,
Oxygen,	1·0 volumes,
Carbonic acid,	·05 volumes,

making a total of nearly 3 volumes. The amount of gases commonly dissolved in 100 volumes of rain-water is stated to be 2½ volumes.

At higher temperatures, less of these gases is taken up; and by boiling the water they are completely expelled.

Sulphurous acid is nearly 3000 times as soluble as nitrogen, hydrochloric acid more than 30,000 times, and ammonia more than 50,000 times as soluble. Thus, the air is purified from these gases by the rain, which, in some manufacturing districts, may become even poisonous to vegetation because of what it has dissolved. These highly soluble gases are not driven off from water by boiling.

When water is exposed to a mixture of gases (such as air) at a given pressure, the quantity of any one gas taken up by the water is proportional to the quantity of that gas in contact with the surface of the water; or, more exactly, with a square inch of surface. We have seen above that, when the atmosphere has its average pressure and composition, 100 volumes of water will dissolve from the air ·03 volumes of carbonic acid; if the air contain twice its usual percentage of carbonic acid, the water will dissolve ·06 volumes, and if pure carbonic acid replace the air (at the same pressure), the water will dissolve $\frac{10,000}{3}$ times as much, that is, it will take up its own bulk of carbonic acid[1]. Now the quantity of gas in contact with the water can be still further increased by increasing its pressure; when the pressure of air (or any other gas) is doubled, every cubic foot contains twice as much air (or gas) as it did before. Hence, water exposed to carbonic acid at a *pressure of 2 atmospheres* will take up twice its own bulk of the gas, or—to put the same fact in other words—nearly 7000 times the amount that water can take up from ordinary atmospheric air. This property is used by the manufacturers of aerated waters: they pump carbonic acid gas at several atmospheres' pressure into iron tubes containing water, and the water, taking up many times its own volume of the gas, is bottled in this condition. When the bottles

[1] We have seen (§ 6) that in 10,000 parts of fresh air there are 3 parts of carbonic acid.

are opened the gas escapes, at first violently, then more gently, until the quantity of gas contained in the water is equivalent to that which it would take up from the air around it. A similar "loading" or "charging" with gas characterizes some natural waters, such as those of *Seltzer* or of *Spa*. In their underground wanderings they encounter carbonic acid gas (formed by some of the chemical actions which are always going on in the earth's interior), and at high pressures. They absorb it, and so become converted into the effervescing waters that we know.

In the second place, **substances in solution** (other than gases) are present. These are substances dissolved by water as it passes through the air (rain, dew, fog), or as, later, it passes through the earth (streams, lakes, rivers, wells, and the sea), and they may be conveniently distinguished as **inorganic** and **organic** (compare above, § 11).

Of the **inorganic substances** in solution perhaps the most important are the *salts of calcium*, that is, *lime*. These are found in all water which has fallen upon or trickled through limestone rocks (calcium carbonate) or rocks in which sulphate of lime is present, and are found all the more abundantly because the water contains carbonic acid: in pure water, they are but slightly soluble, but when carbonic acid is present, they dissolve with ease. Calcareous waters are termed *hard waters*, a term which has come to denote their behaviour with *soaps*. Soaps, when they are mixed with pure water, form a lather,—the peculiar filmy froth with which everyone is familiar. But soaps are alkaline salts of fatty acids, and they form insoluble salts by chemical action with the salts of hard waters: curdy precipitates fall—precipitates of these insoluble salts,—and not until the chemical action which they indicate is at an end, can the "lather" be formed. Thus some soap is wasted, so far as the purposes for which soap is used are concerned. It is clear that rain waters can never be hard; much of the spring water of England and some well water is very hard, and river water is, as a rule, intermediate, holding less chalky matter than many springs.

We have spoken of these calcareous salts as the most important soluble, inorganic constituent of waters, both because of their widespread distribution, and because, as we shall see, they are especially important from a domestic point of view. Other salts are richly present in some waters, mainly in the water of springs: among these are *sulphate of magnesia*, found in the saline springs of *Epsom*; *sodium carbonate* in the waters of *Vichy* and *Malvern*; *carbonate of iron* in the chalybeate wells of *Tunbridge*. The boiling springs of *Iceland* which are familiar as *geysers* have a good deal of *silica* dissolved in their waters,—that is, of the substance of which rock crystal and flint are composed,—and the brine waters of *Droitwich* are rich in *sodium chloride*, *bromide*, and *iodide*. All these however are medicinal and commercial, rather than domestic. But there are yet two inorganic salts which must be named, because both are due to the actions of man. The first is **sodium chloride**, occurring not as it does in the brine springs just named, nor in the waters of the sea, but in waters whose derivation shows that it can have had no legitimate origin, but is rather an indication of impurity springing from the refuse of man. The second is a **salt of lead**, generally the oxide combined with water (that is, the hydrate) which is formed by the joint action upon lead, of water and air. Rain-water standing on leaden roofs, or in leaden gutters, comes to contain this impurity, so also does any "soft" water which stands in leaden pipes; water containing sulphates and carbonates does not act upon and dissolve lead in this way, so that the hardest waters are usually lead-free.

But **organic substances** are also found in solution in water. From this group, since we are dealing with soluble substances, we must exclude all living creatures, for the tiny organisms which inhabit water are, of course, not dissolved in it. But we include substances which *they produce as part of their life work*, either turned out from themselves (all soluble excreted matter), or produced in their surroundings. We have said above (§ 1) that all putrefaction is the result of the work of bacteria, and one feature of this work is the production of substances which can be carried off in solution by water which comes in contact with decaying matter. If we consider for a moment the little runnels which, draining off a patch of peaty soil, form some small stream, or the water draining away from a farmyard, we can realize how heavily charged water may be with the products of decay. Even when these small beginnings run into rivers, and become mixed with rain water and spring water, soluble organic matters may still be present, although they must be greatly diluted and have sometimes undergone chemical change. In rain, in deep wells and in springs, soluble organic impurities are not common; it is in the water of lakes, of rivers and of surface wells that they are often found. And this is what we might expect; rain has not yet touched the decay of the earth's surface; the water of deep wells and springs has undergone changes in its slow journeyings through the substance of the earth; but lakes[1], rivers and surface wells are more immediately connected with the excreta or the decaying remains of animals and plants.

There can be no doubt that the soluble organic substances of which we are now speaking must be very various in nature. All living creatures can be killed and then broken up into substances which are very much the same for each creature, if the breaking up is carried far enough; such are *free nitrogen*, *ammonia*, *free hydrogen*, *sulphuretted hydrogen*, *carbonic acid*. But what are called intermediate products, or by-products, are different according to the nature of the

[1] Lake water is very variable in composition, and sometimes has very little matter inorganic or organic in solution.

organism from which they are formed. Speaking of them as impurities in water, however, we usually group them together as "organic substances," partly perhaps because their special nature is not always determined (in "domestic" water their quantitative amount is small), partly because, as we shall see, it is important not to neglect organic matter whatever may be its nature.

Closely connected with the soluble organic impurities of water are certain bodies, themselves inorganic; these are **nitrates** and the less highly oxidized **nitrites.** They form a most noteworthy link in the chain of chemical processes by which plants and animals are bound together, for they are the bodies which form the main nitrogenous food of green plants living on the earth. At the same time their source is found in all decaying animal and vegetable matter, in all the nitrogenous excreta (or waste matter) of animals. The soil, the mud of rivers and lakes, every sewer and every refuse heap, all these are rich in organic nitrogen, i.e. organic nitrogen-holding compounds. And among these compounds, when the conditions of temperature and moisture are suitable, bacteria are working incessantly; certain forms break up the proteins; other forms break up the less complicated nitrogenous matter of the excreta (urea or uric acid); others finally seize on the broken-up matter (ammonia) and build it into the nitrates of which we are speaking. So it comes to pass that when nitrates or nitrites are found in water they are taken as indicating that organic matter is or has recently been present; it is inferred from their occurrence that the water holding them has come in contact with the processes of putrefaction, or of that special form of it, ammoniacal fermentation, and therefore certainly with bacteria, and with substances suitable for the propagation of the bacteria of disease.

In the third place, **substances** are found, **suspended in water.** These are most varied in nature, for we can say briefly that any particles which go to make up the dust of the air may also be suspended (if they are insoluble) in water exposed to the air. As dust "settles" it settles upon water, as upon land, and though most water is constantly moving—trickling or running from higher to lower levels—nevertheless it can only escape from dust when it moves within the earth—for in the air, dust is everywhere, and everywhere is falling. In § 11 we have considered the nature of dust; we have seen that inorganic and organic particles may be present in it and the classification made there may be applied to the particles in water. The sooty rain-water of towns is rich in **suspended carbon,** and it is mainly *inorganic matter* in very fine division which gives a **glacier stream** its well-known milky colour. In the mud of any muddy water, too, there is abundance of suspended inorganic matter, and a moment's thought reminds us of the **sand** and **gravel** washed down from high lands in many rapid mountain streams. But *organic particles* are often present too, and, as we shall see, have an importance all their own. Among them we must distinguish all *débris* of plants and animals which are insoluble in water, on the one hand, and, on the other, the tiny organisms which inhabit water and are invisible to the naked eye. Such are certain members of the Protozoa (as that group is named which contains the simplest animals known), the *amoeba*, the *flagellate infusoria*, which are sometimes made the subjects of popular scientific shows; such too are the **Bacteria**, and it is with them that we are concerned here. We have seen in an earlier chapter that the presence of bacteria or their spores is almost universal. In the air, on the surface of the earth, in all natural waters, even in glacier-ice they are found, of various species, and of varying habit. But it is when the conditions best suited to their life are realized, that they are vigorous, and grow and increase. Thus, in distilled water they may live, and as many as 35 specimens have been found in a litre of rain-water, but in these fluids there is no abundant food; again, we can hardly suppose that the bacteria in glacier-ice are in full activity for the time being. Water is indeed all important for their well-being, but it must be water bearing some food-materials. These are found both in soluble organic matter and in dead organic matter in suspension; the waters of springs, lakes and rivers contain bacteria in numbers which depend largely upon the amount of organic matter present, and water which has received the outpourings of sewers becomes a nutrient fluid in which bacteria thrive. It has been estimated that 1 cubic centimetre of the water of the river Spree taken above Berlin contains about 6000 bacteria, while in 1 cubic centimetre of water taken below the city 243,000 are present. The total number of these minute creatures at any moment, in any water, must depend on very complex conditions; even the water of rain is unlike, according as it has fallen through dusty air or through air washed by long previous rain; and the waters of deep wells have lost by filtration through the earth varying numbers of the small organisms which they gathered on the earth's surface, while the completeness of the filtration must depend on the nature of the layers, or *strata*, which have acted as a filter. Again, a shallow river flowing through sunny land has its bacteria exposed effectively to the action of sunshine, and we have learned that sunshine is a valuable germicide. It can naturally act much less in the turbid waters of some deep river flowing between high banks or beneath clouds and smoke. And in addition to these factors we have what is of great importance, the strife of different kinds of bacteria and between bacteria and protozoa. When many different kinds are present in any given water it is practically certain that a struggle takes place among them; some are weakened or killed; others are able to get the upper hand, and flourish, making use of such food matters as the water supplies.

In Chapter II. we have distinguished between pathogenic and non-pathogenic bacteria,—those respectively which do and do not produce disease in human beings. Many of the organisms found in the water of springs and rivers belong to the latter group; they are not disease-producing; but disease-producing forms do occur, for example, when water has been in contact with human refuse. It will be readily understood that such refuse is often disease-bearing, and the soil of the earth, always rich in bacteria, almost always contains some pathogenic forms when it is taken from cultivated spots, such as gardens, in which especially, the dangerous tetanus germ is often found.

We see then that *natural waters are never pure.* Their impurities are :

(*a*) **Gases** of various kinds; the gases of air, although not in the proportion in which they exist in the atmosphere; sometimes nitric acid; sometimes ammonia.

(*b*) **Inorganic substances in solution.** The salts of calcium (hard waters) have the widest distribution; salts of magnesium, sodium and iron are also found. Nitrates and nitrites springing from the breaking down and mineralization of organic nitrogenous matter occur, and salts of lead follow the action of soft water on leaden pipes, gutters, and roofs.

(*c*) **Organic substances in solution,** mainly the products of the activity of plant life and animal life, or substances immediately arising from the breaking down of these.

(*d*) **Inorganic substances** not dissolved but in **suspended particles**; mainly carbon, or the solid substance of the earth, and therefore very varied in nature.

(*e*) **Organic substances** in suspension; living or dead **microscopic organisms**; Protozoa or Bacteria or very simple fungi.

B. *The importance of the impurities in natural waters.*

§ 20. We have now to ask, What is the importance of these foreign constituents? How far may they be disregarded in what is commonly called the use of water for domestic purposes?

(*a*) **Gases.** Ammonia and nitric acid are poisonous except in exceedingly small quantities, but the gases of ordinary atmospheric air are without effect in drinking water except upon the palate (that is, probably, upon certain nerves), and their presence does not touch the value of water for cleansing purposes. The action on the palate is clear with most persons; water from which the atmospheric gases have been expelled by boiling is usually distasteful, and the "stimulus" of abundant carbonic acid (in sparkling waters) give rise to sensations that are generally pleasurable.

(*b*) **Inorganic substances in solution.** These have important action in washing waters and in drinking waters.

In *washing waters* it is salts of lime which are especially disadvantageous. We have said that it is they which make water "hard," and that the term "hard" expresses the fact that the water which it describes is a *soap destroyer*. But the use of soap, in cleansing either clothes or utensils, is to break up the greasy matter which helps to form "dirt" so that by rubbing and other suitable treatment it may be removed; if the soap is used to make chemical combination with the salts of hard waters, i.e. is "destroyed," it is **wasted** from a commercial point of view. To a less degree, the hardness is a drawback when water is used for cleansing the person. Probably, for cleansing all but the very unclean, water and rubbing are more important than soap; they are enough to stimulate or excite the skin to proper activity, and to remove the products of its action. But, for susceptible or delicate skins, water charged with lime is harmful, not as a soap destroyer but in another way. Unless used carefully, it may irritate the skin surface generally, or it may aid in blocking the exit ducts of some of the minute skin glands, so that small "cysts" filled with hardened substance, or with matter, arise. As a *drink*, hard water offers a protection when leaden pipes are employed for carriage; the series of chemical changes by which the pipes are eaten away and a compound of lead is dissolved in water, does not take place, at least where carbonates are present in the water. Drunk in small quantities the salts of hard water have not been shown to be harmful, except in cases of special delicacy of the stomach or intestines, but it is a doubtful benefit to drink large quantities of such waters. Thus a patient, carrying out the Salisbury cure, in a limestone district, would probably be ordered to use distilled water for his large daily consumption, rather than the natural chalky waters of limestone earth.

Of the other soluble inorganic impurities of natural waters, we may say that their importance lies in their presence in drinking-waters, rather than in cleansing-waters. We might, without serious harm, wash a floor with a solution of Epsom salts or with Vichy water; we might wash body-linen in water containing some salts of lead; but these waters used for drinking have marked effect. The *saline waters* are, for the most part, aperient[1]. They induce passage of unusual quantity of fluid from the capillaries of the intestinal walls into the intestine.

[1] See below, § 27.

Thus the waste matters moving down the intestine become more fluid than their wont; their passage is more rapid, their expulsion more easy. It is clear that such an action may be of great service occasionally, and when used intelligently, but that it would upset the healthy action of the body if the waters provoking it were drunk indiscriminatingly. Waters containing *nitrates* and *nitrites* are of themselves without special effect in domestic use, but they are often avoided as undrinkable, lest the inorganic salts should indicate the presence of organic matter, still unchanged, or only partly changed by chemical action and likely to be accompanied by disease germs (cp. above). *Salts of lead* are a most serious impurity in drinking-water. Even in very small quantities they are poisonous, even fatally poisonous; indeed, among the harmful inorganic impurities, they must be placed first.

(*c*) **Organic substances in solution.** The effect of these depends on their nature; some organic substances may be dissolved in drinking-water without acting for ill, but *many soluble products of bacterial action are most harmful.* These are often grouped together and spoken of as **toxines**; for, though physiological proof of their existence and power is well established, they have not in many cases been isolated as separate chemical bodies. Thus, the bacteria of *tetanus* (lockjaw) produce a toxine which can set up lockjaw if introduced into a healthy animal; and the bacteria of *diphtheria* gives rise to a toxine which can set up fatal diphtheria. These actions are performed when, by careful experiment, the toxines are freed from the bacteria of tetanus or of diphtheria respectively, but it will be readily understood that in cases of water-pollution the *disease-producing bacteria and their poisonous products are present together.* We may say, indeed, that organic matter in solution in drinking-water is **always suspicious**: it may have a special harmful action of its own; it does indicate the presence of bacteria with all their possibilities for evil. In cleansing-waters the importance of soluble matters of this nature is less; but it would be inadvisable to bathe or to wash such utensils, as were to be used for the purposes of eating and drinking, in water containing much soluble organic matter.

(*d*) **Inorganic substances in suspension.** We may say, briefly, that these are undesirable in drinking-waters, and often injurious in waters used for cleansing. Thus, the rain-water of large towns cannot generally be used for washing clothes because of its suspended carbon, and this, although its softness would make it an excellent medium for washing. Glacier water, or the water drawn from some deep wells, and containing sand, would not be chosen for purposes of washing or bathing; but it may be argued that the scrubbing action of the fine particles is cleansing and stimulating, and, certainly, a Swiss laundress would not hesitate to make use of a glacier stream. In considering the presence of similar particles in drinking-water we must remember that the alimentary canal (mouth, stomach, intestines, etc.) is really *outside* the body, and, as long as a continuous sheet of cells clothes it, foreign matter *within the canal* cannot do much harm. If such matter be abundant enough or penetrating enough to injure the *cells of the wall*, then grave consequences may follow. We named the stonemason's lung and the knife-grinder's lung as comparable cases of injury induced by breathing impurities; but the lining-cells of the lung are more delicate than those of the bowel, and it would indeed be rare to find, in drinking-water, suspended matter as dense and irritating as that loading the air in the carrying out of certain trades.

(*e*) **Organic substances in suspension.** It will be gathered from what has been said above, that these may be *by far the most dangerous impurities in water.* As regards water used for bathing or cleansing, they are only important if such water can be the means of carrying them to some susceptible part of a living animal. Natives in India have been known to wash milk-cans with unboiled water rich in the bacterium which is the immediate cause of cholera, and to spread a jelly-bag to "air" upon sand or earth abounding in the same pathogenic forms. Fortunately, in England, the conditions which make such action fatal do not often exist; fortunately, of the many kinds of bacteria present in almost all natural waters, the majority are harmless. But, because the harmful or pathogenic forms are so powerful, everything that may indicate or allow their presence should be taken as a danger signal. Chlorides and nitrites are (as we have said) innocent in themselves: but if chlorides indicate pollution with sewage from dwellings, if nitrites show that organic matter has but lately been putrefied in the water, then, remembering the foulness and mixed character of sewage, and the widespread existence of disease among men, we must look on these innocent substances with suspicion.

Indeed, looking back on the list of impurities given, we may say briefly, that if asked to name those which are important before all the rest, we should say:

For **laundry-work**, those constituents which are **soap destroyers.**

For **drinking-water, bacteria.**

C. *The treatment of the impurities in natural waters.*

§ 21. It is not given to most housewives to choose the water which shall be used for domestic purposes and then to purify it. Any water may be purified by distillation, but distillation, to be efficient, needs more than the appliances of an ordinary household. And the choice of water is usually narrow, especially to the dwellers in towns; it is not the housekeeper who organizes the water supply and plans the sanitary appliances. But, these facts notwithstanding, a grave responsibility rests on each housekeeper; she can minimize if she cannot abolish the risks of water-drinking; she can often make water harmless, if she cannot make it pure. Let us remember whence we draw our water; primarily, of course, from rain, but immediately from springs and surface wells, and such deep borings as are needed for Artesian wells; and from rivers and lakes. There is hardly any modern house in which water is not "laid on," running to taps through leaden pipes. All water, then, has fallen from the heavens, and much of it, before use, has had considerable contact with the earth. We will consider briefly which of the impurities named above is specially characteristic of each source.

Rain-water contains gases, bacteria, often suspended carbon particles, sometimes lead, and, under special conditions, nitric acid, sulphurous acid, ammonia.

Surface-well water contains gases, often bacteria and their products, sometimes foulness from the drainage of cesspools and other impurities of cultivation.

Deep-well water contains but few bacteria and their immediate products. The earth has acted as a filter and, during the slow filtration, chemical action has gone on, breaking up the "toxines" or other matters formed by bacteria. But this slow passage through the earth has often caused much inorganic matter to go into solution; such water then, may contain many mineral compounds.

Spring-water has much in common with the water of deep wells; both have had a long passage through the substance of the earth, both, it may be added, contain a relatively great amount of carbonic acid; the "sparkle" of some spring-water is due to the presence of this gas. And in spring-water, as in deep-well water, bacteria and their products are scanty.

River-water and **lake-water** is mixed in origin and varied in character. Bacteria are always present, and, sometimes, disease-producing bacteria; their numbers depend on the course of the water, its depth, its exposure to sunlight, the conflict of various forms, and on conditions so complex that it is difficult to make a statement which shall be true for all lakes and all rivers. But we may say, generally, that their waters are rich in organic matter, and poor in inorganic substances in solution, for on the one hand they have commonly had sewage contamination, on the other hand the "hard" waters of the springs which help to feed them are diluted with rain-water, and probably lose their calcium salts to some of the minute animals living in lakes and rivers.

How should a housekeeper deal with water which may reach her from one or from more than one of these sources?

(*a*) There is no doubt that boiling is the most effectual safeguard, at least for drinking-water. By boiling sufficiently all disease-producing bacteria are killed, or, if spores are present, their vitality—in other words their *virulence*—is lessened. Toxines may possibly be broken up by boiling[1], for they are unstable, but, in such amount as they might occur, they would be comparatively harmless if unsupported by the active bacteria. Boiling also drives off carbonic acid, and thus some of the carbonate of lime which was dissolved by its aid falls as a white sediment or forms a white scum. But it must be remembered that *this precipitated salt of lime should be removed* either by deposit or by straining, because if taken with the boiled water we cannot say that the softening is effectual.

[1] I do not think this has been demonstrated. It must be remembered that, e.g., the diphtheria toxine which has been injected with fatal effect was prepared from a *pure culture* of the diphtheria bacterium; now toxines which occur in drinking-waters must be very largely diluted,—that is to say, that the danger from them is negligible as compared with the danger from living bacteria.

(*b*) **Filtration** is valuable if properly carried out, but very often it is *not properly carried out.* A filter which is at all neglected becomes mainly a **nursery for bacteria**; air, water, organic matter, the bacteria themselves, are all present, and if the filter be kept in some rather warm corner, the temperature is highly favourable too. Commercial filtration and chemical filtration are efficient; domestic filtration may be efficient, but is often a mockery of purification.

(*c*) Neither boiling nor filtration will free a water from the **salts of lead.** Here a housekeeper must consider the nature of the water she uses. If it be a hard water there is little risk of lead pollution; if it be a soft water it should always be taken from the pipes for use after **considerable flow.** It is desirable that drinking water should never stay in a cistern; anyone so placed that the use of a cistern is inevitable, should insure that the drinking water is not stagnant, either in the cistern, or in pipes.

(*d*) Finally, there are two precautions which are less obvious than the foregoing.

It has been found that when river-water is allowed to stand, the bacteria in it increase in number considerably. It is advisable then, that *drinking water should be freshly drawn.*

And it has been found further, that foreign bacteria introduced into sterilized water live better than if introduced into water from the same source, but unsterilized. Clearly then, *boiled water should not be allowed to stand uncovered if it is to be drunk.* It would, in this sterilized condition, prove a medium favourable to the life of contaminating bacteria. In fact, if standing be inevitable, as in some cases of scant water supply, it is well to boil again shortly before use.

It may be urged that the procedure recommended here is a "counsel of perfection"; this may be so, but it is at least procedure which would serve well in times of epidemic disease, or in other specially anxious conditions; it is procedure from which each housewife can shape her own action, having regard to her individual needs. And it may be urged, further, that we have dwelt unduly on the treatment of drinking-water, and neglected the treatment of water for the laundry. It must be remembered however that specialization of work grows as the years pass. The number of households who give "washing" to professional laundries constantly increases; the problem of softening hard waters (by means other than boiling, with precautions) is transferred. But, though many persons do not wash clothes, everyone drinks. And it will be admitted that the destruction of soap, even the destruction of clothes, and the expenditure of labour, are all evils less crying than is the spread of disease which may weaken or destroy man.

CHAPTER VI.

Foodstuffs.

§ 22. We learn, from the teachings of Physiology, that all the living creatures in the world are continually undergoing loss of their substance; the living matter of which they are made up is always breaking down into less complex bodies which are no longer living. The rate at which this takes place varies in the case of different creatures; plants, for example, lose much less substance than do animals. But such an animal as a man constantly suffers loss of nitrogen-holding bodies (of which the chief is urea) by the kidneys, loss of carbonic acid by the lungs, loss of salts of various complexity by the skin, and in each case there is also loss of water. The substances which are taken into the body to replace this loss are in the first place *the oxygen of the air*, and in the second place the *heterogeneous bodies which we call* **Food.** It is our business here to ask briefly how food acts, what part of the various articles of diet which we eat and drink daily are truly foodstuffs, and how, for good or ill, we affect various foods by one treatment of them or another before use.

The Nature of Foodstuffs.

§ 23. We cannot analyse the living substance of which a plant or an animal is made, without destroying it; even the most skilful chemist is unskilled in dealing with the delicate fabric of protoplasm[1]. Now we know that in the absence of protoplasm we do not meet with the voluntary movement, and the sensitiveness, which belong to the popular idea of life; we know that behind these characteristics, and of the first importance to a physiologist, though the world hardly realizes them, are *complex chemical processes* equally inseparable from protoplasm, equally incapable of imitation in the laboratory, and we know that when by analysis, living matter is killed (broken down) and then investigated, certain bodies are always present. This knowledge, although in one sense limited, is of the highest value, for it is our guide in examining the nature, the importance, and the fate of Foods.

The bodies which are always found when "living substance" is thus examined after death are:

(*a*) Proteins[2], which, as we know, are *nitrogen-holding*, and which contain besides the chemical elements, oxygen, hydrogen, carbon (this very abundantly), and sulphur (in varying, but small amount), often phosphorus, and sometimes iron.

(*b*) Salts. These are various in nature; common salt or chloride of sodium is a familiar example and very generally present, but it must not be forgotten that carbonates and phosphates often occur.

(*c*) Water. This is always present, forming about three-quarters of the total weight.

In the great majority of animals and plants, and in man, we find:

(*d*) Carbohydrates, holding the elements carbon, hydrogen, and oxygen.

[1] This term is used as synonymous with "*substance which lives.*"

[2] After evaporating the water from a protein the residue contains (roughly) about $\frac{1}{2}$ carbon, $\frac{1}{4}$ oxygen, $\frac{1}{6}$ nitrogen, and $\frac{1}{15}$ hydrogen by weight.

(*e*) Fats; these also hold the elements carbon, hydrogen, oxygen, but in proportions and arrangement different from those which obtain in the carbohydrates.

Of these bodies the carbohydrates, fats and proteins (notably the proteins), are highly complex in composition; they are represented in the daily waste of a man by the simpler substances named above,—urea and other nitrogenous bodies in the urine, and carbonic acid in the breath. And, as we have seen, there is daily loss of water and of salts. If food is to repair this waste it must consist of the complex bodies thus broken down by the chemical changes of daily life, or of substance which can be built into these bodies. Now the building-up power or constructive power of living beings varies greatly[1]; a green plant yields proteins, fats, and carbohydrates upon analysis, but does not feed upon them: in the sunlight it builds them up indirectly or directly from simpler substances. But a man cannot thus build up, and the food which is supplied to him day by day must contain the more complex bodies. The last stage of construction is, however, performed by man and all living things; protoplasm (that is, living substance) given as food, is killed in the consumption; and thus converted into dead proteins with admixture of other bodies; the annexation of dead substance to make living substance is the work of living substance and of that alone. But, apart from this final step, the constructive power of man is, as we have said, slight, from a chemical point of view, and we find that he is most efficiently nourished when *proteins*, *fats*, *carbohydrates*, *salts* and *water*, form constituents of his daily food.

The **Proteins** must not be grouped together indiscriminately. There are, it is true, certain points of behaviour (or

[1] See above, § 1.

reactions) in which all proteins are alike, but there are others which divide them into groups,—not without interest to the cook or nurse. Thus, many proteins dissolve in *water* (native albumins, proteoses, peptones); others will not dissolve unless some *neutral salt* be present (globulins) or unless the solution be *acid* (acid albumin) or *alkaline* (alkali albumin). Again, many proteins are changed by the action of *heat* so as to become more insoluble,—practically more indigestible,—and among these are albumins and globulins; others can be heated *without losing digestibility*,—this is true of acid and alkali albumin *in solution*, of peptones, and of proteoses. Lastly, some proteins are especially complex; this is true of a group, the members of which are rich in phosphorus (*phospho-proteins*) and of yet another group (*conjugated proteins*) in which the protein constituent is always joined to some substance which is not a protein. Examples of conjugated proteins are found in many salivary glands, in the red colouring matter of the blood and in sweetbreads: phospho-proteins occur in yolk of egg (*vitellin*) and in milk (*caseinogen*)—both of the first importance as food. We will speak presently of the different articles of diet which are rich in one or more or many proteins; this brief statement will serve to show that different protein-holding foods need different treatment if their full nutritive value is to be realized[1].

The **Carbohydrates** are familiar as starch, dextrin, and the various sugars. To these may possibly be added cellulose; it is a carbohydrate, but, for man at least, a doubtful food. If, including it, we arrange the members of this group in increasing order of solubility, the series runs thus; cellulose, starch, the dextrins, the sugars. For *solubility* we may without great inaccuracy read *digestibility*; thus, cellulose is acted upon by none of the digestive fluids of the human alimentary canal; raw starch is almost equally refractory, and boiled

[1] The substance *gelatine* which is allied to proteins will be treated of later. See below, § 28.

starch, incapable of absorption as starch, is changed to sugar by action of the saliva and pancreatic juice. Dextrin is to be regarded as on the way to sugar, and the sugars themselves are in some cases fit for absorption without digestive change.

We notice that among the carbohydrates (as in the case of the proteins) for absorption from the alimentary canal, and probably, later, for transport through the body, relatively insoluble bodies are made soluble by the action of the digestive organs. In various regions of animals and plants we meet with members of these groups which may be called insoluble,—the abundant starch of plants, the glycogen of the human liver, many of the proteins of almost all cells. But these bodies are not taken in or passed on as such, but at times of transfer have been changed to allied bodies of high solubility. This is seen clearly when we recall the physiology of digestion. Of the proteins named above the *proteoses* and *peptones* are the most soluble, and the metaproteins (this word includes acid albumin and alkali albumin) are more soluble than the native proteins of food. Now we know that in gastric and pancreatic digestion, metaproteins are formed (possibly by-the-way) and proteoses and peptones are formed abundantly. And experiment teaches that digestive action in the intestine brings about a more profound change, so that the nitrogenous substances absorbed by the intestinal cells though arising from proteins are simpler than they. And it is clear that *dextrin* and the *sugars*—mainly the latter—form the goal of digestive change on starch.

The **Fats** of food are either (*a*) present in the tissues in which they have been laid down in life and thus enclosed in the cells of these tissues, or (*b*) they are taken out or *extracted*, running together into irregular masses of large size, or (*c*) more rarely kept apart as small, separate globules. In suet, to a certain extent in cooked meat, in most nuts (eaten raw), and in the diseased *pâté de foie gras*, the fat is in the first condition; in dripping, butter, the oils, it is extracted without subsequent mechanical splitting up: and milk is the most familiar example of natural fine division, that is, of an *emulsion.* The chemical form in which fat is usually eaten in Europe is that of **neutral fats,** members of a series of bodies known to chemists as esters. But under certain conditions (and as we know during pancreatic digestion) these change, splitting up into the substance *glycerine* and free *fatty acids.* As any acid, meeting with a base, unites with it to form a salt—and that this is true we know from the most elementary study of chemistry—so the fatty acids combine with bases when these occur suitably. But in this case the resulting salt has a special name,—it is called a *soap*, and it is soluble (e.g. sodium) or insoluble (e.g. lead) according to the nature of the base which has helped to form it. Thus we may, and in the intestine we do, deal with *neutral fats*, with *fatty acids*, and with *soaps.* And in the small intestine there is also a complex of digestive fluids, the secretion of the intestinal walls, the bile, and the secretion of the pancreas. In these digestive fluids the fatty acids and soaps dissolve, and, thus dissolved, they are taken up by the cells lining the small intestine. This is a striking example of digestive action leading up to absorption, by chemical change.

The *variation in melting point* which characterizes different fats is among their most striking physical features. A piece of lard swallowed by a frog may be found, later, in the intestine—partially digested indeed, but with a residue of unchanged consistency. The same substance soon becomes fluid in the stomach of the warm-blooded animal man, whereas we may gather that the wax of a bee's honeycomb passes unmelted through the human intestine, since it is solid up to a temperature of 63° C. It is, on the whole, characteristic of vegetable fats that they have lower melting points than the fats obtained from animals, and this has perhaps been associated with the use of the term *oil* in speaking of them; but a series arranged with regard to melting points, shows a certain admixture of the products of animals and plants, for animal fats differ widely among themselves. The fat of mutton is hard,—but it is fluid during the life of the sheep, and practically all fats, or mixtures of them, which are important constituents of the food of man are fluid at the temperature of the human stomach.

Not only are the fats of food melted during digestion, but they are also *emulsified.* Sometimes the natural emulsion, milk, is part of food, sometimes artificial emulsions are eaten. Among them are such sauces as *mayonnaise*, *Hollandaise*, and such prepared nutrients as *Cremor hordeatus* or some forms of *cod-liver oil.* But, in the food of the healthy, the fat (butter, cheese, fat of meat, nuts) is relatively massive, and it is the work of the pancreatic juice (in the presence of small amounts of fatty acids) to break up these massive irregular drops into minute particles, forming a sort of cream. In past years it was believed that this creamy mass of (chiefly) neutral fats was taken up as such by the cells of the intestinal walls; we have said above that chemical change before absorption has been established,—change to fatty acids and further, to soaps. But even in this event the emulsification is of great importance, for *all chemical change is carried out more readily, more thoroughly, if the body changed is in a state of minute division.*

Saline Matters or **Salts** form part of every natural diet, and an animal, deprived of them by careful artificial treatment, dies. The term *salts* is popularly associated with mineral compounds; and indeed chloride of sodium and phosphates of lime and of sodium play especially important parts in the chemistry of the living body. Such inorganic salts are sometimes eaten uncombined with articles of food, and merely accompanying them:—we know that the great majority of dishes are served with *sodium chloride* as an ingredient or an addition. But the action of the saline matter is more effective when it forms an integral part of food. Instances of this union will be given later (§ 47), but we may here recall the fact that milk and yolk of egg are rich in *lime*—a substance all-important for the healthy growth of young animals. On the other hand peas, white of egg, and potatoes are poor in lime, but they hold much *potash*,—or at any rate combined potassium.

But, besides these inorganic salts, organic salts and organic compounds having some mineral constituent must be reckoned with. Experiment and observation have shown that they are needful, although the exact share taken by them in the chemical changes of life is yet undiscovered. Thus, *iron* is indispensable to proper nourishment, and it is most readily absorbed and assimilated in such complex combination as we find in beef, in yolk of egg, and in some vegetables. And many fresh fruits are rich in organic acids or salts.

In a certain sense, **Water** must be separated from the foodstuffs here considered, and yet, in importance, it is second to none. We must remember that the constant loss of sweat from the surface of the body is the evaporation of a watery solution, that all waste matter which leaves the human kidney is in watery solution, that the air bearing waste matters from the lungs is loaded with watery vapour, and that water is always mixed with the waste from the intestine (fæces) although its amount varies. Remembering this, we shall not wonder that water must be taken abundantly, either alone or mixed in various ways with food. Some facts concerning this admixture we shall speak of later; here it may suffice to remember that *fluids form the medium of all chemical interchange*, and that, to water falls the important task of being a first essential in the formation of such media in the human body.

§ 24. TABLE OF FOODSTUFFS MENTIONED IN THE FOREGOING PARAGRAPHS.

Proteins

contain **Carbon, Nitrogen, Oxygen, Hydrogen,** and *Sulphur*; sometimes *Phosphorus*. Traces of salts are commonly found with them.

I. *Native albumins.* Soluble in water, solutions coagulated by heat.

II. *Globulins.* Insoluble in water, soluble in solutions of neutral salts, such as *sodium chloride, magnesium sulphate;* solutions coagulated by heat.

III. *Phospho-proteins.* When digested in the stomach give an insoluble phosphorus-holding residue. Are insoluble in water, soluble in dilute alkalis: alkaline solutions not coagulated by heat.

IV. *Conjugated proteins.* Specially complex: protein is always united to some non-protein body.

V. *Meta-proteins.* Acid and alkali albumin; soluble respectively in dilute acid and alkaline solutions; solutions not coagulated by heat; neutralization precipitate is coagulated by heat.

VI. *Proteoses and Peptones. Diffusible, especially the peptones.* Soluble in water; solutions not coagulated by heat.

Coagulated proteins produced by the action of heat on albumins and globulins, are insoluble in water, in salt solutions, in dilute solutions of acid and alkali. Soluble in gastric juice and pancreatic juice, they are changed by these fluids to proteoses and peptones, and finally in the bowel to simpler nitrogenous substances.

Of these groups of proteins I, II, III, IV are found in the living animals or in their secretions; V and VI are formed in the course of digestion; coagulated proteins, formed artificially by heat, are the most insoluble form of protein.

Carbohydrates

contain **Carbon, Hydrogen,** and **Oxygen,** the two latter elements being here (and in a few substances which are not carbohydrates) in the proportions in which they exist in water.

I. *Cellulose*, forms the cell-wall or protecting membrane of most plant cells. Insoluble in all the digestive fluids of man; dissolved and changed by action of certain bacteria and by certain ferments found by plant cells.

II. *Starch.* Insoluble in cold water; swells in boiling water to form mucilaginous fluid or jelly; changed by ferments of saliva and pancreatic juice to dextrins and sugar (maltose and glucose).

III. *Dextrin.* Soluble in cold and hot water, solution clear. Dextrins are intermediate bodies formed in change of starch to sugar. Very like the *glycogen* of the liver.

IV. *Sugar.* Very soluble in hot and cold water; solution clear and sweet. Many sugars known; they are found plentifully in nature, especially in plants.

Carbohydrates are absorbed as sugar from alimentary canal.

Fats

contain **Carbon, Hydrogen** and **Oxygen,** combined and arranged differently from the carbohydrate combinations.

I. *Neutral fats.* Insoluble in hot and cold water; solid at temperatures which vary for different fats. Form *emulsion* (a creamy liquid) when broken into minute particles, e.g. by alkali.

II. *Fatty acids.* Formed by splitting up of neutral fats with separation of glycerine. This is one action of *digestion in small intestine.*

III. *Soaps.* Formed by union of fatty acids with some base. Are salts; soluble or insoluble according to nature of base. This is one action of *digestion in small intestine.*

Fats are mainly absorbed as fatty acids and as soaps.

The action of Foodstuffs in nourishing the body.

§ 25. We have thus gained some idea of the raw materials which, in the shape of food, are placed at the disposal of the body in order that this body may build itself up and repair waste. And we may now go a step further, asking the question, "How are these raw materials used by living substance?" In the body, as we have seen, *proteins*, *fats*, *carbohydrates*, *salts* and *water* are always present; do the proteins of the food form the body proteins? do the fats of food give rise to fats, and the carbohydrates to glycogen or some sugar-like substance? To answer this question fully we should have to go beyond the limits which are suitable here; we must be content (as a partial answer) to consider what is indicated by the chemical constitution of the foodstuffs, and to name some of the results of long-continued and careful experiments in physiology.

From a chemical point of view fats and carbohydrates, either alone or combined with each other, cannot give rise to protein, for they are *without the element* **nitrogen.** Proteins, on the other hand, hold all the elements which fats and carbohydrates contain, and it was taught at one time that they could act as the source of both these simpler compounds. But, as regards fats, the evidence brought forward to support this view has been shaken by the work of recent years.

(*a*) Relation of Proteins of food.

1. (*To proteins of body.*) It is undoubted that the protoplasmic part of the tissues of the body cannot be built up without proteins, and can be built up when the food is practically all protein; animals have lived for some weeks on a diet of lean meat.

2. (*To fats of the body.*) In such a case of almost pure protein-food, no fat is laid on, nor is there any clear evidence from other sources that proteins can give rise to fat.

3. (*To body carbohydrates.*) In certain cases of the disease, diabetes, sugar is excreted in large quantities by the kidneys, it has been shown that at least some of this sugar comes from

the breaking down of nitrogenous substance. On these (and other) grounds it is believed that the proteins of food may give rise to carbohydrates in the body.

(*b*) **Relation of fats and carbohydrates.**

1. (*To proteins.*) It is clear that a diet made up of these only, cannot support life: a minimal amount of protein must be present to repair the nitrogenous waste of active tissues.

2. (*To each other.*) It has not been shown by experiment that, in the animal body, food fats give rise to body carbohydrates; but the cells of plant-seeds in which there are reserves of fat do use the fat in germination—absorbing oxygen, and with this forming sugar, starch and cellulose from the fat-stores. On the other hand, carbohydrates can and do give rise to fat in the body; we are familiar with the change in daily life. Bees form abundant fat (wax) from food which is largely sugar; a carbohydrate diet is commonly given when fattening is desired, and it will be remembered that potatoes (starch holding) are one of the first articles of food forbidden, by a doctor, to a patient who is too fat.

It is characteristic of fats and carbohydrates that when not needed at once they may be stored in the animal body. Fatty tissue, found under the skin and in many other places, becomes more bulky when suitable food is abundant and the chemical changes of the body are not vigorous; it is the first tissue to be drawn upon in starvation. Carbohydrates are stored as glycogen; this is built up by the liver cells when much sugar is absorbed from the intestine, and is broken down again to sugar in times of scarcity.

§ 26. In shaping a diet which involves determination of quantities, there are other important points to be considered besides the chemical changes possible to foodstuffs which have just been roughly indicated. The animal body is constantly expending energy: sometimes this energy takes the form of heat, sometimes it takes the form of work. The source of this energy is food. But the body must also maintain itself in structure; and, when growing from childhood to maturity, or, when recovering from some exhausting disease, must add to its substance. This maintenance of structure or growth of substance is also due to food. Thus, diet should vary according as the person fed has one or another physiological task to perform, and, in the case of the healthy adult, with whom we are chiefly concerned here, it should provide energy for daily work and should maintain adequately the framework of the body.

(*a*) Now a diet in which proteins are used to the exclusion of fats and carbohydrates, is a most extravagant diet from the physiological point of view. If we eat enough protein to yield the energy requisite for average adult life, we eat far more than enough to repair the daily waste of the body's framework. The dog referred to above, fed for weeks on lean meat, had a diet that was physiologically as well as financially extravagant. Further, it is found that protein food makes the total chemical change which is constantly going on in a man's body more active; we might almost say the *living substance lives faster*. This is sometimes a gain, as for example, in the case of soldiers in the trenches, where, in spite of exposure, intense cold and depressing discomfort, it may be vital that the muscles should be in excellent condition, ready for severe and unexpected calls. And in the system known as "Banting," or in the "Salisbury treatment," abundant or almost exclusive use of protein is claimed to be curative because the chemical changes of the body (abnormally sluggish, here) are made more active. But if a man is maintaining his weight, and is in good muscular and respiratory condition, then increase of the total chemical changes of his body (increased **metabolism**) is harmful rather than a benefit.

(*b*) There can be no doubt that the fats and carbohydrates are invaluable as subsidiaries in the chemical changes of the tissues, and as sources of energy. It is indeed only the narrowest conception of a tissue which could exclude them from its constituents. Apart from the bulk of fatty tissue which is familiar to all, there is evidence of fat in close connection with the substance of cells which can only be shown to hold it by special examination. We remember, again, the union of carbohydrate with protein to form a group of bodies of which mucin is the best known example, and we recall how abundant is the non-nitrogenous waste of the body.

Further, the non-nitrogenous foodstuffs have this property, that they check or lessen the chemical changes in proteins: in other words, they spare nitrogenous waste; *the tissues, we may say, live more slowly.* And this in times of health is a valuable economy. Sometimes indeed the life of the tissues is already too sluggish, for example, in such disordered conditions of the body (referred to above) as lead to excessive stoutness. To give a diet of fats and carbohydrates here would be unsuitable: the foodstuffs which are needed are such as will excite chemical change.

On the whole, although, in the history of animals, the first digestion was probably protein, there can be little doubt that a diet in which nitrogenous and non-nitrogenous foodstuffs are mixed is the "happy mean" physiologically for man. When it is given, the digestive juices are taxed in fair proportion, the ferments acting upon starches, proteins, and fats, all having materials on which they can act: at the same time, no excretory organs are taxed unduly. Under certain conditions it may be most desirable to let one substance or another come to the front in diet, either because one digestive organ is weak, or because the chemical changes of the whole body (and we must remember that to these changes the formation and maintenance of the different tissues is due) have run riot in some way and need the checking which unusual food can bring about. And infancy, extreme old age, and sickness all need special arrangements of food; it must be remembered that here we are intentionally leaving aside these states, and dealing only with the healthy adult.

In speaking of the *rôle* of non-nitrogenous foodstuffs we have not discriminated between the fats and carbohydrates, and it may be asked, "Is it a matter of indifference whether either or both be introduced into the diet?" Within limits they can replace each other, and each has its special drawbacks and advantages. A given weight of fats is more useful to the body, that is, yields more energy than the same weight of carbohydrates; on the other hand, fats are somewhat difficult of digestion. Carbohydrates are easier to digest, and they are cheaper, commercially. A diet from which carbohydrates are completely excluded leads to grave disorder of the chemical processes in the body, and the complete exclusion of fats is accompanied by more subtle yet acute disturbances.

§ 27. The question of the exact fate of the **salts** and **water** of diet is, in some ways, more difficult than that we have just been considering; it is indeed too difficult for long discussion here. But one or two points may be borne in mind.

(*a*) In the first place we must realize that all the tissues of the body are *wet*; that is to say, that water is present in varying amounts, but generally forming about three-quarters of the total weight of the tissue.

(*b*) In the second place *all foods contain water.* That this varies, and how it varies, we shall see in succeeding paragraphs, but we may mention here that in what is called *dry oatmeal*, 15 parts out of 100 are water, and that 8 parts in 100 are found in butter—a food which seems almost purely fatty. As we might expect, the water present in *raw meat* is more abundant; in *lean beef* there are about 74 parts in 100; in *white fish* 78 in 100 parts.

But, apart from this water, taken half unconsciously with food, much is drunk as hot or cold water, and in various made beverages. *This has important special action.* It may excite **peristaltic movements of the intestines** (i.e. the movements which shift the contents of the bowel and pass undigested matters towards the lower opening) and may thus help digestion, while it checks constipation. It also acts as what is known as a **diuretic**, bringing about more vigorous action of the kidney, and greater flow of urine, and so helping the discharge of important waste matter. Probably the intestinal movements are quickened more by cold water than by hot water or tea,—almost any hot drink has the diuretic property—and such hot fluids also tend to the formation of sweat. We know that the temperature of a healthy man remains fairly constant, and further that all the small blood vessels of his body are in more or less close connection by means of delicate nerves. When much hot fluid is introduced into the body there is (through the action of these nerves) a flushing of the blood vessels of the skin—so that hurtful rise of the temperature of the body generally is avoided—and with this flushing there may be marked outpouring of sweat, and thus further increase in the discharge of waste matter, and further reduction of temperature by evaporation.

The action of saline drinks is aperient; it has been mentioned above, § 20.

Of the *salts* we may say briefly that, as all tissues of the body, when analysed, show saline matter among their ingredients, so we can hardly find the article of food which is absolutely salt-free. But there are certain parts of the body where the presence of salts is very marked and of great importance,—we may instance all bony matter, and the red colouring matter of the blood, which is indeed a protein compound, but is iron-holding. And to meet the special needs of such tissues, pressing above all times during growth, there must be choice of special food in which the suitable salts or elements abound. Thus a large part of the saline matter which makes bones strong and rigid is *phosphate of lime*, and milk is distinguished by its richness in lime; it is on this account, among others pre-eminently the food for the very young.

§ **28.** There are two substances which have been merely mentioned in the foregoing pages, and upon which we should yet dwell briefly, as they are very commonly present in articles of food. The one is **Gelatine**[1], not a typical protein yet closely allied to protein, and nitrogen-holding; the other is **Cellulose,** a member of the groups of carbohydrates.

[1] See above, p. 68,

Gelatine in Food.

In its extracted form, extracted for example from calves' feet, or prepared commercially from other animal substances, **Gelatine** is familiar to most housewives; as are its properties of setting to a jelly in the cold, of becoming liquid when warmed, and of remaining uncoagulated when greatly heated. In the body the source of gelatine is *Collagen*, the main constituent of connective tissue and of the ground substance of bone and of cartilage. Collagen may be roughly described as an impure protein especially difficult to dissolve, and gelatine is one of its hydration products, and can be formed from it by prolonged boiling with water. It is this method of preparation which is in use in the kitchen; the veal-stock or beef-tea which "sets" on cooling has been prepared from meat rich in connective tissue (*tendon* or *sinew*) or by long boiling from young bone, and it is the gristly or cartilaginous character of the calves' feet which makes them a rich source of gelatine. What is the value of this gelatine in diet? Is it a true food?

Gelatine cannot replace the proteins of food; it cannot build up the body; indeed an animal which received all its nitrogen in the form of gelatine would first draw upon its own nitrogenous tissues, and would presently die. But, on the other hand, it has a distinct value as *an economiser of protein.* We have said above that the non-nitrogenous foodstuffs act as "sparers" of the chemical changes in protein; the action of gelatine goes beyond theirs, and an animal will thrive on a diet which does not hold much protein, when gelatine is eaten at the same time, although the protein cannot be removed altogether.

Besides having this direct value, gelatine is often the means through which some food or stimulant is given;—food such as meat-juice, fruit-juice, sugar, or cream;—stimulant such as brandy or wine, or extractives of meat.

Lastly, it may be regarded as a pleasant accompaniment to solid food in various preparations of aspic and sweets.

Cellulose in Food.

We know that, in the human alimentary canal, starch is turned to sugar by ferment action. A ferment having this power is formed by the cells of the salivary glands and then poured into the mouth, and a similar ferment is formed by the cells of the pancreas, whence it reaches the intestine. This ferment has no power on the more insoluble carbohydrate, cellulose; indeed *there is no ferment formed by the gland-cells of man which can dissolve it.* Yet cellulose is largely eaten by man. All vegetable cells, all fruit cells are clothed by cellulose or by some substance allied to it or derived from it, which may be even more difficult to dissolve. Its fate then is a matter of interest; is it, we may ask, useless matter—the inevitable but inconvenient load of true food?

(*a*) This question can be answered in the negative. In the first place some living matter is capable of forming a ferment which acts upon cellulose—the living matter of certain plant cells. The living matter of certain *bacteria*, either by means of a ferment, or directly, also has this solvent power. Now these bacteria are found in the intestines of probably all mammals, and there is evidence that to them is due the disappearance of cellulose which certainly does take place in human digestion. This disappearance is only partial at the best, and varies much in extent; the products of solution are not simply sugars but more complex, and, it is safe to say, less nutritious; still it must be remembered that not all the cellulose eaten is cast out unchanged, and that the agents which bring about change in a part of it are in one sense foreign inhabitants of the intestine.

(*b*) But in the second place the *cellulose which is not digested has a use which is probably of high importance.* It stimulates mechanically the walls of the intestine, helping those wave-like movements which we have learned to call *peristaltic*, and which shift the food that it may be thoroughly exposed to the ferments present and that, when its nutritive matter is used up, it may be passed to the exterior. The intestines of animals who feed differently have different characteristics: thus, flesh-eaters have a notably short intestine; on the other hand herbivora (grass-eaters) have a very long intestine, and to them the stimulus of cellulose is all-important. Man, intermediate in the character of his food, has an intestine of intermediate length, but the removal of cellulose from his diet has generally to be met by special treatment. It is well known that in carrying out the "Salisbury" cure (in which one aim is the digestion of protein food) some sort of aperient is often used, and equally well known to most people is the aperient action of brown bread, porridge, and other foods rich in "indigestible" cell walls.

We have just said that many plant cells do form a ferment or ferments which dissolve cellulose. These ferments do not continue their action after such cells are eaten by animals, but before this point they have in some cases produced an effect which has especial interest for the cook. The term **pectine** has been used to indicate a substance or substances which may be yielded by ripe fruits, substances which in hot water are liquid (form a solution), but, in the cold, set to a jelly, and which form the ground-work of the true **fruit jellies** with which we are familiar. And these substances, pectine and its near allies, probably spring from change in the very insoluble carbohydrates of the cell walls of various fruits. The change is not a simple one, and to discuss its exact nature would be out of place here. But we may remember that while the gelatine of animal tissues is nearly allied to the proteins, the bodies which in plants most resemble it physically (i.e. which are liquid in the warm and set to a jelly in the cold) are **non-nitrogenous** derivatives of the abundant carbohydrates of the cell walls, and are derived from them, when the conditions are suitable, by special ferment action. The exact value of *pectine* in diet has not been found, but the assumption that it is without value must not therefore be made. In ruminant animals where the abundant cellulose of the food is profoundly changed

6—2

by bacterial action, the products resulting are absorbed by the walls of the large intestine.

Summary.

§ 29. It may be helpful to gather together briefly the most important points which have been dealt with in the foregoing paragraphs.

(*a*) We have seen that *a diet of non-nitrogenous foodstuffs only would starve the body.* For there is a daily waste of nitrogen—a loss which they cannot repair.

(*b*) On the other hand we have seen that *life can be maintained on a diet of protein foodstuffs.*

(*c*) But we have seen further that such *a protein diet would be a physiological extravagance*—a waste of nitrogenous material for the adult who is healthy—a *régime* often accompanied by injurious consequences.

(*d*) Thus we are led to regard as best for such an adult **a mixed diet,** *a diet which is, moreover, never destitute of salts and of water, and has its due proportion of insoluble material such as cellulose and woody fibre.*

§ 30. The question which naturally follows on these conclusions is this: "How do we gain such a diet from the foods at our disposal? What foodstuffs belong to various articles of diet?" The answer to this question forms the subject of the next chapter. But before turning to deal with it we may say a word upon one of the most widespread misapprehensions which is betrayed by students of elementary dietetics. This is the ready use of the terms "tissue-formers" and "heat-producers" to indicate respectively proteins on the one hand, and fats with carbohydrates on the other.

How are tissues formed in the body? The common idea of a "tissue" includes fatty tissue, the liver, the mammary gland, in all of which fats or carbohydrates are at some time conspicuous. These cases we may regard, however, as instances of storage: we may even disallow the fat which is so obscurely and intimately associated with the substance of many cells that it cannot be seen with the microscope. But the myelinated components of the nervous system are rich in fats; they can hardly be ignored, nor can their presence disqualify the nervous matter of the body from being termed a tissue. And if we turn from this to the muscular tissues—regarded by all as typically protein—we find the nitrogenous waste so little affected by activity, the non-nitrogenous waste in activity so large that it is impossible to deny an important share in the maintenance of structure to non-nitrogenous food.

How is heat formed in the body? By all chemical change involving oxidation and for the most part (under ordinary conditions) *as a bye-product in the performance of work.* Chemical change in an animal is nowhere more active than in its muscles and glands; we cannot separate these tissues from our conception of physiological sources of energy—we cannot separate their existence and well being from the taking in of protein food.

We may go further than this, however, and trace a two-fold fate for the proteins of food. In part they take that special share in the upkeep or growth of the body framework which is theirs alone; in part, they are *oxidised speedily with production of energy which mainly takes the form of heat.*

These brief statements may indicate that the mode in which animals are nourished by the various components of their food is indeed a complex puzzle. Bit by bit the pieces of the puzzle are fitted by careful and laborious experiments in chemistry and physiology, and the "truths" of one decade are corrected and elaborated by the next.

But it is well for the inexpert to avoid any attempt to epitomize scientific truths in brief dogmatic phrases. These may degenerate into catchwords, used popularly, long after they have become obsolete for the scientific observer. It is true that proteins, fats, and carbohydrates are tissue formers and heat producers: it is *not true* that fats take no part in forming tissues, or that proteins are unimportant in the production of heat.

CHAPTER VII.

The Constituents of Food.

§ 31. In the last chapter we learnt that certain foodstuffs must be present in the food of man if he is to live healthily; we have still to learn how food may be chosen intelligently. The knowledge which should help in this choice is really to be gathered from the information we have already acquired, together with further facts brought out in the following chapter, for we must know in the first place how the *different foodstuffs are distributed among, or contained in, different raw articles of food*, and in the second place how these *articles of food are affected by cooking or by other preparation for the table.*

Nevertheless as preliminary to both these divisions of the subject, we may say that *no one diet can be described as a perfect diet for mankind.* Bodies of similar composition have to be maintained by food in widely different regions of the world and under different conditions of wear and tear; and, partly from choice, partly from the necessities of the situation, the diet of man is now animal, now vegetable, sometimes taken in the raw state, more often prepared for eating by some process of cookery. That all these varieties of diet are of equal value we cannot pretend; their economy (in a physiological sense) is very varying, but what we shall see is that similar combinations of foodstuffs may be drawn from different sources. It may be urged further that as the same food is not appropriate to the infancy, the manhood, and the old age of a man, so, when many adult men are gathered together and fed upon similar daily rations these rations do not meet the needs of each individual with equal success. When a group of persons are clothed in ready-made clothing, those persons who diverge most widely from the mean size show a misfit most clearly, and, in the same way—though the fact is less readily appreciable—there must be many "misfits" in a common diet such as that of a prison, of a battalion, of an orphanage, or of a ship. These diets may be chosen with great care, but we can hardly look on them as in each case the best for each of the many individuals who share them. We would not, then, prescribe a diet, but rather give the data from which intelligent individuals may shape a diet. To this end we will here consider the foodstuffs in order, saying something about the various foods in which they are found and the condition in which they are found. For like constituents are present in different parts of plants and animals in different proportions; liver and kidney, for example, are unlike fat bacon; the seed of a pea is unlike the pod or the leaf; and, while milk is the source of cheese and butter, it differs widely from both in food contents.

PROTEINS.

A. Proteins in animal substances.

§ 32. We will take as a point of departure a well-known protein-holding animal food, namely *lean beef*, and consider its composition. It is, as we know, the flesh (that is, the muscles) of the ox, made up of bundles of muscular fibres of the variety known as striated, and each of these fibres possesses its own protoplasmic substance and nuclei, and is bounded by a delicate sheath of somewhat different composition. The separate muscular fibres, and, again, the bundles of these fibres, are held together by connective tissue which has no power of contraction; this tissue varies in amount,—thus rump-steak has very little of it, but all sinewy meat has much. Running in the connective tissue are the blood vessels and nerves of the muscle, abundant in number but not important in bulk; and we must not forget that much blood with lymph is still clinging to the muscular fibres, although much has been lost in the process of "cutting up" the ox. When fat is present in mass it is stored between the fibres of muscle and in the connective tissue, but for the moment we are considering *lean beef*.

With this characteristic structure we find a certain characteristic chemical constitution bound up:

(*a*) About 75 parts by weight in 100 parts of uncooked beef are water.

(*b*) About 20 parts by weight are made up ot nitrogenous substance. This, though nearly all protein, is not pure protein; it includes the connective tissue, of which mention has been made, and which, on heating in moist heat, yields *gelatine*; it includes also certain nitrogenous bodies which probably spring from chemical changes in the proteins and are sometimes spoken of collectively as *nitrogenous extractives*.

Analyses of human muscle yield figures which correspond with these, but it will be understood that some constituents are variable. Among them are fat and glycogen: almost 1 p.c. of glycogen is found in fresh, healthy muscle but, on standing, this is partly changed to sugar (glucose). The extractives, significant as they are qualitatively, are not abundant; the most abundant only forms about ·3 p.c. of muscle.

(*c*) The most important proteins in beef belong to the group of the *globulins*. It will be remembered then that they do not dissolve in pure water, but that they do *dissolve in solutions of neutral salts* (e.g. common salt), and also that they *coagulate* or become more insoluble (indigestible) on heating (§ 23).

(*d*) Salts are present, between 1 p. c. and 2 p. c.

It has been found that lean beef, eaten raw, is digested in about 2 hours, and the digestion of its proteins is almost complete. Complete digestion is hardly known in the alimentary canal of man, but, in the case of raw beef, only 2½ parts by weight in 100 are passed from the bowel unabsorbed.

Cooked beef is digested less quickly, needing from 2½ to 4 hours, but the residue need hardly be greater than with the raw substance.

Briefly, beef must be looked upon as very nutritious and very digestible; it ranks high among protein-holding foods. Eating it, we eat proteins which are for the most part made insoluble by heat, and which in the natural state do not dissolve in water but do dissolve in solutions of salts. Further, they are proteins which, in the beef, are associated or bound up with water and with very small amounts of salts.

§ 33. These characters are possessed not by beef alone but by the muscular substance of great numbers of animals, and it is on this ground that we eat animal flesh so largely. Butcher's meat, poultry, game, fish, crustacea (crabs, lobsters, prawns, etc.), molluscs (oysters, mussels, etc.) are different in small points from each other and from beef, different in the exact amount of water and proteins they contain, different now and then in the character of their proteins. But, in all, the water present amounts to between 70 and 80 parts p. c., the proteins to from about 18 to 22 parts p. c., and among these proteins *globulins* are found. The same may be said of *heart-muscle* and of *tripe* (*stomach*), in both of which the muscular fibres lack the delicate sheath which the fibres of voluntary muscle possess; and the *tongue* is another highly muscular article of diet in which the fibres (of the voluntary or striated type) are arranged in a curiously rectangular network which is, probably because of its arrangement, easy of access by the digestive fluids.

We are also in the habit of eating certain other organs of the animal body, chiefly certain of the glands: among these are the *liver* and *kidney*, the *thymus* and *pancreas* (known as sweetbreads); while the *brain*, though hardly a staple article of diet, is well known as occasional food. These are all non-muscular, but they are all distinctively nitrogenous—holding proteins, extractives and sometimes gelatine, and holding 70 to 80 parts by weight of water in 100 parts. Among the proteins, globulins are always found, and often a compound protein is present such as was described in § 23. Of these organs the kidney, with its dense structure, is perhaps the least easy to digest, unless its preparation for the table is carefully carried out; the liver and brain are more friable, more readily broken up, and in the pancreas a certain preparation for digestion may be bound up with traces of pancreatic juice (which moistens it), until the ferment is destroyed by cooking.

It is probable that, similarly, residues of digestive fluid increase the digestibility of those animals which, although eaten partly for their muscle, also contain a large and complex digestive gland. Such a gland is the so-called "liver" of the *crab*, in which however at the moment of eating the digestive ferments have been killed by cookery; such too is the "liver" of *molluscs*, so that we can understand the superior digestibility of uncooked oysters.

§ 34. We may now contrast with the lean beef, which formed our starting point in the consideration of animal foods rich in protein, certain foods which are the *natural products of animal life* or are prepared artificially—and in this comparison we shall regard only the amount and characters of the proteins present.

Of such foods, none is more familiar than **milk**. Milk varies a little in composition, according to the pasturing and condition of the cow, or other animal, from which it is drawn, but it is always more watery than beef (87 parts in 100 are water) and its total protein contents do not generally amount to 4 parts in 100. Further, the proteins present are unlike those of beef; we do not find globulins (or only in very small amount); the coagulable protein of milk is an *albumin* (soluble in water, and becoming changed by heat) while the protein *caseinogen*[1]—more abundant in milk than albumin—belongs to the class of compound proteins which have been named above, and which may be described as especially rich in phosphorus. Caseinogen is not made more insoluble by heat, but it is changed by the rennet ferment contained in the digestive fluid of the stomach, and "sets," or forms a clot which action of the pepsin dissolves. This clot, imprisoning the minute fat globules of milk, turns any quantity of milk in which it is found into an opaque jelly familiar to us as **curd**; and thus recalls the action of fibrin when it binds the red and white corpuscles into a jelly-like blood-clot.

[1] See above, p. 72 footnote.

This peculiar action of the digestive fluid of the stomach upon milk lies at the root of all cheese-making, and we may look upon cheese as the rennet-clot of milk, condensed by drying under pressure, and changed by the action of certain bacteria (compare above, § 3), and by the addition of flavourings and colouring-matter. This condensation gives a richly protein food, one that contains about 30 parts by weight of protein in 100, while in 100 parts only 34 are water; it is, however, a food which, as we shall see, is not highly digestible, although it is highly nutritive.

When the clot of milk, which is destined to form cheese, shrinks or is crushed, the liquid squeezed out from it is known as *whey*. Whey holds much of the coagulable protein of milk (but not the more important caseinogen now changed to casein), together with the milk-sugar and milk-salts. But various substances prepared commercially by the *artificial* splitting up of milk are now on the market; among them are *protene*, *plasmon*, *sanatogen*. In this splitting up, the fat and sugar are separated from the proteins. The result on the one hand is a flour-like substance possessing a high percentage of the main protein of milk, and that in a finely divided form. It is claimed for such preparations that they are highly nutritious and readily digestible. Their place is rather in the diet of the delicate or enfeebled than in that of a healthy adult.

We may look upon milk as a secretion of the animal body intended mainly to nourish young animals who are too helpless to find food for themselves. In **eggs** we find, not indeed the same consistency, not quite the same substances, but yet substances which are highly nourishing and which are used by immature (i.e. very young) animals during their growth. All eggs have to subserve this end, but it will be understood that they vary much in size and in structure; thus, *caviare*, the *roe of the sturgeon*, is made up of multitudes of clustering eggs; and this is true of the hard roe of all fishes, however different in appearance and flavour. In using the word egg, however, we think naturally of the eggs of birds, and especially of the hen's egg, many millions of which are used daily in England. Taking this familiar egg as an example, we may say that in eggs there is less intermixture of foods than in milk (thus, no sugar is found), but nitrogenous matter is abundant. In the white of a hen's egg about 13 parts by weight in 100 are protein and about 84 parts are water; in the same weight of egg-yolk there are 16 parts by weight of protein and about 50 of water. The protein matter of fresh eggs is different in nature according as the yolk or the white is examined; in the former, there are *globulins* much resembling the main proteins of lean beef; in the latter globulin also occurs, but albumin and a form of compound protein (ovo-mucin) are present. These classes of proteins, it will be remembered, are greatly changed by the action of heat, and we shall see later that hardly any article of diet is more affected by different methods of cooking than is the egg.

In all animals except those which are very simple—certainly in those which form staple articles of human food—**blood** is present, and must be looked on as a fluid containing protein, and formed by the cells of the body. The blood of the ox holds more than 7 parts of protein in 100 parts; these proteins belonging to the familiar, coagulable groups of the globulins and albumins. To the majority of Englishmen however all articles of diet prepared principally from blood are distasteful; *black pudding* or "*Blutwurst*" is largely eaten in Germany, and its main constituent is pigs' blood.

§ 35. The articles of diet of which we have thus spoken briefly, form certainly a heterogeneous group, and we shall see later that the value of each member of the group is much affected by its preparation for eating. But, assuming for the moment that all receive the same treatment, or that all are eaten raw, it is interesting to notice some of the points of difference between them, as on the other hand we have noticed the presence of proteins—their point of likeness.

(*a*) In the first place we notice a very *varying admixture of the other foodstuffs with protein matter.* We have seen that there is now one percentage of **water** and now another (compare above, § 27), and examination shows that the **salts** present vary, but within narrower limits. In *butcher's meat*, in *poultry* and *game*, we may fairly say that slightly over 1 per cent. of saline matter is present; taking this as a standard, we may add that in *tripe* and in *milk* the percentage is rather low (although the importance of the lime-salts in milk is great), while the percentage is somewhat high in *fish* and in *molluscs* (oyster). In *cheese*, saline matter is abundant.

But the admixture with **carbohydrates** and **fats** varies still more. It has been estimated that the daily diet of a healthy man should contain 100 grms. ($3\frac{1}{2}$ ozs.) of protein matter; if we suppose for a moment that we wish to gain this quantity of protein from the one description of food, and choose this from the list of foodstuffs named above, this variation in admixture shows very clearly. Thus, in eating 100 grms. protein from *white of egg*, we need eat no carbohydrates and only 2 grms. of fat; if the source of the protein be *yolk of egg*, carbohydrates are absent as before, but the necessary quantity of egg-yolk contains 200 grms. fats. A quantity of *lean beef* yielding 100 grms. protein holds no carbohydrates, and may hold as little as 7 grms. of fats; from *cow's milk*, on the other hand, we can only gain 100 grms. protein if we eat 107 grms. fats and 140 grms. carbohydrates as well.

(*b*) In the second place, there are *differences in digestibility among the animal substances rich in protein.* Sometimes differences in texture, or density, make it easy to understand that this should be the case: thus the muscular fibres of the heart, although they are naked (i.e. without enclosing membrane), are packed very firmly together, and so are the cells of which the kidney is made up. On the other hand, as we have said, the muscular fibres of the tongue (which have enclosing membranes) cross each other loosely, forming a right-angled network, easy of digestion, and the muscle of tripe is unstriped, i.e. made up of naked cells, relatively small, and bound up into thin sheets. This structure and arrangement seem to be in harmony with what we know practically of the ready digestibility of tripe, and in the case of this tissue it is probable also that the cells of the stomach have some digestive action after the animal has been slaughtered, but before the ferment they contain is killed by cooking. Again, the substance of cheese is very dense, and it is easily comprehensible that the digestive juices penetrate it with difficulty, and the same may be said of the glairy mass which we know as raw white of egg. To make cheese more digestible, we "grate" it; by "frothing" white of egg, or beating it well with yolk, the same end is reached.

When the muscular fibres eaten are large, or buried in much tenacious wrapping, their solution may be difficult; and, when fat is closely mixed with protein matter, *two* kinds of digestive action must be vigorous (i.e. the digestion of protein and the digestion of fat) if the mixed food is to be satisfactorily dissolved. Probably for this reason some "rich" fish, such as the salmon (12 parts of fat in 100 parts), or the eel (27 parts of fat in 100 parts) are less digestible than the whiting or the sole.

There are, however, differences in digestibility which can hardly be accounted for by tangible differences in the composition and "build" of the foods concerned. It may be that such differences are introduced by what might be called accidental mixture of "foreign" substances with tissues which are eaten, and that mixture of this kind is responsible, at least in part, for the indigestion which sometimes follows the eating of crab and lobster. But, in other cases, the causes of difference are more subtle still: it is found that the rates of digestion of raw beef and raw mutton are practically the same; but medical experience has pronounced mutton more digestible than beef.

(*c*) Lastly, we must remember that *individual differences abound in the eaters*, and that idiosyncrasy defies explanation. Experiments have shown (as we saw in § 32) that, when lean beef is eaten by a healthy human being, only 2½ parts in 100 of proteins are rejected from the bowel unabsorbed, and we may add that about 3 parts per cent. are thus lost from the proteins of egg, and 8 parts per cent. from the proteins of milk. But there can be little doubt that these figures would vary much, were the human beings examined to be increased in number. The healthy persons who cannot, when adult, take milk or eggs form an important group, and cases have been known in which there was (in health) inability to digest the flesh of poultry—a food which is so commonly regarded as suitable for the feeble digestion of the convalescent.

B. Proteins in vegetable substances.

§ 36. It is a popular belief that proteins belong characteristically to animal substances, and carbohydrates to plants and their products. And the composition of muscle on the one hand, and, on the other, the poverty of animal tissues in carbohydrates do give some foundation to the belief. Nevertheless it is a belief partly founded on misapprehension. From plants alone, any animal may obtain and many animals do obtain proteins and all the other foodstuffs necessary for healthy life.

Let us consider for a moment, setting aside the habits and nutrition of parasites, the scheme of plant life. We recognize in the familiar green plant such parts as are commonly *her-*

baceous; leaves, young shoots, and (in a somewhat modified sense) flowers. These are regions where the chemical changes which belong to life are especially active, but they are regions which for their well-being are closely dependent upon daily food—upon supplies of oxygen and carbonic acid from the air, upon water, and saline matters drawn from the soil. Cut off from such supplies, they wither and, speedily, they die. But there are other parts of plants in which there is storing up of what are known as reserve materials; these are substances which are food or can be turned into food independently of daily supplies from the external world, and they serve to support young plants or young shoots when daily food is scanty or lacking. This storage may take place in many different organs of the plant, such organs being usually modified in connection with it; thus the *potato* of commerce is an altered stem, rich in foodstuffs; in the *onion*, food is stored in the closely-wrapped leaves of the *bulb*; while in the *parsnip*, the *carrot*, and the *beet* we deal with *roots*. But the plant-organ *par excellence* into which foodstuffs are stored is the seed, and this, with certain wrappings or coats of very various structure, forms the *fruit*. The grains of wheat, of barley and maize, the almond, the nutmeg, the cardamom, the date-stone—these are all seeds, seeds which have within them such concentrated materials that the young plant may draw upon them for food in the early stages of its growth; they play a part much like that played by the foodstuffs in milk and animal eggs.

Now when we look at plants, not as members of a great group of living beings, but as the food of man, we realise (and it is a truth often forgotten) that *every living vegetable cell that is eaten must contain some amount of protein*; for nothing can be living which does not hold some protoplasmic constituent however slight, and proteins, as we know, form the basis of protoplasm. In lettuce, in the fruit of the grape or the tomato, in the leaf-stalk of rhubarb, there is a protein element, and, when these succulent parts of plants are eaten raw, it is probable that the protein matter they contain is especially soluble, although it is shielded by indigestible cellulose cell walls. The amount present is *very small*, greater in young green things than in older tissues in which the quantity of water has increased: thus, *asparagus*, which is the young shoot and tightly packed buds of the plant, holds 3 parts of nitrogenous matter in 100 parts; while rhubarb, which is an adult stem, has hardly 1 part in 100. And it must not be thought that on such fresh, green substances *alone*, a man could live healthily. The "grass-eating" animals form a large group, but their teeth, stomach and intestines have special characters and arrangement, fitted for dealing with this food. Man has neither these special characters, nor those which belong to the "eaters of flesh" (e.g. the cat, the lion); he has much more in common with the apes and monkeys who are fruit-eaters by nature. It is the storage organs of plants that must be eaten if nourishment from vegetables is to be sufficient for man; and it is in them that, as reserve materials, the protein substances of plants are chiefly found.

Even among these organs great differences of composition exist: the turnip, the carrot, the beet, and the onion are all poor in proteins, and contain much water—the turnip 92 parts, the onion 91 parts, the carrot 89 parts, the beet 82 parts, all in 100 parts of substance—even the potato, although more substantial than they, has 75 parts of water in 100 parts. The grains which are sometimes grouped together and spoken of as "cereals" show a higher protein content. Thus, 100 grms. of protein may be obtained from 1200 grms. rice or 1000 grms. maize, or 800 grms. wheat or 600 grms. oats. It must be remembered however that these figures refer to analyses of the grains and not to foods prepared from them (always with some addition of water) and ready for use. It is in the seeds of plants which belong to the natural order Leguminosae and are sometimes collectively named "pulse" that proteins are most abundant, and, holding but little water, these seeds are, as we shall see, rich in other foodstuffs also. In the ripe pea, 22 parts by weight p. c. are proteins, and the bean and the lentil have respectively 23 parts and 25 parts p. c. And while we must consume 3000 grms. (five pints) of cow's milk or 5000 grms. (eleven pounds) of potatoes to obtain 100 grms. of proteins, the same quantity of protein is yielded by 430 grms. of peas—fifteen ounces only[1].

§ 37. Thus we see that from all herbaceous vegetable tissue which we eat, we obtain a small but an exceedingly small amount of protein, that from certain organs of plants which are reserves of plant food, but yet watery, we may obtain more, and that, among vegetable foods, edible seeds are the richest in proteins. This is true of the seeds which we know as cereals (in which the percentage of proteins is roughly 10), or the seeds of peas, beans and their allies (in which the percentage of proteins is roughly 25).

We may now ask, can any general statements be made concerning these vegetable proteins?

(*a*) *Globulins* are by far the most abundant of the plant proteins. *Albumins* are found but in small quantities and rarely, especially in the plants most used as food. *Proteoses*, which it will be remembered are very soluble, occur in the milky juice or "latex" of certain foreign plants, and they are described in some flowers. Their presence here probably means that the proteins, which were stored in the seed in some form less easy to dissolve, are beginning to undergo change under the action of some ferment, and to be prepared for the use of the young plant.

(*b*) The plant proteins as they occur in nature are, on the whole, more *mixed with other foodstuffs* than are the proteins which are found in animal foods, and this is true

[1] Various fungi and algae have a considerable amount of protein in their composition, but they do not usually form *pièces de resistance* in diet, and it is uncertain how far their nitrogenous constituents are really assimilable food stuffs.

especially of admixture with the carbohydrates or fats. We have seen that 100 grms. of proteins may be eaten from white of egg, with admixture of no carbohydrates and only 2 grms. of fats; and further that the same weight of protein may be taken from lean beef, with 7 grms. of fats and no carbohydrates. But if we consider peas—and they are a vegetable food rich in proteins—we find that to eat 100 grms. of *protein* from them demands that 7 grms. of *fats* and 230 grms. of *carbohydrates* shall be eaten too, while in the case of corn, 14 grms. of *fats* and 580 grms. of *carbohydrates* accompany 100 grms. of proteins.

(*c*) As among the food proteins of animals, so among those which are obtained from plants, there are differences in **digestibility**. But, taken as a whole, the vegetable proteins are less completely absorbed when eaten by man. We find that of peas, shelled and well boiled, from 17—27 parts per cent. by weight of the proteins present are passed from the bowel unabsorbed; the corresponding loss in the case of white bread is 20—25 parts per cent. by weight of proteins; and as much as 40 per cent. of the proteins of lentils may be thus rejected. It must be remembered that all these proteins lie in cells which have walls of indigestible cellulose, and it is probable that the action of the digestive juices may be hindered by penetration of this substance—which they leave undissolved. It has been found that a flour made from pulse and cereals has unabsorbed remains of about 9 parts per cent. of proteins; here it may be that grinding up the cells with their contents necessarily breaks the walls, and so makes it easier to dissolve what lies within.

CARBOHYDRATES.

A. Carbohydrates in animal substances.

§ 38. It is, probably, the distribution of carbohydrates in foods which has led to the belief that proteins belong characteristically to animal substances, and carbohydrates to plants and their products. The belief is, as we have said, partly founded on misapprehension, for all plants when living have a protein constituent, while the protein content of some edible fungi is large; but the carbohydrates are, certainly, very unequally distributed. We may say that, with the great exception of milk, there is no animal food in which they abound. They do play a most important part in animal life, and the starch-like body glycogen is plentiful in the liver sometimes, and, in very early stages of life, it occurs in the muscles and in other tissues. Yet liver and muscular tissue, as used in the kitchen, have no carbohydrate constituent sufficiently important to be taken into account. Glycogen only accumulates after abundant nourishment of a particular kind has been taken, and animals are not usually slaughtered in full digestion; thus glycogen is absent, nor can we expect to find sugar, which springs from glycogen in animals by *post mortem* change. Milk, as we have said, has much carbohydrate material; in 100 parts[1] of cow's milk 87 are water, but of the remaining 13 parts, 5 are milk sugar, or lactose. Indeed we may say that the only animal carbohydrate of importance from a dietetic point of view is the soluble carbohydrate, *sugar of milk;* and the fact that it is soluble (and therefore at the disposal of the absorbing cells of the

[1] Throughout this section the term "parts," when used of the quantitative composition of foods, expresses parts by weight.

intestine without much preparation), is in harmony with the fact that milk is the natural food of all young sucking animals. When very young, these animals have either scanty saliva, or saliva with weak digestive action.

B. Carbohydrates in vegetable substances.

§ 39. Green plants are the great builders-up of carbohydrate substances. Formed chiefly in the leaves, these substances are used for the nutrition both of the plant which forms them and of the young plant which shall succeed it. For the latter purpose they are stored, generally in some insoluble form, as in the date-seed, which contains much cellulose, or in the potato, which has almost 20 parts per cent. of starch. But the more soluble bodies, dextrin and sugar, do occur,—for example in the chestnut, in the flesh of the date, and in the grape.

It is, then, the *storage organs of plants* which we must examine if we wish to examine vegetable foods which afford carbohydrate food-stuffs. We will consider certain of these organs which may be looked on as types, noting those points about their structure and constituents which are important in the shaping of a diet.

A *grain of wheat* is a familiar storehouse of vegetable carbohydrates, and there are three points about it which concern us here. *First*, it is a mass of small, closely-fitting compartments or cells, the protoplasmic substance of each cell being bounded by walls of cellulose: *second*, the contents of the cells are not of the same nature throughout the grain: *third*, the contents of the cells vary somewhat with the age and condition of the grain.

The first point is of importance because cellulose is practically indigestible to man. If a grain of wheat were eaten whole (except for such crushing and breaking as the teeth bring about in chewing) the digestive fluids—saliva and pancreatic juice—would have to penetrate the indigestible walls before reaching the nutritious carbohydrates which lie within; if the grain be very finely ground before eating, the mixing of digestive juices is more ready, their action easier and more nearly complete. Thus the nutritious matter of a very fine flour can be acted upon more thoroughly than can that which is made up of coarser particles[1].

In the second place, the contents of the cells of the wheat grain are not alike throughout the grain. The contents of the cells may be generally described as starch grains and stored protein, with a small amount of protoplasmic (i.e. living protein) substance; in the cells towards the centre of the grain the starch is most abundant; towards the exterior there is a relative increase of proteins. Further, the walls are unlike in composition; delicate cellulose walls mark the central cells; towards the outside the walls are thicker, and some of them are very dense, so that they form a protective covering. Thus flour prepared from the whole grain of wheat may differ considerably from preparations which contain only the central or only the outside (cortical) parts of the grain; moreover, flours made from the central cells alone can never be rich in proteins, since the protein-rich layer is cortical.

In the third place, the contents of the cells of the wheat-grain vary somewhat with the age and condition of the grain, and with the degree of ripening. There are variations in the amount of protein matter present, and variations in the character of the carbohydrate. A diastatic ferment is present in wheat, and, by its action, some of the stored starch is changed to sugar when the grains are of suitable age and placed under suitable conditions (as in malting for beer-making). This variation is not of great importance in ordinary diet, but some fancy flours owe certain of their peculiarities to the state

[1] See above, § 37.

of the grain from which they are made. For the most part we may say that the carbohydrate of wheat is **starch**, with **dextrin** and **sugar**. About 70 parts by weight in 100 of English wheat are made up of starch; about 2 parts are cellulose; about 11 or 12 parts are protein and other nitrogenous matter; and mineral matters or salts make up 1 to 2 per cent., and are, roughly, equal to the amount of fats present.

The salient points about the carbohydrate food-stuffs in wheat then, are the following:

(*a*) The main carbohydrate **starch** (of which there are about 70 parts per cent.) is indigestible in the raw state: cooked, it needs change to bodies which can be absorbed,—a change which is readily brought about by the ferments of saliva and of pancreatic juice.

(*b*) The starch is mixed with food-stuffs of the other classes; thus when we eat 100 grammes of starch from wheat, we eat with it 17 grammes of proteins and 2½ grammes of fats. In this respect the wheat contrasts with lean beef (which we took as an example of animal protein food); *there is in the beef greater preponderance of its main constituent*, **protein**.

(*c*) Salts are present; rather more than 1½ parts in 100.

The whole groups of "cereals," as they are popularly termed, show a strong likeness to wheat in these salient points. The cereals are the familiar edible fruits of the **Gramineae**, and although there are variations in their constitution—excess of starch and especial deficiency of fat in *rice*; relatively large admixture of fat in *oats*—yet they all hold **starch** as the predominant food-stuff; in all, the starch is enclosed by cellulose walls; in all, nitrogenous matters (§ 37), water, and salts are present too.

In 100 parts of *rice* there are about 76 parts of starch, and there are 63 parts in *oatmeal*, 66 parts in *maize*, 63 parts in *buckwheat* (all in 100 parts of the grain). Fat is almost absent from rice: in oats it may amount to 8 or 10 parts in 100.

In the *chestnut* we have a seed which, though different from a cereal grain in the eye of a botanist, is almost as rich in carbohydrates. When the nut is ground into flour, the cells holding these carbohydrates are broken down, at least in part, and the carbohydrates are set free; they form, with the remnants of cell-walls, a flour—chestnut flour. Analysis of this flour shows that the digestible carbohydrates present are mixed: there are sugar and dextrin as well as starch.

The digestible carbohydrates amount to:—*starch* about 30 parts, *dextrin* about 23 parts, *sugar* about 17 parts, all in 100 parts of chestnut flour.

We may contrast with these storage organs *the seed of such a legume as the pea.* This seed is like the wheat grain in that carbohydrates abound, and in that the important carbohydrate is starch. But less starch is found than in wheat or in the other cereals and, as we know, more protein matter occurs (§ 36). Cellulose walls enclose the stored up foodstuffs, and salts are relatively abundant, that is, they generally amount to more than 2 parts in 100. The same characters that mark the pea are distinctive also of *beans*, *lentils*, and the other seeds which are popularly known as "pulse."

The actual percentage of starch in "pulse" is between 50 and 60. The amount of fat in *haricot-beans*, *peas*, and *lentils* is small (about 2 parts per cent.) but in the less familiar "pulses," *pea-nuts* and *soy beans*, there is much more; 50 parts and about 18 parts per cent. respectively.

A further contrast to the wheat grain, and indeed to all the seeds we have yet considered, we find in the *sugary fruits*, of which the *grape* may be taken as a type. Here the little hard pip or seed corresponds to the cleaned grain of wheat, and we eat the soft, ripe, fruit-wall, which encloses the seeds. This is cellular, but the cells are for the most part large and very thin-walled; their contents are watery, and we find **pectic bodies**[1] and **gum**, substances which there is reason to regard as produced from carbohydrates by some chemical change. The water in a grape makes up 80 parts in 100; about 13 parts are **sugar**, and 3 parts are the **pectic bodies**. With the grape we may group most of the familiar "berries" (including the *orange* and *lemon*), "stone fruit," such as the *cherry*, the *peach*, the *plum;* and *apples*, and *pears*. The relative amounts of sugar and of the pectic bodies vary, and different organic acids are found in different fruits (malic acid in apples and pears; citric acid in gooseberries, lemons, and oranges; tartaric acid in grapes); still, there is strong likeness. In all, we find the large thin-walled cells, with their watery, sugary, contents[2]; in all, some bodies which if not carbohydrates are closely allied to them. The *banana* differs, in that it is especially rich in sugar and the pectic bodies, and lacks organic acid; and in the pod of the *carob-* or *locust-bean* (used as food by some Europeans, though not by Englishmen), we find nearly 70 parts in every 100 made up of sugar, pectine, and gum. The flesh of the *date* is also rich in soluble carbohydrates and their allies (sugar, pectine, gum), and the same is true of *dried figs;* but it must be remembered that the date, the carob-pods and the dried fig have lost water since they were fresh and ripe. *Tomatoes*, *melons*, *marrows and cucumbers*—all of them fruits which may be considered in this group, can hardly be looked upon as containing stores of carbohydrates; for even the tomato has only 6 parts per cent. of sugar, and the others, poorer still in this, their only digestible carbohydrate, are not eaten for their nutritive value.

[1] In § 28 brief mention has been made of the characters of pectine. It is probable that this name has been used to denote a group of substances rather than one chemical substance, and to indicate this the term *pectic bodies* has been used in this paragraph.

[2] Certain of the cells, e.g. in the pear, are quite different and practically indigestible: they are the "scleroblasts" of botanists and have greatly thickened, woody cell-walls; they do not hinder the digestion of cooked pears.

It may be of interest to arrange the chief members of the group of fruits here described (and the group is of course purely artificial and formed for present needs) in series, indicating their richness in carbohydrates and their richness in water. The order is, naturally, nearly inverse.

Fruit.	Carbohydrate in 100 parts.	Water in 100 parts.
Dried figs	60	17
Dates (dried)	55	21
Carob pods (dried)	51	15
Bananas	19	74
Grapes	13	80
Oranges	8	86
Pears	7	84
Apples	7	83
Tomatoes	6	90
Peaches, cucumbers, and Vegetable marrows	2	94

These percentages are approximate, and bodies of the *pectic group* are not here included in the carbohydrates.

§ 40. It is not only in seeds and fruits that we find abundant vegetable carbohydrates: there are storage places for them, as we have said, in other organs of the plant; in stems, leaves, roots. These organs are often changed or modified, so that the leaves are not like typical green foliage leaves, and the stems not like the familiar upright, green, plant-stems. The *potato* may be taken as a well-known example. It is a stem, changed and swollen, a mass of cells whose cellulose walls with their thin lining of protoplasm enclose watery contents (75 parts in 100 parts are water), and contain abundant starch (about 18 parts per cent.) with a small amount of other carbohydrates and of pectic bodies. That is to say, the potato is watery, but yields a starchy food. And, resembling it in general plan, although differing from it in some details, we have almost all those vegetables that are popularly known as "root vegetables": these may be true roots, as the *carrot*, the *beet*; stems, as the *Jerusalem artichoke*; inconspicuous stems bearing prominent leaves, as the *onion*, and the *true artichoke*. For the most part their stored carbohydrate is a sugar,—this is so in the beet, the parsnip, the carrot, and the onion: in the parsnip and the sweet potato[1] starch is present too. The pectic group of bodies is always found; indeed in the turnip they seem to replace stored carbohydrate; for pectine and its allies form 3 parts in 100, while starch, dextrin, and sugar are absent.

All the organs which we have just considered have more than 75 parts per cent. of water, and in onions and turnips the percentage of water is over 90. Their carbohydrate content is, approximately, as follows:

	Starch in 100 parts.	Sugar in 100 parts.	Pectic bodies in 100 parts.
Potatoes	18	—	2 (with some dextrin).
Sweet potato	15	1½	3 (with some dextrin).
Parsnip	3·5	5	nearly 4 (with some dextrin).
Beetroot	—	10	2½
Carrot	—	4½	2½
Turnip	—	—	3
Onion	—	about 5	about 5

From the list just given it will be realized, that the carrot, the turnip, and the onion have no claim to be regarded as foods rich in carbohydrates; and the same is true of the various salad plants (*lettuce*, *watercress*, *mustard*, *endive*) and of the many leaves and herbaceous stems that are used as "vegetables" or "fruits." Celery contains a little sugar (2 parts per cent.); watercress, between 3 and 4 parts per cent. of starch and its "gum" derivatives; rhubarb a little sugar with "gum"; but the value of these and other green foods depends on other characteristics (see below, § 46).

[1] This is *Convolvulus Batatas*, and not related to the true potato, *Solanum tuberosum*.

Carbohydrate food-stuffs in plants.
Summary.

§ 41. From the facts given in the foregoing paragraphs we gather one or two general statements easier to remember, perhaps, than actual statistical details.

A. **Starch** is the carbohydrate most generally found and most abundantly found in plants. Dextrin and sugar occur sometimes, but in much smaller quantities: in certain parts of certain plants the imperfectly understood **pectic bodies** are found, and they are probably to be looked upon as derivatives of carbohydrates. The carbohydrate (**starch**) in which plants are the richest, is one which must be changed before it can be absorbed by the digestive cells of animals.

B. The **Cereals**, as they are popularly termed, hold the richest stores of starchy food; they include most of the grains which are commonly ground to form meal or flour, and which are the main sources of bread and cakes.

C. **Pulse** is the name given to a group of seeds not quite so rich in starch as are the cereals, but more widely nutritious, since they (for the most part) contain larger store of protein. These seeds may be ground to meal (pea-meal, bean-meal, lentil flour), but are not adapted for bread making.

D. A group of sugary fruits may be next distinguished, they all contain much more water than do the cereals or the "pulses," and **sugar** takes the place of starch: in most cases the **pectic bodies** appear too. The fruits which may be placed in this group are varied in character; dried figs have abundant sugar; dates and bananas a considerable amount; while the peach can hardly be looked on as a storehouse of any carbohydrate.

E. Another rather heterogeneous group is formed by *stems*, *roots*, or *leaves*, in which the function of storing up reserves is added to, or replaces their usual function. In these there is sometimes a considerable amount of starch (as in the potato); sometimes only sugar, and that in small amount (the carrot); sometimes mainly the pectic bodies (the turnip).

F. The edible green leaves (cabbage), stems (asparagus), or whole plants (cress seedlings), which have great dietary value in some ways, are unimportant as sources of carbohydrate food-stuffs.

G. There are certain seeds, fruits, or other parts of plants which have marked characters, but are not easily included in the foregoing groups. Thus the **chestnut** is rich in starch, sugar, and dextrin; the **filbert** has a fair amount of carbohydrates; and **Iceland moss** is very rich if not in starch, in a body which resembles it closely.

FATS.

A. Fats in animal substances.

§ 42. When fat is formed in the animal body it is formed as the work of **living cells**. These cells, fed by the lymph and blood,—which carry absorbed foodstuffs throughout the animal,—deposit in their substance minute oil-drops. And when this particular activity is carried very far, the oil-drops run together, growing at the expense of the substance of the cell, so that this substance remains as a very delicate case for the fat which it holds.

Suet is a mass of fat formed in this way by the joint action of thousands of cells; so too is the *fat* of *beef*, *mutton*, *pork*, *goose*, *salmon*, the *eel* and of all *fatty fishes and meats*.

And *marrow* (that is to say *yellow marrow*) is nearly pure fatty tissue.

In the *nerves* and in *brain* we find fatty substance of a special kind—the medulla or myelin sheath of the nerves. The nerves in general do not form a food by themselves, for, as we know, they are scattered through the tissues of the body. But brains are eaten, though they are a delicacy or adjunct to food rather than a staple food: they are nutritious and digestible, and fat is one of the food-stuffs they yield.

Liver we have placed among the protein-holding foods, and its main value is as a source of protein. But a little fat is almost always found in liver and sometimes, as in certain fish and in the diseased geese which furnish *pâté de foie gras*, the amount is considerable.

Thus we see that the **fat-laden tissues** of animals form one great source of fatty food—fat meat, fat fish, marrow, brain, liver. In fat meat and fish and in marrow the fat drops are formed within connective-tissue cells; in the brain it is the nerve fibres which have a fatty constituent; in the liver the liver cells are changed and come to contain fat, and in many cases the connective tissue of the liver is loaded too.

But the activity of the cells which form fat does not always end in the production of such a mass of fat-cells as we find in suet. Let us consider, for a moment, the yolk of an egg; chemically it holds about 30 parts per cent. of fats and 15 parts per cent. of proteins; histologically it is a gigantic cell, with very, very little protoplasm, and a large quantity of reserve-material destined to nourish the growing bird. The fat of the reserve-material is for the most part in tiny drops which do not run together: *yolk of egg is in fact an emulsion, though not quite a typical emulsion.*

Now let us turn to consider milk. The cells of the mammary gland form fat-drops within themselves, but do not end by becoming mere fat-cells. They cast off the small droplets of fat which they have formed, into the duct or gland-passage which leads to the exterior, and here the fat-drops remain separate from each other, by reason of the other constituents of milk which are also formed and turned out by the gland-cells. *The fat of milk is very finely divided; it forms a true emulsion.*

Thus we see that fat formed by living cells, but set free from those cells (milk), or loosely held in the substance of a vastly extended cell (yolk), and remaining in a state of fine division, is important as fatty food.

Lastly, we may have foods containing a very high percentage of fat prepared from the various fatty tissues or from milk. Familiar examples are butter, dripping, lard, together with the different imitations of butter. Here the fat *is not within cells and not emulsified:* in lard and dripping it is pressed or drawn out of the cells which formed it; in butter, the shaking and stirring of the churn have destroyed the emulsion of milk. Cheese may claim to be a fatty food, but has an equal quantity of protein—about 30 parts per cent. In cheese-making, the protein is precipitated and the milk fat clings to it; then, by pressure, a very dense food is formed.

We may arrange examples of the groups of foods just mentioned, in a descending series, beginning with those in which the percentage of fat is the highest, and giving approximately the percentage composition in fat.

Article of food		Fat in 100 parts by weight
Marrow of bones	about	95 parts
Butter	,,	87 ,,
Bacon	,,	65 ,,
Fat mutton	,,	35 ,,
Cheese	,,	30 ,,
Yolk of egg	,,	30 ,,
Salmon	,,	12 ,,
Brain	,,	8 ,,
Milk	,,	4 ,,

It is interesting to note that milk—the food which is in itself a complete and satisfactory food for the early months of human life—comes low in the list. Indeed the foods which have a very high percentage of fat are not suitable for digestion alone, at least in temperate climates: we eat bread with butter or dripping, and beans with fat bacon.

§ 43. Looking at animal fats as forming a group, can we make any statement about them which is important from a dietetic point of view? We can do little more than recall the statements made in § 23.

A. They are as a rule **mixtures of fats**. And this fact is of importance; for different fats have different melting points, and thus, mixtures which contain the fats in varying proportion will also vary in melting points. Speaking of animal fats generally, we may say their *melting points are high;* they are not liquid at the ordinary temperature of the air in England, but there are distinct differences among them, so that we come to have what are called *hard fats* and *soft fats*. Thus mutton fat is particularly hard (melting point high); pork fat, and goose grease are especially soft (melting point low).

B. But, further, the animal fats, as eaten in England at least, are **neutral fats.** A very small amount of fatty acid may be present; when its amount increases we say the fat is *rancid*, and rancid fats are usually rejected as food.

C. And lastly, with the exception of the fats in milk and in yolk of egg, the animal fats of food are **not emulsified.** Freed from the tissue cells in which they lie, by digestion, or by previous treatment, the fat-drops run together into larger drops and irregular masses.

Thus a good deal of physical change and chemical change is called for by the fats of food before they can be absorbed by the cells of the intestinal wall. They must, as a rule, be melted; they must be **emulsified**; and they must be split up into fatty acids and glycerine.

As we have said, **milk offers fat which is already emulsified**: we have seen, earlier, that its protein is a soluble protein and that its carbohydrate is sugar of milk; the constitution of milk is admirably adapted for the nourishment of the young animal.

B. Fats in vegetable substances.

§ 44. Changing only a few words here and there, much that has been said above in § 39 about the occurrence of carbohydrates in plants might here be said touching the occurrence of fats. Like carbohydrates, the fats are mainly stored in *seeds* and *fruits*, like carbohydrates they are found, but less abundantly, in stems and leaves. A fatty seed is a closely grouped mass of little cells, as is a starchy seed; the cell-walls are of indigestible cellulose, some delicate sheet of living substance lines them, a mineral residue (i.e. some form of "salt") is always present.

But, changing the point of view a little, we might with equal justice draw a parallel between the occurrence of fats in plants and their occurrence in the tissues of animals. We do not, indeed, use commonly any fatty vegetable secretion which is comparable with milk (although the "milk" of the cocoanut has resemblances in more than name), but we must distinguish vegetable fats as (*a*) *Fats laid down in the tissues* and eaten with them, or (*b*) *Fats expressed or prepared from these tissues.*

(*a*) The **fats laid down in tissues** are comparable with those eaten in fatty meat (adipose tissue), but, whereas the residue of cell-substance which encloses fat in animal tissues is digestible, there is in plant-cells an additional, indigestible cell-wall. A seed such as the almond holds more than 50 parts per cent. of fats, and the cocoanut, the brazil nut, the walnut, varying somewhat in percentage composition, are all richly fatty. In the olive, it is not only the seed (kernel) but also the fleshy fruit wall that is laden with fat (much as the date-flesh is laden with sugar), and as an example of fat in plant stems we may take the whole natural order to which belong *Angelica*, *Chervil*, and *Fennel* (the *Umbelliferae*). Here we cannot perhaps speak of concentrated stores, but in both stems and leaves there is a volatile oil which, at least in the fennel, is sometimes combined with bread to make a palatable and nutritious food.

(*b*) **Fats prepared by chemical or mechanical means** from the plant substance which formed them are among the most familiar in domestic and commercial life. **Olive oil** alone must rank very high in popularity as a food-stuff, especially in southern Europe, and the oils prepared respectively from walnuts and almonds and from linseed are eaten, though less generally, and less abundantly.

A list of typical fat-yielding vegetable foods, arranged according to the percentage of fat they contain, forms an interesting pendant to the list of fatty animal foods given in § 42.

Article of food		Amount of fat in 100 parts by weight
Brazil nut	about	65 parts
Almond	,,	55 ,,
Olive	,,	40 ,,
Linseed	,,	38 ,,
Cocoanut	,,	35 ,,
Walnut	,,	30 ,,
Oatmeal	,,	10 ,,

We meet with the grains of oats once more in this place; in earlier paragraphs we recognized them as valuable for their starch (63 p.c.) and their proteins (16 p.c.).

Can we group together these vegetable fats and make any general statements about them?

§ 45. (A) They are in the main **neutral fats.** Decomposition into fatty acids and glycerine is easily brought about, especially in the case of non-purified fats; when this decomposition is vigorous we have (v. *supra*, § 43) the condition of rancidity.

(B) In the cells of fruits and (especially) of seeds, fats are often **associated with nitrogenous food-stuffs.** It is rare to find starch and fat in the same seed at the same time (both are present, however, in the filbert kernel): but the almond, the pistachio nut, the pea-nut, have all more than 20 parts per cent. of proteins and related bodies. Thus many of these seeds are highly nutritious; but on the other hand they are **difficult of digestion,** for both proteins and fats are shielded by the indigestible cellulose walls within which they lie. Indeed the digestive organs of civilized man—so often weakened by hereditary and present habits—make no great use of highly fatty seeds.

The case is different with the pressed out or prepared oils; here nothing stands between the fatty food-stuff and the digestive organs, but the oils are *not native emulsions*, but are massive, and therefore a first action in digestion is their emulsification.

(C) The vegetable fats have as a rule **low melting points.** It is perhaps because we are accustomed to see them in the liquid (or melted) state that we instinctively speak of them as *oils.* Oils are fats; and the fats characteristic of the olive, the almond, the rapeseed, the linseed, the walnut, and other seeds and fruits are liquid at ordinary temperatures. But the fats of the palm and the cocoanut are solid at these temperatures, and in this property they recall the groups of the animal fats.

SALTS AND WATER.

In discussing the nature of food-stuffs in Chapter VI. we pointed out that in one sense proteins, fats, and carbohydrates, by complex chemical change, upheld and formed anew the living substance of the animal body. But in a wider sense inorganic and organic salts and water share in the labour; without them an animal would die. We will dwell briefly on the distribution of (1) salts, (2) water, in animal and vegetable foods considered together.

1. Salts in animal and vegetable substances.

§ 46. It is open to us to eat various salts, inorganic and organic, either in a pure state or mixed with food, and one inorganic salt—chloride of sodium—is largely eaten in the latter fashion. But though the behaviour of salts within the body, i.e. the part they play in physiology, is obscure, one thing we can say—that that part is better played when they are eaten as constituents of food than when they are eaten alone, or as adjuncts to food, or drunk in solution. In the latter case, indeed, they seem to have the character of drugs—their use belongs rather to disordered conditions than to healthy life. But a discussion of the mode of action of saline matters is beside the point here; accepting the facts that they are important qualitatively in food, although the amount present is always small compared with the total amount of food, we have to consider briefly *what is their distribution among foods.*

We will take first a group of animal foods, including in it all organs of animals which are commonly eaten.

In **butcher's meat** we find rather more than 1 part of mineral matter in 100, but in fat meat (unsalted) there is sometimes only $\frac{1}{2}$ part p.c.

Poultry and **game** have also from 1 to $1\frac{1}{2}$ parts p.c.

Fish for the most part contain more, varying from 1 part in the eel, to 3 parts in the flounder.

Eggs have about 1·3 parts p.c., and the yolk is slightly richer in salts than the white.

Milk and **cream** have less than 1 part p.c.; there are $\frac{4}{5}$ in cow's milk, $\frac{1}{5}$ in human milk, and nearly $\frac{1}{2}$ p.c. in a fairly typical cream.

The **cereals** generally hold more mineral matter than the meats when the whole grain is examined. (*Oats* 2 parts, *maize* 2 parts, *rye* $1\frac{1}{2}$ parts p.c.) Removal of the outside layers of the grains lessens the content in saline matters; *rice* has only $\frac{1}{2}$ part p.c., a fine *white flour* hardly more than $\frac{1}{2}$ p.c., while a fairly coarse *bran* (bran representing the part of wheat rejected in making white flour) has 6 parts p.c.

The seeds known as **pulse** have still more mineral matter; in *peas* there are 3 parts, in *lentils* $2\frac{1}{2}$ parts, in *haricot beans* nearly 3 parts p.c.; and the oily seeds which are commonly called **nuts** are in many cases as rich (*almonds* contain more than 3 parts p.c.). The storage organs which are popularly known as **root vegetables** may rank nearly on a level with butcher's meat in regard to saline matters, but they are slightly poorer (*potatoes* 1 part, *carrots* 1 part, *turnips* less than 1 part p.c.).

Among **green vegetables** we find that *sea-kale* and *celery* have less than 1 part p.c. of salts; *cabbage*, *lettuce*, *watercress* have 1 part p.c. or slightly more, and *spinach* heads the list with 2 parts p.c.

The **sugary fruits** are poor in inorganic salts; apples, pears, grapes, peaches, oranges, have all $\frac{1}{2}$ p.c. or less; but in these fruits *important organic salts occur*—the salts of malic acid, of tartaric acid, of citric acid, or the acids themselves. The lemon stands out conspicuously among these fruits: it holds about $1\frac{1}{2}$ parts p.c. of mineral matter, and 5 parts p.c. of citric acid.

Briefly, we may say that to have 2 to 3 parts of saline matter in 100 parts of a natural food is to be rich in saline matter, and that the pulses and some of the nuts answer to this definition. Cereals must be placed next, to be followed in order by fish, eggs, game and poultry, butcher's meat. About on a level with butcher's meat we place green vegetables; the root vegetables come rather lower in the list. We place milk next, and last, the groups of sugary fruits —which are however rich in organic acids.

§ 47. We have drawn up this list having regard only to the saline constituents of the various foods and looking upon them in each case as forming *one* item. *But the saline constituents of different foods are not alike.* In the most important foods we find iron, magnesium, potassium, chlorine, sodium, phosphorus, calcium (lime), but these are present in varying proportions. Further, what is called the *acid radicle* may vary; thus one food may hold chiefly chlorides; another, phosphates; another, silicates. And, lastly, the "mineral" element may exist not as a familiar inorganic salt such as sulphate of iron or sulphate of lime, but linked to or chemically hidden in some complex organic substance probably very important in the chemistry of life.

These facts show that the simple terms *salt*, *saline matters*, *mineral matters*, cover wide variety; we cannot pretend here to enter minutely into their meanings even for the chief forms of food; but one or two points are not only especially interesting, but are charged with significance to anyone who shapes a diet. We will consider briefly the presence of calcium, iron and phosphorus-holding bodies in the mineral matter of some of the more familiar foods.

But in connection with the consideration, two points must be borne in mind. To examine the mineral constituents of complicated foods, the foods are usually *dried and burnt.* Thus all organic matter is broken up and dispersed, as various volatile substances, and an **ash** remains which is the mineral residue; all the metals which were present in the original foods are present still, but we may be almost certain that they existed originally in different combinations,—complex combinations which have been split up by the necessary process of analysis.

In the second place, the total amount of mineral matter is so small that only very minute fractions of its constituents are present in 100 parts of food in the raw state. It is slightly easier then to consider 1000 or 10,000 parts of food: we will speak of the content of 10,000 parts, but it must not be forgotten that this is so, and the figures must not be compared with percentages.

Lime.

(Foods arranged in descending series)	Calcium as oxide in 10,000 parts raw food
cow's milk	20
yolk of egg	18
peas	12
wheat	6
human milk	3
potato	$2\frac{1}{2}$
white of egg	2
beef	1

Iron.

	(Foods arranged in descending series)	Iron as oxide in 10,000 parts raw food
equal	yolk of egg	2
	peas	2
	wheat	2
equal	beef	1
	potato	1
	white of egg	$\frac{1}{2}$
equal	human milk	$\frac{1}{20}$
	cow's milk	$\frac{1}{20}$

Phosphorus.

(Foods arranged in descending series)	Phosphoric acid in 10,000 parts
yolk of egg	92
peas	85
wheat	80
beef	56
cow's milk	24
potato	16
human milk	5
white of egg	3

We have chosen these mineral constituents because each has an importance of its own in the animal body. **Phosphorus** is an integral part of calcium phosphate, and calcium phosphate forms more than 30 parts p.c. of bone. And in all nervous tissue (nerve-cells, nerve-fibres) complex phosphorus-holding substances are present. The importance of healthy bones and healthy brains can hardly be rated too high.

Calcium shares with phosphorus in the composition of bone, and is present not only as the phosphate but as the carbonate.

Iron is always present in the red colouring matter of the blood (haemoglobin), and we know that this is the great oxygen-carrier of the mammalian body. And it has been shown by experiment that iron is also hidden away in combination with the living substance which forms the nuclei of cells.

It is clear however that the importance of these substances is not the same at all periods of life; the building up of healthy bones and teeth belongs especially to childhood: it is only their maintenance which is important when growth has ceased. Thus organic foods rich in lime-compounds are especially valuable for the young. In old age their value is less determinate, for an undue laying down of lime-compounds, as for example in cartilage and in the walls of blood-vessels, is one of the physiological dangers in age. Phosphates (or some more complex phosphorus-holding bodies) are also doubtless of great importance to children; but if, as seems probable, we must associate them with chemical change in all nervous matter, then they are of importance in all phases of life.

The demand for iron also runs through life, but is especially urgent in such conditions of poverty of blood as have been named anaemic: it is probable that very minute quantities of iron satisfy the needs of the body, and probable, too, that the smallness of the quantity in milk is bound up with the fact that the young animal which is nourished by milk after birth, receives iron from its mother before birth.

2. Water in animal and vegetable substances.

§ 48. When we remember that about three-fourths of the living body are made up of water; that all the nitrogenous waste of the body is discharged in watery solution; that the undigested residues of food are always moist when they are ejected; that every breath expired, is loaded with watery vapour, we realize easily that **water** must be an important constituent of diet. In the foregoing paragraphs, we have seen incidentally how different an amount of water is contained in different raw foods, and what must be said now is hardly more than a recapitulation of what has been said, but with a new emphasis.

If we arrange the groups of foods which we have been considering, in a descending series, having regard only to the amount of water they contain, we must head the list with **green vegetables**, the salad plants, green stems (for example rhubarb), and the herbaceous parts of plants generally. *The percentage of water in this group is over* 90 *and often over* 95 *parts.*

Most edible **fungi** have 90 parts **p.c.**; but the truffle is exceptionally solid, and contains slightly less water than the potato.

The **sugary fruits,** and **"root vegetables"** (as they are called), have as a rule more than 80 p.c. **Milk, game** and **poultry, butcher's meat, eggs,** and some **fish** have all as much as or more than 70 parts p.c.

"Nuts," cream, and **cheese** have considerably less, and may be looked upon as intermediate between the foods which we call "watery" (roughly speaking three-fourths water) and those in which the water is less than one-fourth of the total weight. Such are **bacon,** the **cereals,** the **pulses, butter,** and **oatmeal.**

In the following series the percentage composition is approximate:

Food (raw)	Water in 100 parts
Green vegetables	95
Fungi (mushroom)	90
Milk	86
Sugary fruits	80 to 85
"Root" vegetables	75 to 80
Game and poultry	75
Eggs	71
Butcher's meat	70
Fish	60 to 80
"Nuts"	40 to 50
Cheese	34
Bacon	22
Cereals (usually)	14
Pulses	12 to 14
Butter	9 to 10
Oatmeal	5

It must be remembered that the amount of water in **raw foods by no means represents the amount in foods as they are eaten.** Mutton has more than 12 times as much as freshly ground oatmeal, but mutton, when it is roasted, loses water in the process, while oatmeal, made into porridge, must often be eaten with 10 times its bulk of water.

In fact, if water is not found in foods it is taken with them; salads, apples, tomatoes, are eaten with no sensation of thirst, and the Neapolitans have a saying that in the melon there is "something to eat and something to drink and quite enough for washing." But dry flour or meal is not thought of as a finished article of diet.

The question may be asked: Do we lose by taking water *in addition* to foods instead of *as a part* of them? If we dry an apricot and, after the lapse of years, cook it in water, is it like a fresh apricot, from a dietetic point of view? This question cannot be answered positively; in drinking water, we usually face the possibility of bacterial contamination—less serious if the water is boiled or heated in cooking—and any large dilution of food may bring about slackening of digestive action in the stomach of the healthy adult. But apart from these considerations, the intimate admixture of water in living cells, which belongs to growth, commends itself to us as likely to provide a fair field for digestion. It cannot be said that observation or experiment has settled the point; we know far less about it than even about the dietetic importance of inorganic and organic saline compounds.

CHAPTER VIII.

The Preparation and Cooking of Food.

§ 49. IN the preceding chapters we have considered certain questions:

(1) What are those **foodstuffs** which are essential to the well-being of the human body?

(2) What is the **action of these foodstuffs** in nourishing the body?

(3) What is the **distribution of these foodstuffs** in different raw articles of food?

It remains for us to discuss here the effect which cooking and other preparation of food for the table have upon the nutritive value of the foodstuffs present. In discussing this we are concerned with the physiological side of digestion and with its chemical side. For the action of the saliva, the gastric juice, and the pancreatic juice is a *chemical action*, and these juices, removed from the body, will (under suitable conditions) digest in a cup or glass. But the pouring forth of these juices is a *physiological action* (*secretion*): they are made by the living cells, and poured out by them into the mouth, the stomach, the intestine; and this action can only be performed by **living substance**. Thus we have to ask, A. How is food affected by preparation as regards the chemical action of the juices upon it? B. How is the exciting or stimulating effect of food on the digestive organs affected by processes of preparation? Does food treated in the various ways call forth an abundant flow of secretion? We will make these questions the main divisions of the chapter.

A.

1. We will consider first, *the relation between the chemical action of the digestive juices and the food as it is variously prepared.*

The fine division of food.

§ 50. Under this heading we may place:

(1) **Chewing**, with such knife and fork action as is supplementary among many European nations.

(2) **Mincing**, with which we may associate braying (or pounding) in a mortar, and rubbing through a sieve.

(3) **Grating.**

(4) **Whisking** or beating.

(5) **Emulsification.**

(6) **Dilution.**

Now we may say that all chemical action, at least *all solution, goes on more rapidly and more thoroughly when the bodies concerned are finely divided.* And this is true of the solution which accompanies digestion. If we take a piece of beef, 1 inch cube, and take the same amount cut into 1000 *cubes*, it is clear (cp. above, § 10[1]) that the fragments offer ten times as great a surface,—the gastric juice can get at them better,—and the conditions, in this respect, are highly favourable for thorough and rapid digestion. *Thus, all fine division is an* aid *to digestion.*

[1] p. 32.

(1) Chewing.

This is really all-sufficient to the primitive ancestors of man, and the use of the knife and fork and all the artificial modes of division which are before us belong to civilization, and probably to artificial diet, and slightly weakened digestion. But we cannot return to the condition of our tree-inhabiting ancestors, and thus, with advantage, we supplement the chewing of food. Nevertheless it is desirable to chew very thoroughly; the slow admixture of saliva aids in the digestion of any cooked starch or dextrin in the food, and even when the food is protein, thorough mastication is the natural action which prepares the way for digestion by the gastric juice. It is some years now since a group of dietetic reformers taught that scanty food would yield nourishment adequate to the needs of the human body if it were chewed with sufficient elaboration. These teachings probably take too hopeful a view of the facts of nutrition and human appetite, but they deserve more than satirical consideration.

(2) Mincing.

By this process the work of chewing is forestalled; we can see, then, that it is a process to which the food of the very young, the very old, and the weakly may be subjected with advantage. *Pounding in a mortar* and *rubbing through a wire sieve* may be looked on as extreme forms of mincing: in the latter, some fibre of meat is necessarily left behind, and this is not always a gain—indeed rubbing through a sieve belongs to aesthetic rather than to physiological cookery; it is wasteful, but gives a velvety texture to the purée which passes through, that is much prized in the ingredients of certain dishes. Mincing and pounding are however invaluable: *Scotch collops*, *boudin of rabbit*, *chicken panada*[1],—in the case of all these, digestion is easier than if roast beef, stewed rabbit, boiled chicken, were offered.

[1] To prepare these dishes with finish, it is needful to rub through the sieve.

(3) Grating.

With this we may associate **grinding**—the production of flour and meal—: it takes the place of mincing, when foods of suitable texture are used. Here again the difference of digestibility is marked; coarse flour or meal is more digestible than the whole grain (it has been found by experiment that more of the proteins of peasmeal is absorbed than of the proteins of peas[1]), and a fine flour is more digestible than a coarse flour. Grated almonds are, in the same way, more open to the attack of the digestive fluids than almonds simply broken up by mastication: and grated cheese is far more digestible than the fatty, compressed, mass of raw cheese. To lunch satisfactorily on bread and cheese needs fairly good teeth and good digestion; a cheese *soufflé*, or *fondu* has less compressed nutriment, but is far more digestible. Again, a hard boiled egg is a recognised tax on the civilized stomach, but in an omelette the yolk and white of the eggs are so intermixed that no large mass of either remains. This intermixture however can hardly be properly included under the heading "grating"; it is rather transitional to

(4) Whisking, beating, and aeration.

We may indeed almost regard this as a special form of grating or mincing. Instead of having solids separated into tiny fragments which form a powder or flour, we have glairy or viscid fluids beaten up into what is practically a sponge, holding air. Thus the substance beaten is formed into little compartments or artificial cells, all having but thin walls and all easy of access by the digestive fluids. We may have gelatine thus broken up (as in *lemon sponge*), and carrying with it some nutritious or stimulating matter; we may have frothy *white of egg* (raw white of egg is difficult of digestion although rich in nourishment); we may have cream as in any of the familiar *whips*. The warmth of the stomach must alter

[1] See above, § 37.

the condition of the cream and gelatine soon after they have been swallowed; still it is a frothy, permeable mass which the gastric juice encounters, not an unbroken block of solid or liquid. And because the white of egg is more glairy and tenacious, more susceptible of this "whisking" than is the yolk, therefore in *soufflés*, in *invalid puddings*, in delicate *cakes*, in an *omelette soufflée*, the white is whisked alone, and mixed only at the last moment with the other ingredients which it is to support and make "light." It is really whisking "with a difference" that gives us the proper effect in *bread*, *cakes*, *pastry*, of all kinds. Either air—as in puff pastry—or some gas—carbonic acid gas, as in short pastry, in cakes, and in bread—is introduced, and what would, without this aeration, be a dense mass, hard of penetration, becomes a porous substance into which the digestive fluids can make their way.

(5) **Emulsification.**

This is the *fine division of fatty particles* and therefore is related to the results of beating or whisking which we have just considered; the nature of oil is such that we cannot readily "froth" it as we do the tenacious white of egg[1], but we can beat it into minute particles, separated by air—as in the case of butter beaten to a cream—or by some non-mixing fluid. *Milk* is an example of the latter form of emulsion, and *cream* is milk containing a disproportionally large amount of milk fat; *cod liver oil* is often emulsified before it is given to invalids; *Cremor hordeatus* and other preparations have, as their basis, fat, thus made easy for digestion. *Salad oil*, if drunk without preparation, would run into irregular masses in the stomach, and be emulsified later by the pancreatic juice; in the sauces *mayonnaise*, *hollandaise*, and their derivatives, some of this emulsification is done in the kitchen[2].

[1] It will be remembered that in cream we do not deal with pure oil.

[2] See above, § 24.

(6) Dilution.

It is really chiefly in connection with the natural food, milk, that this process is important. Cow's milk is clotted by the rennet of the stomach, and forms the jelly which we know as curds. But the firmness of the jelly depends (with rennet of a given power) on the concentration of the milk, and *diluted milk does not clot firmly.* Now the massive clot is not easily digested, therefore to avoid its formation is sometimes desirable in the case of invalids and infants. To dilute milk for a baby with boiled water or thin barley-water, is a very general practice, and many invalids take diluted milk.

There are, further, certain processes which are almost a mixture of dilution and whisking, the processes by which a *syllabub* and *koumiss* are made. A syllabub is really milk, frothed up with wine or spirit and flavouring; koumiss is, in like manner, highly frothy milk, but here alcohol and carbonic acid have been introduced by the action of yeast upon sugar. No solid clot is formed from milk taken after this treatment; koumiss and syllabub are related to fresh milk much as is beaten white of egg to the native "white." We can see that syllabub must be a more digestible food than raw milk or than junket, and koumiss—a stimulant as well as a food—has been used to support life in certain cases of great exhaustion.

We repeat that in itself, the fine division of foods is an aid to digestion; it furthers the chemical action of the digestive fluids.

2. *The effect of heat upon foods.*

§ 51. All digestion of food by man is best carried out at the temperature of the human body (36·9° C.) 98·4° F.; such moderate warmth is wholly beneficial both to the chemical action of solution, and, as we shall see later, to the pouring out of the digestive juices. What concerns us now is the effect upon subsequent digestion of a much greater degree of heat, applied to foods. We shall find that this effect varies; in the case of some foods heat aids digestion; in the case of other foods, digestion is hindered; occasionally, foods are deprived of, or made poor in, certain of their constituents when they are cooked. And there is one action of heat which is not directly related to digestion, but which has so important a bearing on nutrition that it must be named here. This is **sterilization.** The meaning of the term has been explained at length in chapter II., but we repeat, that in sterilized tissue or fluid all life is destroyed; therefore any bacteria or larger parasites which might have been present before heating are killed. The risk of infection from any disease-producing forms is thus much reduced; **thorough cooking** is one great **safeguard** against the *spread of disease by means of food.*

(1) *Heat as an aid to digestion.*

All foods containing raw **starch** are made digestible by the action of heat. Raw starch is digested very slowly by human saliva or pancreatic juice; starch paste (or cooked starch) is rapidly digested, and dextrin is a bye-product or an intermediate product in the change from starch to sugar. When starch is boiled, stewed for a long time, fried or baked, the change to starch paste, or to cooked starch, takes place. When dry heat is used there is often a change to dextrin (see above, § 23) as well: this is the case in the crust of well-baked bread, of cakes, and probably in that of pies; in pulled bread, in toast, and in many biscuits.

From this point alone, we can hardly over-estimate the importance of thorough cooking of starchy foods; potatoes, porridge, all breads, all milk puddings, all pastry, and preparations such as cornflour, arrowroot, revalenta, lose greatly in nutritive value if any starch is left in the raw state. Thorough boiling, baking, or frying, or long-continued cooking at a lower temperature is essential. When digestion is very delicate, then the further change to dextrin is desirable, and it is to ensure this change as well as to ensure fine division that doctors recommend to dyspeptic patients thin toast, slices of dry bread "pulled" or browned, rusks and other highly cooked foods. It is a change to dextrin too, that is brought about in baking flour after the fashion recommended for babies' food. Prolonged heating not only cooks the starch in flour, but turns some of it to dextrin, and the flour in its altered state may be mixed with a baby's milk at such time (say 6 months) as supplementary starchy food has become desirable.

The beneficial action of heat upon the **cellulose** of foods is less well-established, but the point is worth brief consideration. We have seen in § 28 that the digestive fluids of man do not dissolve cellulose, but that a portion of what is present in food is broken up by some of the bacteria which always inhabit the human intestine. Probably this action is not of great nutritional importance and there is no direct proof that it is furthered by the previous cooking of cellulose. What this cooking certainly does, however, is to *make limp and flaccid* the cells which, in uncooked fruit and vegetables, were tense—or in the words of botanists, turgid,—to rupture the walls very generally, and to kill and coagulate the protoplasmic contents, and to make digestible any starch which may be present. And here we have both a gain and a loss: the rupture of the cells, and death of the cell-contents makes it easier for all fluids and thus for the digestive secretions to attack them, but, on the other hand, coagulated protein is, as we have said, hard to dissolve. And an amoeba sends its digestive fluid readily through the wall of a swallowed vegetable cell, and readily dissolves the cell substance which lies within.

The point is a little obscure, but practically we know that tomatoes, apples, pears, plums, are far easier of digestion after they have been cooked, and none of these contain starch when ripe. Thus the increase in digestibility must be connected with action on the cellulose walls or their watery contents. And of one thing we are sure; the disintegrating and softening effect is *very important indirectly*. The flesh of chicken or the flesh of fish is soft enough to be rubbed and pounded to a *purée* in the fresh state; but hardly any vegetable can be treated thus. It is only after long stewing or boiling that carrots, haricot-beans, artichokes, chestnuts, and many other "vegetables" are sufficiently soft to be pounded into their respective *purées*.

It cannot be claimed that the action of heat upon **fats** furthers their digestion importantly. It is true that the work of melting the harder fats may, by preliminary heating, be spared to the alimentary canal, but this is no great gain as compared with the gain of previous emulsification. And it is discounted, when digestion as a whole is regarded, by the fact that melted fat, penetrating the particles of accompanying foods, makes them difficult to digest. Hot buttered toast and cakes are, as we know, unsuitable for the dyspeptic.

Lastly, we must speak of the action of heat which is not all a gain,—the action by which **solutions, infusions,** and **decoctions** of food are made. This is helpful up to a certain point, for *liquids are easier to digest than solids*,—the digesting fluids can mix with them and act on them more easily;—but, if the heat applied is great, then the action on **proteins** which we are about to discuss takes place, they do not go into solution, or if in solution they are thrown down as insoluble substance. This loss or precipitation of proteins is a serious loss from the point of view of nutrition, but other constituents do remain in a fluid which has been boiled; thus in a decoction of meat the **salts** of meat are there, often **gelatine** has been formed in the boiling from its precursor collagen (cp. above, § 28), and there are members of that group of substances known as the "**extractives**" of muscle[1]. Of the importance of saline matter we have already spoken, and we saw in § 28 that gelatine, if it cannot be regarded as a food, is at least important in affecting the chemical changes of the body; it is a protein-sparer. The extractives *kreatin*, *xanthin*, *inosite*, *lactic acid* and other complex, soluble, organic bodies, are not foods, but they have a stimulating action on the body, comparable rather to that of tea. Briefly, we may say that solutions or infusions made from *slightly warmed meat* are both nutritious and digestible; that decoctions (and to them the various **broths** belong) are very poor in dissolved proteins but are still stimulating, and are not without their importance in nutrition. And in all these cases the body can readily avail itself of what the liquid concerned has to offer because of its existence in solution. If precipitated proteins are present (as in the brown sediment common in beef-tea) then, although not readily soluble, their solution is aided by fine division.

A word may be added touching infusions and decoctions of vegetable matter. Many of these are in no sense food, but are valued for their stimulating or medicinal qualities; we may instance *tea*, *senna-tea*, *bran-tea*, &c. Others are dilute starchy foods, and for them, thorough cooking is wholly a gain; in this group we may include the various gruels, barley-water, arrowroot-water and rice-water. Others again contain salts, soluble organic substances and potent flavouring, often due to some essential oil. In none do we find any important amount of protein; we have seen earlier that although small amounts of proteins are present in all parts of all plants it is only in certain reserve organs that the percentage is high, and, whether the amount is small or great in the fresh state, the proteins are made insoluble (see below) by that long-continued cooking which is requisite to carry into solution the ingredients for which most vegetable extracts are valued.

[1] See above, § 32.

(2) *Heat as a hindrance to digestion*[1].

With the exceptions of proteoses, peptones, and derived albumins all proteins are **changed by the action of heat.** At varying temperatures they are precipitated from their solutions and in an especially insoluble form as **coagulated proteins.** But proteoses, peptones and derived albumins are but rarely met with in ordinary food—they belong rather to the products of digestion—so we may safely say that *the great mass of protein food taken by man is made less readily digestible by cooking.* This is true of proteins whether **boiled, steamed, baked, braised,** or **fried**; and even **stewing** is rarely if ever carried out at a temperature below the coagulating point of albumins and globulins. It must not be supposed that protein food is made actually indigestible by cooking; the healthy human gastric and intestinal juices can still cope with it successfully; but, when the most readily digestible protein nutriment is necessary, then we give *meat-juice*, *raw-beef tea*, or *raw scraped* and *pounded meat*, spread into sandwiches. And it is advantageous that at all times **protein matter should not be overcooked.** To this end stewing and braising are at their best carried out at a temperature below the boiling point of water; "boiled" eggs if treated with real care are also kept below the boiling point of water, for all the proteins in egg coagulate at or under 75° C. In roasting, baking, and grilling, the heat applied *at first* is great, so that a dense, coagulated, outer layer or shell is formed; then, at a *lowered temperature*, that gradual cooking—we might almost call it internal stewing—goes on which shall make tender all the flesh bounded by this dense layer. And carefully-made beef-tea *is very lightly cooked* (cp. above).

[1] The understanding of this paragraph will be clearer if § 23 be re-read here.

(3) *Heat as an agent in depriving foods of various of their constituents.*

Loss of **water.** This takes place in all dry cooking; the "steaming" of toast as it is made, is familiar and the drying of meat and bread; and besides water which escapes into the air, we have water which helps to form gravies.

Loss of **fat.** All dripping is fat, lost to meat in process of cooking. The fat is melted by the heat, and exudes in drops, from its containing cells. In an analysis given by Church, the composition of a cooked mutton-chop with and without its own gravy and dripping are recorded, and in this it appears that 6 parts p. c. of fat are lost in cooking. The amount must vary with the nature of the meat and the thoroughness of the cooking, but the quantity of dripping which accumulates in an average household testifies to its importance.

Loss of **salts**, organic and inorganic, and of other **soluble organic bodies.** All those ingredients which we named as a gain to infusions or decoctions are a loss if we consider, not the broth, but the meat or vegetables. In fact what the *bouilli* yields to the *bouillon*, it yields at its own cost. And for the most part, we do not eat meat or vegetables which have been made to yield largely of their substance to fluid, but some loss is inevitable in the case of all boiled food[1].

Burning. When food is exposed to very great heat it is burnt, and volatile compounds, products of combustion, escape into the air. When the heat is still great but insufficient to burn completely we get *charring of organic matter.* "Burnt" toast, "burnt" crust, grilled steak that bears the "marks of the fire"; all these have lost some of the constituents of their organic compounds with partial setting free of the carbon. And short of this point, we have the formation of those brown compounds, rich in flavour, which belong to the "outside" of browned meats or vegetables. So little is known

[1] Cp. below, par. 55.

of these that we cannot say definitely that their formation is associated with loss of substance, but it is highly probable that this is so.

Loss of **ferments.** Any ferments present in food are killed by the action of heat in cooking, although their death may not be accompanied by any actual loss of substance. Tripe, sweetbreads, oysters—and with them all animals not deprived of digestive glands—contain digestive ferments when they are fresh; these are killed by cooking, and the same fate attends such vegetable ferments as diastase or the peptic ferment found in the juice of the papaw-tree (*Carica papaya*).

We see, then, that the *relation of heat to the digestion of foods is complex.* At a gentle heat, i.e. at the temperature of the human body, all the processes of human digestion go on best, and the same temperature is most favourable for making solutions (watery or saline) of meat. But while great heat (prolonged boiling or "simmering") is all a gain as regards the digestion of starch (for it makes starch digestible, or turns it to bodies still more soluble, dextrin and sugar), there are few proteins found in foods which are not made less easy of digestion by heating.

3. *The effect of cold upon the digestion of foods.*

§ 52. This is really only important inasmuch as it lowers the temperature far beneath that at which digestion goes on best. Thus, the labour of warming food which has been eaten, falls upon the digestive organs and the blood circulating within their walls. If a cream ice be taken, the ice is soon melted, but melted to a very cold fluid, and though digestion does go on slowly in the cold, it does not become energetic until the temperature is raised. It is, then, inadvisable to eat ices when full digestion holds sway, e.g. at the end of dinner; and large draughts of cold fluid—water, milk, alcohol—should not be taken with food.

4. *The effect of mixture upon the digestion of foods.*

§ 53. We can see that if, by mixing, one food is hidden away in, or coated by another, its digestion is *hindered* until such time as, by digestion, or some removal of the former, the latter is set free. It is a *help to* digestion when admixture ensures fine division. Milk and barley water are given to babies in the hope that the clot of milk formed in the stomach may be flocculent and easily digested. But the former type of mixing occurs in frying, when particles of (usually) starchy food are coated with fat; and we cannot doubt that, making a dish more nutritious, such treatment does also make it more difficult of digestion. Some difficulty in digestion is no great drawback where the food of the healthy is concerned, but fried dishes are unsuitable for invalids' diet. A mixing of foods of yet another type occurs when beef and potatoes, beans and bacon, and a thousand other dietetic combinations are eaten, and this mixing is advantageous. The earliest natural food of infant man is a mixture, and since all food eaten excites the flow of all the digestive juices, it seems that only special reasons can make it desirable not to tax them all.

5. *The effect of food preservatives upon the digestion of foods.*

§ 54. This varies with the method of preservation: sometimes a large quantity of one form of food is the preservative; this is the case with **condensed milk**, to which much sugar is added. Sometimes **salt** is in excess; sometimes the meat, fruits or vegetables are preserved by **drying**, or drying with **smoking**; sometimes by excluding the air after much heating; sometimes by the injection of **antiseptics**. There is no doubt that salting and drying render food less digestible, and that antiseptics do not form a desirable ingredient in food; the various tinned meats, vegetables and fruits, *considered solely from the point of view of their preservation*, stand in much the same relation to digestive activity as do other somewhat over-cooked foods, the cooking being that of moist heat.

In the preceding paragraphs we have attempted to group, as general statements, the most important facts established touching the relationship of cooking to digestion. We will now, as a recapitulation, treat the facts from the opposite point of view, and summarize the changes which belong to the more familiar processes of cookery.

Boiling and Steaming.

§ 55. Here, the outer layers of **protein** food are **coagulated** by contact with the boiling water or steam[1]. The inner part of the food is cooked more slowly (but still coagulated), protected from the loss of its fluid constituents by the hardened outer layers. There is a certain escape of salts and soluble organic matter into the surrounding water in boiling; in steaming this loss is minimized. *Neglect of the possibilities of steaming is one of the defects of English cookery.* The flavour of potatoes steamed in their skins, and of steamed green vegetables is excellent. Long-continued boiling forms **gelatine** in the connective (gelatiniferous) tissue of meat: and then dissolves it in the surrounding water.

Fats are melted and in part set free if boiling water surrounds the food.

Starch is burst and made **digestible**; in prolonged boiling some starch becomes dextrin.

Cellulose is softened, and partially broken down, so that it no longer forms intact cell-walls.

[1] The reference here is to the cooking of fresh meat; salted meat—already hardened by salting—is placed in cold water and heated gradually as the temperature rises to the boiling point.

Stewing and Braising.

Here the **proteins** are coagulated, **fats** are melted, **starch** grains are burst and made digestible, **gelatine** is extracted. The processes differ from boiling and steaming however, in that a gentle heat is applied throughout, and no effort is made to form any outside layer of quickly coagulated protein. Occasionally, flavour and aroma are developed by a very light frying which precedes stewing (in jugged hare, stewed rabbit, various meat stews), but this is solely for the development of flavour :- the gravy which forms in stewing is eaten with the meat, and therefore no nourishment which passes into the gravy is lost; there is no need to imprison it within the meat. In braising, distinct flavour is given to the meat by the fact that it is *steam rising through vegetables* which is the cooking agent. As meat, before it is stewed, is lightly fried, so meat, after it is braised, is crisped by dry heat; but before this happens there has been no effort to imprison the "juices" of meat.

Roasting and Baking.

These are brought about by dry heat either in the oven or before a fire; as in boiling, a crust of coagulated substance is formed on the outside, and the inner portions are stewed more slowly within this; **proteins** are coagulated, **fat** is melted and partially escapes, **gelatine** is formed, and alsc partially escapes. And there is, further, a surface change which we call "browning," which carried far enough is "burning." This produces savoury but probably indigestible compounds from the meats, sweets, and vegetables concerned; and makes food cooked in this way more appetizing, but, on other grounds, less suitable for weak digestions. **Starch** is made soluble by roasting and baking and is partly turned to dextrin.

Grilling and Broiling.

These are practically the same process, and are closely related to roasting. The formation of the outer coagulated shell is more complete, the escape of "gravy" is minimized,—for the heat applied is fierce, and the pieces of food to be cooked (usually fish or meat) are relatively small, and therefore easily penetrated by heat.

Making of Soups and Broths.

We may say that this is the converse of boiling; in boiling meat, we seek to prevent the escape of its constituents into the surrounding water; in making soup or "stock" we seek to get as much as possible out of the meat or vegetables and into the fluid. Thus the meat and vegetables are cut into small pieces, are placed in cold water (usually with salt), and are slowly brought to the boil. This is in order that a warm, saline extract (which dissolves all that water dissolves and more besides) may be formed, that as much as possible may be dissolved of the various proteins before their coagulation point is reached. When this is reached they are precipitated it is true, but precipitated in small fragments[1] in the soup and not coagulated *in situ* in the meat. This coagulation is inevitable if any starch present is to be cooked, and if vegetable cell-walls are to be softened and disintegrated, and the long-continued boiling or simmering which does this, also carries on the extraction of gelatine.

[1] It is noticeable that in clear soup all these proteid particles are deliberately removed by "clearing"; only salts, soluble organic substances, flavouring and an insignificant amount of gelatine remain; of all soups, it is the least nourishing.

Fluids that "jelly" have always been subjected to long cooking, and rarely contain protein food.

In a *purée*, more than the liquid extract is present; the liquid is thick with suspended particles—the solids of the soup rubbed through a sieve.

B.

2. We will turn now to the second of the main divisions of the chapter, and consider the relation of the cooking of food to the physiological side of digestion, asking, *How does the cooking, or other preparation of food affect the flow of the digestive juices?*

§ 56. Food is the most powerful agent in calling forth a flow of digestive secretion; the sight, smell, or thought of food often makes the saliva flow abundantly—the "mouth waters"; the chewing of savoury food calls forth not only saliva but gastric juice, and that before any food has been swallowed; the entrance of food into the stomach arouses a flow not only of gastric juice but of pancreatic juice, although the pancreatic juice acts in and belongs to the intestine and not to the stomach. In fact the living constituents—the cells—of all the digestive glands are governed by the nervous system; they pour forth their secretion as a result of impulses travelling along nerves. But if we recall for a moment such a nervous impulse as that which makes a striated muscle contract, we remember that it may be started *directly*, as by electrical excitation of the nerve (motor) going to the muscle; or *reflexly*, as when some nerve going to the brain from an appropriate sensitive surface (say the retina) is disturbed. The disturbance of such a "sensory" nerve sets up action in the central nervous system (brain, spinal cord), one result of which is a further disturbance set up in the particular "motor" nerve we are considering (say the nerve to the eyelid), a disturbance which travels down the nerve and makes the attached muscle contract,—as in winking. In a similar way the nerves which bring about, not movement of muscles but **secretion by glands**, may be excited directly but are also called into action **reflexly**. And it is this reflex action that the taste, smell, or sight of food brings about; nervous impulses or disturbances started in the mouth, in the nose, in the eyes, travel up to the central nervous system and then start other nervous impulses which travel down to the digestive organs and rouse the secreting cells. These cells are further and similarly roused when food is actually in that part of the alimentary canal to which they belong, and digestible food is more effective—more powerful—as a disturbance, than substance that cannot be digested.

These facts are of importance because they may be made the text of a sermon upon dainty, well-finished, and appetizing cookery. We cannot doubt that food which is pleasant to the sight, to smell and to the taste is a stronger indirect excitant of all the nerves which can bring about flow of digestive fluids than is raw or ill-dressed food. Of course the term "appetizing" has no absolute meaning for all men and all times; the food that is eaten with relish by the Patagonians and the Esquimaux could not be set upon an English dinner-table; but its meaning for our own race and day needs little explanation. It is to produce this quality that frying, grilling, roasting are used so widely; there is no doubt that raw protein food, minced, or extracted, would be the most digestible form of protein food[1]; that fats—to this end—should be warmed and emulsified; that starches should be cooked by thorough boiling. But we sacrifice something of digestibility to the pleasures of the palate, and this, within limits, rightly, so long as we deal with digestion that is not

[1] Raw meat is digestible, but dangerous unless it is chosen with care; it may contain disease-producing bacteria and other noxious parasites.

specially weakened. That pleasurable sensations of smell and taste should lead to a generous outpouring of digestive secretions is more important than that all food should be submitted to the action of those secretions in its most digestible form. It is no hardship for the healthy to deal with food that is somewhat hard of digestion, and even insoluble residues are valuable up to a certain point, in aiding the wave-like peristaltic movements of the intestines[1].

With the food of the very young, the very old, and the sick, the case is different; we deal with digestion by cells which have not yet grown strong, or, having been strong, are now weakened. Hence that they should be provided with food which can be readily absorbed, is of high importance. But in order that its work may be well done, attractiveness is not to be neglected. Indeed the preparation of this food demands *especial* care; for the admissible means of attraction are more limited; "lumpiness" in a cup of gruel or arrowroot is as disastrous from a physiological as from an aesthetic point of view. We remember that not only is secretion of the digestive fluids under nervous control, but there is a nervous machinery which brings about **vomiting**; and distasteful food, promptly rejected, can have little chance of nourishing.

The words just written refer more especially to changes in texture, flavour, &c., which cooking and dressing produce in the foods themselves. And they may be extended in part to the use of **flavourings** and **condiments.** These are used with care and reserve in nursery and sick room cookery, and in certain special cases their use is to be regretted even where food for the adult is concerned. Thus, to eat vinegar with starchy food, is to strike a blow at such digestive power as the saliva possesses, and the inordinate use of pickles and other irritating condiments inflames the mucous membrane (the internal surface) of the stomach and bowel.

The intelligent eater, however, does not prize such excess,

[1] See above, § 28.

but rather that delicate touch of flavour which is given by the restrained use of condiments and flavourings. The best curries are not exceedingly hot; we should be conscious, but not more than conscious, of the presence of cloves and of lemon, of vanilla and of tarragon in their appropriate places: that flavouring of a sauce is most successful which, "half suspected, animates the whole."

§ 57. We may perhaps illustrate these general statements by brief examination and comparison of a day's diet suitable for convalescence, and a carefully chosen dinner suitable for the healthy. The menu for dinner is one taken from Sir Henry Thompson's work on *Food and Feeding.*

Diet for convalescent who is ordered to take light food.

8 A.M.	Cup of café au lait *or* cup of freshly infused tea.
	Toast, toasted slowly and thoroughly. Buttered when cold.
10.30 A.M.	Beef tea, cooked lightly; fingers of dry toast.
1.30 P.M.	Fillets of plaice *or* sole, steamed. Bread and butter (not new bread).
	Sago pudding *or* baked apple.
5 P.M.	Freshly infused tea.
	Toast *or* biscuits.
8 P.M.	Oatmeal gruel with milk *or* Bread and milk.

What points are characteristic in such a scheme of diet?

We notice in the first place that the quantities are small. The convalescent is doing no active work; his digestive glands are probably acting feebly: we do not, then, tax them severely at any one moment; but, on the other hand, the intervals between meals are shorter than is advisable in health.

In the second place the food is very simply prepared and in such fashion that easy digestion is aimed at; all the foodstuffs are present, but fats are used with care. One meal—luncheon—has a fluid for its main feature, and this if cooked lightly will contain extractives and salts in solution and finely precipitated proteid in suspension. In the sago pudding the yolk and white of egg are separated and the white, beaten in at the last moment before cooking, gives porosity to the whole mass. Moreover the sago is "fine" sago and cooked thoroughly. It is fine oatmeal also that is used for the gruel, and of this only the finest part; all the coarse particles are allowed to "settle" before cooking; and gruel at its best is a bland, almost gelatinous liquid, faintly flavoured with sugar, lemon, or, if it be permitted, butter. In the baked apple the cellulose cell-walls are thoroughly softened and much broken; valuable organic salts are present (for little is lost in baking) and the flavour is delicate and distinctive. The toast is thin and thoroughly cooked, so that no soft spongy indigestible central layers remain; and there is change to dextrin in the external layers.

Thirdly, the tea is freshly infused; it is long stewing of the tea which gives it the constituents most harmful to digestion; tea which has infused only for two minutes is as refreshing and stimulating as the tannin-laden product of a day's "stewing." The nutritive value of café au lait is considerable, thanks to the milk it contains, and probably the coffee diluted by milk is less potent as a nerve stimulant than if taken strong, and black.

Menu of Dinner.

Soup.	Paysanne.
Fish.	Fillets of turbot à la ravigote.
Remove.	Braised veal and macédoine of vegetables.
Entrée.	Scalloped oysters.
Roast.	Wild duck.
Entremets.	Stewed celery in gravy.
	Apricots with rice.
Savoury.	Caviare.

We notice first that a clear soup introduces the dinner. Now a soup, cleared by modern methods, is exceedingly poor in nourishment; but it is pleasant to the eye and palate, and slightly stimulating. Useless as a meal alone, therefore, it is a fitting introduction to an abundant dinner.

In the second place we see that hardly any article of food in this menu is prepared without dressing or accompaniment; only the wild duck stands alone, complete in itself. That oysters should be served in any way but *au naturel* may be regretted by some diners, and there is undoubtedly a loss of digestibility in cooking: but on the other hand cooked oysters are less dangerous as a source of bacterial infection. The dressing of the veal is all a gain; veal is the somewhat indigestible flesh of an immature animal, less full-flavoured than mature meats; and the slow cooking, in fragrant vapours from vegetables, is a happy treatment. The final crisping by "top-heat" probably lessens digestibility, but is certainly welcome to the palate.

Thirdly, we see that the amount of food offered is large; such a meal, taken in its entirety, should follow a long period (say five hours) of abstinence from food, a period which also includes some form of activity. The menu is, however, a thoroughly good one of its kind; there is hardly a dish in it (with the exception of the veal and the almost negligible caviare) which might not be offered singly to a convalescent somewhat more advanced than the invalid we have imagined above. There is change of "colour" in the dishes, there is variation of flavour; the excellence of the simple *roast* is allowed its full effect; the *entremets* are simple.

CHAPTER IX.

Clothing.

§ 58. To deal with *clothing as an adornment*, demands an excursion into the domain of aesthetics which would be out of place here. We will therefore consider clothing only from *the point of view of utility.*

In this consideration we will divide the subject into two main sections, but it must be remembered that the division is purely arbitrary and made only for convenience of discussion.

The first section (A) deals with the *mechanical effects of clothing;* the second section (B) with its *physiological effects.* In one sense, indeed, the mechanical effects are physiological also, for they are only important to us in as far as they help or hinder physiological processes; but in the sense in which we shall take the words, the distinction is just, for the physiological effects, grouped together in *section B*, are direct; whereas the effects described in *section A* are mechanical directly, and indirectly, physiological.

A. The mechanical effects of clothing.

§ 59. We distinguish here the effects of **weight** and of **pressure**, and we may note, in passing, that these effects are largely independent of the nature of the materials of which clothes are made. A very tight garter may be made of silk, of wool, of cotton, or of leather: so far as the pressure it exerts is concerned, the effects are the same in each case. A gown may carry many pounds' weight of jet, or it may be weighted round its edge with lead: a slight difference in mechanical effect is produced, because, in the former case, the weight is more evenly distributed; but this difference is unimportant compared with the total effect in each case.

Effects of pressure.

§ 60. **Pressure** is exerted by all clothing that binds or confines. We ought strictly then, to speak of all "fitting" clothes. But for practical purposes we need only speak of clothes which sometimes exert excessive pressure,—of garters, collars, belts, boots, stays,—and with the last-named we may count such a garment as a tight and heavily whaleboned bodice. How do these garments act? In the first place, when organs can be displaced, the pressure displaces them. There is probably hardly an adult foot in England among the "well-shod" which shows the great toe and the second toe in the relative positions in which they stand on the foot of a healthy baby; in a baby the great toe is almost "opposable," that is, it can almost be used as a thumb is used, but after long practice of the habits of civilized life this power is lost, and the use of boots, which are so unlike the foot in shape, often crushes together the first and second toes. The organs in the abdomen, and to a less degree those in the chest, can also be displaced; so it comes about that, when tight waist-belts or stays are constantly worn, the diaphragm has not its right play, the lungs are pressed upwards, expand feebly themselves, and probably impede the heart; the liver, stomach, and bowel do not have their natural relations[1].

[1] In a somewhat different way, unnatural pressure is set up by the use of *high heels to boots*. This pressure alters the range of action of the striated muscles of the foot and leg, and upsets the healthy balance or

In the second place, *pressure has very important action upon the blood-vessels of the body.* We remember that the **heart** does hard work; that it drives the blood through the **arteries,** through the minute **capillaries** (which offer great resistance to the flow), through the widening **veins,** back to itself,—for the circulation is a closed circuit.

We remember too that the arteries, even down to their small branches, the **arterioles,** are highly muscular, that they grow narrow and widen through the contraction and relaxation of the unstriped muscles in their walls. Now the proper circulation of the blood depends on the one hand upon efficient action of the heart, and on the other hand upon the healthy condition and efficient action of the walls of the blood-vessels. In the healthy condition, and with a good heart-beat, the **capillaries** allow interchange between the blood within their delicate walls and the tissues outside, and one important outcome of this interchange is the formation of lymph. Lymph is the fluid which moistens all the cells of the body, and is at once the medium by which they are supplied with food, and drained of waste matters. The healthy **arteries** are delicately responsive to the needs of that part of the body in which they run; and under the stimulus of nerves, they narrow or widen according as a scanty or abundant blood-supply is desirable for the moment. Moreover by means of the nerves which run to and fro between themselves and the central nervous system, there is ready interaction among all the arteries of the body: so that (for example) events taking place in the brain may affect the condition of the small arteries in the intestine. The healthy **veins** play a more passive part; they can shrink and expand slightly, and so accommodate themselves to varying quantities of blood, but they are to be looked upon primarily

relation between various muscles of the abdomen and the back, and secondarily, by the consequent unnatural attitude of the back and muscular strain, may affect the nervous system generally, and even the sight.

as channels by which the blood can return freely to the heart; it is of the **first importance** that they should be patent or open tubes, i.e. that this return of the blood should be easy and complete.

Now of these blood-vessels, the arteries are probably the least affected by external pressure; they do not generally run near the surface of the body, and their walls are made stout by the presence of muscular and elastic fibres. The capillaries are pressed upon when the organs in which they run are compressed, but it is the **veins**—thin-walled, and lying comparatively near the surface—which are the first to feel pressure from the outside.

When *tight boots* or *tight gloves* are worn, capillaries of the hand or foot are narrowed, for the tissues in which they run are compressed. Cold hands and cold feet are the result of this, for it is abundant and vigorous blood-supply which gives us the feeling of warmth.

When the pressure is on a narrower zone, i.e. when we have a *high*, *tight collar*, or a *tight garter*, it is more especially the veins that are touched; swollen feet (following on excessive lymph-formation, due to obstructed venous outflow), varicose veins, and again, coldness of the extremities; these are some of the penalties paid.

Pressure round the *waist* or upon the *abdomen* needs especial note; excessive pressure is, of course, bad; the blood-supply of the important abdominal organs is diminished, their nutrition is affected; digestion, kidney activity, and other physiological activities slacken. But slight pressure does aid in the emptying of the great abdominal veins; it aids the venous blood-flow to the heart, it is said even to increase the heart's output. Must we then accept or even urge the use of waist-belts and stays? For the healthy human being—**No.** If we apply such pressure, we apply a pressure which, at the best, does not vary delicately. The muscular walls of the abdomen have always, in health, that partial contraction which is known as **muscular tone**; and this can be increased or lessened with every change of posture, with all variations of exertion, or rest. To place these muscles within some rigid support is to weaken them; but, on the other hand, to make demands on them, from childhood upwards, for unsupported activity, is to harden and strengthen them, together with all the muscles of the body. By means of nerves they are in intimate relation with the central nervous system, and so, potentially, with all parts of the body; they are able to respond through nerves to varied nervous impulses[1]. But no waist-belts or stays can be thus responsive reflexly; they can only be roughly adjusted from time to time. There is no doubt, however, that if tight lacing has been a cause of death to some, others—far more numerous—literally *strait-laced*, have lived to be old. There is no doubt too that thousands to whom this term cannot be applied, wear moderately tight stays and belts with no clear injury to health. But then there are thousands of human beings who hardly know what full physiological life is, whose muscles, nerves, glands, and lungs are habitually sluggish in action, and even moderate constriction of the waist, while not clearly injurious to health, slackens the vigour of the abdominal muscles. There is abundant evidence that artificial support of the abdomen and compression of the waist are of great use when special weakness exists; we would urge that this support should be kept in reserve for special need, and not be looked upon as part of the regular outfit of young and healthy women.

Effects of weight.

§ 61. **Weight**, in itself, is to be looked on merely as a special encumbrance. Let us suppose that a man of 14 stone weight, walks 20 miles. He does a great deal of muscular work in that walk, and the most important item is that,

[1] See above, Introduction.

step by step, he lifts 14 stone. Now, if he wears clothing which weighs 14 lbs. the amount he lifts is 15 st. at each step. If the extra weight is well distributed it is not so much noticed as if it were represented by a lump of iron carried in the hand, for in this case certain muscles are specially and greatly fatigued. Still the encumbrance is there, and we all know the rapid fatigue which follows physical exertion taken in heavy clothes. And two drawbacks, even more serious, attend upon weight in dress. The first is the pressure set up by *unevenly distributed weight.* This belongs most perhaps to heavy skirts, which often drag upon the waist and hips. The second is *volume.* Voluminous sleeves, and voluminous skirts are both sources of inconvenience, but, when the volume of a skirt takes the form of excessive length, then (for walking) it is an unmitigated evil. We may say that **real cleanliness is incompatible with the use of long walking skirts.** Even when such skirts are lifted with care, there are, almost certainly, moments in which they fall to the ground, and the practice of allowing them to trail along a street or road is **absolutely indefensible.** We have urged elsewhere (§ 11) that the surface of the earth is covered with dust, dust of mingled and often harmful nature. Among this dust in every large town are **bacteria** of most varied powers—often disease-producing—and light fragments of **dried excreta** of man and of other animals—healthy and unhealthy. The trailing skirt whirls this filthy dust into the air, to be breathed not only by the wearer, but by defenceless passers-by. It is also carried home clinging to the skirt, scattered into the air there by "brushing the dress," and probably brought into contact with other clothes. We can hardly picture the end of the disasters that may follow. *Garments which trail in the streets should certainly be counted among the carriers of disease.*

§ 62. To inveigh against the use of trailing skirts may seem absurd at a time when fashionable gowns clear the ankles. But we are concerned, not with the style of the moment, but with the points that are faulty or admirable in all dress.

The demands of fashion vary irrationally. When the first edition of this book was published, long skirts were often seen in the streets, and very high heels were uncommon in England; to-day the hem of the skirt may be 6 inches above the ground, but the reappearance of high, slender heels spoils the gait of some smartly dressed women. Fashion, as we have said, is irrational; and equally irrational are her devotees. The point which is cheering to the observer of modern women's dress is the greater predominance of clothes suitable for special activity; and the increasing tendency—at least among thoughtful women and in face of the gravity of our national life to-day—to subordinate fashion to other interests.

B. The physiological effects of clothing.

§ 63. In considering these effects we have to deal equally with the dress of women and men. Moreover the material of which the clothing is made is of greater importance than its arrangement. For the great physiological effect of clothing is the checking of loss from the surface of the body, and different materials act very differently in this direction[1].

Now the loss from the surface of the body is in the first place a loss of **heat**, and in the second place a loss of **substance**. And the substance lost is varied in nature;

[1] See above, § 12.

it is, firstly, that complex fluid to which the name of *sweat* or perspiration has been given—water holding in solution inorganic and organic salts—; secondly, *fatty matter* from the sebaceous glands; thirdly, *epidermal scales*, that is, fragments of skin, rubbed off from the surface.

Let us examine these processes a little more nearly.

Loss of heat. We know that the temperature of a healthy warm-blooded animal is approximately constant. Heat is generated by metabolism, that is to say by the sum of the chemical changes in the living body. Heat is lost by warming food and the egesta, by warming the air expired from the lungs, but *mainly from the skin.* The loss from the skin is a loss by evaporation, by radiation, and by conduction. Thus there are in the body two great antagonistic regions, a *warming internal region* and a *cooling skin area*, and the blood gains heat in the one, loses it in the other, and, by means of nerves, is directed now to the one region, now to the other, as the needs of the body demand. We at once recall illustrations of this. If the surrounding air is very cold the blood is withdrawn from the skin (in obedience to nervous impulse) and circulates chiefly through the warming internal parts (muscles, glands, &c.); on the other hand, if great muscular exercise be taken and the production of heat by metabolism be increased, the vessels of the skin dilate, blood passes freely through the cooling area which they form and so there is compensating loss of heat. Now, a relatively bloodless skin gives us the sensation of cold; when the skin is flushed we "feel hot"; it must be remembered then the sensation of cold arises when loss of heat is really being lessened, while the sensation of warmth arises when the loss of heat from the skin is great.

Loss of substance. The substance which is lost from the skin is waste matter. The epithelium scales are the remnants of what were once living cells of the skin; the fatty matter of the sebum has been used as lubricant for the hairs and the surface of the body generally; the sweat carries off waste matter which springs from chemical changes in the tissues. The amount of sweat excreted varies greatly; with severe exercise or in hot dry air the glands pour forth sweat which may amount to many litres in the course of the day[1].

We have said that **clothing checks loss from the skin**; is this action advantageous or disadvantageous?

In certain conditions the checking of *loss of heat* is a great gain. The chilling effect of very cold air upon the skin would be dangerous to the naked human being[2]. However great the withdrawal of blood to the great internal heating region, it would not be sufficiently warmed *in ordinary metabolism* to prevent serious disturbance of health. In the case of many warm-blooded animals, fur or feathers protect from such disaster; man protects himself in cold climates by garments which prevent loss of heat

(*a*) by their own thickness,

(*b*) by their low conducting properties,

(*c*) by the fact that they enclose strata of fairly warm air, which air is more or less stationary.

When metabolism is greatly increased, the need for clothing is less: thus the crew of a racing boat are quite warm when they are "rowing a course" in winter, although their clothing is scanty. Conversely, when metabolism is more than usually quiet, and the temperature surrounding the body is low (as in sleigh-driving), abundant, fur-lined garments are not too warm. It is almost always disadvantageous to check the *loss of substance* from the skin. The epithelium scales are dead; others are ready to replace them; the sebum and sweat are, as we have said, waste matters. The complete removal of all these effete matters is the ideal here; thus, to wear clothes is to depart from the ideal.

[1] Insensible perspiration through the cuticle is always going on: in temperate climates, under normal circumstances, about 700 c.c. of water are got rid of in this way daily through the skin.

[2] Certain races, however, go unclothed even in a severe climate. We hear of the Patagonians sleeping naked upon the snow.

The physiological effects of clothing, then, are mixed: there are, doubtless, climates in which, if these effects only were considered, all clothing would be rejected; in the climate of England and with modern habits of life this is impossible, but the choice of clothing may be such that the physiological gain may be as high as possible, the physiological loss as low as possible. Let us recapitulate the conditions which we should endeavour to satisfy:

As to the form of clothing:

(*a*) Pressure should be avoided.
(*b*) Weight should be avoided.
(*c*) Contact with the earth should be avoided.

As to the substance of clothing:

(*a*) The body should be shielded from direct contact with great changes of external temperature; to this end material which conducts heat badly should be chosen.

(*b*) Clothing should, as far as possible, permit the free passage of water and excreted matter from the skin, so that evaporation is checked as little as may be.

§ 64. What materials, shaped in what form, will meet these needs? Any garment that is loose (but not shapeless), light, and hung from the shoulders, is good in form, provided that (if for out-door use) it does not touch the ground, or hinder locomotion. And this is widely recognized: the suspension from the shoulders may be direct, as in the case of the *combination*, or the *Princess dress*, or indirect, as when a skirt is hung on to its bodice, or trousers upon braces. An unconscious acknowledgment of the value of looseness in dress is found in the lasting popularity of *blouses*, and in the shape and fit of all "flannels" and "blazers." Suitable skirts have long been used for hockey, for shooting and bicycling, and the use of tunic and leggings for climbing or professional gardening is now generally accepted.

We may consider the **materials** of clothing first as regards their *warmth-preserving properties*, and we may first recall the fact that these materials are both animal and vegetable in origin; wool, silk, leather, kid, feathers, fur, are derived from animals and are nitrogenous; cotton and linen are made from non-nitrogenous vegetable fibre, really from cell-walls. The constituent threads of wool are really hairs and have rough irregular surfaces; the threads of silk, of cotton, and of linen are variously shaped but of smooth outline; they always lie distinctly, in the fabric which they compose, whereas threads of wool may be milled to form a hardly distinguishable mass. Of these materials, fur and feathers take the first place as warmth-preservers; next come the various woollens, the softer "wools" probably coming before the harder worsteds; then the silks, then cottons (with muslin), and linens (with cambrics). Cottons and linens are poor warmth-preservers, but their powers may be heightened by suitable treatment. Both cotton thread and linen thread are manufactured into those fabrics which are now widely known as *cellular*. The manufacturers of these fabrics claim that by the tiny depressions or pits in which the cloth is woven, a mechanical arrangement is made which imprisons a layer of almost stationary warm air next the body; and there can be no doubt that, from the point of view of sensation, the cellular cloth is much less chilling than plain linen or cotton cloth.

When we turn to consider the *permeability* of materials we must place the woollen fabrics first. Doubtless they differ among themselves, but they are all more permeable than silk, cotton, or linen. Among the cottons and linens, the cellular cloths must be counted as exceptionally permeable, as we have just seen they are (for cotton and linen respectively) exceptionally warm. Fur and feathers (which head the list when warmth is the property considered) are not permeable forms of clothing; for they are mounted on dead skin, and that has been subjected to a form of tanning. Now tanning makes the skin durable, and pliable, but relatively impervious, so that all skins—whether still bearing hair, or made into leather or kid—do not allow free escape of water and dissolved substances from the body of the wearer. Probably only one article of clothing is less permeable than they—namely mackintosh (and with this oilskin may be included)—and this allows so little escape of skin-excreta that it is highly insanitary for anything beyond a narrowly limited use, and its properties as a warmth-preserver are rightly disregarded.

§ 65. It would seem then, that, when the utility of clothing is considered, the woollen materials stand easily first in advantage. They may be light in weight, they are poor conductors of heat, they are readily permeable; thus, while retaining heat, they do not check excretion. There is however one great drawback attending upon the use of wool. It forms fabrics which shrink readily; they must always be washed with great care, and they **cannot be boiled** without lasting damage. Therefore woollen garments may be a serious source of infection. If they come in contact with disease-producing bacteria it is very difficult to free them from these. Special methods of disinfection there are, but the safe and ready method of sterilizing by boiling cannot be used; and the practice of wearing cotton dresses for nursing is hygienically sound.

Even for the healthy we are not prepared to urge the constant use of loose, light, short, woollen garments, varying in number with the time of year. Man is a creature of a hundred occupations; and clothing, which might be suicidal in one occupation, is fitting or even ornamental in another. In fact, in suiting the dress to the occupation, lies the secret of really rational clothing. The secret is learnt in part, but as yet only in part, and perhaps more nearly by men than by women. A man's dress, even when formal, is cleanly and his garments are not voluminous. Roughly speaking it is arranged in layers, so that body and limbs are clothed. The hard, impenetrable hat and high collar do not hinder quick walking and allow a good deal of free action, and the conventions which demand these unhygienic items of dress are relaxed as the years pass. There is hardly an Englishman who would climb, or row, or play cricket, except in "flannels," or woollen clothes of some sort; but we may criticize the universal fashion of dancing in the regulation "dress" shirt.

As we have said above, the dress of women has grown less faulty of recent years. We have only to recall the multiplied skirts, rigid stays, and "single-sole" shoe of early Victorian days to realize how women have gained in comfort and freedom. Increased physical activity has become part of the life of girls and the effort to be active in unsuitable dress has ended in the evolution of suitable garments. The general use of woollen combinations—often high-necked and long-sleeved, the adoption of stocking suspenders instead of garters, the use of knickerbockers instead of underskirts—these changes are reforms, they show dress fitted to occupation. And it is this sort of reform which we would urge. There can be little harm in allowing a dinner dress to trail over well-kept carpets, and it is all a gain that its lines should be guided by long petticoats, frilled or shaped; there can be little harm that a man should dine in a somewhat chilly and impervious shirt front. Excessive changes of outside temperature are suspended at these times; the metabolism of the skin, too, is not active. But to undertake physical exertion in these clothes would be a physiological as well as an aesthetic sin.

Rest.

In the foregoing pages an attempt has been made to state simply certain facts of the physical sciences which may be a guide in "The ordering of a House which is a Home." In the Introduction (Chapter I) we have tried to indicate that Man—for whom the home is shaped—is, in his physical life, a complex machine ceaselessly affecting, and affected by the air, the water, and the food, with which he is supplied. A last word may fittingly emphasize this close connection, especially as it should be realized by those who study and those who teach Domestic Economy. For in regarding man as a machine we must never forget that he is unlike a machine of the workshop in this,—that the making and renewal of his various parts depend upon their own activity. Further, all parts are interdependent: they are bound together for nourishment and defence by the network of the vascular system; they are, wonderfully, connected and controlled by the nervous tissues.

An intelligent grasp of these facts has practical value in the ordering of a Home. Our physical ideal is perfect health—inevitably shattered by death, but menaced with a hundred antecedent risks from land, and water, and air. It is in the power of the housewife to lessen these risks by caring for cleanliness of the person, cleanliness of the home, and cleanliness and quality of food and drink. And there is yet another means of defence, powerful, yet often neglected: this is **rest**. To rest the body is to allow that repair of its parts which those parts alone can effect; it is to bring back the organism towards the ideal of perfect health,—and to make ready for activities which must follow. So far is this realized in modern medical treatment that, when the body is actually fighting disease, reliance is increasingly placed upon its own powers rather than upon drugs. To this end, the food given to patients in a sanatorium is ample, and its nutritive value is high; to this end, strict recumbent rest before meals is a feature of the daily routine and, in the opinion of some, the most important feature.

It is the physiological principle underlying this treatment which is of importance in the home. Sleep is the natural restorative, the condition in which expenditure of energy is at its lowest and repair is least impeded; but it will be granted that for the enfeebled, the aged and the very young the night's sleep should be re-inforced by daily rest. What we are concerned to urge is that all workers would gain from rest taken before the chief meals of the day, and that there is magic in this rest, for the harassed and overworked. We are accustomed to teach that only by careful eating and thorough chewing can food yield us its maximum of good, but perhaps it is of greater importance that the stomach should be ready for its task of digestion. Wearied and irritable nerves can hardly guide aright the digestion and absorption of a meal: pain, flatulence, disturbed heart's action—in extreme cases, vomiting—are ills which attend abuse of the machinery of digestion. Rest after meals, a familiar prescription of earlier years, has its value, but can never *prepare the stomach* for work; there can be no doubt that if one daily rest only can be taken, it should be taken *before the chief meal of the day*. Digestion, as we have said, is a complex series of chemical processes, governed by the nervous tissues of the body: that the nerves may act delicately and steadily they must be well nourished; that they (with all other parts of the body) may be well nourished, the digestion and absorption of food must be vigorous and complete. By good nourishment and by good digestion is established that *margin of resistance*, which carries us unhurt through infection and unusual fatigue; by them our mental state is steadied. For the mental states of man are inseparable from his physiological condition, and there can be little doubt that, if we could raise the level of physical health in England, we should lessen greatly the suffering due to drunkenness, crime and ennui.

To be free minded and cheerfully disposed at hours of Meat, and of Sleep, and of Exercise, is one of the best precepts of long lasting.—BACON.

INDEX

CAMBRIDGE: PRINTED BY J. B. PEACE, M.A., AT THE UNIVERSITY PRESS

Arnold of Rugby. His School Life and Contributions to Education. Edited by J. J. FINDLAY, M.A. With an Introduction by the Lord Bishop of Hereford. Crown 8vo. 5*s.*

Educational Aims and Methods. Lectures and Addresses by Sir JOSHUA G. FITCH, M.A., LL.D. Crown 8vo. 5*s.*

Lectures on Teaching, delivered in the University of Cambridge during the Lent Term, 1880. By Sir JOSHUA G. FITCH, M.A., LL.D. Crown 8vo. 5*s.*

Know Your Own Mind. A Little Book of Practical Psychology. By W. GLOVER. Fcap 8vo. 2*s.* net.

Studies in French Education from Rabelais to Rousseau. By GERALDINE HODGSON, B.A. Crown 8vo. 3*s.* 6*d.* net.

A Manual of School Hygiene. Written for the guidance of Teachers in Day-schools by EDWARD W. HOPE, M.D., EDGAR A. BROWNE, F.R.C.S.E., and C. S. SHERRINGTON, M.D., F.R.S. Crown 8vo. With several diagrams. 4*s.* 6*d.*

Scientific Method in Schools. A Suggestion. By W. H. S. JONES, M.A. Crown 8vo. 1*s.* net.

How We Learn. A Short Primer of Scientific Method for Boys. By W. H. S. JONES, M.A. Crown 8vo. 1*s.* 6*d.*

Scottish Education, School and University, from early times to 1908. By JOHN KERR, M.A., LL.D. Demy 8vo. Re-issue with an addendum 1908—1913. 4*s.* 6*d.* net.

John Amos Comenius, Bishop of the Moravians. His Life and Educational Works, by S. S. LAURIE, A.M., LL.D. Sixth edition. Extra fcap. 8vo. 3*s.* 6*d.* Pitt Press Series.

Studies in the History of Educational Opinion from the Renaissance. By S. S. LAURIE, A.M., LL.D. Crown 8vo. 6*s.*

The Training of Teachers and Methods of Instruction. Selected Papers. By S. S. LAURIE, A.M., LL.D. Crown 8vo. 6*s.*

Educational Charters and Documents 598 to 1909. By ARTHUR F. LEACH. Crown 8vo. 10*s.* net.

Some Thoughts concerning Education, by John Locke. With Introduction and Notes, by the Rev. R. H. QUICK, M.A. Extra fcap. 8vo. 3*s.* 6*d.* Pitt Press Series.

The Making of Character: some Educational Aspects of Ethics. By JOHN MACCUNN, M.A., LL.D. Crown 8vo. Sixth impression. Revised, with three new chapters. 2*s.* 6*d.* net.

The Principles of Intellectual Education. By F. H. MATTHEWS, M.A. Crown 8vo. 2*s.* 6*d.* net.

Milton's Tractate on Education. A facsimile reprint from the Edition of 1673. Edited, with an Introduction and Notes, by OSCAR BROWNING, M.A. Extra fcap. 8vo. 2*s.* Pitt Press Series.

State Intervention in English Education. A Short History from the Earliest Times down to 1833. By J. E. G. de Montmorency, B.A., LL.B. Crown 8vo. 5*s.* net.

An Introduction to Experimental Psychology. By C. S. Myers, M.D., Sc.D. With 22 illustrations. Royal 16mo. Cloth, 1*s.* 3*d.* net; leather, 2*s.* 6*d.* net. Cambridge Manuals of Science and Literature.

Dissenting Academies in England. Their Rise and Progress and their Place among the Educational Systems of the Country. By Irene Parker, M.A. Crown 8vo. 4*s.* net.

The Purpose of Education. An Examination of the Education Problem in the Light of Recent Psychological Research. By St George Lane Fox Pitt. Second edition, with Preface by Prof. Émile Boutroux. Crown 8vo. 2*s.* 6*d.* net.

Plato. The Education of the Young, in the *Republic* of Plato. Translated into English, with Notes and Introduction, by Bernard Bosanquet, M.A., LL.D. Crown 8vo. 2*s.* 6*d.*

Life in the Medieval University. By R. S. Rait, M.A. Royal 16mo. Cloth, 1*s.* 3*d.* net; leather, 2*s.* 6*d.* net. Cambridge Manuals of Science and Literature.

The Psychology of the Organized Group Game, with special reference to its place in the Play System and its educational value. By Mabel Jane Reaney. Royal 8vo. 5*s.* net.

The Teaching of Geography in Switzerland and North Italy. Being the Report presented to the Court of the University of Wales on a Visit to Switzerland and North Italy in 1898, as Gilchrist Travelling Student, by Joan B. Reynolds, B.A. Crown 8vo. 2*s.* 6*d.*

Voice-Training for Choirs and Schools. By C. B. Rootham, M.A., Mus.D. Fcap. 4to. With 83 Exercises. 4*s.* net. The Exercises are also published separately. 1*s.* 6*d.* net.

On Stimulus. A Lecture by A. Sidgwick, M.A. Extra fcap. 8vo. 1*s.* Pitt Press Series.

The Moral Life and Moral Worth. By Prof. W. R. Sorley, Litt.D., F.B.A. Royal 16mo. Cloth, 1*s.* 3*d.* net.; leather 2*s.* 6*d.* net. Cambridge Manuals of Science and Literature.

Chapters on the Aims and Practice of Teaching. Edited by Frederic Spencer, M.A., Phil.Doc. Crown 8vo. 6*s.*

Theory and Practice of Teaching. By the Rev. Edward Thring, M.A. Extra fcap. 8vo. 4*s.* 6*d.*

A Course of Lectures on the Growth and Means of Training the Mental Faculty. Delivered in the University of Cambridge. By Francis Warner, M.D., F.R.C.P., etc. Crown 8vo. 2*s.* 6*d.*

The English Grammar Schools to 1660: their Curriculum and Practice. By Foster Watson, D.Lit. Crown 8vo. 6*s.* net.