RALPH'S SCIENCE NOTE-BOOKS.

ELEMENTARY HYGIENE.

(Sections I. & II.)

RALPH, HOLLAND & Co.

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ELEMENTARY HYGIENE.

(SECTION I.)

BY J. H. NANCARROW,

Author of "Elementary Physiography," "Advanced Physiography," etc., etc.

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CONTENTS.

PREFACE.

THIS book is not intended to take the place of a text-book. Nor does it pretend to fill that of the teacher, or to enable students to prepare for examination without the practical work which is indispensable in this subject. It is what its name implies—a note-book. The Author has attempted to deal briefly with such points in the Syllabus as, in his experience, are likely to present difficulty to the student.

In dealing with the Syllabus in Part I., some attempt has been made to group its various parts in something like logical order. Hence, the order of the book differs from that of the Syllabus. In certain cases subjects have been omitted from Part I. as being more suitably treated under Part II.

J. H. N.

INTRODUCTORY.

Chemical Preliminaries.—A chemical change is one that results in some alteration in structure. When any given substance undergoes a chemical change the result is the formation of a new substance, the properties of which are often entirely different from those of the original one. Chemistry is the science which treats of chemical changes, and the form of energy concerned in bringing them about is known as *Chemical Affinity*.

Elements.—An element is a substance which resists all attempts to break it up into simpler substances. Some seventy-six such elements are known to exist. They are Nature's raw materials—the bricks and mortar of the universe. Probably future chemists, armed with the powers consequent upon greater knowledge, may succeed in proving that some of these are not really elements by resolving them into simpler forms.

Mixtures and Compounds.—When elements are made to combine chemically the result is the formation of a new substance termed a compound. This often possesses properties totally unlike those of the constituent elements. Moreover, these elements are always present in perfectly definite proportions, so that if we take a certain weight of a compound we can readily calculate the amount of each constituent present in it. The elements forming a compound cannot be separated by any mechanical means such as sifting, filtering, dissolving, washing, &c.

Chemical Notation.—We may *mix* elements in any proportion and the mixture formed will possess the properties characteristic of its constituents, and these constituents can be readily separated by mechanical means. In illustrating chemical changes it is customary to employ *symbols* to indicate the nature and quantity of elements involved. The symbol is often the first letter of the name of the element. Thus C stands for Carbon, O for Oxygen, and so on. To prevent confusion some symbols consist of two letters, *e.g.*, Ca for Calcium, Si for Silicon, and others of two letters from the Latin name of the element as, *e.g.*, Hg for Mercury (*Hydrargyrum*), Na for Sodium (*Natrium*). In every case the symbol stands for one atom of the element.

To represent a compound the symbols of the various elements composing it are placed side by side, as in CaO, Calcic Oxide (Lime). If more than one atom of any element be contained in the compound the number is denoted by a small figure placed after the symbol or below the line, as in $CaCO_3$ (Calcic Carbonate or Chalk). Such an expression is termed a *formula*, and the formula $CaCO_3$ shows that one molecule of Calcic Carbonate contains one atom of Calcium, one of Carbon, and three of Oxygen. The formula for Sulphuric Acid, H_2SO_4, shows every molecule of it to contain two atoms of Hydrogen, one of Sulphur, and four of Oxygen.

To express a change the formula are combined into equations. Thus Calcium Oxide (CaO) and Carbon Dioxide (CO_2) will unite to form Carbonate of Calcium. The process is expressed by the following equation :—

$$CaO+CO_2=CaCO_3.$$

If Hydrochloric Acid be added to this Carbonate it will decompose it, the result being the formation of Calcic Chloride, Water, and Carbon Dioxide. The equation

expressing the change is:—

$CaCO_3$	+	$2HCl$	=	$CaCl_2$	+	H_2O	+	CO_2
(Calcic Carbonate.)		(Hydrochloric Acid.)		(Calcic Chloride.)		(Water.)		(Carbon Dioxide.)

Solubility and Solution.—Certain liquids, termed *solvents*, have the power of separating the particles of substances placed in them and dispersing them throughout the liquid in an invisible form. The substance thus broken up is said to be dissolved; the process is known as solution, and the result of it is termed *a solution* of the substance dissolved.

The dissolved substance need not necessarily be a solid. Thus alcohol or glycerine dissolve readily in water, oil in turpentine or benzine, while it is the carbonic acid gas dissolved in water which enables that water to dissolve lime. The oxygen dissolved in water is breathed by fishes and submarine plants. Its presence, too, causes metals to rust.

The student must carefully distinguish between *solution* and *fusion*. Salt placed in water does not "melt," although melting is a term commonly applied to the process by which it disappears. In melting, cohesion is overcome by the influence of heat, in solution by the agency of the liquid—the *solvent* or *menstruum*.

Different bodies require different solvents. Water dissolves more substances than any other, and is sometimes known as the Universal Solvent. But resins and gums insoluble in water, are soluble in alcohol or chloroform, oil in turpentine or benzene, indiarubber in naphtha, metals in acids, &c. The hotter a liquid, too, the greater quantity of solid will it generally dissolve, the heat reducing the cohesion of the particles in the body dissolved. Exceptions, however, exist—*e.g.*, lime; water just above the freezing point will dissolve about twice as much lime as water at the boiling point. Gases, however, are dissolved more readily by cold water. Thus, when cold water, saturated with lime, is heated, some of the lime which is held in solution by CO_2 previously dissolved in the water must be precipitated when the CO_2 is driven off by heating. This is the cause of the "fur" which collects in boilers and kettles used for heating "hard" water. Note that when a solution contains as much of any given substance as it can hold it is termed a "saturated" solution of that substance. The amount of various substances required to saturate, say, water, may be determined by first making a saturated solution, then evaporating a weighed quantity of it to dryness. The solid residue will be the amount of matter required to saturate the quantity of water taken.

MASS, VOLUME AND DENSITY.

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UNITS.—In the practical part of the science of Hygiene it is often of value to be able to form an estimate of the exact volume of various substances. To do this it is necessary that we should have a standard of volume with which they may be measured. The standard adopted is termed the unit, and the unit of volume is in ordinary English measure the cubic foot—the quantity of any given substance which would fill a space a foot long, a foot broad, and a foot deep. For smaller quantities the cubic inch is the measure adopted. In the metric system the cubic centimetre is the unit of volume.

The volume of a liquid may be readily found by pouring it into glass vessels which have been carefully graduated, markings on the sides showing cubic inches or cubic centimetres, with the sub-divisions of each. Such vessels are the graduated cylinder, the burette, with a tap or pinch-cock at the bottom—a tube, usually graduated to show fractions of a centimetre and used for measuring out any required quantity of a liquid, and the pipette—a small tube used to transfer fixed quantities from one vessel to another, and the measuring glass.

The volume of a regular solid—*e.g.*, a cube or a pyramid—may be calculated from direct measurement. That of an irregular solid can best be found by immersing it in some fluid contained in a graduated vessel and noting by the rise of the fluid the volume of it which is displaced. If a stone, when placed in a graduated cylinder, causes the water to rise two inch spaces, it follows that the volume of the stone is two cubic inches. Thus, we may find the volume of a piece of slate pencil by dropping it into a burette partly full and noting the rise in the level of the water.

THE WEIGHT OF THE CUBIC CENTIMETRE OF WATER.— Weigh a glass. Measure into it, by means of the burette, 10 cu. cm. of water. Weigh again. The increase in weight is found to be 10 grams, and the weight of 1 cu. cm. of water is therefore 1 gram. Repeat the experiment using 20, 30, 50, &c., cu. cm. of water. The result is the same in every case.

Hence the volume of a solid may be estimated in another way. Take a vessel with a small hole pierced at the side. Fill with water to the level of the hole. Introduce the body whose volume is to be calculated and collect the water that flows through the hole. Weigh the water. Suppose it to be 19 grams. Then, since a cu. cm. weighs 1 gram, the volume of water displaced is 19 cu. cm., and the volume of the mass is also 19 cu. cm.

By cutting cu. cm. of various solids and measuring cu. cm. of various liquids, we may compare their weight with that of water. The relative weight is different in every case. Hence we conclude that equal volumes of these substances do not contain equal masses—in other words, that the heavier ones contain a greater number of molecules in a given bulk than the lighter ones. They must therefore be denser—that is, the molecules must be packed closer together. The density of these bodies, as compared with the density of water, is termed their *Relative Density*. This ratio is, however, commonly known as the *Specific Gravity*. Thus, the specific gravity

$$\text{of clay} = \frac{\text{Weight of any number of cu. cm. of clay.}}{\text{Weight of an equal number of cu. cm. of water.}}$$

As the volume varies with the temperature, the comparison, to be accurate, should be made at a uniform temperature. That of 4° C.—the maximum density point of water is commonly chosen. The comparison should be repeated with the various liquids in common use in the household—*e.g.*, milk, oil, vinegar, beer, &c., the specific gravity of each being found. The experiment may be best performed with a glass-stoppered bottle. This should be weighed, then filled with water, and then weighed again. The difference in the two weights will be the weight of the water. From this weight in grams we can determine the volume, which will be as many cubic centimetres as there are grams. If the bottle is now filled with milk, oil, vinegar, &c., successively, and weighed, it will be easy to compare the result with that obtained in the case of water, and this will be, as we have already seen, its specific gravity or density relative to that of water.

Thus, suppose that the water filling the specific gravity bottle, as it is called, weighs 20 grams, and the weight of the same volume of olive oil is 18·4 grams, the specific gravity of the latter is found to be $\frac{18 \cdot 4}{20} = 0 \cdot 92$.

Specific Gravity and Adulteration. — When two liquids of different density are mixed together the specific gravity of the mixture is necessarily different from that of each of the compounds. Hence the determination of the specific gravity of a liquid becomes an excellent means of detecting any adulteration. Take, for example, the case of milk. The greater proportion of the fluid is water. In this certain solids are dissolved which raise the specific gravity, and certain particles of fat—the cream—are suspended. These, being lighter than water, have the effect of lowering the specific gravity. Taking an average sample of milk, we find the specific gravity to be somewhere near 1·030. If the proportion of dissolved solids is high, the specific gravity may reach 1·032, if the proportion of cream is in excess, then the specific gravity may fall to 1·028. Anything beyond these extremes should lead one to suspect adulteration.

The Principle of Archimedes.—It has been already shown (p. 10) that when a body is immersed in a fluid it displaces a quantity of water equal to its own bulk. The principle to which Archimedes has given his name is that a body immersed (or partly immersed) in water loses a portion of its own weight, and that this loss is equal to the weight of the liquid it displaces. If we hang two 1 lb. weights from the arms of a pair of scales they will balance one another. But if a bowl of water is brought under one of the weights and raised until it is immersed, the other will weigh it down, showing that the immersion has caused a loss of weight. The loss is due to the fact that the water presses more powerfully against the bottom than the top of the immersed weight, just as the pressure on a diver increases with the depth to which he descends. Consequently the weight is forced upward more strongly than downward. This upward pressure is known as the buoyancy of the water, and the weight of the body, as long as it is immersed in the water, is diminished by this buoyancy. If we hang the weight from a spring balance we find that the indicator, instead of pointing to 1 lb. points to 13¾ ozs., and if by using a jar with a hole in the side, as described on p. 10, we collect and weigh the water displaced, we shall find it weighs 2¼ ozs. Hence the law of Archimedes—"*The weight of a body immersed in a fluid is diminished by an amount equal to the weight of the fluid it displaces.*" Hence the weight of the milk displaced by a lactometer equals the weight of the lactometer itself, and so the greater the specific gravity of the milk, the less will the lactometer sink in it.

FLOTATION.—When a body is less dense than the liquid into which it is put, the quantity of the liquid displaced—its own weight—occupies a smaller space than the body itself. Hence the body will not be completely immersed, but will float with a portion of its volume above the surface. A new laid egg will sink slowly in pure water, but if the density of the water be increased, as by dissolving salt in it, a time will come when the density of the water is the same as that of the egg, and the latter will remain in any position in the water in which it is placed. If more salt be added, the water will become denser than the egg, which will displace less than its own volume of water, and consequently float with part of its bulk above the surface. The density of the solution may be ascertained by weighing against an equal volume of water or by the use of the hydrometer.

THE HYDROMETER.—It is not customary to determine the specific gravity of common fluids by experiment or calculation, as in the examples already given. They may be readily found by means of the instrument known as the Hydrometer. This consists of a graduated tube, blown into a bulb at the bottom so that it will float in the water, and weighted at the bottom to keep it upright. The depth to which it sinks in pure water is shown by a mark on the stem. If immersed in a liquid denser than water it will float with a greater portion of the stem above the surface; if in a liquid less denser than water it will sink further below the surface. The depth to which it is immersed will show the specific gravity. Thus, if it sinks to the point on the scale marked ·798, the specific gravity is ·798. If it rises to the point marked 1·025, the specific gravity is 1·025, and so on. The instrument is often used to test the variation in the specific gravity of one fluid alone, and appears under various names, as the alcoholometer, the lactometer (milk), the galactometer (milk), and so on. The term *Lactometer* is often restricted to an instrument employed to determine the *quantity of cream* in a given sample of milk and the amount of water added to it. This consists of a graduated glass beaker, in which the milk is allowed to stand until the cream separates and floats to the top. Then the thickness of the layer of cream is measured by means of the scale on the glass. The instrument is also termed a creamometer.

HEAT.

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HEAT.—Heat is a form of energy. Old scientists affirmed that a heated body contained a substance termed Caloric, which a cold one did not, and that the temperature of a body depended upon the amount of "*Caloric*" it contained. But since a body, when heated, weighs no more than when cold, the rise in temperature can have been due to no addition of matter, since that would have implied an addition of weight also.

HEAT A MODE OF MOTION.—Experiments as to the manner in which heat may be produced help us to determine its real nature. One familiar fact is the appearance of heat whenever motion is arrested. Thus a piece of iron may become very hot as a result of arresting the motion of the blacksmith's hammer that falls upon it; a cannon-ball becomes hot, and often partially melted, when it strikes the target; the fragments of steel ground off the wheel of a railway carriage by the friction of the brake fly off as sparks. In each case motion is arrested and heat produced. Arguing on these lines we arrive at the general fact that mechanical motion may be transformed into heat. The converse of this, that heat may be transformed into mechanical motion is familiarly illustrated in the case of the steam engine. In addition to this, Dr. Joule, of Manchester, discovered in 1843 that whenever a certain amount of mechanical energy is used up, a corresponding amount of heat appeared in its place. In other words, it was possible to find a mechanical equivalent for any desired quantity of heat—a given quantity of heat being capable of doing a given amount of work.

Heat a Form of Energy.—Evidently heat is an agency capable of doing work. In other words, it is a form of energy, and the instances to which we have referred, of the change of mechanical motion into heat, were merely instances of the transformation of energy—the muscular energy of the blacksmith's arm, the energy of the moving cannon-ball, and the rotary energy of the carriage-wheel were all transformed into heat energy.

To put it in another way, the motion of the hammer, the shot and the wheel had been transformed into another form of motion. Molar motion—the movement of the body as a whole has become molecular motion—the motion of its particles. Heat, then, consists in a vibration of the molecules of a body, and the higher the temperature of a body rises, the more rapid the motion of its particles becomes.

Heat and Temperature.—Temperature is not heat, but the state of a body as regards its power of imparting heat to other bodies, or of abstracting heat from them, and when we speak of the temperature of a body we refer to its state of molecular vibration. If two bodies, A and B, be placed in contact, and A can impart some of its heat to B, its temperature is said to be higher than that of B. If, on the contrary, it is in such a state that it abstracts heat from B, its temperature is lower. Put in another way, if the molecular vibrations of A are more rapid than those of B, its temperature is higher than B's; if less rapid its temperature is lower than that of B. If the molecules of both bodies vibrate at the same rate, they are of the same temperature. It must be remembered that the fact of two bodies being at the same temperature does not imply that both contain the same quantity of heat. The addition of cold water to hot causes the temperature of the latter to fall, but the quantity of heat in the mixture remains the same.

THE EFFECTS OF HEAT.—One of the effects of heat on a body has been already noted. Heating a body increases its power of communicating motion to the particles of other bodies. We express this by saying that its temperature rises. But the increased motion of its particles increases the amplitude of their vibration. They fly farther apart, the body expands, and the force of cohesion which binds the molecules together becomes weakened, so that a solid tends to become liquid and a liquid gaseous. The effects of heat are therefore threefold :—

Change of Temperature.
Change of Size.
Change of State.

The change in state is, of course, visible; the change in temperature is rendered sensible by the thermometer; and the change of size may be actually measured, as in the following experiments :—

> Take a flat metal bar, fix it at one end, and allow the other to move freely over a knitting needle as a roller. Run the needle through a long straw to serve as a pointer. Heat the bar by means of a spirit lamp or Bunsen burner, and its increase in length will be shown by the rotation of the needle, which is made evident by the movement of the straw.

> Take flasks of coloured water, alcohol, or turpentine. Fit them accurately with corks through which tubes have been fixed. When each cork, with its tube, is forced into the flask, the liquid rises up the tube. Place them all in a bath of hot water, and note (1) that the liquid rises up each tube, (2) that the alcohol rises most, the turpentine next, and the water least.

THE MEASUREMENT OF TEMPERATURE.—To describe temperature we require some fixed temperature as a starting point, and a unit of temperature with which to indicate the distance from the fixed point. Two such points are readily available: the temperature above which ice melts and below which water freezes, and which is known as the freezing point, and the temperature above which water boils and below which steam condenses at the sea-level, which is known as the boiling point.

The Thermometer.—The expansion of a body when heated and its contraction when cooled are approximately regular within ordinary limits of temperature. Hence, by measuring the amount of the expansion a heated body has undergone, we are able to estimate with considerable accuracy its increase in temperature. It is not customary to measure the expansion or contraction of the body itself. It is brought into contact with some other body whose changes of size can be easily measured, and the two are left in contact till they become of the same temperature.

An apparatus specially designed to show temperature by indicating the changes in volume a body undergoes when being heated or cooled is known as a thermometer.

A rough thermometer may thus be made from any substance that will expand when heated. For convenience liquids are generally chosen. Solids expand too little for the change to be easily measured, gases too much, except for delicate observations. Very great changes, however, are registered by the expansion of metal bars (*pyrometers*), slight ones by means of *air thermometers*.

The Clinical Thermometer.—This is a small thermometer used in finding the temperature of the body. In its usual form the range of temperature shown by it is about 25°, from 90° F. to 115° F. The normal temperature of the blood, 98·6° F., is plainly marked, and the graduation shows one-fifth of a degree. It is commonly placed under the patient's tongue or in the armpit, and allowed to remain

for some minutes until it has acquired the temperature of the body.

The Construction of a Thermometer.—Procure a tube with a bulb blown at one end and a basin of mercury (or whatever fluid is to be used). Dip the mouth of the tube under the surface of the mercury and gently heat the bulb. The air in the tube or bulb expands and part is driven out through the mercury. When the tube cools the mercury is forced up into it by the pressure of the air. The process is repeated until sufficient mercury has entered the tube. Then, the tube being held bulb downwards, the mercury in the bulb is heated and expands, driving the air before it until the tube is filled with mercury alone. Then the top of the tube is sealed by softening in a gas flame. Note that if any air be left in the tube it will act as an elastic cushion, and by pressing on the mercury in the tube, decrease its rate of expansion.

To graduate a thermometer, first find the freezing point by placing the thermometer in melting ice and marking the point at which the contracting column of mercury comes to rest, and then the boiling point by placing the bulb in the steam rising from boiling water and marking the point at which the column ceases to ascend.

The unit of measurement is a degree, and is found by dividing the distance separating the freezing from the boiling point into a given number of equal parts—180 on the Fahrenheit scale, 100 on the Centigrade scale, and 80 on Réaumur's scale.

It should be remembered that the temperature of these points will differ if other substances than water be used, if the pressure on the surface be allowed to vary, and if the substances tested are impure. Thus, 0° C. (32° F). is the freezing point of pure water, under a pressure of one atmosphere—*i.e.*, at the sea level. 100° C. (212° F) is the boiling point of pure water, at the sea-level. Different substances have different boiling points and melting points. Pressure, as a rule, raises the temperature at which a substance melts* or boils. The presence of matter in solution lowers the melting point and raises the boiling point. Hence, the boiling point of salt water is higher than that of fresh, while its freezing point is lower.

Boiling Point and Pressure.—Water boils when the outward tension of its vapour can overcome the pressure on its surface. At a temperature of 100° C. the vapour-tension is sufficient to overcome the ordinary pressure of the atmosphere at the sea level. But, if the pressure on the surface be increased—as it would be if the water were taken down a mine, or if the steam were prevented from escaping and so formed an elastic cushion in the vessel—the temperature would have to be increased before the water could boil. Hence, it is possible to raise water to a very high temperature without its boiling. In the boiler of a steam engine it frequently reaches 350° F. Water so hot as this is capable of extracting nutriment from bones, cartilage, &c., and an apparatus, known as Papin's digester, is employed for this purpose. In like manner, the decrease of surface pressure causes water to boil at a lower temperature. Hence, on a mountain, boiling water is not so hot as at the sea level. Indeed, if the mountain is sufficiently high, the boiling point may fall below the cooking temperature—about 180° F.—and the traveller finds much difficulty in preparing his food. In such a case it is a good plan to weight the lid of the vessel used with stones, so as to prevent the steam from escaping. The pressure of the confined steam on the surface of the water in the pot will raise its boiling point to the required temperature.

* Water and other bodies that expand on solidifying are exceptions to this. Thus, pressure lowers the melting point of ice.

THERMOMETRIC SCALES.—The space between the boiling and freezing points marked on the tube of the thermometer is divided into equal parts, termed degrees. In Fahrenheit's scale there are 180 parts, in the Centigrade scale 100, in that of Réamur 80. Hence, to change from Fahrenheit to Centigrade scale, it is only necessary to remember that 180 Fahrenheit degrees equal 100 Centigrade degrees, and that the Centigrade scale commences at the freezing point, and the Fahrenheit scale 32° below it. Hence, *after* reducing Centigrade (or Réamur) degrees to Fahrenheit degrees, it is necessary to add 32°, and *before* reducing a Fahrenheit reading to a Centigrade (or Réamur) to subtract 32°. Thus, the following relations hold good:—

$$F.^\circ = \tfrac{9}{5}C.^\circ + 32^\circ \qquad C.^\circ = \tfrac{5}{9}(F.^\circ - 32^\circ).$$

LATENT HEAT.—When a solid is sufficiently heated it changes into the liquid and then into the gaseous state. The heat used in producing this change of condition is known as Latent Heat, for the energy in this case being utilised in causing a change in the molecular condition of the body, it cannot, at the same time, cause any alteration in its temperature. Hence the name, *latent* (lying hidden). It is not sensible to thermometric measurement. Steam and boiling water, as far as the thermometer is concerned, are at the same temperature. But 1 lb. of steam contains 536 heat units more than 1 lb. of boiling water. Hence the reason that scalding steam is so much more dangerous than scalding water. In the same way, 79 heat units are utilised in converting ice at the freezing point into water *at the same temperature.* Hence, we say that the latent heat of steam is 536 and that of water 79. When steam is condensed the 536 heat units are set free, raising the temperature of bodies in the vicinity. Hence the warming effect of a fall of rain or snow. When 1 lb. of water freezes, the 79 heat units are set free in like manner.

Note :—

i. When ice is placed in water and put over a fire, the temperature does not rise till the ice is melted.

ii. When liquids solidify or gases condense, *e.g.*, when water freezes or vapour changes to water, heat is given off.

iii. When solids melt, or liquids evaporate, heat is absorbed (has become latent).

iv. One pound of steam at 100° C. passed into cold water will raise the temperature much more than 1 lb. of boiling water (*at 100° C.*) passed into it.

The Transmission of Heat.—Heat is transmitted in three ways—by conduction, convection, or radiation. In *Conduction*, heat passes from one particle of a body to the next: the particles themselves do not change their relative positions. In *Convection*, the molecules move from one place to another. In *Radiation*, heat is transferred from one body to another in the form of radiant energy. Heat, as radiation, is transferred to the Ether, throwing it into vibration. Radiant energy falling upon material bodies is transformed back again into heat.

Air and water are bad conductors. Heat is much more readily transmitted through them by convection. Hence water is far more quickly raised to the boiling point when heat is applied below than when it is applied above it. For the same reason loose garments and those of loosely-woven texture are warmer (*i.e.*, retain the heat of the body better) than tightly fitting ones of closely-woven material. In the former case the air enclosed by the garment, or contained in its pores, opposes a barrier to the outward passage of the heat.

Note that radiant energy does not warm the air through which it passes. Hence a person feels cool in the shade, *i.e.*, where sheltered from the direct rays of the sun. For the same reason a thermometer exposed to the direct rays

of a fire indicates a far higher temperature than that of the air which surrounds it. The reason is that Radiation is not Heat.

Convection.—When a body is heated it expands. The amount of expansion varies with the body under experiment. The result of this expansion is to make the body less dense, and consequently lighter, bulk for bulk. Hence cold water introduced into a vessel of hot water will sink to the bottom, and the heated water at the bottom of a kettle rise to the top. For the same reason air, when heated, decreases in density and rises, or rather is forced, upward by the heavier surrounding air until it reaches a region where the surrounding air is of the same density as itself. Movements brought about in fluids (liquids or gases) by variation in density are known as Convection Currents. The water in a kettle is heated, the air of a room made to circulate and—by providing suitable inlets and outlets—is changed by this means. Air Currents (winds) and Ocean Currents are largely due to similar causes, on which, too, most ordinary systems of ventilation are based.

Convection Currents in water may be shown by the motion of tiny particles of bran or oak dust which, when thoroughly saturated, move with the currents.

Hot Water Systems.—Houses are often warmed by systems of hot water pipes. Essentially they consist of a coil of pipes, through one side of which hot water is conveyed to any part of the house, there to give up its heat and thence to return by the pipes on the other side to a boiler in the basement. The water in the boiler being heated, rises through the pipes, while that in the pipes at the top of the house, having given up its heat, becomes denser and sinks to the boiler again. In this way regular convection currents are set up in the pipes, the water continuing to circulate as long as the fire is alight. Branch coils proceed from the central one to any rooms which it is desired to warm, the water in these being shut off from the general circulation at will by means of taps.

The air round the pipes becomes heated and rises, and thus convection currents are also set up in the air of the room.

Evaporation.—Water passes into vapour when raised to the boiling point. In this case the change is known as Ebullition, and begins at a fixed temperature or occurs throughout the body of the liquid. Water also passes into vapour at all temperatures, but slowly and at the surface only. This process is known as *Evaporation*. (Note that even ice evaporates.) Evaporation is due to the fact that the air has a certain capacity for absorbing or holding vapour. When this capacity is exhausted, the air is said to be saturated.

Condensation. — The amount of vapour needed to saturate the air increases or decreases with the temperature. But since hot air can hold more vapour than cold, it is clear that if a body of hot air, saturated with vapour, is cooled it must give up some of its vapour. It does so; the vapour is changed into water (condensed), and in the form of moisture (tiny water-drops) begins to fall through the air. Clouds are formed of moisture, and consist not of vapour but of tiny drops of water. The drops run together to form rain drops. When the condensation goes on close to the ground the moisture is deposited as dew. The temperature at which the vapour in the atmosphere, at any time or place, becomes sufficient to saturate it is known as the *dew-point*. If the temperature falls below the dew-point, vapour is condensed as moisture. The amount of evaporation will depend upon the quantity of water in the air. If the air is already saturated, there can be no evaporation. To make the change from liquid to vapour, heat is required—the latent heat of evaporation.

If water evaporates from the body, the heat is withdrawn from the body: if from a thermometer, then heat is withdrawn from the thermometer. In the latter case the thermometer falls, showing a lower temperature than that of the surrounding air. This difference is due to evaporation. The more rapid the evaporation the greater the difference between a wet thermometer and a dry one. But the rate of evaporation depends on the quantity of vapour already in the air. Hence, the difference between the reading of a thermometer which has been wetted and that of a dry one affords an indication of the quantity of vapour in the air. That the evaporation may be regular, the bulb of such a thermometer is encased in a muslin bag, the end of which dips into a vessel of water. Such an instrument is termed a *Hygrometer* (G. *hugros*=moist, *metron*=a measure). Generally, the wet bulb thermometer is placed side by side with a dry one for purposes of reference.

However dry the air may seem, it always contains moisture. Certain substances make this evident by their power of absorbing it. Such substances are known as hygroscopic substances. Among them are calcium chloride, sulphuric acid, ordinary washing soda, human hair, seaweed, catgut, &c., all of which absorb moisture readily.

FOOD AND FOODSTUFFS.

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THE COMPOSITION OF THE BODY.—The chief constituent elements of the body are four—the gases, Carbon, Hydrogen, Oxygen, and Nitrogen. As these are constantly passing out of the body as waste, in the form of carbonic acid (CO_2) and urea (CON_2H_4) they require to be replaced. To replace them we require food. But they are needed only in certain proportions, and no substance contains them in the exact proportion necessary for the needs of adult life. Some contain too much of one constituent, others too little. Hence, to get exactly the quantity required, it is best to compose the diet of a mixture of various substances. Such a diet is termed a mixed diet, and its chief merit is its economy. It is not necessary to take a wasteful excess of one constituent in order to get enough of another. Note that milk and eggs are sometimes termed perfect foods. They are perfect only for the purpose for which they are designed—the nourishment of the young animal during the earliest period of its life. Both contain far too much nitrogen for adult needs.

FOOD AS FUEL.—The body cannot assimilate its constituents in their pure state, but only when built up into the complex tissues of animals and plants. The energy to build up the plant tissues is derived from the sun's heat. When eaten by an animal, the vegetable tissue is broken down again, and the energy utilised in building it up is

set free. This energy takes the form of heat. Heat is produced in the human body as the result of chemical changes in the food eaten. This heat serves to maintain the temperature of the body, and by another change, is transformed into the energy required to do the work of the body. But a great proportion of the changes going on in the body are due to the union of oxygen with various other substances. Thus, for example, it unites with carbon, producing carbon di-oxide (CO_2), and with hydrogen, producing water (H_2O). The process is known as *oxidation* or *combustion*, and is analogous to the combustion that goes on in a grate. The oxygen required enters mainly through the lungs. Hence the air which we breathe is essential to those chemical changes by which the body derives all its heat and energy, and through which old tissues are destroyed and new ones formed. For this reason air has the right, in one sense, to be entitled food.

PUTREFACTION.—Decay is the result of the action of certain microscopic organisms—the ferments known as putrefactive bacteria. These obtain the materials essential to their growth or multiplication from dead animal and vegetable tissue. They are unable, like the bacteria of disease, to invade the tissues of living animals and produce specific fevers, but play an important part in the decomposition of dead organic matter. They are the scavengers of Nature, the means by which organic substances, after death, are resolved into their more elementary forms, which can be taken up as plant food. The process is analogous to the "fermentation" of the brewer, in which sugar is broken up into carbon di-oxide and alcohol by the yeast ferment, or the process by which food is changed by the digestive ferments of the body. But certain conditions of moisture and oxygen supply are essential for the completion of the process. Since this is so, it is obvious that decay may be prevented or delayed by modifying these conditions so as to render them unfavourable to the development of the organisms. Among the means usually adopted are :—

i. The exclusion of air (or the admission only of air from which germs have been excluded by filtration).

ii. Desiccation, the removal of water by heat or pressure.

iii. Exposure to extremes of heat or cold.

iv. The use of antiseptics or germicides.

The Preservation of Foods.—In the process of tinning the food is placed in tins, and the covers soldered on, leaving only a little hole in each. They are then placed in a bath containing water, the boiling point of which, by dissolving chloride of lime in it, has been raised to 260° or 270° F. The heat kills any germs in the food and expels all air from the tins. Then the tin is hermetically sealed by closing the hole with a drop of solder.

If air should enter or the heating process be insufficiently prolonged, and putrefaction thus ensue, the fact becomes apparent by the bulging of the tin. Note, however, that the temperatures necessary are so high that the food is overcooked and its flavour and consistency impaired.

Desiccation is employed in producing the "charqui" or jerked beef of South America, the "biltong" of South Africa, and the "pemmican" of North America. It is also employed in the case of certain vegetables, the bulk being thus greatly reduced. Dried fruits are well known, dried eggs are used in the French army, and dried vegetables of all kinds are used on shipboard, and by Arctic explorers, &c.

While heat destroys the putrefactive bacteria, cold renders them inert. Hence it is possible to bring vast quantities of meat from Australia and New Zealand in refrigerating chambers. Note that unless the meat has been frozen immediately after being killed putrefaction

begins soon after thawing, and is very rapid. Hence, such meat will not keep. If putrefaction has begun, freezing suspends the process and conceals its effects and the condition of the meat may pass unnoticed. Since one effect of the putrefaction of proteids is to produce poisonous compounds—ptomaïnes—the danger is evident.

Meat may also be preserved by the addition of antiseptics, in the presence of which the germs of putrefaction will not multiply, or germicides, which destroy them. The objection in each case is that the majority of such substances unpleasantly affect the flavour of the meat. Simple illustrations of this method are: the preservation of fruits and vegetables in alcohol or vinegar; the addition of sugar, as in jam, in condensed milk, and in fruits preserved in syrup; and the curing of meat, fish, &c., by smoking. Pickling in salt is a familiar method of preserving meat and fish. Various substances are applied to its surface with like effect. These include vinegar, borax, charcoal, and salicylic acid. Solutions of salt or alum may be injected into the blood vessels. Spices, too, are used to preserve potted meats for short periods.

Milk and Dairy Produce.—Milk is a model food for the young mammal, containing, as it does, all nutrient materials needed and in due proportion. The nitrogenous constituent is albumen or lacto-protein, the hydro-carbon is butter, while the carbo-hydrate is lactose or milk-sugar. There is also a sufficiency of mineral matter, chiefly calcic phosphate. The proportions are as follows: in a pint of milk, 17 ozs. 419 grs (87 per cent.) is water, 307 grs. (3·4 per cent.) nitrogenous, 343 grs. (3·8 per cent.) fat, 1 oz. 10 grs. (5 per cent.) lactose, and 63 grs. (·8 per cent.) mineral. Note, however, that the composition varies. Morning milk is often more watery than evening milk, and much watery food—*e.g.*, brewers' grains—will make the milk poorer in solids. The same result will follow when cows are pastured on poor or overstocked land. On the other hand, the milk of cows fed on oil cake is rich in solids, while the "strippings"—the milk last drawn from the udder—will be found specially rich in fat.

Skim Milk has had the cream, together with about 12 per cent. of the casein, removed. Milk turns sour in hot weather, the change being hastened when the vessels are not scrupulously clean and the air of the room is impure. The souring is the work of a bacterium, and consists in the formation of lactic acid from the lactose. The lactic acid separates and coagulates the casein, and this, with a considerable proportion of entangled fat, forms the *curd*. The liquor in which the curd floats—the "serum" of the milk—is known as *whey*, and contains about one-fourth of the nitrogenous matter, all the sugar, and most of the mineral matter. This process of souring is hastened by heat. If the temperature is too high and the air close and confined, a poison (a ptomaïne) may develop during the process. Hence, sour milk sometimes produces vomiting, purging, colic, &c.

Condensed Milk has been prevented from "turning" by the addition of sugar and condensed by the removal of water. Since it contains an excess of sugar it cannot replace milk as a "perfect food." Note that milk is sometimes kept "sweet" by the addition of a little carbonate of soda or boracic acid. It is, however, doubtful whether the latter may not prove injurious in some cases.

Adulteration of Milk.—Milk is adulterated by the removal of cream, the addition of water, and sometimes, to hide the latter, of colouring matter. The removal of cream increases the specific gravity, the addition of water lowers it. Two tests are therefore needed to ascertain the purity of milk: the determination, by means of the lactometer, of the specific gravity, which should be about 1·032; the other the estimation of the amount of

cream, which should fill about 10 per cent. of a tall glass in which the milk has been allowed to stand for twenty-four hours.

Butter consists chiefly of milk-fat, but contains also water, casein, salts, and sugar. The following is the composition of an average sample: water 10 per cent., casein 1 per cent., fat 87·7 per cent., salts (chiefly common salt) 1 per cent., lactose ·3 per cent. It can be obtained from cream or by churning the milk. Note that the unpleasant taste often possessed by butter is the result of its great absorbing powers. Hence, it should be always kept in a place free from all foul or strong odours. The same result will follow if the cows have been improperly fed. About twenty-two pints of milk are needed to make one pound of butter. Butter is sometimes adulterated by adding an excess of salt. This absorbs water, and so increases its weight without adding to its cost or its value as a food. About 1 per cent. of salt is the average that should be used, but 8 per cent. is sometimes found in salt butter.

A simple test for good butter is to melt it in a test tube immersed in hot water. As its constituents are of different specific gravity, they separate and form distinct layers. On top comes the melted fat in the form of oil, and then the curd, with the water at the bottom. If the water fills more than a tenth of the tube there is ground for suspicion. Adulteration with other fats can only be detected by chemical analysis. Any such mixture, however, must be described as margarine. This and other butter substitutes are most frequently wholesome and pleasant to the palate. The offence lies in selling them at the price of butter.

Cheese is made by the coagulation or curdling of casein through the action of an acid (as lactic acid in the souring of milk) or of certain ferments, the chief being *rennet*. The process is exactly that described under the "souring" of milk. Rennet is commonly used in lieu of acids. It is prepared by soaking the fourth stomach of a calf in brine. Roughly speaking, cheeses may be classified as skim-milk, whole-milk, and cream cheeses, according to the amount of fat they contain. Dutch cheese is a good example of a skim-milk, Cheddar is a fair sample of a whole-milk cheese, American falls below it in fats. Good cheese should be pale yellow or straw coloured. Often, however, cheeses are coloured with annatto. This, being somewhat costly, is liable to be adulterated, and some of its substitutes are injurious.

Cheese is not easily digested – the rich, "short," or crumbly varieties being, however, superior to the skim-milk ones. This objection is commonly removed by grating the cheese and mixing it with starchy substances —*e.g.*, macaroni, bread, and rice. The blue mould of cheese is due to the action of a fungus. The growth of this adds to the flavour of the cheese at the expense of its nutritive value.

THE CEREALS.—These, the edible grains or breadstuffs, are the fruit of certain grasses, of which the chief are wheat, oats, barley, rye, maize, and rice. Their relative composition may be determined from the following table.

	WATER.	PROTEIDS.	STARCH.	FAT.	SALTS.
Wheat Flour	15	11	70·3	2	1·7
Oatmeal ...	15	12·6	63	5·6	3·0
Barley ...	14	11	65·5	2	3·0
Rye	13·5	13·1	68	2	2·1
Maize... ...	13·5	10 ·	64·5	6·7	1·4
Rice	10	5	83·2	·8	·5

Note.—Each grain contains a certain amount of cellulose. This is a carbo-hydrate in composition, but is entirely indigestible, and hence is without food value. The presence of varying quantities of this will account for the apparent discrepancies in the table of percentages on p. 32.

Wheat.—Of all cereals, wheat yields the best bread. This is due to the fact that the nitrogenous material of the grain is in the form of gluten, which enables it to form a sponge. When yeast is added to a mixture of flour and water, and the whole placed before a hot fire, some of its starch is changed into sugar through the action of an unorganised ferment—diastase—in the grain. Yeast added to this produces a further process of fermentation—the ferment in this case being the cells of the yeast, which attack the sugar, resolving it into alcohol and carbonic acid gas. The coherent nature of the gluten prevents this gas from escaping. Hence it forms for itself little cells in the substance of the dough, making the mass porous. Any alcohol that may be formed, being highly volatile at the temperature of the oven, escapes. Baking coagulates the gluten just as boiling coagulates the albumen in white of egg and gives the dough that solid appearance which we know in bread.

Unfermented Bread.—Bread may be made without fermentation by forcing carbonic acid gas, previously manufactured, into the dough. Bread made in this way is known as *aërated.* It can also be made by mixing in the dough certain chemicals which, by their reaction, liberate carbonic acid gas. Bi-carbonate of soda and dilute hydrochloric acid have been used for this purpose.

What is known as "baking powder" is a mixture of various ingredients capable of producing the same result, the substances commonly employed being bi-carbonate of soda and tartaric acid, the effervescence arising from the evolution of carbonic acid, when these substances are mixed in a glass of water, being a familiar phenomenon. In other baking powders the acid sulphate of potash (potassium bi-sulphate) is substituted for tartaric acid. Similar powders, generally coloured yellow, are sold as egg powders. The only feature they possess in common with the egg is the name.

Brown Bread—i.e., bread which is made from the whole meal—is often recommended. It certainly contains more nutrient material than white bread, but the additional matter is highly indigestible. The particles of the hard outer covering of the grain irritate the walls of the intestine till they force the food along before it has time to be properly digested. Moreover, the coarse "branny" particles are virtually impervious to the action of the gastric juices, so that only the exterior is digested. Still, for persons of costive habit, the use of whole meal bread is sometimes advantageous.

Oatmeal contains a much larger proportion of fat than wheat, and is also richer in nitrogenous material. The latter, however differs from the gluten of wheat, and does not cohere so as to imprison bubbles of gas. For this reason oatmeal cannot be made into bread. It is taken in the form of porridge and also makes "short"—friable—cakes.

Barley and *Rye* can both be made into bread, though neither is equal to wheat. Rye, however, is little used in this country, and barley is raised chiefly to furnish malt for making beer. As food it is mainly employed as pearl barley, for thickening soups or making barley water.

Maize, or Indian corn, is the "corn" of America. It contains more fat than any common grain. It makes inferior bread, but excellent cakes—Johnny cakes. In England it is chiefly used in the form of *Cornflour*, *Oswego Flour* and *Maizena*—preparations consisting of nearly pure

starch. In America the ears are roasted as *pop-corn*, and the grain, when crushed, is termed *hominy* and used for porridge. Ground maize is boiled to form *mush*. In Italy it is known as *polenta*. Soaked in water and then ground into pulp, it is made into the characteristic Mexican cakes, *tortillas*. Mixed with wheat flour, it makes excellent bread. The *mealies* of South Africa are the ears of maize.

Rice is more widely used than any other cereal. It is too deficient in nitrogenous or mineral matters to form a perfect food, and is most usefully employed in conjunction with meat, eggs, or pulse, and some form of fat.

THE LEGUMES OR PULSES.—There is a vast difference in composition between the pulses and the cereals. In each case it is the seeds which are eaten ; but, whereas the prominent constituent of the latter is starch, the former are remarkable for the large proportion of proteid matter they contain. The difference is clearly seen by comparing the following table with that giving the composition of the cereals on p. 32.

	WATER.	PROTEIDS.	STARCH.	FAT.	MINERALS.
Peas	15	22·5	51	2·5	3
Beans	14	23	52	2·3	2·9
Lentils ...	12 5	25	56	2	2·5

The nitrogenous constituent of this family is *legumin*. As will be seen from the table of composition, the pulses are highly nutritious, the only deficiency being in fat. Hence, they are best eaten with food containing a surplus of this constituent. They are, however, somewhat indigestible, and in their dried state require prolonged soaking and boiling before being used. When green they contain a certain amount of sugar, and their legumin is more easily digested. In the case of the French bean and the scarlet runner, the unripe pods are eaten. These differ materially in composition from the seeds, approximating rather to green vegetables in this respect. Roughly speaking, they contain about 92 per cent. of water and 2 per cent. of nitrogenous matter.

Succulent Vegetables.—These are valuable from the salts and vegetable acids contained in their thick, fleshy leaves, together with certain active principles which give a characteristic flavour to many—as, for example, the watercress, asparagus, and celery, spinach, leek, mustard, and cress.

Among the chief salts contained in the group are the various salts of potash and phosphates of lime and soda. These are essential for the formation of bone and the maintenance of the alkalinity of the blood. Without them the blood fails to do its work, and the result is a condition of mal-nutrition, which in an extreme form is known as scurvy. The potash salts are mainly the phosphate, carbonate, chloride, and nitrate. Fleshy plants are rich in potash salts formed by the combination of potassium with one of the organic acids—oxalic, tartaric, citric and malic acid. These—the oxalate, tartrate, citrate and malate of potassium—are changed in the body into carbonate of potash. Salts of iron and manganese are also found in similar plants. The value of all is their effect on nutrition. They aid in the transference, digestion, absorption, or elaboration of the nutrient material taken as food.

Roots and Tubers.—In this class of food stuffs the potato easily holds the first place in point of nutrient value. It contains from 20 to 25 per cent. of starch,

together with acids and salts which make it an excellent anti-scorbutic. Its want of nitrogen, however, unfits it for becoming the staple food of a whole race, like oatmeal, maize, or lentils. Potatoes are most valuable when full grown; young potatoes, composed mainly of immature tissue and starch cells, are less nutritious and also less digestible. Parsnips, carrots, and beetroot, which contain about 10 per cent. of food material—mainly sugar—come next to potatoes in nutritive value. Turnips contain less nutrient material, and, if at all old, the development of woody fibre makes them exceedingly indigestible. But, as in the case of green vegetables, roots, with the single exception of the potato, are eaten rather for their flavour and for the valuable acids and salts they contain than for their actual food value.

Flesh Foods.—All meat contains water, proteids, fat and mineral matter. But the proportion in which these constituents is present varies considerably, not only in different animals but in different joints of the same animal. The former is illustrated in the following table:—

MEAT.	WATER.	PROTEID.	FAT.	SALTS.
Beef... ...	70	19	9·5	1·5
Fat Beef...	55	16·5	27·3	1·2
Mutton ...	71	19	9	1
Veal... ...	72	18	9	1
Pork ...	71	21	6·8	1·2
Fat Pork...	45	12	42·5	·5

But each of the constituents mentioned above includes several distinct compounds under the one head. Thus, the term proteid includes albumen, myosin, chondrin, gelatin and ossein, besides the bodies known as creatin and carnin, which are found in a concentrated form in the gravy of cooked meat and form a considerable proportion of meat extracts. Gelatin, however, has only about one-fourth the nutritive value of albumen while chondrin, and ossein have still less. But in some parts of the animal these form the bulk of the nitrogenous matter. Thus the shin contains a large amount of gelatinous material, so that although cheaper it is less nutritious than other portions of the animal. The same is true of the head and of the "hand" of pork. Cowheel and similar portions contain much chondrin. Gelatin also exists in the membranes, tendons, &c. Again, kidneys and hearts contain a large proportion of nitrogen, but their dense and heavy texture renders them highly indigestible. Liver contains about 77 per cent. water, 17 to 19 per cent. proteid, and about 3 per cent. fat. Hence it is eaten with fat foods like bacon to supply its deficiency in this respect. Again the proportion of fats varies greatly in different parts, and this affects the nutritive value. Moreover, where fat is in excess, there is a deficiency of water.

Fish.—The composition of fish, like that of flesh, varies greatly according to the kind of fish and in different parts of the same fish, and also according to the season of the year. Speaking generally those fish which are least oily are the most wholesome and easily digested. But all are so highly nitrogenous that it is essential to consume a considerable proportion of starchy matter with them in order to form a suitable diet. Fish, the flesh of which is dry, fibrous, or tough, are always indigestible. Hence their composition affords little clue to their nutritive value. The average composition of various fish is shown in the following table :—

FISH.	WATER.	PROTEID.	FAT.	MINERALS.
Salmon ...	64	22	12·5	1·5
Mackerel...	72·5	17·5	8	2
Herring ...	80	11	7	2
Whiting ...	81	14	2	3

The Effects of Heat.—The effect of heat on meat is to coagulate the albumen, to loosen the fibres by softening the connective tissues which bind them together, to cause the fibres themselves to shrink, to break the envelopes of the fat cells and convert the fat itself into oil, to develop flavouring substances absent from raw meat, to kill any parasites which may be present, to stop any decomposition which may have begun, and, to a certain extent, to remove the traces of any previous decomposition and prevent its harmful effects. If the heat is excessive, the albumen coagulates and the meat becomestough, while the juices of the fibres are evaporated and the meat made dry and flavourless. Hence, in roasting, when it is desired to retain the flavour and the nutritive properties of the meat, the joint must first be subjected to fierce heat, which, acting on the outside of the joint, has the effect of coagulating its albumen and causing its fibres to contract, thus forming an external casing to the joint, which retains its juices. When the nutritive properties are to be extracted and the flavour imparted to a gravy, as in stewing, then the process is conducted at a temperature not sufficiently high to coagulate the albumen, *i.e.*, a temperature below 170° F. In frying, the object is to form a thin external casing on the outside which shall retain the juices as in roasting. This is done when the fat used is boiling. There are two dangers, one that the meat may become hard, dry and flavourless by too prolonged exposure to too great heat, and the other that the meat may become sodden with fat while its juices exude into the pan. This occurs when it is placed in fat which is not hot enough to produce the external casing. In boiling the same principle is to be observed. If the juices of the meat are to be extracted, however, as in making broths, soups, beef tea, &c., then the meat must be placed in cold water and subjected to prolonged cooking at a low heat. It should be remembered that, speaking generally, raw meat is much more readily digested than cooked meat, and that the more thorough the cooking, the longer the period required for digestion. Thus, while raw beef will require two hours for its proper digestion, underdone beef will need three hours, and well cooked beef four hours.

The general principles enunciated above apply also to fish, with the exception that cooking has the effect of making most fish soft.

The effect of heat on vegetables is highly important, many vegetable substances being nutritious when cooked which are totally indigestible when raw. The changes produced are the softening and breaking down the woody fibre—mainly cellulose—by which the plant cells are bound together, and the liberation of the proteid, starch or sugar contained in it. Heat also increases the digestibility of starch by changing or partly changing it into the soluble substance known as dextrin (see p. 43). The fresh juices are, however, unaffected by cooking—they are as valuable in the raw as in the cooked vegetable. Another effect is to burst the envelopes of the starch cells so as to expose their contents to the action of the digestive juices.

CARBON COMPOUNDS.

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THE CARBON COMPOUNDS.—Carbon enters into the constitution of all organic substances, *i.e.*, of all substances that form, or have formed, part of living tissue. Hence Organic Chemistry is also called the Chemistry of the Carbon Compounds. All animal or vegetable foods are compounds of carbon. The carbon is united with other elements, the chief of which are nitrogen, hydrogen, and oxygen. Those that contain nitrogen as well as carbon, hydrogen, and oxygen are termed nitrogenous or *proteids*. Of non-nitrogenous substances there are two great classes—the *Carbo-Hydrates*, which includes all starches, gums, and sugars, and the *Hydro-Carbons*, the class containing fats and oils. A third important food group is that containing the *Vegetable Acids*, oxalic acid, tartaric acid, citric acid, malic acid, and the salts which they form in combination with other substances, particularly the metals sodium and potassium.

The presence of carbon in any animal or vegetable substance may be readily detected by placing a small quantity on a piece of platinum foil and heating it. Many such substances char, and then, when still further heated, burn away; others burn at once. The carbon of the compound unites with the oxygen of the air to form carbonic acid gas. Another test is to subject the given substance to the action of strong sulphuric acid, when it will show a black residue. If this is burnt in air and the gas produced by its combustion be passed through lime-water, the lime-water becomes milky, proving that the gas was carbonic acid, which has united with the lime in the lime-water to form calcium carbonate. This is insoluble and, consequently, after floating in tiny particles in the water, for a time, slowly settles to the bottom. The production of carbonic acid proves that the black substance burnt was carbon.

GROUP I.—THE CARBO-HYDRATES.

Starch ($C_6H_{10}O_5$).— A glance at the formula shows starch to be composed of carbon, hydrogen, and oxygen, and to contain twice as much hydrogen as oxygen. This is a characteristic of all carbo-hydrates. They derive their name (hydrate—Gr. *hydor*=water) from the fact that they contain sufficient oxygen to oxidise all their hydrogen and so form water. Fats and oils (hydro-carbons) contain a far less proportion of oxygen. When seen with the naked eye starch appears a soft white powder ; when examined under the microscope it is found to consist of *granules*—the starch cells. Each cell contains *granulose*, enclosed in a wall of *starch cellulose*. One of the objects of cooking is to burst the cell wall and liberate the contents. The granules vary in shape according to their source, so that the starch grains of various plants can be readily distinguished—a fact very useful in detecting adulteration.

The *granulose* is nearly insoluble in cold water, but almost entirely soluble in hot. The cellulose is soluble in neither. A strong solution of starch forms a jelly when cold. The starch used by laundresses for stiffening linen is an example of such a solution.

Test for Starch.—Mix a small quantity of the powder to be tested into a paste with cold water, and then pour this into boiling water and boil for a few moments. When cold add a small quantity of the alcoholic tincture of iodine

(*i.e.*, the alcoholic solution of iodine). If it contain starch, the paste will be coloured deep blue. The colour will disappear on boiling and return on cooling.

If starch is heated to 320° F. it is changed to *dextrin*—a substance which has the same composition but is soluble in cold water, and which goes by the name of British gum. The change may also be brought about by heating it with nitric or sulphuric acid, or mixing a small quantity of malt flour, or extract of malt, with it. During digestion starch is changed first into dextrin. Hence cooking, which begins this change, renders starch more digestible. Dextrin, therefore, is of equal food value with starch, and much more easily digested. Hence it is widely used in prepared foods for infants, *e.g.*, Mellin's, Nestlé's, Benger's, &c. The change from starch into dextrin, and the solubility of the latter, should be tested by actual experiment.

Gluten.—This is the nitrogenous constituent of the cereals. It may be readily prepared from wheat flour by placing the flour in a muslin cloth and holding under the water from a tap. The stream of water which passes through the bag becomes milky with particles of suspended starch. If collected and allowed to stand this will settle to the bottom, and be found to form about 70 per cent. of the total weight of the flour. Remaining in the bag is a yellowish grey, sticky substance, which adheres to the fingers, pulling out into long threads. This is gluten. Both gluten and starch contain carbon, a fact which may be tested in the usual way by heating on a piece of platinum foil. If the gluten be exposed to the air it soon putrefies and its decomposition, like that of other proteids, may produce injurious substances.

Sugar ($C_6H_{12}O_6$).—Sugar differs from starch mainly in four particulars—composition, structure, solubility, and taste. The formula shows that it contains two molecules of hydrogen and one of oxygen more than is contained in starch. But these combine to form one molecule of water. Hence the change from starch to sugar consists in the building up of one molecule of water into the substance of the starch. In structure sugar is crystalline; starch granules show no trace of crystallinity, and while sugar is very soluble in cold water, starch dissolves only in hot. The former, too, may be readily distinguished by its sweet taste.

The solubility of sugar and its tendency to crystallise may be shown by dissolving it in hot water and noting the quantity required to make a saturated solution by suspending threads of cotton in it. As it cools, the crystals of sugar are deposited on the threads in the well-known form of sugar candy. If heated with a little water to 365° F. it will not crystallise on cooling, but forms instead the familiar, clear, golden, brittle barley sugar. Cane sugar is so soluble that one ounce of water will dissolve two ounces of it.

There are many kinds of sugar. Cane sugar (sucrose or saccharose) is most important and, as its name implies, is obtained in quantity from the sugar-cane. Other plants which furnish it are maize, the Chinese sugar-millet, the sugar maple, and many palms. Another variety—maltose—occurs in cereal grains, and is produced in greater quantity from the starch when the grain is malted.

A third important variety—glucose or grape-sugar—is found in sweet fruits, crystallising in lumps when the fruits are dried (*e.g.*, in raisins). It is also found in honey, unripe peas and beans, and in meat (as inosite—muscle sugar). Milk sugar—lactose—has the same composition as cane sugar.

None of the grape sugars are as sweet or as soluble as cane sugar, a fact which may be tested by experiment. If honey is washed with spirit the residue will be grape sugar—levulose. This form crystallises with great difficulty, and is generally obtained as a syrup or, when dried, as a

resinous-looking mass. The grape sugars are valuable as foods, especially for children, but may in some cases produce acidity, due to presence of lactic acid—a substance readily formed from them. If sugar be heated in a dry test-tube it melts, evolves water, and then gradually blackens. The pungent smell characteristic of burnt sugar is prominent. The residue may be shown to be carbon. In the same way, when sulphuric acid, which has a great affinity for water, is carefully added to a strong solution of cane sugar, the same smell will be noticed; the mixture will turn black and froth up, forming when cool a spongy solid mass of carbon, the water being taken from the sugar by the sulphuric acid. The frothing is due to the sudden formation of steam, carbon dioxide, and sulphur dioxide. The sulphuric acid must be poured gently down the side of the vessel to prevent accidents. When cane sugar is boiled with a little acid it will be converted into grape sugar, both varieties—dextrose and levulose—being present.

GROUP II.—THE HYDRO-CARBONS.

FATS AND OILS.—Fats and oils are chemical compounds formed by the combination of an acid, termed a fatty acid, and glycerine. Thus, for example, if three parts of oleic acid be heated with one of glycerine in a closed tube, these substances disappear, olein (the fatty principle of olive oil) being produced. This, with two other fats, palmitin or stearin, forms the bulk of the fats used in food.

The oils are liquids, and mostly obtained from the vegetable kingdom; the fats are solid, and mainly animal products. If we take animal fat, tie in a bag and immerse it in hot water, we find that it melts at about 150° F. If treated with super-heated steam (at a temperature of 600° F.) it decomposes into stearic acid and glycerine. Stearic acid is also produced when animal fat (tallow) is boiled with a solution of caustic potash as in the manufacture of soap (see p. 66). The fat dissolves in this, and gradually decomposes to form potassium stearate and glycerine. If hydrochloric acid be added the stearate decomposes, the potassium combining with the acid to form potassium chloride, while the stearic acid, being insoluble in water, separates out as a precipitate.

This, after being washed, may be dissolved in boiling alcohol. When this solution is cooled, the stearic acid separates in the form of shining needles. Stearic acid has a higher melting point than tallow, and hence is used for making "composite" candles, which have a much higher melting point than tallow ones. It is also an important constituent of hard soaps, combining with the alkalies to form stearates, which are mostly insoluble. Stearin may be procured by boiling suet in alcohol, separating in the form of crystals when the solution is cooled. When an alkali is added to it it forms a soap—a stearate of the alkali—and glycerine is set free.

Glycerine.—This, when pure, is a syrupy, colourless, sweet liquid which, when at a low temperature, solidifies, forming crystals like those of sugar candy. It boils at 554° F., but if impure is decomposed. It is best prepared by forcing steam at a temperature of about 600° F. into a retort containing some fat or oil. The steam decomposes the fat and the glycerine distils over. It is very soluble in water and alcohol, but is insoluble in ether. If a little be placed in a dry test tube and heated it blackens, decomposes, and gives off a disagreeable odour. Glycerine, as we have seen, is a constituent of all oils and fats of animal or vegetable origin. Its chemical composition shows, it to be really an alcohol. It is invariably produced in the alcoholic fermentation of sugar. Its great use is as a solvent, many substances dissolving in it even more readily than in water.

In addition to the fats and oils mentioned above, there is a long series of hydro-carbons of mineral origin. These differ from those of animal and vegetable origin in containing no oxygen and, according to their position in the series, are either gaseous, liquid, or solid. Among the gases are methane (marsh gas) and acetylene; among the liquids, naphtha and benzene; and among the solids, paraffin and naphthalene. Strictly speaking, the name, hydro-carbon should be restricted to these substances.

GROUP III.—THE ORGANIC ACIDS.

VEGETABLE ACIDS.—Green vegetables, roots, and fruits derive most of their food value from the presence of vegetable acids, which exist either free or in combination with various minerals with which they form salts. The chief of these acids are oxalic acid, citric acid, tartaric acid, and malic acid. To these we must add acetic acid, which occurs in certain over-ripe fruits.

Vinegar.—Acetic acid is best known as the acid of vinegar, the best kinds of which result from the fermentation of the alcohol of wine and beer. The presence of a ferment—the *mycoderma aceti*—a fungus similar to yeast, is essential to this process, as is also a free supply of oxygen. Where the oxygen is limited in amount the same organism will set up further alcoholic fermentation, hence the free access of air is essential. The fermentation is most active at a temperature from 24°—27° C., a rise to 35° C. causing a complete cessation of the process. Simple exposure to warm air suffices to reduce weak alcohol to acetic acid.

Four varieties of vinegar are in use—wine vinegar, malt vinegar, wood vinegar, and vinegar made direct from starch, sugar, &c. Good vinegar contains about 5 per cent. of pure (glacial) acetic acid.

Acetic Acid has a pungent smell and strong acid properties. In its concentrated form it is known as glacial acetic acid, and is strongly corrosive. Note that it does not redden litmus paper until mixed with water. It is usually made in commerce by the destructive distillation of wood, the crude acid being known as pyroligneous acid. If iron filings be placed in the acid they will slowly dissolve, the iron taking the place in the acid of the hydrogen which is given off, and so forming a salt—an acetate. Oxide of lead dissolved in it produces the sweet, white crystalline substance known as sugar of lead (lead acetate). This, it must be remembered, is highly poisonous. Like other acids, acetic acid is neutralised by the addition of an alkali, *e.g.*, soda. The neutralisation is shown by the loss of the property of turning blue litmus red. If we take the resultant salt, sodium acetate, and add sulphuric acid, it will be broken up; the sulphuric acid will combine with the sodium to form sulphate of sodium, the acetic acid being again freed. Its presence may be detected by the "vinegary" smell—which is absent from the salts—and its acid properties by testing with litmus.

Tartaric Acid occurs in its most characteristic form in grapes. When grape juice ferments, as in the manufacture of wine, the acid combines with potassium to form potassium tartrate. This salt forms the "crust" deposited by wine, and, in this impure form, is commonly known as *Argol.* When freed from its other constituents it appears as cream of tartar, which is therefore the pure tartrate of potassium. Tartaric acid crystallises in colourless prisms, which are very soluble in water or in alcohol. Its elements, carbon, hydrogen, and oxygen are the same as those of acetic acid, but their proportions differ. Tartaric acid is neutralised by an alkaline solution, with effervescence caused by the evolution of carbonic acid gas. It is often used with sodium carbonate for effervescing drinks, which are refreshing and mildly purgative. In a Seidlitz powder 120 grains of tartrate of soda and potash (Rochelle

salts) are mixed with 40 grains of bi-carbonate of soda. This is dissolved in water and 35 grains of tartaric acid—the substance usually put up in white paper in the powders bought at the chemists—added to produce effervescence. Any tartrate, heated in a dry test tube swells up, giving off the characteristic odour of burnt sugar and leaving a black residue of carbon.

Tartaric acid is found in many acid fruits, besides grapes, *e.g.*, tamarinds, mulberries, and pine-apples. It is also present in potatoes, cucumbers, and the Jerusalem artichoke. It is used in making acidulated sweetmeats, and in numerous saline effervescent drinks.

Citric Acid.—The salts—called citrates—are abundant in the fruits of plants of the orange kind, particularly in the lemon or lime. It is also found in gooseberries, currants, strawberries, and others; sometimes free, but more often in combination with potash, soda, magnesium, &c. It forms the basis of many acidulated drinks, and is quite wholesome. It is sometimes used to replace pure lemon or lime juice as an anti-scorbutic. Like tartaric acid, it will decompose alkaline bi-carbonates, forming effervescent mixtures. Such drinks, however, should not be used indiscriminately, or serious harm may result.

Of other acids *Malic Acid* is found in apples, pears, plums, and all fruits belonging to the Rose order. *Oxalic Acid* is found in wood sorrel, in rhubarb, and many other plants. This is the acid commonly sold as "salts of lemon."

Spirits.—The intoxicating constituent of beer, wine, and spirits is Alcohol or Spirits of Wine. It is produced by the action of a ferment on grape sugar. In the case of beer this ferment is introduced in the form of yeast. Grape juice already contains a ferment. The process is as follows:—

$$\underset{\text{Grape Sugar.}}{(C_6H_{12}O_6)} = \underset{\text{Ethyl Alcohol.}}{2\,(C_2H_6O)} + \underset{\text{Carbonic Acid.}}{2\,CO_2}.$$

The alcohol is colourless, neutral in reaction, has a faint, pleasant smell, and a burning taste. Next to water, it is the most important of solvents, dissolving many fats and resins that are entirely insoluble in water. It will itself dissolve in water, the solution being accompanied by a shrinkage in volume and the evolution of heat.

The boiling point of alcohol is 75° C. (167° F), a point which is considerably lower than that of water. Hence it may be boiled by placing it in a test tube in hot water. For the same reason when beer, wine, or spirits are heated, the alcohol distils over as vapour before the rest of the fluid has reached boiling point. By allowing this to pass through a tube leading through a vessel of water it may be condensed. If to this we add quicklime or solid potassium carbonate, to get rid of any water which may be contained, and then distil again, we shall obtain a more concentrated spirit. The proof of concentration is the readiness with which it catches fire, and the more strongly burning taste.

> DISTILLATION.—The process of distillation consists in volatilising a liquid by subjecting it to heat and then condensing it again. The method commonly employed is to place the liquid in a boiler—termed a *still*—from which proceeds a coiled tube known as the *worm*, which passes through cold water. When heat is applied to the still, the liquid is volatilised, and the vapour passes into the worm, where it is cooled and becomes condensed into the liquid form again. In this way volatile liquids are separable from non-volatile ones, or from solids dissolved in them. Liquids which have different boiling points may also be separated in this way, that which has the lowest boiling point passing off first.

Alcohol may be produced as follows:—Take any sugary fluid, add yeast, and set in a warm place. The liquid will

become cloudy, and a frothy scum rise to the top. If the flask be fitted with a tube passing through the cork, and this tube be bent so as to dip under the surface of lime water contained in another flask, the fact that the process is accompanied by the evolution of carbonic acid gas may be ascertained by the effect on the lime water. This becomes milky owing to the precipitation of calcium carbonate. This salt is formed by the carbonic acid given off combining with the lime dissolved in the water. If, after the lapse of a few days, the fluid in the flask be heated, alcohol distils over, and may be collected as described above.

When alcohol is perfectly free from all admixture of water it is termed *Absolute Alcohol.* "*Proof*" *Spirit* is not absolute alcohol, but a mixture containing 49¼ per cent. of pure alcohol and 50¾ per cent. of water. The specific gravity of pure alcohol is 794 (water being taken as 1,000), that of proof spirit 920.

Ethyl, or Ethylic Alcohol, forms the basis of all intoxicating beverages, beers, wines, and spirits. Whatever differences exist in flavour are the result of differences in manufacture and the presence of ethers or flavouring matters, or other—higher—alcohols. As a matter of fact, inferior kinds of gin, brandy, and whiskey are often made from what is known as "silent" spirit—a perfectly flavourless alcohol, often distilled from the commonest materials—starch, old rags, paper, or woody fibre, which have been previously treated with sulphuric acid.

Cheap spirits, too, often contain alcohol distilled from beetroot or potatoes, and hence commonly known as "potato spirit." An important constituent of this is "fusel oil," a mixture of the higher alcohols—butylic, amylic, and propylic alcohol. This is strong, coarse, and of a nauseating flavour. When spirits are kept in wood these higher alcohols are absorbed by the cask. Hence such spirits acquire a softer or more delicate flavour with age. On the other hand, the improvement that wines undergo with age arises from the conversion of a portion of their alcohol into volatile ethers, which have high flavouring qualities.

Methylated Spirit is alcohol to which about 10 per cent. of methyl alcohol (CH_4O) has been added. This gives it a disagreeable flavour, and so prevents its being used for drinking. Consequently it is allowed to pass duty-free—an important consideration, since it is widely used in the arts of manufactures.

ELEMENTARY CHEMISTRY.

THE COMPOSITION OF AIR.—If we burn a piece of phosphorus, under a glass jar which stands in a dish of water, so that no more air can enter, we find that, as the burning progresses, the water rises higher and higher in the jar until, when the phosphorus goes out, the water occupies a space which is one-fifth of the jar in volume. Repeat the experiment, using sulphur instead of phosphorus, and the result will be the same. Evidently the result of the burning has been to use up a fifth part of the air in the jar. If, now, we introduce a lighted match or a taper into the jar it goes out. The effect of the burning has been to use up that portion of the air essential to combustion. Hence we may say that, as regards combustion, air contains an active part and an inactive part. The active part is the gas oxygen; the inactive, the gas nitrogen. It is important to remember that air is a mixture, and that its oxygen is consequently *free*; in water, on the other hand, which is a compound of oxygen and hydrogen, the oxygen is in combination.

TESTING A GAS.—In determining the properties of any new gas the student should :—

i. Test with litmus paper to determine whether it it has an acid, an alkaline, or a neutral reaction.

ii. Test, by introducing a light, whether it is combustible or will support combustion.

iii. Test whether it is lighter or heavier than air by ascertaining whether it will pour up or down into another vessel.

iv. Test, by shaking it up with lime water, whether it is carbonic acid. If so it will turn the lime water milky.

iv. Test its solubility by shaking up with water.

Nitrogen.—Applying these tests to nitrogen, we determine that it affects neither red nor blue litmus—that is, it is neutral, that it neither takes fire nor supports combustion, that it is about the same weight as air (slightly lighter), that it does not turn lime water milky, and that it is only slightly soluble. If, instead of phosphorus, we had burned charcoal or a candle under the jar and tested the gas it contained afterwards, we should find that it will turn lime water milky, and therefore contains carbonic acid.

Oxygen.—If we prepare oxygen, which we can readily do by heating a small quantity of potassium chlorate, mixed with about one-fourth its weight of manganese dioxide, and fill several jars with it, we shall be able to test its properties. Proceeding as before, we find that it is neutral to litmus paper, incombustible, heavier than air, very slightly soluble in water, and a great supporter of combustion, since even iron may be made to burn in it, forming the black oxide of iron (Fe_3O_4).

If we burn sulphur, phosphorus, charcoal, each in a jar of oxygen, we find that the combustion is much more violent but that the products of combustion are the same as when these substances are burnt in air. We are therefore justified in concluding that oxygen is the active part of air, and that nitrogen simply serves to dilute it.

COMBUSTION.—From the preceding paragraphs, it will have been seen that when an element which has great

affinity for oxygen combines with it, heat is evolved. If this is great, light may also be produced, and the substance which is combining with oxygen is said to burn. In the ordinary sense of the term, therefore, the combustion of any substance consists in the violent combination of the elements of which it is composed with the oxygen of the atmosphere. Thus, when coal gas or lamp oil, or the fat forming the candle, is burnt, the hydrogen of these substances combines with oxygen to form water—oxide of hydrogen (H_2O), and their carbon takes up oxygen to form carbon dioxide (CO_2). Similarly, sulphur and phosphorus, when burnt in air, produce oxides—sulphur dioxide (SO_2) and phosphorus pentoxide (P_2O_5) respectively. The study of chemistry, however, furnishes many examples of gases, other than oxygen, in which various substances will burn, and which therefore, in a broader sense, are termed supporters of combustion.

RUSTING.—If, instead of *burning* phosphorus in a jar of air as on p. 53, a stick of phosphorus is suspended in a jar for some days, the water will be found to rise in the jar as before, and the phosphorus, if weighed, to have become heavier. The residual air of the jar will, if tested, be found to be nitrogen. Hence, at the ordinary temperature of the air, phosphorus will combine with oxygen. Note the changed appearance of the outside of the stick, which is now covered with a coating of oxide of phosphorus. In this case, however, the combination is slow and is not characterised, as in the case of combustion, by the evolution of great heat and light. The phosphorus has "rusted." But rusting is, as we have seen, chemically the same process as combustion, only much less vigorous. It is *slow oxidation.*

Again, place a dish of iron filings in a jar containing water, or suspend them in a bag, over water in a jar as before. After two days weigh the filings. They will be found to have increased in weight. Examine them. They are covered with a reddish brown coating of what is known as iron rust. The water has risen in the jar, indicating that some of the gas it contained has been removed. Testing, as before, will show that the missing portion is oxygen. The inference is that the oxygen has combined with the iron to form iron rust, which is therefore an oxide of iron ($Fe_2 O_3$). But if the experiment be tried in dry air the iron will not rust. Neither will it do so in pure water—*i.e.*, water which has been boiled long enough to dispel the gases dissolved in it. Hence we conclude that both oxygen and water are essential to the formation of iron rust, which is therefore not a simple oxide (compound of iron and oxygen). As a matter of fact, it has the same composition as brown haematite, an ore of iron formed from the red oxide by the (chemical) addition of water. Such an oxide is termed a hydrated oxide.

Flame.—Flame is volatilised matter heated by combustion to such an extent as to become self-luminous. It is always attended with great heat, but the brilliancy of the illumination depends upon the character and completeness of the combustion. This process is due to the chemical union between the combustible matter of the fuel and the oxygen of the air. *Hence it can only proceed where the two are in contact.* For this reason a flame is generally a hollow case containing combustible matter. Thus, a simple flame—say, that of a candle—consists of three parts. The dark central part consists of volatilised combusible matter which has risen by capillary attraction through the wick. Surrounding this is a highly luminous envelope, and outside this a second envelope, less bright but intensely hot. The double envelope is due to the double nature of the combustion. Hydrogen has a stronger affinity for oxygen than carbon has. Hence, when both are

present and the supply of oxygen is limited, the hydrogen takes all, to the exclusion of the carbon. But the heat produced by the combustionof the hydrogen raises the particles of carbon to incandescence. These incandescent particles form the luminous envelope. Outside this the carbon, drawing an unlimited supply of oxygen from the air, undergoes complete combustion. The result is intense heat and little light.

Most luminous flames are the result of the presence of solid bodies in a state of incomplete combustion. Thus, the non-luminous flames of hydrogen, carbonic oxide, and alcohol become luminous if powdered carbon, zinc, or lime be allowed to fall through them. On the other hand, non luminous flames result from immediate and complete combustion. Hence, if the whole body of combustible material were thoroughly mixed with the air, instead of being merely surrounded by it, the combustion would be complete, the heat intense, and the light practically nil.

THE BUNSEN BURNER.—Since, in the ordinary illuminating flame of a lamp or a candle, or gas jet, the area of combustion is confined to a shell in contact with the air, it is obvious that the combustion in such a flame is far less vigorous or complete than it would be were every particle of the gas of the fuel in contact with the oxygen needed for its combustion. If, therefore, we could by any means introduce oxygen into the interior of the shell of flame, we should produce a much more complete combustion and obtain far greater heat. This is the principle which underlies the well-known Bunsen burner. At the base of the burner are holes which admit a current of air. This mingles with the gas which issues from a tube inside the burner, and the current of mingled gas and air is ignited at the top. The result is a flame in which the combustion is nearly complete and which is consequently very hot. But as the illuminating power of a flame depends upon the incandescence of particles of carbon which have not undergone combustion, it necessarily follows that the Bunsen flame gives very little light. If, however, the air holes are closed, the flame becomes an ordinary luminous one. The blowpipe is a similar contrivance, the combustion being even more complete, since a current of air is blown into the gas, giving it an even greater supply of oxygen and producing an intense flame.

The same principle is utilised in the incandescent burners now commonly in use. These are furnished with air-holes similar to those of a Bunsen burner, and the mixture of air and gas is ignited in the same way. The result is a similar slightly luminous, but intensely hot flame. The temperature of this is sufficiently high to heat to incandescence a "mantle" composed of certain rare earths, which are incombustible. The result is a brilliant white light. If an accumulation of dust or any other obstruction is allowed to interfere with the supply of air or gas, the combustion becomes less vigorous, the heat produced is less and the "mantle" gives a poor light.

Gas Explosions.—An ordinary gas explosion furnishes an example of the extremely rapid combustion of a large body of gas. When air and gas are mingled in such quantities that there is present sufficient oxygen to oxidise the combustible material of the gas an explosive mixture is formed. Hence, when a light is applied, combustion is instantaneous. The destructive effects consequent upon explosions are due to the fact that the gaseous products of the combustion occupy a far greater space than the original substances. In other words, the gas combines with oxygen to form an immense volume of intensely heated matter which exerts great and sudden pressure

on surrounding objects. Hence, the most explosive mixture is one which contains sufficient oxygen to combine with all the combustible material. Thus, olefiant gas (CH_2—heavy carburetted hydrogen)—one of the chief constituents of coal gas—forms an explosive mixture with oxygen in the proportion, by volume, of one to three; light carburetted hydrogen (CH_4—marsh gas, or methane—the fire-damp of the miner) forms an explosive mixture with about twice its own volume of oxygen. This would be contained in ten times its volume of air. Hence an explosion of fire damp occurs when it is present in air to the extent of about one part in eleven. This is also a constituent of coal-gas. The latter explodes with air when present to the extent of about one part in eight. Hence the danger of looking after an escape of gas, however slight, with a light. When an escape occurs, the gas should be immediately turned off at the meter, all lights extinguished, and the house thrown open to the air. Gas, itself, will burn but not explode.

The Combustion of Carbon.—If we burn charcoal, or any other form of carbon, in oxygen, and collect the products of combustion, we shall obtain a gas which, if shaken up with lime water, will turn it milky. If the milky water be allowed to stand the milkiness will subside and we shall discover that it was caused by tiny particles of calcium carbonate, which have now settled to the bottom. Hence we know that the gas given off by the burning charcoal was carbonic acid (the same gas as is produced by the fermentation of sugar), since it combines with lime to produce calcium carbonate. Testing, as before, we find this gas is acid, is not combustible and will not support combustion, is heavier than air, and is soluble in water.

The experiment may be varied by passing a stream of oxygen over a known weight of carbon heated to redness, and absorbing the gas produced by passing it through a tube containing caustic soda or caustic lime. These will increase in weight as a result of the absorbed gas, which may be shown to be carbonic acid. Hence, if they are weighed before and after the experiment, the difference will give the weight of carbonic acid produced. This will be found to be greater than that of the carbon; showing that when substances are burned in oxygen the weight of the products of the combustion is greater than that of the fuel consumed.

Carbonic Acid.—Carbonic acid gas (carbon dioxide, CO_2) and water vapour (hydrogen oxide, H_2O), are continually being poured into the atmosphere as the products of the combustion in fires, lamps, &c., and that slower process continually going on in the bodies of animals and plants. It is also the result of the slow process of oxidation which occurs in the decay of organic tissue after the death of the organism of which it formed part. That water vapour is the result of burning, as in a candle or lamp, may be shown by inverting a cold glass over the flame. The interior will soon become bedewed with moisture. That it is a product of the combustion going on in the body may be shown by breathing on a mirror or cold pane of glass. The presence of carbonic acid may be readily detected by its effect on lime water. The gas unites with the lime (calcic oxide, CaO) dissolved in the water to form calcic carbonate ($CaCO_3$). But this is insoluble, so that the water, clear at first when the lime was dissolved in it, becomes cloudy, and even milky, owing to the precipitation of the calcium carbonate in the form of a very fine white powder. This slowly settles to the bottom, and the water becomes clear once more. It is, however, no longer *lime-water*.

We may perform the experiment by blowing the air of a room through the lime-water by means of a bellows, or by blowing the expired air from the lung through it by means of a glass tube, one end of which dips into the lime water. In this way we can show that carbonic acid is present in both cases. Another method of testing the air of a room is to bring into it a bottle full of water. When this is emptied the bottle fills with the air of the room. Now introduce a small quantity of lime water and shake thoroughly. The lime-water will become cloudy as before. By using lime-water containing a known quantity of lime in solution and a bottle of a definite size, this test may be made to give, with sufficient accuracy, the proportion of CO_2 present in the air of the room. If half an ounce of lime-water (containing ·0195 grains of lime) be placed in a $10\frac{1}{2}$ ounce bottle, and after being well shaken, no turbidity appears, the CO_2 present does not exceed ·06 per cent. As this is the limit of respiratory impurity, the air may be considered pure. If an 8 oz. bottle be used, the CO_2 does not exceed ·08 cent., if a 3 oz. bottle, ·025 per cent., and so on.

The presence of CO_2 in the air of a room may be detected by exposing a saucer of lime water for some hours. If the air contains an appreciable quantity of CO_2 the water will be found covered with a filmy crust.

Atmospheric Carbonic Acid.—As a result of combustion, there must be a constant passage of carbonic acid gas into the atmosphere. But as it forms an important plant food and is absorbed by the leaves of all kinds of plants, which obtain from it a great proportion of the carbon contained in their tissues, the demand is about equal to the supply, and the quantity in the atmosphere remains constant at about four parts per ten thousand. Indeed, the supply would probably prove insufficient were it not supplemented from two other sources—the decay of organic matter and the combustion which goes on in the bodies of animals, as a result of which carbonic acid gas is continually being poured into the air from their lungs.

The presence of this gas in expired air may be shown by expelling the air, through a tube, into lime water (see p. 61), when the characteristic milkiness will be observed. The presence in air is shown by exposing a saucer of lime water to the air. The water becomes coated with a film which may be shown to be carbonate of calcium.

WATER.—Water is essential to the nutrition of the body and to the performance of the functions of life. Hence it may justly be classed as a food. It forms a large proportion of the various tissues of the body, and is the means by which the digestive juices are enabled to permeate the food, and by which the food is absorbed into the blood. It is also necessary for the elimination of the waste products of the body and for the regulation of temperature.

Further, it is a necessity for purposes of cooking, for the ablution of the person, the washing of clothes, utensils and houses, and for the removal of sewage and the flushing of streets. Its uses and impurities, the distinction between hard and soft water, and the methods of softening hard water are dealt with in pp. 19-22 of "Notes on Hygiene," Part II. It will suffice here to touch upon its composition.

THE COMPOSITION OF WATER.—Water is a compound of the two gases, oxygen and hydrogen. As we have seen, it is one of the products of combustion, and hence is an oxide of hydrogen, the proportions being one volume of oxygen to two of hydrogen (or by weight, one part of hydrogen to eight of oxygen, a result of the fact that oxygen is sixteen times heavier than hydrogen).

The truth of the statement may be shown by mixing one volume of oxygen with two of hydrogen in an ordinary

soda water bottle. Wrap the bottle carefully in a thick cloth and hold its mouth to a light. The two gases unite with a loud explosion and the interior of the bottle is seen to be covered with moisture, which has condensed on it. Also water may be decomposed or analysed by passing a current of electricity through it, the oxygen may be collected by holding a tube over the end of the wire by which the electric current enters the water and the hydrogen by holding a tube over the end of the wire by which it leaves the water. Each end of the wire is generally furnished with a tiny strip of platinum and the whole apparatus is termed a voltameter.

Hydrogen.—This gas is the lightest known element, and is colourless, tasteless, and transparent. As we have seen, it unites with oxygen to form water. To put this in another way, we may say that hydrogen is combustible in oxygen. Note, however, that combustion is a mutual process, and just as hydrogen will burn in oxygen, so oxygen will burn in hydrogen. Coal gas will burn in air, and air will also burn in coal gas. We may procure hydrogen from water by analysing the water by means of the electric current, as described in the preceding paragraph; or by introducing into the water some substance which has a greater affinity for oxygen than hydrogen has, and so robbing the water of its oxygen. Thus, a piece of the metal sodium, introduced into water will unite with its oxygen and a part of its hydrogen to form sodium hydrate, while the remaining hydrogen bubbles up through the water and may be collected in a jar, which must be kept carefully inverted, as the hydrogen is much lighter than air. An easy method of preparing hydrogen in sufficient quantity for experimental purposes is to take a flask with two necks, cover the bottom with granulated zinc, and pour in dilute hydrochloric acid through a thistle funnel fixed in one neck and extending to the bottom of the flask. Hydrogen is given off and passes out through another tube thrust through the cork in the other neck.

If the end of this tube be brought under a cold bell jar and a match applied to it, the escaping hydrogen ignites, burning with a dimly luminous flame. (Care must be taken that all the air in the flask is expelled before the light is applied, or an explosion may occur.) The inner surface of the jar becomes coated with tiny drops of fluid which may be shown to be water, since it will boil at 212° F. (100° C.) and freeze at 32° F. (0° C.). That the hydrogen flame is virtually non-luminous, while the combustion of coal gas produces a brilliant light, is due to the fact that in the former there are no particles of carbon to be raised to incandescence.

If the hydrogen produced in the last experiment be made to pass through a tube containing heated copper oxide—copper scale, the copper will give up its oxygen, which will unite with the hydrogen to form water. This may be collected by making it pass through another tube containing calcium chloride, a substance which readily absorbs water. If the calcium chloride tube be weighed before and after the experiment, the difference in the weight will be due to the quantity of water absorbed. If coal gas be employed, the same effect will follow, hydrogen being a constituent of coal gas.

The CO_2 produced may also be estimated by passing the gas through lime-water and weighing the calcium carbonate which is precipitated.

Coal Gas.—This is a mixture of various gases, mostly compounds of carbon, and all produced by the destructive distillation of coal. Its composition is by no means constant, even when manufactured at the same gas works.

The quality of the coal and the temperature of the retort in which it is heated produce considerable variations in the composition of the gas. Roughly speaking, it may be said to contain on an average :—

Olefiant gas (ethylene)	...	about 3·5	per cent.
Marsh gas (methane)	...	,, 35·0	,,
Hydrogen	...	,, 52·0	,,
Carbon monoxide ...	...	,, 9·0	,,
Acetylene / Oxygen } small quantities		,, ·5	,,
		100	per cent.

Many impurities are also found, the chief being ammonia, carbonic acid, water, and sulphur compounds such as ammonium sulphide, sulphuretted hydrogen, and sulphur dioxide.

The illuminating power of coal gas arises from the incandescence of the solid particles of carbon which are set free, by combustion, from the gases it contains.

Coal gas may be made for purposes of experiment by heating coal dust, contained in a hard glass flask, over the flame of a Bunsen burner. If the flask be fitted with a tube terminating in a fine nozzle, the gas may be ignited as it escapes into the air. If made to burn in a jar containing air, it may be shown that carbonic acid is one of the products of combustion by introducing a little lime-water in the jar and shaking it up ; a precipitate of chalk will be formed. Water is another product and will be condensed on the sides of the jar.

Clarke's Soap Test for Hard Water.—Hard water may be artificially produced by passing carbonic acid gas through lime-water until the solution becomes clear. The degree of hardness may be determined by the soap test.

This depends on the fact that, whereas soap immediately forms a lather with pure water, it will not do so with hard water until the mineral substances which made the water hard have been neutralised by the soap. Hence we may compare the hardness of two samples of water by noting how much of a given soap must be used before a permanent lather is obtained. Castile soap is dissolved in pure water until 2·2 cu. cm. of it will give a permanent lather when shaken up with 50 cu. cm. of a solution of barium nitrate, containing ·26 grains of the nitrate to a litre of water. Each cu. cm. of the soap solution that is required to produce a permanent lather with 50 cu. cm. of water indicates the presence of 2·5 milligrams of calcium carbonate. Dr. Clark, the originator of this test, expressed the result in grains per gallon. If it be remembered that a gallon contains 4,545 cu. cm., and that 1 gram equals 15·432 grains, the process will be seen to be an easy one. Water which contains 7 grains of calcium carbonate per gallon is water of 10° of hardness.

Soap and Soda.—A soap is a compound formed by the chemical union of an alkali and a fatty acid. The fats employed in its manufacture are many—stearin, olein, palmitin being the chief; the alkalis are two—soda and potash. Hard soaps are made with soda, those made with potash do not dry, and are termed soft soaps. The method of manufacture is chiefly as follows:—A given quantity of any of the above fats is placed in an iron pan. To this is added the "lye" or solution of soda, made by boiling a solution of carbonate of soda with lime. Stronger and stronger lyes are added, any excess of alkali being neutralised by the addition of fresh fat until combination takes place. Then the soap is "salted out"—about 10 lbs. of common salt being added to every 100 lbs. of the mixture, with the result that the soap, being insoluble in the briny liquid, rises to the top, leaving the

glycerine and brine at the bottom of the pan. Small quantities of soap may be experimentally made by boiling dripping with a solution of caustic soda and salting out as described above. Care is necessary in using caustic soda, (NaHO), as its caustic properties are powerful. It will dissolve all animal matter and reduce vegetable to pure cellulose. Good soap should contain about 30 per cent. water, 63 per cent. fat, and 7 per cent. soda. If kept in a dry place it loses part of the water and becomes harder, and is more economical in use. Various devices are resorted to by unscrupulous manufacturers for making their soaps take up an excess of water, while remaining apparently hard and firm. Marine soap, which is made from cocoa-nut oil, is not salted out, the soap being soluble in brine, and consequently adapted for use with sea water. Both potash and soda soaps are soluble in hot water and in alcohol, but the solution in water is always milky from the deposition of some of the fatty acid, which results in the liberation of a corresponding quantity of the alkali. The latter is the active ingredient in removing grease, and is quite insoluble in salt water. Note that the compounds of stearic, oleic, and palmitic acid with calcium and magnesium—the oleates, stearates, and palmitates of calcium and magnesium—are also soaps. They are formed by the free fatty acid when soap is used with hard water. But they are insoluble, and it is their precipitation which produces the scum which forms under such circumstances. The soap thus used up is wasted for cleansing purposes. Hence it is that the use of hard water is wasteful, much soap being wasted in forming these compounds before any cleansing effect is produced. Some soaps—those with a reputation for rapid cleansing properties—contain an excess of alkali. This is injurious, as it removes the natural oil which lubricates the skin, which thus becomes dry, rough, and liable to chap.

Removal of Stains.—From the foregoing, the reason for the use of such alkalis as soda and ammonia, in the removal of grease stains, &c., is clear, the result of their application being the formation of soluble soaps. For the same reason, soda is employed for the removal of paint stains and the washing of greasy dishes and utensils, and for cleansing the interior of ovens and other places likely to become coated with fat, which, unless removed, will putrefy, giving off disagreeable odours.

The cleansing properties of water depend upon its solvent powers, and as grease of any kind is insoluble in water, this is useless for cleaning greasy articles without the addition of some alkali. Certain other substances—*e.g.*, benzene and turpentine—will dissolve fats and oils, and hence are sometimes used for the removal of grease stains from clothes, &c., in cases where an alkali would injure the fabric or alter its colour. Paraffin oil will also dissolve grease and is used for cleansing machinery, and also, sometimes, in washing clothes.

ZYMOTIC DISEASES.

—:—

Ferments.—We have already seen, in the case of the yeast plant, that a ferment is capable of making changes in sugar, splitting it into carbonic acid and alcohol, one result of the process being a rise of temperature. Other ferments—the putrefactive bacteria—attack dead organic matter, resolving it into simpler combinations. Here, again, heat is produced. A familiar example is the rise in temperature which occurs in a manure heap, and which is utilised by the gardener in forcing the growth of seeds and plants. A third group of ferments—the bacteria of disease—attack living tissue, producing changes in them which are again accompanied by the evolution of heat. One symptom of their activity in the system is, therefore, a rise in the temperature of the body, bringing about that condition known as fever. As each of the diseases brought about in this way differs according to the nature of the ferment causing it, they are termed specific fevers; as each can be communicated from one person to another by the transfer of its specific ferment, they are termed *infectious*, while because they are the result of changes wrought in the body by the action of ferments, they are known as Zymotic diseases from the Greek, *Zyme*—a ferment.

The chief zymotic diseases which affect man are cholera, diarrhœa, diphtheria, erysipelas, small-pox, influenza, measles, scarlet fever, enteric (typhoid) fever, phthisis (tubercular), and whooping cough.

THE LIFE HISTORY OF AN INFECTIOUS DISEASE.—This bears a striking resemblance to that of the yeast ferment. There are three well-marked periods in a favourable case:—

i. *The period of incubation*, during which the organism is multiplying in the system.

ii. *The period of activity*, when the organism is most vigorous and most numerous and the symptoms of the disease most marked.

iii. *The period of decline*, during which the activity of the organism diminishes and finally cease, leaving the patient free from disease but prostrate with weakness.

The length of the period of incubation varies with the disease, as does also the length of time during which the infection may be spread. Each disease, too, has its special features, which can only be explained by assuming that each germ finds a certain set of conditions most suitable for its development. Thus age, sex, race and season all play their part in modifying the activity of each ferment. Scarlet fever is essentially a disease of early childhood, and the mortality from it is greatest among children of from three to five years; measles and whooping cough are also children's diseases. Enteric fever, on the other hand, is most deadly between the ages of fifteen to twenty-five. Influenza is a disease of middle life and age, nearly fifty per cent. of the deaths from it being of persons over sixty.

Each, disease, too, has its seasonal character. Small-pox is most active in the winter; enteric fever in the early autumn; cholera in the late summer. Roughly, intestinal diseases, like enteric, diarrhœa, dysentery, and cholera are most prevalent in summer, respiratory diseases in winter. Hence mild winters and cool summers both tend to lessen the amount of disease. Again, certain diseases are endemic in certain places, *e.g.*, yellow fever in the Gulf of

Mexico, cholera in the Ganges Delta, malaria on the West Coast of Africa.

Nearly all zymotic diseases are of a cyclical character. They occur as epidemics, with a certain amount of regularity. This points to perhaps the most interesting fact associated with their study—the immunity which one attack gives against another.

The Protective Effect of an Attack of an infectious disease is well known. The period over which the protection extends, however, varies considerably both with the disease and with the individual. Thus, with most people, the immunity given by an attack of small-pox or scarlet fever is life-long; that given by an attack of diphtheria in many cases, only temporary. The reason is most probably that the changes wrought by the organism of the disease in the body result in the production of substances which are poisonous to the germ and thus destroy it, putting an end to the first attack, and, so long as they remain in the body, protecting against a second. It is this fact which forms the basis of what is known as the anti-toxic treatment now employed in diphtheria and other diseases. Certain of these germ-destroying products of the disease are injected into the body in the early stages of an attack in the hope of either checking its course or mitigating its severity.

Vaccination and Inoculation.—Many persons suffer from mild attacks of infectious diseases without even knowing it, and are thus rendered immune. Hence it has been suggested that the best method of providing against the danger of infection is to artificially produce a mild attack. This is known as inoculation. In the last century it was the fashion to inoculate with small-pox, then a terrible scourge, in order that the disease might run its course under the most favourable conditions. Jenner discovered that immunity against small-pox was conferred by an attack of cow-pox, a disease sometimes contracted by dairymen and milkmaids. This disease, virulent in the animal, took a greatly mitigated form in the human system. Hence the modern practice of vaccination, which really consists in producing a disease—*vaccinia*—in the hope, thereby, of giving protection against small-pox. Investigations are now being made with a view to conferring protection against the attacks of other diseases. Considerable progress has been made in the case of diphtheria and typhoid, against the latter of which a great number of our troops were inoculated before being sent to the front, in the war with the South African Republics.

Infection.—No attack of any of the specific fevers can arise save by infection from a previous case. Yet it must be remembered that many circumstances predispose the body to the reception of the germ, and these are, therefore entitled to be considered causes of the disease. Such are bad or insufficient food, overcrowding, bad ventilation, the breathing of foul air, noxious gases or emanations from sewage, and exposure to damp, chills, &c. All these are means by which the vitality of the body is lowered and its power of resisting the onset of a disease impaired. For it is to be remembered that the first stage of an infectious fever is a battle between the body cells and the invading germs. If the former are strong the latter may be surrounded and destroyed. If their vitality is lessened as a result of any of the causes mentioned, the germs establish themselves and begin to multiply in the tissues —the disease, we say, is "taken." Hence, favourable conditions as regards food, fresh air, sanitary surroundings and exercise tend to minimise the risk of infection.

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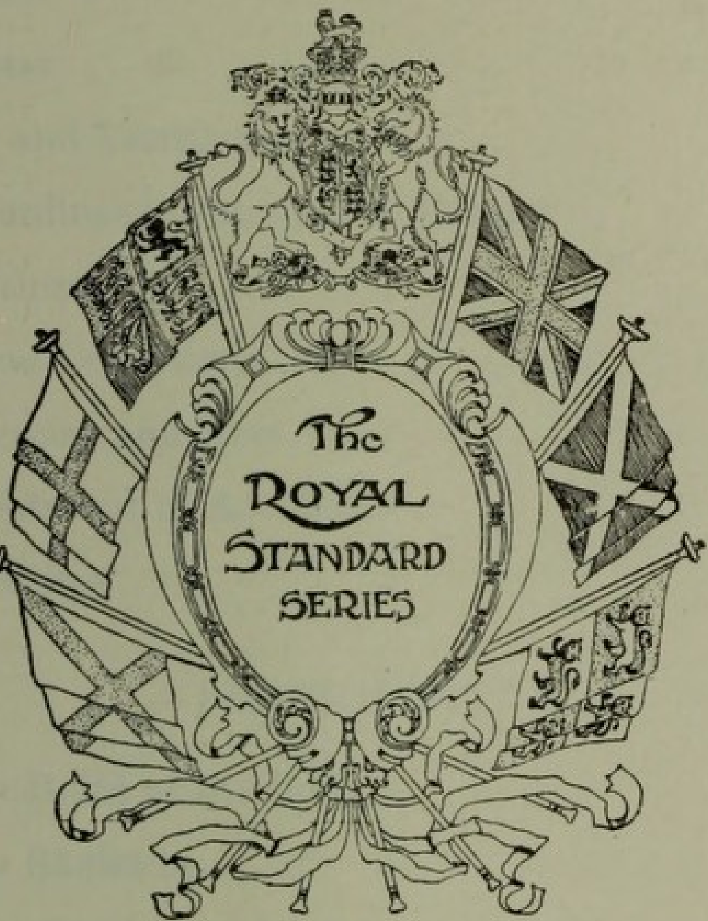
ELEMENTARY HYGIENE.

(SECTION II.)

BY J. H. NANCARROW,

Late Head Master Kingston Public School of Science, and Lecturer in Hygiene at the Richmond School of Science.



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CONTENTS.

HYGIENE.

PHYSIOLOGY.

INTRODUCTORY.

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The word Hygiene is derived from the Greek word "hygieinos," meaning good for the health. It is concerned with the study of everything, outside a person's own body, which is capable of influencing his health. The chief of these will be his food, air, water, the character of his abode, the nature of his work, and his personal habits.

Formerly the necessity for carefully considering these points was, though great, still not so great as now, when the massing of men in large communities tends to seriously aggravate those conditions which are inimical to health, and to render the most careful attention to sanitation absolutely essential, both for the sake of the individual and of the community. Animal life constantly pollutes those essentials, air and water; and Nature, though possessing vast powers of purifying, can act only within certain bounds. In proportion as men crowd together so does the death-rate rise, unless the most anxious care is taken to assist Nature in her work of purification.

Energy.—Energy is the power of doing work. We are familiar in daily life with many forms of energy. The energy furnished by the expansive force of steam drives our machinery. The energy of water running down a hill turns the mill-wheel. The muscular energy of the smith is utilised in wielding the hammer. The wonderful manifestations of electrical energy produce the telegraph, the telephone, the phonograph, the electric motor, and the electric light. Energy is not *produced*. No energy can be created afresh. The sum total of energy in the universe is constant, but it can be made to change its form. Beginning at the ultimate source of all terrestrial energy—the sun, it is possible, briefly, to trace certain of these transformations. The heat of the Sun evaporates the water from the surface of the Earth, to condense in the cool air, into the form of cloud. The clouds break in rain, and the rain, rushing back to the level of the sea from which it came, produces streams and rivers, capable of furnishing motive power for mill wheels and factories placed along their banks.

Again, the Sun's heat, acting on the plants and trees, furnishes the power necessary to their growth. Under the influence of his rays they build up, from air and soil, all their wonderful varieties of form and structure. The energy thus utilised is not lost, but stored in the plant tissues, to be liberated, free to assume other forms, when the tissues are broken down into their constituent elements again. Thus, in coal, the vegetable tissues forming the trees and plants from which the coal was formed, are separated into their elements by burning; and the Sun's radiant energy, by virtue of which they were built up, is, now they are broken down again, set free in the form of heat.

The Body.—The body is a piece of mechanism capable of transforming heat into vital energy. The heat is the result of chemical action upon the food and on the tissues built up from it.

A Tissue (Fr. tisser = to weave) is an arrangement of cells adapted to perform some particular function. Blood, bone, muscle, fat, and skin are all tissues. The various parts of a plant are tissues, and, as we have seen, are built

from constituents contained in the air and soil. The energy to do this work is obtained from the Sun's heat. Energy stored in this way is termed *potential* energy. If compounds, such as the vegetable or animal tissues, are broken down, the stored potential energy is liberated in the form of heat energy. Such changes as produce alterations in structure are termed chemical changes, and when they occur in living tissue are known as *metabolism*. Thus metabolism is the breaking down of tissues into their elements or the building up of tissues from their elements; or, more briefly, metabolism is the name given to changes in the constitution of living tissue.

Potential Energy of Food.—Human food consists chiefly of the tissues of animals and plants which are metabolised, to be reformed into the body tissues or to unite to form other substances which are expelled from the body. In either case the change liberates the potential energy stored in the food in the form of heat, which the body converts into vital energy, necessary to the performance of its functions.

Oxidation.—The chief of the chemical changes that occur in the body is the combination of (*a*) the various food constituents, (*b*) the body tissues, with oxygen. This process is termed *oxidation*. Coal, burnt in the fire, is oxidised, its chief elements, carbon, hydrogen, and sulphur, combining with the oxygen of the air. Another name for the process is combustion. In the case of the fire the union with oxygen is so rapid and violent that sufficient heat is evolved to produce flame. The combustion may, however, be invisible; that is, unaccompanied by flame, as it is in the body. For combustion to take place between two bodies, it is not necessary that oxygen should be one of them, though in the majority of cases it is.

Thus, the energy yielded by the living body, in the form of work and heat, is merely the Sun's radiation stored as potential energy, in the compound substances forming food. Its liberation as heat depends upon chemical change (metabolism), and the more active the change the greater the production of heat. The oxygen which enters into combination with the food substances comes mainly from the lungs, carried by the red corpuscles of the blood. Hence the food and blood must be brought together. The blood vessel system is a closed one, but its walls are permeable to foods in certain conditions. To change food into such a condition that it will enter the blood stream is the work of digestion.

FOODS.

Foods are substances capable of supplying :—

1. Matter to form or renew the tissues.
2. Heat to maintain the temperature of the body.
3. Heat to be transformed into mechanical energy.

Since a temperature of about 90° F. is essential to the performance of the bodily functions, a substance which aids in maintaining this temperature is as much a food as one which assists in the formation of tissue. The temperature is not everywhere the same in the body. Since it depends on chemical change, it must be greatest where the change is most active. Thus it is highest in glands (*e.g.*, the liver) and muscles, and lowest in the skin of the hands and feet. The temperature would vary much more were it not for the equalising effect of the blood flow, which conveys heat from one part to another.

WASTE SUBSTANCES.—The body is unable to deal with certain constituents of the food, which therefore pass out of it unchanged in a solid form, as the fæces. These are really the waste substances of the body, but the term is usually applied to those substances which result from the changes produced on foods in the body. The WASTE PRODUCTS are those substances formed by metabolism, and not taken up by any of the tissues. They are *essentially* two—urea and carbon di-oxide.

UREA is formed in the tissues, taken up by the blood, eliminated by the kidneys, and passed out in the urine.

Carbon Di-oxide is produced in the tissues, absorbed by the blood, carried to the lungs, and passed out in the breath.

From the nature of these wastes can be determined what food substances are necessary to produce them.

For example, a fire burns. The carbon and hydrogen of the fuel are being oxidised. The result of the oxidation is the production of two substances, carbon di-oxide and water. Knowing that these substances are formed by the union of oxygen with (*a*) carbon, (*b*) hydrogen, we at once conclude that these elements are contained in the fuel. Certain matters will not so combine; they remain as ash. In the body the fæces represent the ash, and the results of the combustion (waste products) are carbon di-oxide and urea.

To produce urea (CON_2H_4), the elements carbon, oxygen, nitrogen and hydrogen are necessary; to produce carbon di-oxide (CO_2), carbon and oxygen. The substances used as foods must therefore contain these elements. But oxygen may be obtained from air and water, hydrogen from water. Hence the essential constituents of all foods are carbon and nitrogen.

Proximate Constituents.—The body is incapable of digesting and assimilating pure carbon and nitrogen, nor can it do so when they combine into simple compounds such as carbon dioxide (CO_2), ammonia (NH_4), or nitric acid (HNO_3). In these forms, however, they are available as food for plants. The plants build them into the more complex combinations known as carbo-hydrates, hydro-carbons, and proteids. The plant tissues, when eaten by animals, are built into still more complex forms, still retaining the names of carbo-hydrates, hydro-carbons, and proteids, but containing less useless matter and being generally more easily digestible by human beings.

Note that the carbo-hydrates are nearly all vegetable, the hydro-carbons nearly all animal substances.

The body requires nitrogen from the proteid and carbon from the fat or carbo-hydrate, but can only obtain them when they are combined with other elements into these complex forms. These substances (proteids, etc.) therefore constitute our food, and so are termed proximate constituents or proximate principles.

PROXIMATE ALIMENTARY PRINCIPLES (or constituents) are those compounds of nitrogen and carbon which are available as food, and can be separated, without decomposition, from animal and vegetable tissues.

CLASSIFICATION OF FOOD PRINCIPLES.—The food principles are divided into two groups, those that contain nitrogen and those that do not.

NITROGENOUS (or proteids).	*Animal.*—Gelatin, albumen, fibrin, casein.
	Vegetable.—Gluten, legumen.
NON-NITROGENOUS.	*Hydro-carbons.*—Fats and oils.
	Carbo-hydrates. — Starches and sugars, cellulose, gums and pectose.

The classification of foods as flesh-formers and heat-givers has been abandoned. No substance can be said to be exclusively a heat-giving or flesh-forming food. The division into nitrogenous and non-nitrogenous is an arbitrary one. No food stuff, such as meat, bread, etc., is exclusively nitrogenous or non-nitrogenous. This classification refers to proximate constituents only.

PROTEIDS contain hydrogen in combination with carbon, hydrogen, oxygen and sulphur. Their general composition is $C_{54}H_7O_{22}N_{16}S_1$. They fall naturally into two groups, the albumens (albumin, gluten, legumen, casein, etc.) and the albumenoids (gelatin, chondrin, keratin, ossein. etc.).

In the former the proportion of nitrogen to carbon is 2 to 7, in the latter 2 to 5½. The food value of the latter group is less than one-fourth that of the former.

PEPTONES AND ALBUMOSES are forms of proteid produced by the action of the pepsin of the gastric juice. Their characteristic is their extreme diffusibility, which enables them to pass readily through the walls of the alimentary canal and blood vessels into the blood. They do not, like other proteids, coagulate under the action of heat.

PROTEIDS REGULATE CHEMICAL CHANGE.—The action of Proteids in regulating the activity of metabolism should be noted. An increase in nitrogenous food implies an increased oxidation and a decrease in the amount of material stored, either as glycogen in the liver or fat in the tissues. This principle has been utilised in Banting's system for the reduction of corpulency—the patient being fed with a large excess of nitrogenous food.

FATS ($C_{10}H_{18}O$) are compounds of glycerine with either oleic, stearic, or palmitic acid. The small amount of oxygen contained makes their metabolism slow, the necessary oxygen having to be obtained from other sources. This may explain their extensive use by the inhabitants of cold countries. The heating effect is lasting. The same explanation may possibly be applied to the instructive use of fats and oil in *small quantities* by those living in hot countries, the effect being less *immediately* heating than that of carbo-hydrate.

CARBO-HYDRATE.—The name (Hydrate, Greek—hydor = water) is derived from the fact that, in addition to carbon, foods belonging to this group contain oxygen and hydrogen in the exact proportions to form water. In other words, they contain sufficient oxygen to oxidise, during metabolism, the whole of their hydrogen into water. They are chiefly derived from the vegetable kingdom.

Vegetable Acids.—These are of little value as producing heat and energy by their oxidation. Their work lies in maintaining the proper character of the blood and other fluids.

By keeping the blood alkaline, they enable it to dissolve proteid matter. Consequently their withdrawal produces a badly-nourished body and a general "lowering" of the health of the tissues, which in its extreme form produces scurvy.

Mineral Salts.—These are an essential part of food, (1) partly because they aid in the formation of certain tissues, slightly because their metabolism furnishes some small amount of heat and energy, and mainly because of the part they play in aiding the digestion and assimilation of foods. They include common salt (chloride of sodium), the phosphates of calcium, magnesium, sodium and potassium, and the sulphates of calcium, sodium, magnesium and iron.

Common Salt is the source of the hydrochloric acid of the gastric juice, without which the pepsin could not act, and aids in the solution of the globulins of the blood and of the peptones. Phosphates largely contribute to the formation of bone, and iron is an essential constituent of the red corpuscles of the blood.

A Salt is a chemical compound formed when an acid acts upon a base. The base is the oxide of some metal. The acid contains hydrogen. The metal takes the place of hydrogen in the acid, thus forming a salt, and the hydrogen unites with the oxygen of the base to form water. Thus, when an acid acts upon a base, the result is the formation of a *salt* and water. If a base is soluble in water it is termed an alkali. Its properties are opposite to those of an acid.

Salts are named from the acids from which they are derived. Thus, sulphates, nitrates, carbonates, etc., are salts of sulphuric, nitric, and carbonic acid respectively.

Disposal of Food Stuffs.—Nitrogen enters the body as proteid and leaves it as urea. Proteid is changed to peptone in the stomach, is absorbed into the blood vessels, forms the proteid of the blood plasma, and exudes again through the walls of the blood vessels, bathing the tissues as lymph. The cells of the tissues act upon it, building up a portion into their own substance. This portion thus becomes "fixed" in the organ of which it forms part, and is known as FIXED or ORGAN PROTEID. The balance remains in the blood and lymph as FREE, COASTING, or CIRCULATING proteid, and is used *without being built up* into the substance of the body. If an *excess of proteid* be taken it may be absorbed in the intestines, carried to the liver, and there converted into urea at once. This last process is abnormal, and, if carried to excess, tends to become imperfect and to fail. Then excess proteid is not converted into urea, but reaching the halfway stage of uric acid, is deposited in the joints, giving rise to attacks of gout.

Three Roads from Proteid to Urea:—

1. Long Road.—*Organ Proteid*—Built up into various tissues, to be gradually used up and replaced.
2. Main Road.—*Free, Circulating, or Coasting Proteid.*—Conveyed to tissues by blood and lymph, used by tissues but not built up in them.
3. Short Cut.—*Excess Proteid.* — Never reaches tissues. Absorbed in intestines and changed to urea in the liver.

The urea in each case is eliminated by the kidneys and passes off in the urine.

FAT TO CARBON DIOXIDE.—Carbon enters the body in fat and leaves it by the lungs in CO_2.

The albuminous walls of the fat cells are dissolved in the stomach. The contents are then emulsified (very finely broken up) and saponified (changed into a soap) by the bile and pancreatic juice, and are then absorbed through the villi of the small intestines.

The carbon in fat, after reaching the blood, may combine with oxygen either at once or after being stored among the tissues as "fat."

CARBO-HYDRATE TO CARBON DIOXIDE.—Carbon dioxide enters the body as starch or sugar, and leaves it as CO_2.

The carbo-hydrate is rendered soluble by the saliva and pancreatic juice absorbed into the blood, and carried to the tissues. Its carbon may be oxidised immediately, or after storage as glycogen in the liver.

FOOD.	EXISTS IN BODY AS—	IS OXIDISED TO FORM—
Proteid	Circulating proteid Organ proteid (tissue)	Urea.
Fat	Fat	CO_2.
Carbo hydrate	Glycogen	CO_2.

Note that Proteid also contains carbon, which is oxidised to CO_2 in the same way as in fats and carbo-hydrates. The hydrogen in all foods combines with oxygen to form water. The quantity of nitrogen regulates the amount of oxidation. Thus, to reduce fat, increase the amount of nitrogen supplied. All foods are heat-producers. Proteids may form fat or glycogen in the body, and carbo-hydrates fat. Fats can exist only as fat.

Amount of Food.—The quantity of food necessary varies with age, being greatest in youth—the period of growth, and least in old age—the period of decay; with exertion, being directly proportional to the activity with which the vital functions are carried on; and with sex, women being said to require 10 per cent. less than men. The effects of climate are ill understood. The old idea that fats are needed in cold countries to furnish warmth is seriously discounted by the oily cooking of the South of Europe, and the fondness of certain Eastern nations for fat.

The chief cause of variation in the amount of food required is the work done, as will be seen from the following table.

To obtain the 307 grains of nitrogen and 4,700 grains of carbon, necessary to his health, a man weighing 150 lbs. will require:—

WHEN—	PRO-TEIDS.	FAT.	CARBO-HYDRATE.	SALTS.
	oz.	oz.	oz.	oz.
At rest (subsistence diet) ...	2·5	1	12	·5
In ordinary work	4·5	3	14	1·0
In hard work ...	6·5	3·5	16	1·5

These are dried (water free), and would naturally be combined with quite an equal weight of water, besides which 50 to 80 oz. of water would be drunk in various beverages. Roughly speaking, a person consumes daily $\frac{1}{100}$ of his weight in solid food and $\frac{3}{100}$ of his weight in water.

In a Well-arranged Diet:—

The proportion of nitrogen to carbon = 1:15.

The proportion of nitrogenous to non-nitrogenous food stuffs = 1:4½.

The proportion of fat to carbo-hydrate = 1 : 9.

OUT OF EVERY 100 PARTS—	WATER.	PRO-TEIDS.	FATS.	CARBO-HYDRATE.	SALTS.
Bread contains	40	8	1·5	49	1·5
Meat	75	15	8·5	—	1·5
Butter... ...	12	2	85·0	—	1·0
Potato... ...	74	2	—	23	1·0

A Mixed Diet.—If we look at the above table we shall find that no substance contains both carbonaceous and nitrogenous elements *in their proper proportion.* Thus, in bread the proportion of nitrogenous to non-nitrogenous material is 8 : 50·5, that is, 1 to 6¼ (nearly) instead of 1 to 4½. Thus, if sufficient bread be eaten to supply the requisite nitrogen, there is an excess of carbon, while to take only the correct quanity of carbon implies a deficiency of nitrogen. Evidently the attempt to live on one kind of food would be wasteful. Hence the necessity for a *mixed diet*; that is, one in which various foods are taken, in order to maintain the due proportion of nitrogenous and non-nitrogenous constituents.

It must be remembered that a mixed diet does not necessarily consist of both animal and vegetable substances, though, in practice, such a combination is generally found most convenient.

Perfect Foods.—The foods provided by nature for the nourishment of the young, viz., milk and eggs, form examples of diets perfectly adapted to the purpose for which they are designed. The milk and eggs of various animals differ in composition, and thus one is not always a good substitute for another.

	Proteids.	Fats.	Carbo-Hydrates.	Salts.	Water.
Human milk contains	2·29	3·81	6·20	·30	87·40
Cow's milk ,,	3·55	3·69	4·88	·71	87·17

Thus cow's milk is much richer in proteids and salts than human milk and this excess, though suited to the rapid growth of the calf, would be unsuited to the human infant. The nitrogenous matter would, in all probability, form an indigestible curd in the stomach. Milk is unsuited for adult food for two reasons; (1) The quantity required would be too great; the adult requires his nourishment in a more concentrated form. (2) The excess of proteid, over the quantity contained in an ordinary dietary for adults, would produce *too rapid a metabolism* for the adult, though suitable for the rapidly-growing child. The addition of carbo-hydrates in the shape of bread, outmeal, rice, sago, etc., corrects this disproportion, and, with these, milk forms a most valuable article of diet.

CONDIMENTS are substances, of little or no nutritive value, used with foods for the purpose of improving their flavour, of stimulating digestion, and exciting appetite. They act beneficially where the appetite is poor, stimulating the mucous membrane of the mouth and stomach, causing an increased flow of blood and a greater flow of gastric juice, thereby aiding digestion. When indulged in to excess they render the gastric glands insensible to the milder stimulus of plain food, and may even result in the production of a state of chronic inflammation of the stomach.

The chief of them are *acids*, such as vinegar, lemon juice, pickles, etc.; *pungent substances*, as pepper, mustard, horse-radish, curry, and *aromatic substances*, as cinnamon, cloves, mint, parsley, sage, onion, etc. The use of condiments doubtless arose from a natural craving for variety in food, without which the appetite soon palls, and foods fail to be retained and digested.

WATER.

The source of all natural waters is the rainfall. Water as it falls from the clouds is pure, but as it appears in our cisterns contains always some dissolved substances which it has gathered in transit. Hence the purity varies with the character of the air through which it falls, the surface over which it runs, and the soil through which it percolates.

The matters gained in the air are particles of suspended matter and various gases, chief among which are oxygen, nitrogen and carbon dioxide. The total amount of gas dissolved is about 22 cu. cm. per litre.

The matters gained from the surfaces on which it falls are bird-droppings, soot, etc., and possibly lead and zinc from the gutters.

The matters gained in percolating through the soil are chiefly salts of lime and magnesia.

Effects of Drinking Impure Water.—The diseases resulting from the drinking of impure water are cholera, enteric (typhoid) fever, dysentery, diarrhœa, malarial fever, goître and metallic poisoning. Care should be taken to distinguish between *specific* fevers which arise *only* by infection from a previous case and general ill-health resulting from impure water. Water contaminated with sewage matter only, cannot produce cholera or typhoid fever. To do this the germ of the disease must be present in the sewage. But impure water may produce general ill-health through its poisonous effect upon the digestive organs and intestines. Thus digestive troubles, dyspepsia, diarrhœa, sickness and dysentery may arise from contaminated drinking water. Moreover, the effects of the use of water which contains an excess of lime salts, that is, very "hard" water, may occasion bowel disturbances, constipation, and that peculiar swelling of the neck termed *goître*. In marshy districts, too, dysentery and malarial fevers result from the use of water contaminated with decaying vegetable matter.

Hard and Soft Waters.—Waters which contain more than 10 grains per gallon of dissolved mineral salts are said to be *hard*. They are harsh to the touch, cause soap to curdle in place of lathering, and are, consequently, not suited for domestic purposes, as being both unpleasant and extravagant in the use of soap. Nor are they, at all times, agreeable to the taste, although bright and sparkling. The hardness is estimated by the amount of soap required to be added to form a permanent lather. Water which requires the addition of ·0012 lbs. of soap to a gallon before forming a lather, which will remain for five minutes, is water of one degree of hardness. The salts present are usually carbonate and sulphate of lime. The former produces what is termed *temporary* and the latter *permanent* hardness. In the former, the lime is held in solution by the carbonic acid present. If this is driven off, as in boiling, the carbonate is deposited as a fur. Hard waters are softened by the water companies by the *addition* of milk of lime—the amount used varying with the hardness of the water. This method is termed Clark's process.

Clark's Process for softening water may be explained as follows: 56 lbs. of pure lime will unite with 44 lbs. of CO_2 to form carbonate of lime, which is *insoluble*. If plenty of CO_2 be available, the carbonate will take up 44 lbs. more CO_2 and form a *bi-carbonate*, which dissolves in water. It is the presence of this bi-carbonate which

causes the hardness of water. If 56 lbs. more lime be added, the 144 lbs. of bi-carbonate unite with it, forming carbonate again. This being insoluble, is precipitated as a white powder. Thus, the added lime and that which produced the hardness of the water, both go to form a sediment at the bottom. The process has no effect on the permanent hardness due to the presence of sulphate of lime.

THE DETECTION OF IMPURITIES.—Water may be contaminated by either suspended or dissolved matters. *Dissolved matters* may be salts of lime, various gases, lead, organic matter (ammonia and nitrates), and salt (salt, except near the sea or in salt districts, indicates *sewage* contamination).

SUSPENDED IMPURITIES.—Inorganic matter—mud or dust; organic matter—living organisms, including the bacteria of typhoid (enteric) fever, cholera, diarrhœa, and dysentery. Note that in shallow wells the contamination is chiefly due to organic matter from surface drainings. In deep wells this organic matter is either retained in filtering through the soil, oxidised in its upper layers or gradually changed, in passing through the soil, into harmless nitrates and nitrites.

TESTS FOR IMPURITY.—The presence of organic matter may be simply tested in the following ways :—

I. Add sufficient *permanganate of potash* solution (Condy's fluid) to colour the water a pale rose. If the colour is permanent the water is pure. The more rapidly it fades the greater the contamination.

2. Add one drop of *nitrate of silver*. If the water is impure, a cloudiness results. The depth of the cloud determines the degree of impurity. In bad cases the colour is quite brown.

3. The discoloration of the water and its smell, when heated, also indicate the presence of organic matter.

The Removal of Impurities.—(1) Hardness is reduced by the addition of milk of lime. (2) the separation of suspended matters is accomplished by passing the water through a filter. The action is twofold—(*a*) *Mechanical.* The particles are stopped. (*b*) *Chemical.* Organic matter is destroyed by the oxygen present in the pores of the filtering medium and by *the bacteria which cover the surface.* Cleansing the filtering substance destroys the bacteria, and consequently *impairs* the efficiency of the filter. Efforts are now being made to purify water by means of bacteria alone, which are cultivated for the purpose. The scheme is in use at Sutton in Surrey. A river tends to clear its waters of any organic impurities, in about 30 miles of its course, by the action of fish, aquatic plants, and the oxidation consequent upon the continual exposure of its waters to the air. The rapidity of purification depends upon the rate of flow.

Boiling is one of the best means of purifying water. The lime salts are deposited, and part of the organic matter, together with most disease germs, is destroyed. Astringent substances, such as alum, oak chips, etc., purify water by causing suspended matters to settle. The muddy Nile water is thus clarified by rubbing the inner surface of the water vessel with bitter almonds. The addition of Condy's Fluid also destroys organic matter, and leaves water potable.

Tea and Coffee.—These contain :—

1. *An alkaloid*, akin to quinine and nicotine, upon which the stimulating qualities depend. In tea this is known as Theine, in coffee as Caffeine; but the principle is believed to be identical in both.

2. *An aromatic oil*, on which the flavour depends, and which is produced by the drying and roasting processes to which the substances are subjected.

3. *An astringent substance*, tannin.

4. Traces of albumenoids, gum, dextrin and fat.

Both are stimulants of the nervous system, producing wakefulness, and leaving no after depression, as most nerve stimulants do. Excess in either, however, leads to deplorable derangements of the digestive system, resulting in indigestion, dyspepsia, loss of appetite and constipation. The rapid growth of tea-drinking among the poorer classes is probably doing considerable harm, its stimulating and exhilarating effects causing its use as a substitute for more nutritive substances. Neither tea nor coffee has any food value.

COCOA.—The active principle here is an alkaloid, termed Theobromine, akin to theine and caffeine. There is no tannin to interfere with digestion. The large amount of fat, starch, albumen and gum present make it of decided value as a food. Many people, however, find the fat difficult to digest, and much of it is generally removed in the process of manufacture. The value as a stimulant is very slight.

AERATED WATERS.—These are either natural or artificial. They contain dissolved gases in greater quantity than can be retained at the ordinary atmospheric pressure. Consequently, when exposed to the air, the gas is given off in bubbles, giving a sparkling appearance and a pleasant, brisk taste to the water. The gas chiefly contained is carbon di-oxide. Many natural waters, such as those of Spa, Vichy, and Seltz, contain a sufficient quantity to actively effervesce when exposed to the air. The manufacture of artificial waters depends upon the fact that, under the ordinary pressure, water can dissolve *its own* *bulk* of carbon di-oxide. If the pressure is doubled twice as much can be dissolved; trebled, thrice as much, and so on. If the pressure is removed the liberated gas bubbles out of the water, producing effervescence. The aerated water is run into specially prepared bottles, which prevent the escape of the gas. Such water is frequently sold as soda-water. The addition of a small quantity of fruit syrup produces lemonade, gingerade, &c. Actual soda-water should contain 30 grains of bi-carbonate of soda to an imperial pint, and the pressure of the gas dissolved should equal seven times that of the atmosphere.

Aerated water has a gentle, stimulating effect on the stomach, as well as being grateful and soothing in case of irritation.

Alcoholic Beverages are those produced by fermentation. The fermentation is the work of a tiny organism (or ferment)—the yeast plant, which, in a suitable medium, multiplies with exceeding rapidity. The ferment acts upon sugar in solution, chemically changing it into carbon di-oxide and alcohol. The former escapes, except in the case of effervescing wines, where part of the fermentation is allowed to occur after bottling, the latter remains, giving the fluid its stimulating and intoxicating properties. Wines and brandy are prepared from grape sugar, rum from molasses, whisky and gin from spirit distilled from malted barley. Inferior spirits can be produced from various starchy substances, such as potato, turnips, paper, cotton, flax, rags, and sawdust. The quantity of starch in some of the latter substances is, however, too small for the process to be remunerative. Pure alcohol is termed spirits of wine, and is flavourless. The distinctive flavours of brandy, whisky, &c., are produced in the process of manufacture and by the development of various flavouring substances—chiefly ethers—in the spirit when kept.

The Effects of Alcohol.—Since a certain amount of alcohol is destroyed in the body, it must produce heat, and therefore be considered, to some extent, as a food. It is certainly not an economical food nor a valuable one.

It possesses the power of lessening chemical change (metabolism) and thus of enabling the system to do with less food. Hence, probably, arises its abuse among the poorer classes. The want of nourishment leads to the desire for alcohol, which can still the craving for food. It must be remembered, however, that lessened metabolism means lessened energy, and, consequently, that the habitual indulgence in alcohol tends to seriously impair the working powers. As a stimulant during work it is most dangerous. More work can be done, more fatigue endured, and greater privation and cold borne without it. After work, when the body is jaded, or in old age, when its powers are feeble, its stimulating effect is valuable. A meal taken when one is thoroughly tired is likely to prove valueless, the bodily powers being unequal to its digestion. Alcohol soothes and stimulates the exhausted brain and promotes digestion. Under certain conditions of modern life it is not only valuable, but almost a necessity.

Its beneficial effect, however, vanishes with the employment of any but small doses. In large quantities, instead of stimulating it paralyses the nervous system, and removes speech, judgment and the emotions from under control. The effects of excess on the digestive organs are to delay digestion, to produce inflammatory conditions of the stomach and bowels, and to lead to rapid degeneration of the tissues of the liver and kidney. Of its moral and social effects, which are none the less deplorable, we need not here speak. The limit of safety in alcoholic indulgence will vary with the individual. It is impossible to lay down any definite rules for its use. It is probable, however, that the quantity consumed in 24 hours should never exceed one and a half ounces of absolute alcohol. This amount is contained in about three ounces of brandy or whisky, three glasses of port or sherry, about three-quarters of a pint of claret or champagne, or a pint and a half of beer. Within these limits, the taking of alcohol seems to be merely a question of taste and pleasure, and in ordinary circumstances should be without ill effects.

Alcohol and Cold.—One of the greatest errors in the use of alcohol is during prolonged exposure to cold. Its action on the heart quickens the circulation, its action on the blood vessels of the skin causes them to dilate. Hence more blood is supplied to the skin, where the nerves of touch end, and a sensation of greater warmth is produced. But it is evident that the blood, thus supplied to the skin, must be drawn from the interior of the body, and when thus exposed to the cold air becomes cooled, and the loss of heat, prevented in cold weather by the contraction of the vessels of the skin, is increased. Moreover, when the blood is cooled, the difference in temperature between it and the air is not so marked, and the feeling of cold less intense, producing a feeling of security at the time of greatest danger. After the exposure is over, its use may be beneficial, and its value in disease is indisputable.

AIR AND VENTILATION.

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Composition of Air.—The air is the gaseous envelope surrounding the Earth. It is a mixture of various gases, of which the two chief are nitrogen and oxgygen.

Pure air contains in 100 parts :—

Nitrogen	79·02 by volume,	76·84 by weight.
Oxygen	20·94 ,,	23·10 ,,
Carbonic acid	·04 ,,	·06 ,,

In addition, there are always present water vapour, ozone, and traces of ammonia and other gases, together with various impurities, which vary with the district.

Air a Mechanical Mixture.—That air is a mechanical mixture only, may be shown as follows :—When shaken up with water the air is not dissolved as *air*, but the oxygen and nitrogen are dissolved separately, in the proportion of 1 to 1·87. The elements may be, and are, readily separated, as when oxygen unites with various substances to form oxides. The elements exist in the proportion of 23·2 to 76·8, while they will combine only in proportions which are multiples of 16 and 14 (their atomic weights).

Ozone is a modification of oxygen, and possesses all its properties in an intensified form. It is most plentiful in country and sea air, where its presence may be detected by its fresh pungent smell. It is produced during a thunderstorm by the passage of the electric discharge through the air. It is a powerful oxidising agent, and plays an important part in the destruction of organic matter.

Carbon Dioxide (Carbonic acid).—This gas is always present in the air to the extent of about 4 parts in 10,000. It is produced by combustion, given off by the lungs of animals, and passes up through the soil in volcanic districts. The total amount thus added to the atmosphere is enormous, particularly in places that are thickly populated. Professor de Chaumont estimates that at least 300,000,000,000 cubic feet are passed into the air in a year in London alone. The laws of gaseous diffusion, however, cause it to mix with the surrounding air with such rapidity and thoroughness that, in the open air, the amount of carbonic acid present is practically the same everywhere.

The Action of Plants.—The excess is provided for by the action of plants. While plants breathe as animals do, taking in oxygen and returning it as carbonic acid, they also take in carbonic acid as food, retaining the carbon, to build up into their tissues and returning the oxygen to the air. This action takes place only under the stimulus of sunlight, so that, at night, plants help to vitiate the atmosphere which, during the day, they assist in purifying. The total effect, however, is to remove from the air the carbonic acid produced by the respiration of animals, and to render its proportion constant.

The Vitiation of the Air.—The air is vitiated for respiratory purposes by various substances which constantly pass into it. These are:—

(*a*) *Suspended Matters.*—

1. *From the Soil*: silica, lime, carbon, sand, mud, and ash.
2. *From the Vegetable World*: seeds, pollen, spores, and bacteria of various kinds
3. *From the Sea*: salt.

(b) *Gaseous Substances.*—

1. *Carbon Dioxide* from respiration and combustion: carbonic oxide
2. *Compounds of Sulphur* from coal fires: sulphuric and sulphurous acids, ammonium sulphide
3. *Compounds of Nitrogen*: ammonia, nitric acid, &c.
4. Organic vapours from decaying substances.

EFFECTS OF IMPURE AIR.—Heaviness, headache, sickness and lack of energy result from a surplus of CO_2 and a deficiency of oxygen. The effects of the organic matter present are more serious. Headache, languor, and listlessness are accompanied by decided symptoms of fever, increased temperature, quickened pulse, furred tongue, sickness, sore throat, and diarrhœa. These symptoms are the result of direct poisoning by the organic matter given off from the surface of the body and the mucous membrane lining the lungs. The 123 who died out of 146, in the Black Hole of Calcutta, and the 260 out of 300 Prussians, who died in prison after the Battle of Austerlitz, were poisoned, not asphyxiated.

Animal matter, in decaying, gives rise to various highly poisonous compounds (as in meats badly tinned, stale fish, &c.), and it is the presence of similar compounds in the decaying organic matter given off by the lungs, which constitutes the chief danger of overcrowding. Such poisoning is termed *ochlotic* (Greek *ochlos*—a crowd). The general lowering of the vitality of the body, which results from breathing air vitiated by respiration, produces an impaired power of resistance to the attacks of disease. Hence, in infectious diseases, such as smallpox, typhoid, typhus, and cholera, the mortality is largely increased where, through overcrowding or improper ventilation, the air is allowed to become impure.

The effect of the *combustion* of coal is to send into the air various sulphurous gases, together with solid particles of carbon. These irritate the mucous membrane lining the lungs and result in an increased liability to the attacks of lung and throat diseases. The mortality in towns from these diseases invariably increases during foggy weather, when the products of combustion are unable to escape.

Air vitiated by *sewer gas* produces all the symptoms above described as resulting from decaying organic matter. There is, likewise, the added danger that it may contain the germs of disease. Various forms of blood poisoning may also occur.

THE ESTIMATION OF IMPURITIES.—*Suspended impurities.* As already indicated, the amount of suspended matter in the air is large. A practical proof is the myriads of "motes" which become visible in the path of a sunbeam. These particles may be collected and examined, and counted under a microscope. The instrument usually employed is the aeroscope, by which a current of air is directed through a fine pointed funnel directly on to a drop of glycerine, which retains all the solid particles.

Dr. Aitken found that, in fair weather, a cubic inch contained 2,119,000 dust particles when taken from the open air, 30,318,000 when taken from an inhabited room and 88,346,000 when taken from near the ceiling. In rainy weather the number fell to about half a million, a fact having an important bearing on the effect of rainfall in purifying the air and on the character of rain-water.

The presence and amount of organic matter may be tested by passing the air through water, and then adding Condy's Fluid sufficient to colour the water rose pink. If the colour remains permanent, no organic matter is present. The rapidity with which it fades indicates the amount of pollution. The presence of *carbon dioxide* may be detected and roughly estimated by the smell. Normally

it exists in the air to the extent of 4 parts in 10,000. Two parts more may be added without appreciable result, but beyond this point the air begins to smell "close." When the *added* CO_2 amounts to 6 parts in 10,000, the air is decidedly close, when it reaches 8 parts in 10,000 it is offensive. The odour is due to the presence of *organic matter* from the lungs, but as this is invariably accompanied by CO_2, the amount of the one may be safely taken as an index to that of the other.

Thus, it will be seen, that the amount of CO_2 in the air may be increased to 6 parts in 10,000 without ill effects. This is termed the *limit of respiratory impurity.*

QUANTITY OF FRESH AIR REQUIRED.—Since the addition of 2 parts of CO_2 per 10,000 parts of air is the most allowable in air required for breathing purposes, it is evident that the amount of fresh air required by every person per hour must be sufficient to dilute the CO_2 which he breathes out to this extent. On the average, each person exhales $\frac{3}{5}$ of a cubic foot per hour. If two cubic feet of carbonic acid will pollute 10,000 cubic feet of air, to the limit allowable, it is clear by a simple proportion—

$$2 \text{ cu. ft. } CO_2 : \tfrac{3}{5} \text{ cu. ft. } CO_2 :: 10{,}000 \text{ cu. ft. air.}$$
$$= \frac{10000}{2} \times \frac{3}{5} = 3{,}000 \text{ cu. ft. air.}$$

that he will require at least 3,000 cu. ft. of fresh air per hour.

It must be noted that this calculation refers only to persons at rest, and makes no allowance for lights, etc. When persons are actively engaged much more CO_2 is exhaled, and the quantity of fresh air required is proportionately greater. Moreover, in cases where buildings are inhabited solely by men, as in barracks, the amount required is more than if they were occupied partly by women and children, who exhale much less CO_2.

EFFECTS OF LIGHT.—Lights requires oxygen, and give off CO_2. When they are in use, therefore, the amount of fresh air supplied must be greater. One ordinary candle (six to the pound) will produce about half the quantity of CO_2 per hour given off by a man; a good oil-lamp produces about the same amount as a man, and a gas-burner as much as five or six men. It must be remembered that, while producing CO_2, lights do not produce organic matter, so that it is not necessary to dilute their CO_2 to the same extent. Thus, while a cubic foot of gas yields about as much CO_2 as the breathing of one person, it will only be necessary to dilute it with about 450 cubic feet of air, that is at the rate of about 900 cubic feet of air to each cubic foot of CO_2 produced.

INSPIRED AND EXPIRED AIR.—The exact differences between inspired and expired air may be thus stated :—

INSPIRED AIR.	Parts per 100.	EXPIRED AIR.	Parts per 100.
Oxygen...	... 20·94	Oxygen...	... 16·14
Nitrogen	... 79·02	Nitrogen	... 79·02
Carbon dioxide	·04	Carbon dioxide	4·34

Expired air also contains :—

1. An increased amount of *water vapour*. The normal amount present in the air in this country is 1·4 per cent. Expired air is nearly saturated.

2. A certain quantity of *organic matter*. The water vapour also contains organic substances in solution, which rapidly decompose and become poisonous.

3. A small quantity of *ammonia*, arising from the decomposition of organic matter in the lungs and mouth.

The following differences are also observed :—

1. The *temperature is increased* to about 97° F. (nearly the temperature of the blood.)

2. The *volume of air is diminished*. The amount of oxygen absorbed is greater than that of CO_2 given off.

3. A slight *excess of nitrogen* is also observed.

VENTILATION.—The changes noted in air which has been breathed, indicate the necessity of diluting it with fresh air and of removing impurities. Ventilation is the process by which these ends are attained.

NATURAL AND ARTIFICIAL VENTILATION.—It is difficult to draw an exact line between these two methods. Roughly speaking, *natural ventilation* may be said to be the result of the operation of the natural laws, producing (*a*) Gaseous diffusion, (*b*) Convection currents, caused by inequalities of temperature, whether aided or not by simple appliances for the admission of fresh air or the outlet of foul. Gases of different density diffuse (mix with one another) with great rapidity.

VENTILATION THROUGH WALLS.—This process of diffusion proceeds readily through porous materials, such as many of those used for building purposes. If the air of a room is warmer than that outside, it will be less dense, and the external air will enter. The importance of placing dust-bins, etc., away from the walls of a house will be readily seen from this fact. In the winter the foul emanations from them will be drawn in with the cold air through the walls. In the summer the external air will probably be the warmer, and the reverse will take place. A candle may readily be blown out through a brick, or even a house wall under suitable conditions.

With a difference in temperature of 4° F. air will diffuse through ordinary walls at the following rates :—

Through sandstone	4·7	cu. ft.	per hour.
,, limestone	6·5	,,	,,
,, brick	7·9	,,	,,
,, mud	15·4	,,	,,

for *each square yard* of surface. This is a valuable mode of ventilation, as the inflow is imperceptible. Painting and papering considerably diminish the permeability. It should also be noted that porous walls allow moisture to pass outwards, which would collect on impermeable surfaces, thus rendering the air of the room damp. The amount of ventilation produced by diffusion is, however, insufficient, irregular, and does not affect organic impurities. Hence it is inadequate for general use as a ventilating agency.

WINDS.—The wind is a powerful ventilating agent, and acts in various ways. The chief of these are :—

Perflation.—A moving body of air drives air before it, thus forcing it through walls, crevices, ventilators, etc.

Aspiration.—A moving body of air draws the surrounding air into its current. A small current, moving rapidly, may thus set in motion a large body of surrounding air. As a particular example, wind blowing over the top of a chimney causes an up draught at right angles to itself, thus drawing the air from the chimney and the room with which it is connected.

Both these properties are utilised. Houses may be ventilated by cowls turned to face the wind, which blows down them to a heating apparatus, from which it is distributed to the various rooms, finally passing into tubes leading to the roof and protected by cowls *turned from the*

wind, so that the *aspiratory* power of the wind is used to draw up the foul air. Ships are ventilated in a similar way by canvas tubes, with cowls placed to catch the wind, which are termed Wind-sails. These methods are evidently useless in calm weather.

Effect of Unequal Temperatures.—When air is heated it expands, becomes lighter, and is pushed upwards out of its place by the heavier air around, just as a cork is pushed to the surface of water. Thus, if the air in a room be heated by a fire, it is made lighter, escapes up the chimney, and denser air from outside rushes in through every crevice and fills its place. This is evidently a method which can be constantly used. It practically consists in causing winds on a small scale. As, however, the action increases with the difference of temperature, and the openings available may be few, it will follow that during winter, when the action is most violent, the inrush will be so rapid as to be disagreeably felt; in other words, to cause a draught. A draught is a current of air, which enters with too great a rapidity, owing to the insufficient size of the opening. Thus the remedy lies not in stopping every cranny and crevice, but in providing an inlet of such a size as to allow the air to enter slowly and imperceptibly, and in such a position as to make it impossible, under any circumstances, for the current to interfere with the comfort of the persons using the room.

The Size of Inlet.—Air moving at a rate of three and a half miles per hour produces no perceptible current. This rate may therefore be adopted as the basis for ventilation. The problem is, "What is the size of an opening that will allow 3,000 cubic feet of air to enter a room in an hour, at a rate not greater than three and a half miles per hour (five feet per second)?" If we imagine the air passing through the opening to be suddenly solidified, it is clear that at the end of an hour we should have a solid bar containing 3,000 cubic feet, and three and a half miles long. If we divide the cubical contents, 3,000 feet, by the length, we shall get the area of its section ; that is, the size of the opening. This will be found to be between 23 and 24 square inches. Thus an inlet of at least 24 square inches is necessary for each person habitually using a room. In cases where a room is used only for a portion of each day, the amount may be less. In every case an outlet of similar size, or *a little larger* (as heated air expands), must be provided. In the majority of cases the chimney is found to be sufficient as an outlet. In places used by large numbers of people at a time, chimneys, if existing, will be insufficient, and special outlets must beprovided.

Inlet Ventilators.—If the chimney is sufficient to provide for the escape of foul air from a room, only an inlet ventilator need be provided. It should always be above the level of the heads of the occupants, and should direct the entering stream *upwards* against the ceiling, from whence it is thrown back in a shower of fresh air. Such inlets may be placed in windows, in the shape of *louvred* panes, consisting of strips of glass arranged like the slats of a venetian blind, or in walls. Sherringham's Valves and Tobin's Tubes are two effective forms of the latter. Air bricks may be used. These are drilled with a number of holes, conical in shape, with the wide part of the cone inside. The size of the hole increasing from the outside inwards, the velocity of the air current is checked, and the air diffused. In Jenning's air-brick the holes slant upward, thus directing the air towards the ceiling. An extremely simple arrangement is Hinckes Bird's plan of raising the bottom sash of a window and blocking the opening with a piece of wood. The air current enters between the two sashes at a sufficient height and in an upward direction.

OUTLET VENTILATORS.—Since the outgoing is warmer than the incoming air, it naturally follows that outlet ventilators should be placed near the ceiling. The simplest of all is a shaft leading above the roof. The rapidity of its action will depend upon the extent to which the temperature of the room exceeds that of the air, and on the aspirating effect of the wind. Often, however, the action of shafts is erratic, down draughts are set up, and the shaft becomes an inlet. This may be prevented by placing gas jets within, or immediately below, the opening, which, when lit, cause a steady current. The Sun burner, till lately, largely used in theatres and public buildings, is arranged on this principle. Ventilators provided with valves of very light material, such as mica, are frequently placed above the fireplace, opening into the chimney. The valves open only *into* the chimney, a back draught closes them immediately.

ARTIFICIAL VENTILATION.—There are two systems of artificial ventilation in use ; (*a*) Propulsion, (*b*) Extraction.

Propulsion.—Ventilation by propulsion is carried out by means of fans, large bellows, or sometimes by the hydraulic air-pump. The simplest mode of fan propulsion is the use of the punkah, general in India. This is generally worked by hand, though, occasionally, a bullock is employed. Fans are driven by small engines, usually fixed in the basement. The advantages of this plan are: (1) its certainty; (2) the precision with which the stream may be regulated; (3) the ease with which the air current may be cleansed, warmed, or cooled. The disadvantages are: (1) the cost; (2) the chance of a breakdown.

Extraction.—The common chimney is the best example of *extraction by heat.* Many other modes are merely modifications of this. Thus, the sunlight burner, the outlet shaft with a small gas jet constantly burning in it, and the furnace placed in the upcast shaft of a mine, are all examples of this form.

Extraction by Steam Jet is practised in factories and other places where there is waste steam. The jet is projected up a shaft, thus creating a strong upward current, which draws the air through tubes which open into the shaft from the various rooms.

Extraction by fans is practised in some mines and various factories. The fan is placed, as in the former case, in the upcast shaft, up which it propels a column of air ; in the latter case, in a small room at the top of the building, which is connected by tubes with the various rooms it is desired to ventilate.

CLEANLINESS, REMOVAL OF REFUSE.

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THE SKIN.—Two of the most important functions of the skin depend for their performance upon its cleanliness. In the first place, the skin is an *organ of excretion.* It takes from the blood, by means of the innumerable glands with which it is pitted, various waste substances which, if permitted to remain in the body, would produce serious results. As a rule, when the skin fails in its functions, generally through uncleanliness, its duties are undertaken by the lungs and kidneys. These organs may, in time, thus become overworked and, possibly, diseased.

In the second case, the skin plays an important part in *regulating the temperature* of the body. This it does by means of the perspiration. Everyone has noticed that when the body is hot, the skin is much moister than when it is cold. The moisture evaporates, and to do this requires a large amount of heat, which is abstracted from the body, thus cooling it. Perspiration is going on at all times, but varies greatly in amount, according to whether the temperature of the body needs increasing or diminishing to maintain it at the uniform level of 98·4°F. Under ordinary conditions it is invisible ; in hot weather, or when the body is heated by exertion, it stands on the skin in drops, while, in very cold weather, the skin is almost dry.

Both the excretion of waste substances and the regulation of the temperature depend upon the free action of the tiny sweat glands with which the skin is covered. If their openings are stopped with dirt or the dead scales which are hourly shed by the skin, then neither function can be properly performed. The necessity of washing thus becomes evident. Water alone, however, though an excellent tonic to the skin, is powerless to remove the dirt and scales with which it is covered. The skin secretes an oil, which serves to soften it and prevent its drying and cracking, and which, when poured out upon the skin, will cause its dead scales and dirt to cake, and so block the outlets of the sweat glands. To cleanse the skin effectively, something must be used capable of removing the caked dirt and oil.

Soap.—For this purpose soap is used. It is a compound formed by the union of one of the fatty acids (stearic, oleic or palmitic acid) with either potash or soda. Fat or oil is boiled with a strong solution of soda or potash. The result is that the fat decomposes into fatty acid and glycerine. The former unites with the soda to form hard soap or the potash to form soft soap, and the glycerine remains. The alkali (soda or potash) in soap is the ingredient which removes grease and oil, by combining with it as it does with the fat or oil used in the manufacture. Toilet soaps are generally made from lard. Glycerine soap is simply ordinary soap to which glycerine has been added. Transparent soaps are made by drying ordinary soap until free from water, and then dissolving in alcohol, filtering, distilling to remove the alcohol, and then running into moulds.

Removal of Refuse.—Among nomadic or thinly scattered populations all waste and refuse matters are returned to the soil, and reduced to their elements by the action of the oxygen and the putrefactive bacteria contained in its upper layers. In towns some mode of collection and removal is necessary.

The Dust-bin.—Until recently it was the practice to build dust-bins or ash-pits of brick or other porous materials. These were made to lean against the side of the house, and possessed a wooden cover and a small trap at the side, for the withdrawal of the contents.

The refuse stored in them thus became wet with rain, and rapidly putrified, the stench penetrating into the house, while the foul drainings permeated the soil. These are being gradually replaced by covered tubs or pails of galvanised iron which can be readily carried off the premises and emptied into the scavengers' cart without annoyance.

Nothing that can undergo decomposition should be placed in the dust-bin. Organic matters, such as offal or vegetable refuse, may be burnt in the kitchen fire or buried, so that the only substances that should find a place in the dust-bin are ashes, soot, dust and sweepings from the house, broken glass, etc.

The built receptacles still used in large establishments should invariably be lined with cement or slate, be placed at a distance from the house, and should be emptied at frequent intervals.

CLOTHING.

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The main purpose of clothing is to assist in maintaining the body at an even temperature of 98·4° F. The heat of the body is constantly being lost by (1) radiation to surrounding objects, (2) conduction through objects which touch the skin, and (3) the heat required to evaporate the moisture poured out on the skin by the sweat glands. It gains heat from (1) the chemical action constantly going on within it, (2) the heat produced by radiation from the sun and other heat giving bodies. By means of a beautiful arrangement, by which the perspiration increases and decreases in quantity with the temperature of the body, this temperature may be maintained, without further assistance, under conditions in which the temperature of the surrounding air is fairly even. When, however, the external temperature is liable to considerable variations the strain is greater than the body can conveniently adapt itself to, and some assistance is necessary. This aid takes the form of clothing. It must be clearly understood that clothing does not *make* the body warm; it merely assists in retaining (or in hot countries dispersing) its own heat. Other uses of clothing are:—To shelter the body from rain, storm, etc., to protect it from injury and to adorn it. Clothing to be effective must act as a barrier against the loss of the bodily heat in cold weather and against the heat of the sun's rays in summer. In other words, if the

body is hotter than the air, clothing prevents the passage of heat outwards; if cooler, it prevents the passage of heat inwards. Another point must not be lost sight of. Since the temperature of the body is normally regulated by the perspiration, the clothing used must be of such a character as to assist this action, and not interfere with it. If clothing prevents the escape of perspiration, it condenses upon the skin, setting free a large amount of heat, and preventing the proper cooling of the body, until its surface is covered with a film of water, which soaks through the clothing, and evaporates from the outside, being rapidly cooled in the process, and communicating chill to the body.

Evidently, therefore, clothing must not only resist the passage of heat, but freely allow the passage of perspiration as soon as it is formed. In other words, clothing materials must be *bad* conductors of heat and *good* absorbers of moisture.

Silk is the worst conductor of heat, but is costly. Wool is nearly as good, and has a remarkable power of absorbing moisture, and is, considering its durability, cheap. Hence wool is the best of clothing materials from a hygienic point of view. Cotton is cheap, but conducts heat readily and absorbs moisture badly ; thus, after exertion, a cotton garment is soaked with perspiration, which is beginning to get chilled, while a woollen one is comparatively dry and warm.

Porosity of Clothing.—Air is one of the worst conductors of heat. If the naked body is exposed to air, it becomes cooled ; but this is due, not to the conducting power of the air, but to the fact that its particles which lie nearest the body get heated, rise, and are replaced by others which are heated in their turn. If air were unable to form convection currents in this way, it would surround the body with a covering of non-conducting material, and keep in its heat. The air which exists in the pores of clothing acts in this way. Thus the clothing which allows air to pass most readily is the warmest. For the same reason loose clothing, retaining a layer of air between it and the skin, is warmer than tight, and two thin garments, with a layer of air between them, are much warmer than one thick one. Thus it is better, instead of replacing light summer garments by heavy winter ones, to merely increase their number.

Colour.—The colour of clothing has an important bearing on its power of absorbing and radiating heat. If two garments, one white and the other black, are of the same material, the black one will absorb twice as much of the sun's heat as the white. Also, when materials of various colours are exposed to the sun, the amount of heat absorbed varies with the colour. When the temperature of white material reaches 100° F., that of yellow will reach 140° F., of red 165° F., of green 168° F., of blue 198° F., and of black 208° F. Thus the adoption of dark colours for winter wear and light ones for summer finds scientific justification.

Clothing and Age.—Clothing should vary with the age of the wearer. In early childhood the heat-regulating apparatus is less effective in action, slight causes produce an increase of temperature and feverishness; a rise which might be serious in an adult may, in a child, be due only to a fit of crying, while, on the other hand, changes of temperature to which an adult could readily adapt himself may seriously affect a child's health. Moreover, the surface of a child's body is much greater, in proportion to its bulk, than that of an adult, thus allowing scope for a greater loss by radiation and conduction. For all these reasons, children are extremely susceptible to changes of

temperature, and the question of clothing them becomes of the utmost importance. Speaking generally, no part of the body should be unprotected, and no garment should be sufficiently tight to interfere with the free circulation of the blood. In the case of young children, the neck and the legs, and the lower part of the trunk are commonly exposed, frequently with serious results.

Elderly people also require special protection against changes in temperature. In their case, all the vital powers are in process of decay. Thus, less bodily heat is produced by the tissues, and the skin shows less activity in regulating its loss and gain. The great danger here, as in childhood, is the loss of heat, and, to guard against it, warm materials, loose in texture and in fit, should be employed.

LOCAL CONDITIONS.

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The Soil.—The soil is derived from the rocks which form the Earth's crust, and which have been disintegrated by various influences. The upper layer of the soil is mixed with various organic substances produced by decaying animal and vegetable matter, and is called the surface soil. The under part is termed the subsoil. The soil varies in character, according to the rocks from which it is derived. Some soils are heavy clays, and almost impermeable to water, others are sand or gravel, and almost perfectly porous. When rain falls it soaks into the soil until it reaches an impermeable layer. Here it collects, saturating the soil above the impervious stratum. This body of water is termed the *ground water*. It is obvious that the ground water will rise and fall with the rainfall. Heavy rains cause it to rise, prolonged drought leads to its loss by capillary attraction through the pores of the soil and evaporation from its surface. The distance of the ground water below the surface will, of course, depend upon the depth of the impermeable layer. Above the ground water the pores of the soil are filled with air—the *ground air*. As the water rises the air is forced out of the pores of the

soil, and may, if precautions are not taken, enter dwelling houses. This is a source of some danger, the ground air frequently containing quantities of CO_2 and various noxious gases produced by the decomposition of organic matter always going on in the soil. Sometimes, too, escapes of coal gas are retained in the pores of the soil, and are forced into houses with the ground air, when the water rises.

DRAINAGE.—Clay soils have great powers of absorbing and retaining moisture and are, consequently, much more damp than sandy or gravel soils. If it is necessary to build on these they must first be drained. When this is carefully done they are not unhealthy. The mode usually adopted is to lay *porous* earthenware pipes, from one to three feet below the surface, and at distances of about six feet. These slope down to a main drain which carries off the water. Clays and loams require most careful drainage, then come sandstone, limestones, chalk, and granite. Worst of all soils are shallow beds of sand or gravel lying on clay; such soils are usually formed by alluvial deposits, and are unhealthy, from their power of retaining moisture and the large amount of decaying organic matter they contain. Rheumatism, ague, and malarial fever are common results of living on such soils. In "jerry built" houses the site is often dug out and then filled with scavenger's rubbish. Such a soil is termed a "made soil," and should never be built upon.

DAMP COURSES.—To prevent the ground air and ground water from penetrating into the house, a concrete foundation should be made wherever possible. If this cannot be done a freely ventilated open space, at least nine inches deep, should be left between the soil and the flooring. To prevent moisture rising through the walls of the house by capillary attraction, a "damp proof course" is necessary. This consists of a layer of some impervious material, such as glazed tile, slate, or asphalte, across the full thickness of the wall. If the wall above the damp course is in contact with the soil, an open area should be dug, the earth being removed to below the level of the damp proof course.

Elevation and Climate.—The height of a place above the sea level has a marked influence on its climate. As the temperature of the air depends not upon the direct effect of the sun's radiation, but upon the temperature of the soil with which it is in contact, it follows that the further we get from the surface, the lower its temperature becomes. The direct rays of the sun, however, have not to pass through so great a thickness of air, and consequently produce a greater heating effect. This is further intensified by the freedom from moisture of the air at great elevations. So that at great heights one may be scorched in the sun and almost frozen in the shade. Thus the variations in temperature are extreme and sudden. As a general rule, the fall in the temperature of the air is 1° for each 300 feet of elevation.

Bodies of Water and Climate.—The proximity of large bodies of water has a great influence on climate. Water requires a much larger amount of heat to raise its temperature than land. Consequently, during the hot season the water is always cooler than the land. But the water accumulates a large store of heat in comparison with the land, and radiates it much more slowly. Hence during the cold season the water will be warmer than the land. As air in contact with heated surfaces is warmed, it becomes less dense, and is forced upwards by the heavier air around. Thus a current of air is produced blowing from the sea to the land during the hot weather, and from

the land to the sea during the cold. The winds thus produced are termed Monsoons (season winds). The same process is repeated, on a small scale, near the sea coast, every day and night, forming land and sea breezes. Land and sea breezes might thus be termed "diurnal" monsoons. The effect of the cooler sea in summer and the warmer sea in winter is to mitigate the extremes of temperature, producing what is termed an insular climate.

EXERCISE AND REST.

Exercise implies the use of the various organs of the body. It may thus be physical or mental. Generally speaking, it may be said that the exercise of any organ tends to develop it and increase its powers. The effect results from an increased blood supply. During exercise the chemical changes taking place in the organ are stimulated to greater activity, the amount of waste produced is increased, and, consequently, the demand for oxygen and nutritive material is greater. As, however, the waste can only be removed and the nutrient material supplied by an increase in the blood supply, the effect of the exercise of any one organ is to stimulate the activity of the heart, and thus to indirectly benefit the whole system by increasing its blood supply.

The Heart.—The force and frequency of the heart's beat are increased, thus supplying a great amount of nutrient material to its own substance, and developing its powers. Excessive action causes the heart-beat to become violent and irregular. This should indicate that the exercise had better cease. By regular exercise the heart becomes accustomed to meet sudden calls upon it without inconvenience, hence the importance of systematic training.

THE LUNGS.—As exercise calls for oxygen, its increase implies a corresponding increase of activity in the process of breathing and in the excretion of carbon dioxide. Thus, during rest, a man was found to give out 603 grains of carbon dioxide per hour, during exercise 2,501. The advantage of steady lung exercise is shown in the case of singers and wind instrument players, who are singularly free from lung and chest diseases.

THE DIGESTIVE ORGANS.—Here exercise is always beneficial, and the results of a deficiency readily apparent. A greater supply of blood to the coats of the stomach is accompanied with an increased secretion of gastric juice and a greater power of absorbing food. Lack of exercise, on the other hand, is frequently the forerunner of the indigestion and dyspepsia to which many people of sedentary habits are subject. Sluggish liver is another of the evils arising from deficient exercise, and is accompanied by a sense of fulness, languor and headache, together with indisposition to exertion and easy fatigue.

THE KIDNEYS AND SKIN are similarly influenced. The removal of waste products is accelerated, and the nutrition of the organ improved.

THE NERVOUS SYSTEM.—The exercise of any of the muscles or organs of the body means also the exercise of that part of the nervous system controlling them. Thus physical exercise also provides mental training. The weak physical development generally associated with idiots and imbeciles is worthy of note in this connection. The brain, as a whole, also profits by the increased blood supply.

MENTAL AND PHYSICAL EXERCISE.—Although, within certain limits, muscular exercise benefits the nervous system, yet, after the period of growth is passed, it is no longer possible for heavy brain work and heavy muscular work to go on side by side. The quantity of blood in the body is limited, and the supply to both nervous and muscular systems cannot be increased at the same time. Thus, while mild exercise is beneficial, vigorous physical exertion is detrimental to mental work. Regular physical exercise has also an important bearing on the character, through its influence on the nervous system. Whatever tends to bring the body under more perfect control, assists in strengthening the nervous control; whatever increases the health of the body aids in producing that of the mind. The stronger the body, the more is it under the control of the will.

Excessive Exercise.—Over-exertion produces, at first, fatigue. The waste has been greater than could be repaired; the supply of energy from the nerve centres fails, and the accumulation of waste products in the muscles produces that sensation we term fatigue, accompanied, it may be, by tremblings, cramp, or muscular pains. If the excess is long continued, the muscles may temporarily refuse to perform their functions. This chiefly occurs with small groups of muscles, associated in performing certain complicated movements. Instances in point are "writer's" cramp and the "hammer" palsy, to which pen-blade forgers and file-cutters are liable. Excessive exercise develops the muscular system at the expense of the brain, and by the increased work it throws upon the heart, causes an overgrowth of that organ, or the dilation of its walls under the pressure of the blood upon them. The heart and blood vessels are also liable to injury, under severe strain, when the pressure of blood is sufficiently great to cause a permanent bulge in some part of their walls, giving rise to an aneurism.

Defective Exercise.—The evils here are more numerous than those of excess. Fulness of development is wanting, the muscles are soft and flabby, the circulation sluggish, and the digestion weak. Imperfect nutrition results, accompanied by a general decline in health and vigour and an incapacity for active exertion. The nervous system suffers to an equal extent, the mental powers become impaired and good work an impossibility.

Rest is no less important than exercise, and may be found in recreation, providing a change of occupation and engaging an entirely new set of powers, or in total cessation from labour as in sleep. Recreation should be pleasant and interesting, and should not be prolonged to the pitch of fatigue. No general rule can be laid down as to the amount of sleep necessary, as this varies with age, sex, temperament, and occupation. The infant should sleep for most of its time, the young child from six or seven in the evening till morning, and should also rest during the middle of the day. Adults generally require from seven to nine hours. Some manage with six, and even five hours, but it is doubtful if this can be prolonged, with impunity, over any length of time. After a heavy meal, either the sleep or the digestion must suffer, but no sound and healthful sleep can be enjoyed during hunger. A light supper should be taken an hour or two before bedtime. The best time for retiring is between ten and eleven. Sleep during the daytime cannot replace its loss at night. From two to four in the morning the heart's action is lower than at any other time, and Nature seems to indicate the necessity for repose. Sleep prolonged into the morning is not so refreshing as that taken during the ordinary hours. Old people require less sleep than those who are younger; the vital processes being less active, there is less waste and consequently less need of repair.

TREATMENT OF ACCIDENTS, ETC.

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Asphyxia.—This may result from (1) The entrance of water into the lungs, as in cases of drowning; (2) the inhaling of carbonic acid gas; (3) the stoppage of the air passages.

Drowning.—Death may occur from (1) Suffocation, due to the presence of water in the lungs, (2) exhaustion, (3) syncope or fainting, from fear or shock.

The last two cases are much more readily treated than the first. Persons have been successfully restored after submersion for 15 minutes, probably passed in a fainting condition.

The points to be aimed at are:—

1. The removal of water from the lungs.
2. The restoration of animal heat.
3. The restoration of respiration.

If the heart has ceased to beat recovery is impossible. The method of producing artificial respiration is as follows:—

Preliminary Steps.—Remove all clothing, and place a pillow under the neck; cleanse the mouth and nostrils, and pull the tongue forward.

Artificial Respiration—Sylvester's Method.—Kneel behind the person's head. Grasp each arm by the elbow and pull upwards till they are in a line with the body. The chest is now expanded, and fills with air. Force the arms backward to the sides, letting them lap slightly over the chest. This expels the air. Repeat these movements at the rate of about 15 times per second. An hour is not too long for the attempt to be maintained.

Similar symptoms to those produced by drowning (with the exception of the water in the lungs) are produced by suffocation by any other means, as, for example, by choking, strangling, or inhaling carbonic acid gas. In each case artificial respiration should be tried.

CUTS AND FRACTURES.—The treatment of slight cuts consists in carefully cleaning and then closing the wound, fastening the edges together by binding or with plaster. The treatment of deep cuts consists in stopping the bleeding pending the arrival of a surgeon. To do this some knowledge of the mode in which the blood circulates is needed. If the blood is bright red, escapes in jerks, and only from one side of the cut, an artery has been wounded, and pressure must be applied between the cut and the heart. If the blood is dark, and oozes steadily from both sides of the cut, a vein has been divided, and pressure must be applied on the side farthest from the heart. If the blood is oozing from a considerable surface, a pad of lint should be applied and pressed firmly on it by means of a bandage. Bleeding may also be stopped by the application of astringent substances, such as borax, alum, and friar's balsam, and of cold. The signs by which a fractured bone may be detected are as follows:—

Disablement.—The limbs cannot be used.

Displacement.—The part of the limb below the fracture is distorted.

Crepitation.—On pressing the injured part with the thumbs, the two ends yield and a grating feeling may be experienced.

When only the bone is broken, without injury to the surrounding parts, the fracture is said to be simple ; if the flesh is torn, or blood vessels or nerves injured, the fracture is termed compound. It is of the utmost importance that an injured limb should be kept perfectly still, to prevent the possibility of converting a simple fracture into a compound one, by forcing the ends of the broken bone into the flesh.

Poisoned Wounds may be caused by bites, stings, and the introduction of foul matter into scratches or abrasions of the skin. The symptoms are redness, pain, and swelling of the part, the formation of matter, and the possible destruction of the surrounding tissues. If the case be a serious one the poison is taken up by the lymphatic glands and carried over the body, the inflammatory symptoms following until the whole body is affected. The aim of the treatment is to prevent the poison from entering the system. This may be accomplished by (1) removing it by suction or washing; (2) destroying it by the aid of caustic, by cauterising the wound with hot irons, or by bathing it with some disinfecting substance, such as carbolic acid; (3) preventing the circulation of the blood by a ligature applied between the wound and the heart. It is advisable in every case to scarify the wound so as to make it bleed freely. Snake and dog bites may be similarly treated, but the method must be thoroughly and rapidly applied to be of any value. The injection of a solution of permanganate

of potash is stated to be an effectual remedy for snake bite. The patient's strength should also be kept up by stimulants until the poison is expelled. For the latter purpose, whisky is given in heavy doses, which, however, frequently fail, under the circumstances, to produce intoxication.

POISONING — INTOXICATION. — Poisons are substances which, when introduced into the body, are capable of so altering the action or constitution of certain tissues as to destroy life. Poisons are divided into two great classes—*irritant* poisons and *narcotic* poisons.

The treatment consists in removing the poison from the stomach before it can be absorbed into the system. This can be done by the use of (1) the stomach pump, (2) emetics—substances which cause vomiting.

Some irritant poisons are powerfully corrosive. After swallowing these it is probable that the stomach or gullet may be so softened or eaten away that there is risk of the tube passing through their walls. Hence, in such cases, the stomach pump is unavailable, and it is plainly unadvisible to add to the damage by vomiting. The treatment indicated in such a case is the administration of substances which will neutralise the effect of the poison on the stomach walls. In cases of poisoning by acids this may be done by giving draughts containing soda or potash, magnesia, chalk, lime, whiting, or plaster scraped from the wall, taking care to give them in small quantities, to prevent too rapid a production of gas. In cases of poisoning by caustic alkalies, such as soda or potash, acids like lemon-juice or vinegar may be given. White of egg forms an effective antidote to corrosive sublimate, the two forming an albuminate of mercury, which, being insoluble, cannot be absorbed into the system. In the same way, iron is given in cases of arsenic poisoning.

In narcotic poisoning, by such substances as opium, care must be taken to prevent the patient from falling into a stupor by doses of brandy and water, hot coffee, and by walking him about. Emetics should be given at once, to expel the poison.

Simple Emetics are salt and water (two tablespoonsful of salt to a tumbler of warm water), mustard and water (a dessertspoonful to a tumbler of water), 30 grains of sulphate of zinc in water, or two tablespoonfuls of ipecacuanha wine in water. Tickling the throat with a feather, or passing a finger into the gullet are often useful.

PARASITES.

Parasites are organisms living at the expense of other organisms. They are of two kinds, internal and external. Some of them are microscopic in structure, and produce, as a result of their growth, changes in the tissues of the body that result in the symptoms of the various infectious diseases. The study of these specific fevers and the bacteria that cause them belong to the advanced stage of the subject; but there are certain other forms of life, some vegetable, others animal, that prey upon various parts of the body, and give rise to symptoms of varying severity. The vegetable parasites are chiefly to be found on the outside of the body, the animal both on the surface and in the interior.

External Parasites.—The chief of these are ringworm, thrush, favus and chloasma.

Ringworm.—This is produced by a species of fungus, which flourishes best on the hairy parts of the body. They are readily transmitted from one person to another, and extremely difficult to destroy when firmly rooted among the hair follicles. Painting with tincture of iodine, or touching with a moistened stick of caustic, will readily cure an attack on its first appearance. The popular remedy, ink, is practically useless.

Thrush.—This is a species of mould, resulting generally from the use of milk either turning sour or taken from a dirty bottle or tube. It never occurs in thoroughly healthy children, and so may be held to indicate digestive trouble and want of cleanliness. The treatment is to wipe the child's mouth thoroughly and then wash it out with a solution of borax or chlorate of potash.

Chloasma is characterised by fawn-coloured or purplish patches on the skin. The parasite may be removed by the use of soap and water.

Favus (Scald head) is a form of ringworm in which the irritation is so great as to produce a gummy exudation, which hardens into a scab. Medical treatment should be sought, the disease, if firmly rooted, being most difficult to cure.

Animal Parasites.—These are external and internal. The external parasites are the itch and various kinds of lice.

The Itch.—The irritation indicating the presence of this parasite is due to the burrowing of the female beneath the skin, where she lays her eggs, the young, when hatched, following her example. The insect can be dug out with a needle. Applications of sulphur ointment, and repeated washing with soft-soap and hot water form the best treatment.

Lice.—These infest the hair of the head (head louse); that of the body (crab louse), or may remain in the folds of the clothing (body louse). Those infesting the hair are best killed by an ointment containing mercury, and their nits removed by the use of methylated spirits, and by careful combing. Those remaining in the clothes may be destroyed by exposing the clothes for some hours to a temperature of 220° F.

The internal parasites are of many kinds. Those commonly found in this country are thread worms, round worms, tape worms and trichinæ.

Thread Worms.—These are minute worms infesting the lower bowel, and giving rise to intense itching. They are probably derived from vegetables improperly cleansed or cooked, or impure water. They are readily removed by the daily injection of a quarter to half a pint of water, in which a teaspoonful of salt has been

dissolved. Worm powders, containing sharp purgatives, frequently harm the child more than the worms.

Round Worms resemble the common earth worm. Their habitat is the water of ponds, with which they enter the body. The eggs, which they lay by thousands, cannot be hatched in the body, and the symptoms of their presence are so trifling that it is often unsuspected.

Tape Worms.—These are of various classes. Their presence in the human host is the second stage of their existence; the first being as an embryo, resembling the head of the mature parasite, and termed a Scolex, which embeds itself in the muscles of the pig or ox, surrounding itself with a capsule, termed a Cyst. The flesh of the pig so affected is said to be "measly." Thorough cooking will prevent the scolices of either pork or beef from entering the second (tœnia) stage of their existence in the human bowel.

Trichinæ Spirales are microscopic worms infesting carnivorous animals. They are usually derived from pork, that being the only flesh-eating animal generally used for food. These also have two stages of growth, an active stage in the bowels and a quiescent stage in the muscles. Entering the stomach, they are liberated from their capsules by the action of the gastric juice, and breed in the bowel, causing severe diarrhœa; then, piercing the walls of the blood-vessels, they are carried to the muscles, where they coil themselves up in cysts or capsules. Cooking invariably kills them, hence trichinosis is connfied to those persons who are in the habit of eating pork raw or merely cured. The disease is practically unknown in England.

APPENDIX—PHYSIOLOGY.

THE BUILD OF THE BODY.

PHYSIOLOGY deals with the functions of life. Human Physiology treats of the functions of the various organs of the human body. The science which treats of the structure of these various organs is termed ANATOMY, and some knowledge of anatomy is essential to the student of Physiology. We cannot deal with the functions of the various organs without knowing the main details of their structure.

THE BODY.—The body is composed of head, trunk and limbs. The HEAD consists of the *Cranium* (a bony box containing the brain), the face, the organs of sight, hearing, smell and taste, the teeth, various glands, blood-vessels and other tissues. The TRUNK is a cavity divided into two parts by a partition termed the *Diaphragm* or *Midriff*. The part above the diaphragm is termed the *Thorax* or *Chest*, and contains the heart and its great blood-vessels, the lungs, and the air tubes connecting them with the external air. The lower part is termed the *Abdomen* or *Belly*, and contains the liver, stomach, pancreas, spleen, kidneys, bladder and intestines. Certain vessels pass through the diaphragm, which is, however, airtight, so that the cavity of the chest is hermetically sealed, a fact that must be remembered as having an important bearing upon the work of respiration.

Tissues and Organs.—An *Organ* is a part of the body which performs some special function. Thus the eye is the organ of sight; the heart, arteries and veins are the organs of circulation; the lungs the organs of respiration; the kidneys and skin organs of excretion, and so on. Each organ is composed of certain structures suited to its function, and these structures — termed *Tissues* — are composed of cells. Thus the elements of the body are cells, and these, according to the function they are called upon to perform, are grouped into tissues (Fr., *tisser*=to weave), and the whole of the tissues engaged in the performance of any particular function make up an organ. Thus we have muscular tissue, nervous tissue, fatty tissue, glandular tissue, and so on. Blood is a tissue, consisting of cells—the corpuscles—contained in a fluid inter-cellular substance. Bone is a tissue consisting of cells set in a solid matrix.

Systems of Organs.—The organs of the body are grouped into systems each containing all those concerned in a particular function. Thus, the *Osseous System* contains all the bones of the body, the *Muscular System* all its muscles, the *Respiratory System* all the organs engaged in breathing, the *Circulatory System* all those concerned with the circulation of the blood, and the *Nervous System* all those tissues concerned in governing the functions of life—in storing nervous energy or in transferring it from one place to another.

THE SKELETON.

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The Osseous System—or Skeleton—is the hard framework of the body on which the softer and more yielding portions are supported. There are altogether about 200 separate bones. The points where they meet are termed *joints* or *articulations*. The bones at a joint are held together by strong fibrous bands termed *ligaments*.

The Vertebral Column.—The central column of the skeleton is the *vertebral column*, *spine*, or *backbone*. This passes down the back of the trunk from the neck to the loins. The column in youth consists of thirty-three separate bones, each known as a *vertebra*. In the adult state there are only twenty-six, the seven bottom ones having grown together to form one large irregular bone known as the *Sacrum*. The first seven vertebræ are in the neck, and so are known as the *Cervical Vertebræ* (Lat., *cervix* = the neck); the next twelve, to the middle of the back, and are known as the *Dorsal Vertebræ* (Lat., *dorsum* = the back) (the twelve pairs of ribs which enclose the chest spring from these). Five more form the *Lumbar Vertebræ* (Lat., *lumbus* = the loin), while the next five form the *Sacrum*, at the end of which is a small pointed bony mass, corresponding with the tail in all other animals, and containing what were originally four separate vertebræ. This is known as the *Os Coccyx*. The vertebræ are separated by pads of cartilage, which prevents them from jarring unpleasantly during movement, especially such movements as dancing, jumping, &c. The first two vertebræ are also modified, the top one containing two

grooves, which receive two processes from the base of the skull, and in which the skull rocks, and the next a process —the *odontoid peg*—which passes through a hole in the base of the skull, and serves as a pivot when the head is turned.

THE RIBS.—The chest, or thorax, consists of the twelve dorsal vertebræ behind, the twelve pairs of ribs which spring from them, and the *breastbone* or *sternum*, to which seven of the ribs are attached in front by means of gristle or cartilage. These seven are known as *true ribs*. The remainder are known as *false ribs*. Three of them are joined by one piece of cartilage to the one above. The remaining two have free ends, and are commonly known for this reason as *floating ribs*.

THE LIMBS AND THEIR CONNECTIONS.—The bones of the limbs are very similar, those of the leg closely corresponding to those of the arm. Thus the *femur* or *thigh bone* is represented in the upper arm by the *humerus*; the *tibia* and *fibula* of the leg by the *radius* and *ulna* of the forearm; the *carpal* bones (eight), forming the wrist, by the *tarsal* bones (seven), which form the ankle; the *five metacarpal* bones, which form the back of the hand, by the *five metatarsal* bones, forming the instep; and the *phalanges* (Gr., *phalanx* = a line of soldiers) of the fingers by those of the toes. Moreover, they are connected to the trunk in a very similar fashion. The head of the humerus fits into a hollow—the *glenoid cavity* of the *scapula* or *shoulder-blade*; the head of the femur fits into the *acetabulum*, a cavity in the *hip bone* or *os innominatum*. One bone in the leg finds no counterpart in the arm—the *patella* or knee cap. The two hip bones (*ossa innominata*) meet in the front, and are united at the back by the *sacrum*, forming a basin—the pelvis—at the lower part of the body, in which the lower bowel and bladder are contained. The union of the hip bones in this manner provides a rigid foundation on which the Spinal Column may be supported.

THE HEAD—The bony part of the skull consists of two distinct parts—eight bones forming the cranium (the brain-box), and fourteen bones forming the face. It should be remembered, however, that, in early childhood, certain of these are composed of parts so distinct as to form really separate bones; while, in adult life, certain of the bones, distinct in childhood, are joined into one. The bones of the CRANIUM are united by serrated (saw-like) edges, known as *sutures.* The irregular projections on one bone dovetail into recesses in the opposite, so that the two are held firmly together. The head bones are the *frontal* or *forehead bone*, the *two parietal bones* which form the greater part of the roof of the skull, the *occipital bone* which joins these at the back and curves under to form a great portion of the base of the skull, and the *two temporal bones* which form the sides of the skull and enclose the organs of hearing. The other two are the *sphenoid*, which fills the cavity left at the bottom of the skull between the occipital and the frontal bones, and the *ethmoid*, a spongy bone not visible from the outside, which fills the space between the orbits or eye cavities. There are also, in addition, the four small bones of the internal ear.

The bones of the face are *two superior maxillary bones*, forming the upper jaw, *two palatal*, forming the palate, *two nasal*, *two lachrymal* (small bones, grooved to allow the tears to pass through them into the cavities of the nose), *two inferior turbinated* bones (scroll like bones projecting into the nostrils), one *vomer* (separating the nostrils), two *malar* bones (the cheek bones), and one *inferior maxillary* (the lower jaw bone).

THE TEETH.—The adult has thirty-two teeth, the child in its first set—the milk teeth—twenty. The teeth are divided thus: *Incisors* or cutting teeth, *Canine* or tearing teeth (the dog teeth, Lat. *canis*=a dog), the *Bicuspid* (two ridged teeth), and *Molars* or grinding teeth (Lat. *mola*=a mill). Both child and adult have the same number of incisors (eight), canines (four), and bicuspids or pre-molars (eight). The adult, has in addition, twelve molars, the last four of which (the wisdom teeth) do not appear until between the ages of seventeen or twenty-five. A tooth consists of the *crown*—the visible part; the *fang*—the part buried in the bone of the jaw; and the *neck* which unites the two. It consists mainly of *dentine* —tooth ivory—and is hollow, the cavity containing a pulp composed of the nerves and blood-vessels which enter at the end of the fang. The crown is covered with *enamel* —the hardest substance in the body—and the root is fastened into the jaw by what is known as *cement*, the structure of which is similar to that of common bone. Note that the lower jaw alone is movable. Processes from it, the *condyles*, fit into hollows in the upper jaw, and on these, as pivots, it moves. Note that in carnivora, where the food is *torn* only, the shape of the condyles is such as to admit of an up and down motion; among the rodentia, where the food is *cut*, the shape of the condyles admits of a backward or forward motion; in the ruminants, which chew the cud, the condyles allow a rotary motion; and in man, whose food is torn, cut, and ground, the shape of the condyles permits a combination of all these motions. The process of mastication converts the food (by the aid of the saliva) into a pulp. The tongue, moving against the palate, moulds this into a bolus, which can be seized by the muscles of the gullet and forced down into the stomach.

THE CIRCULATORY SYSTEM.

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THE BLOOD.—Blood is a tissue composed of cells—*corpuscles*—suspended in a fluid—the *plasma* or *liquor sanguinis*. The red colour is due to the *hæmoglobin*, which forms a chief constituent of the red corpuscles. This substance enters into a loose combination with oxygen and its colour varies from bright scarlet to dark purple according as the quantity of oxygen present decreases. The oxygen taken up by the hæmoglobin is procured from the air inspired by the lungs and is carried to the tissues, where it is used up in the process of oxidation. Hence, in vessels proceeding from the lung the blood is of a bright scarlet, in vessels carrying it to the lung it is dark. It is common to call the bright-red blood *arterial*, since it is found in the arteries which convey it to the tissues, and to call the dark blood *venous*, since it is found in the veins which return it to the heart to be pumped into the lungs in order to become re-oxygenated. NOTE, however, that these names do not hold in the case of the *pulmonary arteries*, which contain dark blood, going to the lung to be oxygenated, or in the case of the *pulmonary veins*, in which bright oxygenated blood is returned from the lungs to the heart.

The change from bright to dark blood may be exemplified in the case of a clot which will be bright red outside where it is in contact with the air and dark inside where the air has no access. For similar reasons the blood in the vessels which lie close to the skin, *e.g.*, in the cheek, is red.

Roughly speaking, the blood forms one-thirteenth of the body weight, and of this one-fourth is contained in the heart, lungs and blood-vessels, one-fourth in the liver, and one-fourth in the muscles.

THE CLOT.—If blood be allowed to stand for a few minutes it becomes a jelly-like mass known as a *clot*. The clot is formed by the coagulation of *fibrin*, the albuminous constituent of blood *plasma*. This forms a net-work of fibres crossing the clot in every direction and entangling the corpuscles. As the fibres shrink, the fluid portion of the blood (the *serum*) is squeezed out until we have a very much smaller and denser clot, composed of fibrin and corpuscles, floating in serum.

THE TEMPERATURE OF THE BLOOD.—Near the surface of the body the temperature of the blood is about 98·4° F·, a level which is constant whatever the temperature of the surrounding air. A constant blood heat is characteristic of all warm-blooded animals, uniformity being mainly brought about by the decrease of perspiration during cold weather and its increase during hot weather. The temperature of cold-blooded animals varies with that of their surroundings.

THE BLOOD CORPUSCLES.—The solids suspended in the blood are of three kinds—Red Corpuscles, White Corpuscles (*Leucocytes*), and Blood Platelets (Hæmatoblasts).

The *Red Corpuscles* are circular discs, concave on both sides, and presenting a striking tendency to run together in rouleaux like piles of coin. Seen under the microscope, they are of a pale straw colour. The red hue of blood is due to their presence in mass. *Hæmoglobin* is the chief constituent, and forms the vehicle by which oxygen is carried to the tissues, the hæmoglobin taking up oxygen in the lungs, and forming an unstable compound, *oxy-hæmoglobin*, which is readily decomposed by the tissues.

The corpuscles are formed (*a*) in the red marrow of bone, (*b*) from the white corpuscles, and (*c*) from the blood platelets. The two last sources, however, are rather matters of surmise than of certainty. The red corpuscles are broken down in the spleen.

The *White Corpuscles* are irregular and of continually varying form. They are the ordinary *Lymph Corpuscles* and are formed in lymphatic tissues. Their function appears to be the building up of new tissue or the removal of foreign matter which is likely to prove noxious to the body.

The Emigration of Leucocytes is a phenomenon observed when tissues have been damaged. There is a rush of blood to the place, the white corpuscles, in greater numbers than usual, pass through the capillary walls to the seat of the injury. Here they may (1) surround, remove, and destroy a foreign particle, disease germ, or a portion of decaying tissue; (2) become connective tissue cells, helping to form the cicatrix by which the wound is closed; (3) be destroyed, forming matter or pus.

The Functions of the Blood.—The functions of the blood may be conveniently summarised as follows:—

(*a*) *It carries oxygen to the tissues.*—This is the function of the red corpuscles of the blood. The process of oxidation—the chemical union of the oxygen with the tissues and their constituents—is the main source of the heat and energy of the body.

(*b*) *It conveys nutriment to the tissues.*—This is the function of the fluid part of the blood. Nutrient material is absorbed *through the walls of the blood-vessels*, save in the case of fats, and exudes through the walls of the blood-vessels as Lymph. This bathes the tissues, enabling their cells to draw from it the nutriment they require.

(*c*) *It carries off wastes—e.g.*, carbon dioxide and urea—from the tissues where they are produced to the organs of excretion, by which they are passed out of the body.

(*d*) *It conveys the raw materials of the various secretions—e.g.*, the bile, gastric juice—needed in the work of the body, to the glands, by which these secretions are built up.

(*e*) *It serves to equalise the temperature of the body.* The body is the hottest where chemical changes are most active. The blood becomes heated in these parts (*e.g.*, the glands and the muscles during exercise, &c.), and carries the heat to other parts of the body.

The Circulation of the Blood.—There are three systems of blood circulation: one, the *General Circulation* round the whole body, to carry out the functions mentioned above, and the others special circulations with a specific purpose. The first of these is the *Pulmonary Circulation*, in which the blood passes through the blood-vessels of the lungs to be oxygenated by exposure to the air; and the second is the *Portal Circulation*, in which the blood, fresh from the intestines with its load of carbo-hydrate food, passes through the Portal Vein into the liver, there to store its nutritive burden in the form of *Glycogen* or *Liver-starch*, until such time as the economy of the body calls for its use.

In each case the object is to force the blood into the *Capillaries*, minute hair-like vessels which everywhere permeate the tissues in a close network. Through their walls the blood constituents, fluid or corpuscular, readily exude, the oxygen of the blood readily passes out to the tissues, and the carbonic acid produced in the tissues passes freely into the blood. The blood is carried to the capillaries by means of vessels termed *Arteries*, and carried away from them by means of *Veins*. The motive power is the beat of the *Heart*.

THE HEART.—The heart is a hollow muscle, conical in shape, and about the size of the owner's fist. It is placed in the thorax, slightly to the left of the central line, its base being upwards and towards the left. It is divided by a longitudinal partition into a right and a left half, and each half is divided transversely into two chambers, the upper being the *Auricle* and the lower the *Ventricle*. The two auricles receive the blood brought to the heart by the great trunk veins, the two ventricles pump it from the heart through the great trunk arteries. The right side of the heart receives the vitiated blood from the system and forces it, for purification, through the capillaries of the lungs, the left side receives it from the lungs and forces it through the capillaries of the body generally. The auricles are separated from the ventricles by *valves*, opening downwards into the ventricle. That on the right side is the *tricuspid* valve, which, as its name implies, has three flaps; that on the left is the *bicuspid* or *mitral* valve, which has two. When the muscles of the wall of the ventricle contract, the effect is to decrease the size of the cavity until it almost disappears. Hence, any blood contained is forced out. Two openings exist—one leading into the arteries, the other back into the auricle. But the contraction of the ventricle forces the blood behind the valves, floating them up and closing the ventriculo-auricular opening. The valve-flaps are prevented from being forced backwards into the auricle by cords—the *chordae tendinae*, which fasten their free edges to muscular projections in the walls of the ventricles, known as *columnae carnae* (fleshy columns). As the walls of the ventricle contract the cords naturally grow slack. But the muscular pillars to which they are attached contract also, being part of the heart muscle, and this has the effect of tightening the cords again.

The Course of the Blood through the Heart is as follows. Returning impure from its course round the body, it enters the *Right Auricle* through the Venæ Cavæ. It then passes through the tricuspid valve into the *Right Ventricle*. The ventricle contracts, the Tricuspid Valve closes, and the blood is forced into the *Pulmonary Arteries*, through which it passes to the *Lungs*. It returns thence through the *Pulmonary Veins*, entering the *Left Auricle*, whence it passes by way of the Mitral Valve into the *Left Ventricle*. The ventricle contracting, the mitral valve closes, and the blood is forced into the *Aorta*, which, by means of its branches, carries it to *all parts of the body*.

Arteries, Veins, and Capillaries.—The Capillaries are the smallest of all blood-vessels. Their wall is composed of a single layer of cells, held together by connective tissue. The fluids and solids of the blood readily pass through this wall. Their number is, however, immense. Hence the total area of their walls, if spread out, would be hundreds of times greater than the area of the artery (aorta) through which the blood leaves the heart. Hence the friction of the blood stream against the wall of its vessels is greatly increased in the capillaries, and as this forms the main resistance to its flow, it is evident that the rate of the blood current will be greatly checked in passing through the capillaries. To put it another way, the blood meets with a constant resistance in the capillaries. This resistance has two great results :

i. It keeps the arteries always full, so that each beat of the heart sends about 4 oz. of blood into a system of pipes which is already full, and hence

ii. It maintains what is known as arterial tension, that is, the outward pressure of the blood against the wall of an artery. It is this tension which causes the blood to spurt out when an artery is wounded. From a vein it flows in a sluggish stream.

THE ARTERIAL WALLS.—Since the heart-beat pumps additional blood into an arterial system already full it is obvious that the arteries must increase in capacity if they are to receive it. This is provided for in their structure. The wall of a large artery contains a great preponderance of elastic tissue. This yields to the heart stroke and the wall, say of the aorta, bulges to receive the additional supply of blood. But its elasticity causes it to resume its former size. The *semi-lunar* valves at the mouth of the aorta prevent the blood from being forced back into the heart. Thus the additional blood is driven forward to a part of the artery where the wall is weaker. This yields to the strain and bulges in its turn, and the process is repeated again and again, a wave of expansion and contraction passing along each of the greater arteries. When any of these arteries come near the surface of the body, as in the wrist, thigh, neck or temple, the expansion and contraction can be felt by pressing the artery with the finger—a process known as "feeling the pulse."

Note that the farther from the heart the weaker its impulse, since it will be divided up among many vessels. Hence, as a result of the elasticity of the arterial walls the shock of the heart's beat becomes a steady pressure before the blood stream reaches the capillaries. Were it not so their thin walls would give way under the strain.

There is no blood pressure in the veins. The blood passes through them mainly as a result of their compression by the movements of the tissues in which they are embedded. This compression forces the blood away from the point where it is applied. The blood can only go one way, for the veins are furnished with pouch-like valves, the free ends of which lie toward the heart. If blood is forced backward from the heart it forces these valves up, so as to block the passage and interpose a barrier to its own progress.

THE RESPIRATORY SYSTEM.

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Respiration is the name commonly given to the visible act of breathing. Strictly, however, it includes two processes—one *lung-breathing*, comprising the exchange of gases which occurs in the lung between the blood and the air; and the other *tissue-breathing*, comprising the exchange of gases which goes on in the tissues between the oxygen-laden corpuscles of the blood and the cells of the tissues. In lung-breathing, oxygen is taken up by the blood, and carbonic acid given off by it into the air; in tissue-breathing, oxygen is taken up by the tissues and carbonic acid by the blood.

The Exchange of Gases.—When gases of unequal tension are separated by a thin, moist membrane, they diffuse through it until the tension (pressure) of each gas is the same on both sides of the membrane. If, therefore, the blood (which has been robbed of its oxygen during its passage round the body, but which has at the same time taken up carbonic acid) be separated from the air (which contains more oxygen and less carbonic acid) by a thin membrane, the oxygen of the air will diffuse into the blood, and the carbonic acid of the blood will diffuse into the air, until the tension of each is the same on both sides. The change may be familiarly illustrated by plunging a moist bladder filled with blood into a jar of oxygen. The blood will gradually become a bright scarlet. If now plunged into a jar of carbonic acid the blood will become dark.

The Lung.—The lung is essentially a thin, moist, membranous sac, with blood on the outside and air on the inside. In its rudimentary state, as in the frog, it is a simple membranous bag. But the frog does much of its breathing by means of its skin. Moreover, being a cold-blooded animal, it requires less oxygen in proportion than an animal which needs to maintain its bodily temperature at a considerably higher level than that of the surrounding air. Hence in man we should expect to find the lung surface vastly greater in proportion to bulk than in the frog. As the increase in the size of the chest is only a proportional one, it follows that the increased lung surface must be gained in another way. Briefly, this is as follows. Air enters the lung through the windpipe or *trachea*. This tube branches into two *bronchi*, each of which branches in turn into innumerable *bronchial tubes*, which divide and subdivide until they are of microscopic size. At its termination each of these tiny air-tubes widens out into a kind of bulb known as an *infundibulum*. The walls of this are filled with depressions, like the cells in a honey-comb. These depressions are known as the air cells or *alveoli* (Lat., *alveolus* = a tiny cavity). Each air cell is about $\frac{1}{50}$ inch in diameter, and its walls are composed of the finest membrane. On one side of this membrane is the air which has entered through the windpipe. The other side is covered with a close network of blood capillaries. Hence nothing separates the blood from the air but the thin membranes which form the walls of the air cells and capillaries. Consequently, the gases of the air and the blood diffuse through it.

An additional factor in the interchange is the affinity of the hæmoglobin of the red blood corpuscles for oxygen, with which it enters into a loose combination. This is a chemical process; the other—diffusion—merely a mechanical one.

Note the following points:—

(i.) The larger air tubes are kept open by means of incomplete rings of cartilage in their walls.

(ii.) The lungs contain about 330 cu. in., but only some 30 cu. in. of air (the *Tidal Air*) pass in and out at each breath. The deepest inspiration will introduce another 100 cu. in. (the *Complemental Air*), and the deepest expiration possible expels a further 100 cu. in. (the *Supplemental Air*). There always remains a body of 100 cu. in. of air the volume of which is independent of respiration, and this is known as the *Residual Air*.

(iii.) The composition of the air in the lung is not the same as that of external air, the proportion of oxygen being lower and of carbonic acid higher in the former case (17 per cent. and 3·5 per cent. as against 21 per cent. and ·04 per cent. respectively).

The chief differences between inspired and expired air are :—

Expired air contains—

About 5 per cent. less oxygen.

,, $4\frac{1}{2}$ per cent. more carbonic acid.

Slightly more nitrogen.

Organic matter from the inner surface of the lungs.

It also contains water vapour enough to nearly saturate it, while its temperature has risen from that of the external air to nearly that of the body.

The Mechanism of Respiration.—The thorax and lung make a kind of bellows. Just as when the cavity of the bellows is enlarged, air rushes in as a result of the ordinary pressure of the atmosphere, to be forced out when the top and bottom of the bellows are brought together again, so when the cavity of the chest is enlarged, air is forced by atmospheric pressure down the windpipe and inflates the lungs, and when the sides of the chest are brought back to their former position, the quantity of air which entered is driven out again. The enlargement of the chest is brought about in two ways :—

(*a*) By the flattening of the diaphragm forming its floor.

(*b*) By the upward and outward movement of the ribs.

These movements result (*a*) from the contraction of the muscular part of the diaphragm, and (*b*) from the contraction of the *intercostal muscles*, which lie between the ribs, and join them one to another. Thus, inspiration comprises two mechanical processes:—

i. The expansion of the thorax as a result of muscular contraction.

ii. The expansion of the lung as a result of atmospheric pressure.

Note that (ii.) depends upon the fact that there is no atmospheric pressure on the outside of the lung, the chest being air-tight. If a hole be made into the chest the lung, which normally fills it, shrinks away from its sides and will not expand. The pressure is equal on both sides of it, and its own elasticity keeps it contracted.

THE NERVOUS GOVERNMENT OF RESPIRATION.—The muscular movements of the chest wall are governed by the currents of energy sent along certain nerves. That going to the diaphragm is the *phrenic* nerve ; those going to the muscles of the ribs are the *intercostal* nerves. The impulses sent along these nerves come from a tract at the top of the spinal cord, known as the "RESPIRATORY CENTRE," and their nature is determined by that of the blood which passes through the respiratory centre. If the blood is poor in oxygen the centre is stimulated, impulses pass rapidly to the muscles of the ribs and diaphragm, and breathing becomes more hurried. If the blood passing through the centre is rich in oxygen, the impulses sent from the centre are fewer and the rate of breathing decreases. Anything (*e.g.*, exercise), therefore, which causes the blood to lose its oxygen, and anything which hinders its re-oxygenation (*e.g.*, a vitiated atmosphere) will quicken the rate of respiration.

THE DIGESTIVE SYSTEM.

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The Alimentary Canal.—The tube by which food enters the body is known as the alimentary canal. The canal begins at the mouth and ends at the rectum, and is in no part in direct communication with the interior of the body. Hence, the food entering it has to be rendered into such a condition that it will pass through its walls and those of the blood-vessels which lie upon its outer surface. This change is known as digestion. Substances which enter the tube and are not capable of being digested are useless for food purposes, and are passed out unchanged. But the foods are of various kinds, and different changes need to be brought about in them in order to render them capable of passing into the blood. The structure of the alimentary canal is modified in various parts in order that it may deal with the various classes of foods. Broadly there are three classes—Starches and Sugars (*Carbo-Hydrates*), Proteids (*Albumens*), and *Fats*. Hence the process of digestion carried on in the alimentary tube is a threefold one—

Carbo-Hydrates are digested in the *mouth*—Oral Digestion.

Proteids are digested in the *stomach*—Gastric Digestion.

Fats are digested in the *duodenum*—Intestinal Digestion.

The process differs with the character of the food stuff. The change is in each case brought about by the action of a *ferment*. Thus :—

Oral Digestion—

The ferment *Ptyalin* converts starch into sugar.

Gastric Digestion—

The ferment *Pepsin* converts proteid into peptone.

Intestinal Digestion—

The ferment *Trypsin* converts proteid into peptone.
The ferment *Amylopsin* converts starch into sugar.
The ferment *Steapsin* converts fats into fatty acid and glycerine.

Ptyalin is contained in the saliva, pepsin in the gastric juice secreted in the stomach, and trypsin, amylopsin and steapsin in the pancreatic juice. In the intestine, too, the bile juice emulsifies fats— that is, divides them into tiny particles as in milk, while the fatty acids combine with the salts of the bile to form a soap. The effect of the changes is :—

(i.) The starches are made soluble and at once begin to pass through the walls of the alimentary canal and of the blood-vessels into the blood.

(ii.) The proteids are changed into peptones—a form resembling gelatine, in which state they can pass through into the blood.

(iii.) The fats are (*a*) divided into particles so fine that they can be absorbed, by passing through the walls of the villi in the small intestine (emulsified), (*b*) chemically changed, being formed into a soap (saponified).

The alimentary canal may be divided into the *mouth*, the *œsophagus* or *gullet*, the *stomach*, the *small intestine*, and the *large intestine*.

The Mouth.—Here the food is masticated so that, being finely divided, every part may be accessible to the action

of the digestive juices. Saliva is poured upon it from the salivary glands, three pairs of which exist—the sub-lingual, beneath the tongue; the sub-maxillary, below the jaw; and the parotid, behind the ear. It fulfils a dual function—the mechanical one of moistening the food so that it can be moulded by the tongue against the roof of the mouth into a bolus, and the chemical one of changing soluble starch into soluble sugar.

THE GULLET, OR ŒSOPHAGUS.—This consists of a tube leading from the mouth into the stomach. The chief feature in its structure is the existence of muscular rings throughout its length, which, by contracting in turn, force the food gradually onward. Such contractions are termed peristaltic, and it is by similar means that the food is passed along the intestines and the wastes finally excreted.

GASTRIC DIGESTION.—*The Digestion of Proteids.*—The Stomach is an expansion of the alimentary canal, and is the portion of that canal set apart for the digestion of proteids. Here, also, the albuminous envelopes of the fat cells are dissolved so that their contents may, on entering the intestines, be freely exposed to the action of the bile and pancreatic juices. The process of gastric digestion is twofold:—

(i.) *The Change from Proteid to Peptone.*—This is the work of the ferment *pepsin*. Note that this can only work in an acid medium. Hence the gastric juice contains not only pepsin—secreted by the *peptic* glands of the stomach wall, but hydrochloric acid secreted by the *parietal* glands. This is derived mainly from the salt taken with food.

(ii.) *The Mixing of the Food* by the continual movements of the walls of the stomach. This has the effect of exposing every part of it to the action of the gastric juices. (Note the analogy between this and mastication.) The peptones are of a soft, gum-like consistency, while the liberated fats give the whole mass contained in the stomach a milky appearance. In this state it is known as *Chyme*. When gastric digestion is complete the *Pyloric Valve* opens and the chyme passes into the small intestine.

INTESTINAL DIGESTION.—*The Digestion of Fats.*—The small intestine is about 21 ft. long and 1 in. in diameter. The food from the stomach passes through the *Pylorus* into the *Small Intestine*, the first part of which is known as the *Duodenum*. In the intestine the fat, reduced by the action of the gastric juice in dissolving its cell walls to the consistency of oil, is acted on by two digestive fluids or juices—the bile juice and the pancreatic juice.

Bile is formed in the *Liver* and passed into the duodenum through the bile ducts to the extent of about a quart a day. It is an alkaline fluid, and neutralises the acidity of the food which has left the stomach. Its action is to emulsify fats—*i.e.*, to divide them very finely, as in milk, to assist the passage of fat globules through the walls of the intestine, to prevent the food in the intestine from putrefying (*i.e.*, it acts as an antiseptic), and to excite the intestines to regular contraction, so that the food is forced steadily through them,

The Pancreatic Juice is secreted by the *Pancreas* or *Sweetbread*. It plays a highly important part in digestion, containing three ferments—one capable of converting insoluble starch into soluble sugar, another capable of changing proteid into peptone, and the third capable of emulsifying and saponifying fats. Under the action of the pancreatic juice, the digestion of starches, begun in the mouth, and proteids, begun in the stomach, is continued and that of fats commenced.

ABSORPTION IN THE INTESTINE.—Much of *the starch or proteid* has been already passed into the blood. More

now enters through the walls of the intestine, and is carrried into the portal vein or through the liver. For *the absorption of fats* a special provision is essential.

The wall of the small intestine is covered with tiny projections like the "pile" on velvet. These are the *Villi.* Each villus contains a central vessel termed a *Lacteal.* Into this the fat previously emulsified and saponified passes through the walls of the villus. When the lacteal is full, the muscular fibres of the villus contract and squeeze the contents into vessels known as *Lymphatics*, which join, forming larger and larger vessels until they discharge their fatty contents into the *Thoracic Duct.* This is a tube, about as thick as a goose quill, lying to the left of the spinal column. The bottom widens into a funnel-shaped reservoir known as the receptacle of the chyle—the name given to the food as it appears in the intestines. This duct opens into the blood-vessel system at the junction of the left jugular and the left sub-clavian veins, and through this opening the fats are poured into the blood stream.

The Liver.—This is the largest gland in the body. It weighs about 50 oz., and is divided into five *lobes.* It is situated at the top of the abdomen and on the right side. Its convex upper surface fits into the concavity of the diaphragm, and it is partly covered by the ribs. It consists of cells separated into groups, each group forming a *lobule*, and each lobule being about $\frac{1}{20}$ inch in diameter. The granular appearance of liver is due to the lobules, although they are not separately visible to the naked eye. The liver has a dual blood supply. In common with other organs, blood reaches it directly from the heart. This is carried by the *Hepatic Artery.* A second supply reaches it through the *Portal Vein*, a vessel formed by the union of the various blood-vessels of the intestines. This blood is laden with the food products absorbed by the capillaries which form a network on the walls of the intestines. Both the Hepatic Artery and the Portal Vein branch into interlobular vessels, which separate the lobules one from another, so that a lobule is surrounded by interlobular vessels. From these, capillaries pass into the substance of the lobule. Thus the blood is brought into contact with the cells of the liver, which are thus enabled to secrete from it *bile* and *glycogen*. In each lobule the capillaries discharge into a central—the *intra-lobular*—vessel, whence the blood passes into *sub-lobular* vessels. These are branches of the *Hepatic Vein*, by which the blood is conveyed to the heart.

The Functions of the Liver.—The functions of the liver are :—

(*a*) Secretory :—

(i.) *The Formation of Bile.*—This is secreted from the blood by the liver cells, is collected in tiny ducts—the *hepatic ducts*—and carried to the *gall bladder*, where it is stored. When needed for digestive purposes, it passes to the intestine through the *bile duct.*

(ii.) *The Formation of Glycogen.*—Glycogen is animal starch. It is the form in which carbo-hydrate food substance is stored in the body. When needed, it is changed to sugar by a ferment.

(iii.) *The Formation of Liver Diastase*—the ferment which changes glycogen into sugar (dextrose).

(*b*) Excretory :—

(iv.) *The Formation of Urea*—the great nitrogenous waste substance of the body.

(v.) *The Elimination of Poisonous Substances* which may have been taken in the food or formed during digestion. (The latter are similar to the poisons formed during the putrefaction of meat.)

The Pancreas.—This organ, commonly known as the sweetbread, runs across the body from left to right. It

lies behind the stomach, its head filling the curve formed by the duodenum (the first part of the small intestine) where it joins the stomach. It is from six to eight inches long, about one and a-half broad, and one and a-half thick. It is divided into lobules by branching blood-vessels. The capillaries from these penetrate the cells of the organ. The cells secrete the pancreatic juice, which is collected in tiny ducts, which finally unite to form the *pancreatic duct.* This joins the bile duct on its way to the intestine, so that the bile and the pancreatic juice reach the duodenum by a common tube.

THE FUNCTIONS OF THE PANCREAS.—The function of the pancreas is to secrete the pancreatic juice. This contains four distinct ferments, the most important being,—

(*a*) *Amylopsin.* This converts insoluble starch into soluble sugar.

(*b*) *Trypsin.* This converts indiffusible proteids into diffusible peptones.

(*c*) *Steapsin.* This emulsifies and saponifies fats so that they can be absorbed by the villi.

The pancreatic juice, therefore, completes the work of digestion begun by the saliva in the mouth, the gastric juice in the stomach, and the bile in the intestine.

THE SPLEEN.—This organ, about the same size and shape as the palm of the hand, is situated on the left side of the abdomen, beneath the ninth, tenth, and eleventh ribs. It is deep red in colour, and has a plentiful blood supply. It is covered with a fibrous capsule from which fibrous partitions enter its substance, forming a kind of framework in which the spleen pulp is contained. The spleen pulp consists of cells, some resembling white corpuscles, others similar to the red corpuscles of the blood, while others contain colouring matter similar to that of the blood. One peculiar feature of the splenic blood supply is that the capillaries of the splenic artery do not invariably unite with those of the splenic vein, but end in open cavities, from which also the veins arise.

THE FUNCTIONS OF THE SPLEEN are :—

(i.) *The storing of nitrogenous food*, to be introduced into the blood when demanded by the system.

(ii.) *The formation of blood corpuscles*. The blood of the splenic vein contains a far greater proportion of white blood corpuscles than that of any other vessel.

(iii.) *The disintegration of worn-out blood corpuscles.*

EXCRETION.

—o—

Excretion is the process by which waste products are removed from the body. These waste products are the result of the chemical changes brought about during life in the tissues and in the food. They are mainly three—Carbonic Acid, Urea, and Water. They are excreted by three organs—the lungs, the kidneys, and the skin. Water is passed out of the body by all three, but the lungs are mainly concerned with the excretion of carbonic acid, the kidney with that of urea, and the skin with that of water. The indigestible refuse of food is passed out of the body as the fæces; but this process is not excretion in the proper sense. The excretion of carbonic acid in the Lung has been dealt with under respiration.

The Urinary System.—The urinary system consists of the *kidneys*, which extract urea and water from the blood which flows through it; the *bladder*, in which these are collected previous to being passed out of the body as urine; and the *ureters*, the tubes by which the urine is carried to the bladder.

The Kidney.—The process in the kidney is a two-fold one:—(i.) *Filtration*, by which water is forced through the walls of the blood-vessels into the tubes of the kidney, and (ii.) *Secretion*, by which the urea is extracted from solution by the cells which line the tubes.

The kidneys lie on each side of the backbone, in the region of the two lowest dorsal and two highest lumbar vertebræ. The right one is rather lower than the left, the liver being situated on that side. Each is about 4½ in. in length, 2½ in breadth, and 1½ in thickness, and weighs about 4 oz. In shape it is like a bean, and to the *hilus*—the concave part—is attached the trumpet-shaped mouth of the ureter. The kidney is covered by a tough membrane, termed a capsule. If split lengthwise we see that it consists of a deep red outer layer—the *cortex*, a paler wider part—the *medullary layer*, and a hollow part termed the *pelvis*, into which the medullary part projects in the form of twelve pyramids. The pyramids appear striated, being composed of bundles of tubes—the *tubuli uriniferi*, which open into the pelvis at the apex of each pyramid. Each tubule begins in the cortex in a dilated part—a tiny round sac known as a *glomerulus*. Into this the blood enters by a tiny artery which breaks up and forms a branch of capillaries nearly filling the glomerulus. These capillaries unite to form a vein still *smaller than the artery*, so that the outflow of blood is checked and the capillaries are always in a congested state. The effect is that part of the fluid of the blood is forced through their walls, which act as a sort of filter. The liquid now passes along the tubule until the latter broadens out and becomes greatly convoluted. Here its walls are lined by selective epithelium, the cells of which can secrete urea from the blood contained in the fine meshwork of capillaries which surrounds the tubule. This is washed down by the fluid in the tubule to the pelvis and is carried down by the ureter to the bladder.

THE BLADDER.—This is a pear-shaped bag, with walls of elastic and muscular tissue. The urine enters it by the ureters, and is prevented from being forced back into them by a valve which closes the mouth. The bladder contains about a pint. The urine is retained in it by a sphincter muscle which closes the opening of the urethra.

THE SKIN.—The skin has two distinct layers—the outer skin or *Epidermis*, and the true skin or *Derma*, which lies beneath it. The epidermis contains no blood-vessels or nerves, the derma is plentifully supplied with both.

The Epidermis.—This is composed of cells arranged in two chief layers. The outer is known as the *cuticle* or scarf skin. Its cells are of a horny character, the result of their secretion of a substance known as *keratin*, which also enters largely into the composition of the nails and the hair. The outer cells of the cuticle are continually being worn off. The thickness of the epidermis varies greatly, being greatest on the palms of the hands and the soles of the feet. Pressure or irritation (*e.g.*, friction) causes it to increase in thickness, as seen in the case of corns and the horny hands of the manual labourer. The inner layer is softer, and is known as the *rete mucosum* Here lie the cells which secrete or store the pigment whence the skin derives its colour. Having no blood supply, the epidermis derives its nourishment from the lymph exuded from the blood vessels of the true skin.

The True Skin.—This is thicker than the epidermis, composed mainly of fibrous tissue, and is well supplied with nerves and blood-vessels, Its surface is covered with conical projections termed *papillae*, which contain knots of blood capillaries and the nerve endings connected with the sense of touch. The papillae lie in ridges on which the epidermis is moulded. The latter is thus thrown into corresponding ridges, which can be plainly seen in the palms of the hands.

MODIFICATIONS OF THE SKIN.—The epidermis is modified to form nails and hair.

A nail is simply a thickened or hardened portion of the epidermis.

A hair is a modification of the epidermis growing out of a follicle or sheath, at the bottom of which is a papilla, which the root of the hair surrounds, and from the blood-vessels of which the hair derives its nutriment. Each hair consists of a hollow shaft, containing a fibrous pith known as the *medulla*. Here also the pigment cells which give the hair its colour are to be found. The cells of the epidermis on the outside of each hair overlap, forming a kind of scaly outer sheath.

THE GLANDS OF THE SKIN.—These are of two kinds:—

Sebaceous glands, secreting oil, which renders the skin supple and prevents it from becoming sodden with perspiration. The oil also keeps the hair from becoming too dry, being poured out from a duct by the side of each hair.

Sudoriparous or sweat glands, secreting perspiration. These are tubular glands, each tube ending in a coiled knob, which is surrounded by a network of blood-vessels.

THE FUNCTIONS OF THE SKIN.—The skin fulfils many purposes, the chief being the following:—

(i.) *It protects* the tissues lying beneath it.

(ii.) *It supports the tissues* lying beneath it, keeping them in their proper positions.

(iii.) *It is an organ of secretion.* The sebaceous glands secrete oil, the sweat glands secrete perspiration.

(iv.) *It is an organ of excretion.* About 2 lbs. of water is passed off from it daily, together with small quantities of urea, salts and carbonic acid.

(v.) *It is a sense organ.* The papillæ contain the special nerve endings capable of receiving tactile impressions.

(vi.) *It is an organ of respiration.* Oxygen passes in through it, CO_2 passes out. (The amount is roughly $\frac{1}{150}$ of that passed through the lung. In certain animals—*e.g.*, the frog—the amount is much greater).

(vii.) *It possesses absorbent powers.* Hence the method of introducing medicaments into the body by means of rubbing lotions, ointments, &c., into the skin.

(viii.) *It regulates the temperature of the body.* The evaporation of the perspiration cools the body. Hence, the greater the amount of perspiration, the greater the loss of heat. But the quantity of perspiration excreted is always greatest when the body becomes heated. Hence, the higher the temperature of the body is raised—*e.g.*, by exercise—the greater the loss of heat. The heat gained by exercise is lost by perspiration.

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