

Peep-Show at St Petersburg, where we are easily reminded of Godfried Schaleken. Dietrich tried every branch of art except portraits, painting Italian and Dutch views alternately with Scripture scenes and still life. In 1741 he was appointed court painter to August III. at Dresden. With an annual salary of 400 thalers (£60), conditional on the production of four cabinet pictures a year. This condition, no doubt, accounts for the presence of 52 of the master's panels and canvases in one of the rooms at the Dresden museum. These pieces enable the spectator, if careless of more serious occupation, to study the numerous varieties of a changing style. It is needless, perhaps, to add that Dietrich, though popular and probably the busiest artist of his time, never produced anything of his own; and his imitations are necessarily inferior to the originals which he affected to copy. His best work is certainly that which he gave to engravings. A copious collection of these at the British Museum, produced on the general lines of earlier men, such as Ostade and Rembrandt, reveal both spirit and skill. Dietrich, after his return from the Peninsula, generally signed himself "Dietericij," and with this signature most of his extant pictures are inscribed. His death took place at Dresden, after he had successively filled the important appointments of director of the school of painting at the Meissen porcelain factory and professor of the Dresden academy of arts.

**DIEZ, FRIEDRICH CHRISTIAN** (1794–1876), the founder of Romance philology, was born at Giessen, in Hesse-Darmstadt, March 15, 1794, and died at Bonn, May 29, 1876. He was educated first at the gymnasium and then at the university of his native town. There he studied classics under Welcker, who had just returned from a two years' residence in Italy to fill the chair of archaeology and Greek literature. It was Welcker who kindled in him a love of Italian poetry, and thus gave the first bent to his genius. In 1813 he joined the Hesse corps as a volunteer and served in the French campaign. Next year he returned to his books, and this short taste of military service was the only break in a long and uneventful life of literary labours. By his parents' desire he applied himself for a short time to law, but a visit to Goethe in 1818 gave a new direction to his studies, and determined his future career. Goethe had been reading Raynouard's *Selections from the Romance Poets*, and advised the young scholar to explore the rich mine of Provençal literature which the French savant had opened up. This advice was eagerly followed, and henceforth Diez devoted himself to Romance literature. After supporting himself for some years by private teaching, he removed in 1822 to Bonn, where he held the position of privat-docent, which is the lowest grade of the German professoriate. In 1823 he published his first work, *An Introduction to Romance Poetry*; in the following year appeared *The Poetry of the Troubadours*, and in 1829 *The Lives and Works of the Troubadours*. In 1830 he was called to the chair of modern literature. The rest of his life was mainly occupied with the composition of the two great works on which his fame rests, the *Grammar of the Romance Languages*, 1836–1844, and the *Lexicon of the Romance Languages—Italian, Spanish, and French*, 1853.

In these two works Diez has done for the Romance group of languages what Jacob Grimm has for the Teutonic family. In both cases much remains to be accomplished, many words and forms are not yet accounted for, some errors have already been pointed out, but all future philologists must build on the foundations which these two men have laid. "Nothing," says Max Müller, "can be a better preparation for the study of the comparative grammar of the ancient Aryan language than a careful perusal of the comparative grammar of the six Romance languages by Professor Diez."

In order to appreciate the importance of Diez's work it is necessary to take a rapid glance at the history of philology in France. The earliest philologists, such as Perion and Henri Estienne, sought to discover the origin of French in Greek and even in Hebrew. For more than a century Ménage's *Etymological Dictionary* held the field without a rival. Considering the time at which it was written (1650), it was a meritorious work, but philology was then in the empirical stage, and many of Ménage's derivations (such as that of "rat" from the Latin "mus," or of "haricot" from "faba") have since become by-words among philologists. A great advance was made by Raynouard, who by his critical editions of the works of the Troubadours, published in the first years of the present century, laid the foundations on which Diez afterwards built. The difference between Diez's method and that of his predecessors is well stated by him in the preface to his dictionary. In sum it is the difference between science and guess-work. The scientific method is to follow implicitly the discovered principles and rules of phonology, and not to swerve a foot's breadth from them unless plain, actual exceptions shall justify it; to follow the genius of the language, and by cross-questioning to elicit its secrets; to gauge each letter and estimate the value which attaches to it in each position; and lastly to possess the true philosophic spirit which is prepared to welcome any new fact, though it may modify or upset the most cherished theory.

Such is the historical method which Diez pursues in his grammar and dictionary. To collect and arrange facts is, as he tells us, the sole secret of his success, and he adds in other words the famous apophthegm of Newton, "hypotheses non fingo."

The introduction to the grammar consists of two parts:—the first discusses the Latin, Greek, and Teutonic elements common to the Romance languages; the second treats of the six dialects separately, their origin, and the elements peculiar to each. The grammar itself is divided into four books, on phonology, on flexion, on the formation of words by composition and derivation, and on syntax.

His dictionary is divided into two parts. The first contains words common to two at least of the three principal groups of Romance,—Italian, Spanish and Portuguese, and Provençal and French. The Italian, as nearest the original, is placed at the head of each article. The second part treats of words peculiar to one group. There is no separate glossary of Wallachian.

Of the introduction to the grammar there is an excellent translation into French by Gaston Paris, a pupil of Diez, and an English translation by O. B. Caylor. The dictionary has been published in a remodelled form for English readers by T. O. Donkin. A second edition, enlarged and corrected, appeared in 1861, and a third edition was begun in 1869.

**DIFFERENTIAL CALCULUS.** See **INFINITESIMAL CALCULUS.**

**DIFFUSION.** Some liquids, such as mercury and water, when placed in contact with each other do not mix at all, but the surface of separation remains distinct, and exhibits the phenomena described under **CAPILLARY ACTION.** Other pairs of liquids, such as chloroform and water, mix, but only in certain proportions. The chloroform takes up a little water, and the water a little chloroform; but the two mixed liquids will not mix with each other, but remain in contact separated by a surface showing capillary phenomena. The two liquids are then in a state of equilibrium with each other. The conditions of the equilibrium of heterogeneous substances have been investigated by Professor J. Willard Gibbs in a series of papers published in the *Transactions of the Connecticut Academy of Arts and Sciences*, vol. iii, part i, p. 108. Other liquids, and all gases, mix in all proportions.

When two fluids are capable of being mixed, they cannot remain in equilibrium with each other; if they are placed in contact with each other the process of mixture begins of itself, and goes on till the state of equilibrium is attained, which, in the case of fluids which mix in all proportions, is a state of uniform mixture.

This process of mixture is called diffusion. It may be easily observed by taking a glass jar half full of water and pouring a strong solution of a coloured salt, such as sulphate of copper, through a long-stemmed funnel, so as to occupy the lower part of the jar. If the jar is not disturbed we may trace the process of diffusion for weeks, months, or years, by the gradual rise of the colour into the upper part of the jar, and the weakening of the colour in the lower part.

This, however, is not a method capable of giving accurate measurements of the composition of the liquid at different depths in the vessel. For more exact determinations we may draw off a portion from a given stratum of the mixed liquid, and determine its composition either by chemical methods or by its specific gravity, or any other property from which its composition may be deduced.

But as the act of removing a portion of the fluid interferes with the process of diffusion, it is desirable to be able to ascertain the composition of any stratum of the mixture without removing it from the vessel. For this purpose Sir W. Thomson places in the jar a number of glass beads of different densities, which indicate the densities of the strata in which they are observed to float. The principal objection to this method is, that if the liquids contain air or any other gas, bubbles are apt to form on the glass beads, so as to make them float in a stratum of less density than that marked on them.

M. Voit has observed the diffusion of cane-sugar in water by passing a ray of plane-polarized light horizontally through the vessel, and determining the angle through which the plane of polarization is turned by the solution of sugar. This method is of course applicable only to those substances which cause rotation of the plane of polarized light.

Another method is to place the diffusing liquids in a hollow glass prism, with its refracting edge vertical, and to determine the deviation of a ray of light passing through the prism at different depths. The ray is bent downwards on account of the variable density of the mixture, as well as towards the thicker part of the prism; but by making it pass as near the edge of the prism as possible, the vertical component of the refraction may be made very small; and by placing the prism within a vessel of water having parallel sides of glass, we can get rid of the constant part of the deviation, and are able to use a prism of large angle, so as to increase the part due to the diffusing substance. At the same time we can more easily control and register the temperature.

The laws of diffusion were first investigated by Graham. The diffusion of gases has recently been observed with great accuracy by Loschmidt, and that of liquids by Fick and by Voit.

*Diffusion as a molecular motion.*—If we observe the process of diffusion with our most powerful microscopes, we cannot follow the motion of any individual portions of the fluids. We cannot point out one place in which the lower fluid is ascending, and another in which the upper fluid is descending. There are no currents visible to us, and the motion of the material substances goes on as imperceptibly as the conduction of heat or of electricity. Hence the motion which constitutes diffusion must be distinguished from those motions of fluids which we can trace by means of floating motes. It may be described as a motion of the fluids, not *in mass*, but by *molecules*.

When we reason upon the hypothesis that a fluid is a continuous homogeneous substance, it is comparatively easy to define its density and velocity; but when we admit that it may consist of molecules of different kinds, we must revise our definitions. We therefore define these quantities by considering that part of the medium which at a given instant is within a certain small region surrounding a given point. This region must be so small that the properties of the medium as a whole are sensibly the same throughout the region, and yet it must be so large as to include a large number of molecules. We then define the density of the medium at the given point as the mass of the medium within this region divided by its volume, and the velocity of the medium as the momentum of this portion of the medium divided by its mass.

If we consider the motion of the medium relative to an imaginary surface supposed to exist within the region occupied by the medium, and if we define the flow of the medium through the surface as the mass of the medium which in unit of time passes through unit of area of the surface, then it follows from the above definitions that the velocity of the medium resolved in the direction of the normal to the surface is equal to the flow divided by the density. If we suppose the surface itself to move with the same velocity as the fluid, and in the same direction, there will be no flow through it.

Having thus defined the density, velocity, and flow of the medium as a whole, or, as it is sometimes expressed, "in mass," we may now consider one of the fluids which constitute the medium, and define its density, velocity, and flow in the same way. The velocity of this fluid may be different from that of the medium in mass, and its velocity relative to that of the medium is the velocity of diffusion which we have to study.

#### *Diffusion of Gases according to the Kinetic Theory.*

So many of the phenomena of gases are found to be explained in a consistent manner by the kinetic theory of gases, that we may describe with considerable probability of correctness the kind of motion which constitutes diffusion in gases. We shall therefore consider gaseous diffusion in the light of the kinetic theory before we consider diffusion in liquids.

A gas, according to the kinetic theory, is a collection of particles or molecules which are in rapid motion, and which, when they encounter each other, behave pretty much as elastic bodies, such as billiard balls, would do if no energy were lost in their collisions. Each molecule travels but a very small distance between one encounter and another, so that it is every now and then altering its velocity both in direction and magnitude, and that in an exceedingly irregular manner.

The result is that the velocity of any molecule may be considered as compounded of two velocities, one of which, called the velocity of the medium, is the same for all the molecules, while the other, called the velocity of agitation, is irregular both in magnitude and in direction, though the average magnitude of the velocity may be calculated, and any one direction is just as likely as any other.

The result of this motion is, that if in any part of the medium the molecules are more numerous than in a neighbouring region, more molecules will pass from the first region to the second than in the reverse direction, and for this reason the density of the gas will tend to become equal in all parts of the vessel containing it, except in so far as the molecules may be crowded towards one direction by the action of an external force such as gravity. Since the motion of the molecules is very swift, the process of equalization of density in a gas is a very

apid one, its velocity of propagation through the gas being that of sound.

Let us now consider two gases in the same vessel, the proportion of the gases being different in different parts of the vessel, but the pressure being everywhere the same. The agitation of the molecules will still cause more molecules of the first gas to pass from places where that gas is dense to places where it is rare than in the opposite direction, but since the second gas is dense where the first one is rare, its molecules will be for the most part travelling in the opposite direction. Hence the molecules of the two gases will encounter each other, and every encounter will act as a check to the process of equalization of the density of each gas throughout the mixture.

The interdiffusion of two gases in a vessel is therefore a much slower process than that by which the density of a single gas becomes equalized, though it appears from the theory that the final result is the same, and that each gas is distributed through the vessel in precisely the same way as if no other gas had been present, and this even when we take into account the effect of gravity.

If we apply the ordinary language about fluids to a single gas of the mixture, we may distinguish the forces which act on an element of volume as follows:—

- 1st. Any external force, such as gravity or electricity.
  - 2d. The difference of the pressure of the particular gas on opposite sides of the element of volume. [The pressure due to other gases is to be considered of no account].
  - 3d. The resistance arising from the percolation of the gas through the other gases which are moving with different velocity.
- The resistance due to encounters with the molecules of any other gas is proportional to the velocity of the first gas relative to the second, to the product of their densities, and to a coefficient which depends on the nature of the gases and on the temperature. The equations of motion of one gas of a mixture are therefore of the form

$$\rho_1 \frac{\delta_1 v_1}{\delta t} + \frac{d\rho_1}{dx} - X_1 \rho_1 + C_{12} \rho_1 \rho_2 (v_1 - v_2) + C_{13} \rho_1 \rho_3 (v_1 - v_3) + \&c. = 0,$$

where the symbol of operation  $\frac{\delta_1}{\delta t}$  prefixed to any quantity denotes the time-variation of that quantity at a point which moves along with that medium which is distinguished by the suffix (1), or more explicitly

$$\frac{\delta_1}{\delta t} = \frac{d}{dt} + v_1 \frac{d}{dx} + v_2 \frac{d}{dy} + v_3 \frac{d}{dz}.$$

In the state of ultimate equilibrium  $v_1 = v_2 = \&c. = 0$ , and the equation is reduced to

$$\frac{d\rho_1}{dx} - X_1 \rho_1 = 0,$$

which is the ordinary form of the equations of equilibrium of a single fluid. Hence, when the process of diffusion is complete, the density of each gas at any point of the vessel is the same as if no other gas were present.

If  $V_1$  is the potential of the force which acts on the gas, and if in the equation  $p_1 = k_1 \rho_1$ ,  $k_1$  is constant, as it is when the temperature is uniform, then the equation of equilibrium becomes

$$k_1 \frac{d\rho_1}{dx} + \frac{dV_1}{dx} \rho_1 = 0,$$

the solution of which is

$$\rho_1 = A_1 e^{-\frac{V_1}{k_1}}.$$

Hence if, as in the case of gravity,  $V$  is the same for all gases, but  $k$  is different for different gases, the composition of the mixture will be different in different parts of the vessel, the proportion of the heavier gases, for which  $k$  is smaller, being greater at the bottom of the vessel than at the top. It would be difficult, however, to obtain experimental evidence of this difference of composition except in a vessel more than 100 metres high, and it would be necessary to keep the vessel free from inequalities of temperature for more than a year, in order to allow the process of diffusion to advance to a state even half-way towards that of ultimate equilibrium. The experiment might, however, be made in a few minutes by placing a tube, say 10 centimetres long, on a whirling apparatus, so that one end shall be close to the axis, while the other is moving at the rate, say, of 50 metres per second. Thus if equal volumes of hydrogen and carbonic acid were used, the proportion

of hydrogen to carbonic acid would be about  $\frac{1}{11}$  greater at the end of the tube nearest the axis. The experimental verification of the result is important, as it establishes a method of effecting the partial separation of gases without the selective action of chemical agents.

Let us next consider the case of diffusion in a vertical cylinder. Let  $m_1$  be the mass of the first gas in a column of unit area extending from the bottom of the vessel to the height  $x$ , and let  $v_1$  be the volume which this mass would occupy at unit pressure, then

$$k_1 m_1 = v_1,$$

$$\rho_1 = \frac{dm_1}{dx}, \quad \rho_1 v_1 = -\frac{dv_1}{dx},$$

$$p_1 = \frac{dv_1}{dx}, \quad p_1 v_1 = -\frac{dv_1}{dx};$$

and the equation of motion becomes

$$\frac{1}{k_1} \frac{dv_1}{dx} \left\{ \frac{d^2 v_1}{dx^2} - \frac{d^2 v_1}{dx^2} \right\} + \frac{d^2 v_1}{dx^2} - \frac{X}{k_1} \frac{dv_1}{dx} + \frac{C_{12}}{k_1 k_2} \left\{ \frac{dv_1}{dx} \frac{dv_2}{dx} - \frac{dv_2}{dx} \frac{dv_1}{dx} \right\} + \&c. = 0.$$

If we add the corresponding equations together for all the gases, we find that the terms in  $C_{12}$  destroy each other, and that if the medium is not affected with sensible currents the first term of each equation may be neglected. In ordinary experiments we may also neglect the effect of gravity, so that we get

$$\frac{d^2}{dx^2} (v_1 + v_2) = 0,$$

or

$$v_1 + v_2 = px,$$

where  $p$  is the uniform pressure of the mixed medium. Hence

$$\frac{dv_1}{dx} = -\frac{dv_2}{dx} \quad \text{and} \quad \frac{dv_1}{dx} = p - \frac{dv_2}{dx},$$

and the equation becomes

$$\frac{d^2 v_1}{dx^2} = \frac{C_{12}}{k_1 k_2} p \frac{dv_1}{dx},$$

an equation, the form of which is identical with the well-known equation for the conduction of heat. We may write it

$$\frac{dv_1}{dx} = D \frac{d^2 v_1}{dx^2}.$$

$D$  is called the coefficient of diffusion. It is equal to

$$\frac{k_1 k_2}{C_{12} p}$$

It therefore varies inversely as the total pressure of the medium, and if the coefficient of resistance,  $C_{12}$ , is independent of the temperature, it varies directly as the product  $k_1 k_2$ , i.e., as the square of the absolute temperature. It is probable, however, that the effect of temperature is not so great as this would make it.

In liquids  $D$  probably depends on the proportion of the ingredients of the mixed medium as well as on the temperature. The dimensions of  $D$  are  $L^2 T^{-1}$ , where  $L$  is the unit of length and  $T$  the unit of time.

The values of the coefficients of diffusion of several pairs of gases have been determined by Loschmidt.<sup>1</sup> They are referred in the following table to the centimetre and the second as units, for the temperature 0°C and the pressure of 76 centimetres of mercury.

	$D$
Carbonic acid and air, . . . . .	0.142
Carbonic acid and hydrogen, . . . . .	0.5558
Oxygen and hydrogen, . . . . .	0.7214
Carbonic acid and oxygen, . . . . .	0.1409
Carbonic acid and carbonic oxide, . . . . .	0.1406
Carbonic acid and marsh gas, . . . . .	0.1586
Carbonic acid and nitrous oxide, . . . . .	0.0983
Sulphurous acid and hydrogen, . . . . .	0.4800
Oxygen and carbonic oxide, . . . . .	0.1802
Carbonic oxide and hydrogen, . . . . .	0.6422

#### Diffusion in Liquids.

The nature of the motion of the molecules in liquids is less understood than in gases, but it is easy to see that if there is any irregular displacement among the molecules in a mixed liquid, it must, on the whole, tend to cause each component to pass from places where it forms a large proportion of the mixture to places where it is less abundant. It is also manifest that any relative motion of two constituents of the mixture will be opposed by a resistance arising from

<sup>1</sup> Imperial Academy of Vienna, 10th March 1870.

the encounters between the molecules of these components. The value of this resistance, however, depends, in liquids, on more complicated conditions than in gases, and for the present we must regard it as a function of all the physical properties of the mixture at the given place, that is to say, its temperature and pressure, and the proportions of the different components of the mixture.

The coefficient of interdiffusion of two liquids must therefore be considered as depending on all the physical properties of the mixture according to laws which can be ascertained only by experiment.

Thus Fick has determined the coefficient of diffusion for common salt in water to be 0.0000116, and Voit has found that of cane-sugar to be 0.0000365.

It appears from these numbers that in a vessel of the same size the process of diffusion of liquids requires a greater number of days to reach a given stage than the process of diffusion of gases in the same vessel requires seconds.

When we wish to mix two liquids, it is not sufficient to place them in the same vessel, for if the vessel is, say, a metre in depth, the lighter liquid will lie above the denser, and it will be many years before the mixture becomes even sensibly uniform. We therefore stir the two liquids together, that is to say, we move a solid body through the vessel, first one way, then another, so as to make the liquid contents eddy about in as complicated a manner as possible. The effect of this is that the two liquids, which originally formed two thick horizontal layers, one above the other, are now disposed in thin and excessively convoluted strata, which, if they could be spread out, would cover an immense area. The effect of the stirring is thus to increase the area over which the process of diffusion can go on, and to diminish the distance between the diffusing liquids; and since the time required for diffusion varies as the square of the thickness of the layers, it is evident that by a moderate amount of stirring the process of mixture which would otherwise require years may be completed in a few seconds. That the process is not instantaneous is easily ascertained by observing that for some time after the stirring the mixture appears full of streaks, which cause it to lose its transparency. This arises from the different indices of refraction of different portions of the mixture which have been brought near each other by stirring. The surfaces of separation are so drawn out and convoluted, that the whole mass has a woolly appearance, for no ray of light can pass through it without being turned many times out of its path.

Graham observed that the diffusion both of liquids and gases takes place through porous solid bodies, such as plugs of plaster of Paris or plates of pressed plumbago, at a rate not very much less than when no such body is interposed, and this even when the solid partition is amply sufficient to check all ordinary currents, and even to sustain a considerable difference of pressure on its opposite sides.

But there is another class of cases in which a liquid or a gas can pass through a diaphragm, which is not, in the ordinary sense, porous. For instance, when carbonic acid gas is confined in a soap bubble it rapidly escapes. The gas is absorbed at the inner surface of the bubble, and forms a solution of carbonic acid in water. This solution diffuses from the inner surface of the bubble, where it is strongest, to the outer surface, where it is in contact with air, and the carbonic acid evaporates and diffuses out into the atmosphere. It is also found that hydrogen and other gases can pass through a layer of caoutchouc. Graham showed that it is not through pores, in the ordinary sense, that the motion takes place, for the ratios are determined by the chemical relations between the gases and the caoutchouc, or the liquid film.

According to Graham's theory, the caoutchouc is a colloid substance,—that is, one which is capable of combining, in a temporary and very loose manner, with indeterminate proportions of certain other substances, just as glue will form a jelly with various proportions of water. Another class of substances, which Graham called crystalloid, are distinguished from these by being always of definite composition, and not admitting of these temporary associations. When a colloid body has in different parts of its mass different proportions of water, alcohol, or solutions of crystalloid bodies, diffusion takes place through the colloid body, though no part of it can be shown to be in the liquid state.

On the other hand, a solution of a colloid substance is almost incapable of diffusion through a porous solid, or another colloid body. Thus, if a solution of gum and salt in water is placed in contact with a solid jelly of gelatine and alcohol, alcohol will be diffused into the gum, and salt and water will be diffused into the gelatine, but the gum and the gelatine will not diffuse into each other.

There are certain metals whose relations to certain gases Graham explained by this theory. For instance, hydrogen can be made to pass through iron and palladium at a high temperature, and carbonic oxide can be made to pass through iron. The gases form colloidal unions with the metals, and are diffused through them as water is diffused through a jelly. Root has lately found that hydrogen can pass through platinum, even at ordinary temperatures.

By taking advantage of the different velocities with which different liquids and gases pass through parchment-paper and other solid bodies, Graham was enabled to effect many remarkable analyses. He called this method the method of Dialysis.

#### Diffusion and Evaporation, Condensation, Solution, and Absorption.

The rate of evaporation of liquids is determined principally by the rate of diffusion of the vapour through the air or other gas which lies above the liquid. Indeed, the coefficient of diffusion of the vapour of a liquid through air can be determined in a rough but easy manner by placing a little of the liquid in a test tube, and observing the rate at which its weight diminishes by evaporation day by day. For at the surface of the liquid the density of the vapour is that corresponding to the temperature, whereas at the mouth of the test tube the air is nearly pure. Hence, if  $p$  be the pressure of the vapour corresponding to the temperature, and  $p = kp$ , and if  $m$  be the mass evaporated in time  $t$ , and diffused into the air through a distance  $h$ ,<sup>1</sup> then

$$D = \frac{h^2 m}{p t}$$

This method is not, of course, applicable to vapours which are rarer than the superincumbent gas.

The solution of a salt in a liquid goes on in the same way, and so does the absorption of a gas by a liquid.

These processes are all accelerated by currents, for the reason already explained.

The processes of evaporation and condensation go on much more rapidly when no air or other non-condensable gas is present. Hence the importance of the air-pump in the steam engine.

#### Relation between Diffusion of Matter and Diffusion of Heat.

The same motion of agitation of the molecules of gases which causes two gases to diffuse through each other also

<sup>1</sup>  $h$  should be taken equal to the height of the tube above the surface of the liquid, together with about  $\frac{1}{2}$  of the diameter of the tube.—See Clerk Maxwell's *Electricity*, Art. 309.

causes two portions of the same gas to diffuse through each other, although we cannot observe this kind of diffusion, because we cannot distinguish the molecules of one portion from those of the other when they are once mixed. If, however, the molecules of one portion have any property whereby they can be distinguished from those of the other, then that property will be communicated from one part of the medium to an adjoining part, and that either by convection—that is by the molecules themselves passing out of one part into the other, carrying the property with them—or by transmission—that is by the property being communicated from one molecule to another during their encounters. The chemical properties by which different substances are recognized are inseparable from their molecules, so that the diffusion of such properties can take place only by the transference of the molecules themselves, but the momentum of a molecule in any given direction and its energy are also properties which may be different in different molecules, but which may be communicated from one molecule to another. Hence the diffusion of momentum and that of energy through the medium can take place in two different ways, whereas the diffusion of matter can take place only in one of these ways.

In gases the great majority of the particles, at any instant, are describing free paths, and it is therefore possible to show that there is a simple numerical relation between the coefficients of the three kinds of diffusion,—the diffusion of matter, the lateral diffusion of velocity (which is the phenomenon known as the internal friction or viscosity of fluids), and the diffusion of energy (which is called the conduction of heat). But in liquids the majority of the molecules are engaged at close quarters with one or more other molecules, so that the transmission of momentum and of energy takes place in a far greater degree by communication from one molecule to another, than by convection by the molecules themselves. Hence the ratios of the coefficient of diffusion to those of viscosity and thermal conductivity are much smaller in liquids than in gases.

*Theory of the Wet Bulb Thermometer.*

The temperature indicated by the wet bulb thermometer is determined in great part by the relation between the coefficients of diffusion and thermal conductivity. As the water evaporates from the wet bulb heat must be supplied to it by convection, conduction, or radiation. This supply of heat will not be sufficient to maintain the temperature constant till the temperature of the wet bulb has sunk so far below that of the surrounding air and other bodies that the flow of heat due to the difference of temperature is equal to the latent heat of the vapour which leaves the bulb.

The use of the wet bulb thermometer as a means of estimating the humidity of the atmosphere was employed by Hutton<sup>1</sup> and Leslie,<sup>2</sup> but the formula by which the dew-point is commonly deduced from the readings of the wet and dry thermometers was first given by Dr Apjohn.<sup>3</sup>

Dr Apjohn assumes that, when the temperature of the wet bulb is stationary, the heat required to convert the water into vapour is given out by portions of the surrounding air in cooling from the temperature of the atmosphere to that of the wet bulb, and that the air thus cooled becomes saturated with the vapour which it receives from the bulb.

Let  $m$  be the mass of a portion of air at a distance from the wet bulb,  $\theta$  its temperature,  $p_0$  the pressure due to the aqueous vapour in it, and  $P$  the whole pressure.

If  $\sigma$  is the specific gravity of aqueous vapour (referred to air), then the mass of water in this portion of air is  $\frac{\sigma}{P} cm$ .

Let this portion of air communicate with the wet bulb till its temperature sinks to  $\theta_1$ , that of the wet bulb, and the pressure of the aqueous vapour in it rises to  $p_1$ , that corresponding to the temperature  $\theta_1$ .

The quantity of vapour which has been communicated to the air is

<sup>1</sup> Playfair's "Life of Hutton," *Edinburgh Transactions*, vol. v. p. 67, note.

<sup>2</sup> *Encyc. Brit.*, 8th ed. vol. i., "Dissertation Fifth," p. 764.

<sup>3</sup> *Trans. Royal Irish Academy*, 1834.

$$(p_1 - p_0) \frac{\sigma m}{P}$$

and if  $L$  is the latent heat of vapour at the temperature  $\theta_1$ , the quantity of heat required to produce this vapour is

$$(p_1 - p_0) \frac{\sigma m}{P} L.$$

According to Apjohn's theory, this heat is supplied by the mixed air and vapour in cooling from  $\theta$  to  $\theta_1$ .

If  $S$  is the specific heat of the air (which will not be sensibly different from that of dry air), this quantity of heat is

$$(\theta - \theta_1) m S.$$

Equating the two values we obtain

$$p_0 = p_1 - \frac{PS}{L\sigma} (\theta - \theta_1).$$

Here  $p_0$  is the pressure of the vapour in the atmosphere. The temperature—for which this is the maximum pressure—is the dew-point, and  $p_1$  is the maximum pressure corresponding to the temperature  $\theta_1$  of the wet bulb. Hence this formula, combined with tables of the pressure of aqueous vapour, enables us to find the dew-point from observations of the wet and dry bulb thermometers.

We may call this the convection theory of the wet bulb, because we consider the temperature and humidity of a portion of air brought from a distance to be affected directly by the wet bulb without communication either of heat or of vapour with other portions of air.

Dr Everett has pointed out as a defect in this theory, that it does not explain how the air can either sink in temperature or increase in humidity unless it comes into absolute contact with the wet bulb. Let us, therefore, consider what we may call the conduction and diffusion theory in calm air, taking into account the effects of radiation.

The steady conduction of heat is determined by the conditions—

$$\begin{aligned} \theta - \theta_0 & \text{ at a great distance from the bulb,} \\ \theta - \theta_1 & \text{ at the surface of the bulb,} \\ \nabla^2 \theta = 0 & \text{ at any point of the medium.} \end{aligned}$$

The steady diffusion of vapour is determined by the conditions—

$$\begin{aligned} p - p_0 & \text{ at a great distance from the bulb,} \\ p - p_1 & \text{ at the surface of the bulb,} \\ \nabla^2 p = 0 & \text{ at any point of the medium.} \end{aligned}$$

Now, if the bulb had been an electrified conductor, the conditions with respect to the potential would have been

$$\begin{aligned} V = 0 & \text{ at a great distance,} \\ V = V_1 & \text{ at the surface,} \\ \nabla^2 V = 0 & \text{ at any point outside the bulb.} \end{aligned}$$

Hence the solution of the electrical problem leads to that of the other two. For if  $V$  is the potential at any point,

$$\theta = \theta_0 + (\theta_1 - \theta_0) \frac{V}{V_1} \quad p = p_0 + (p_1 - p_0) \frac{V}{V_1}$$

If  $E$  is the electric charge of the conductor,

$$4\pi E = - \iint \frac{dV}{dv} dS,$$

where the double integral is extended over the surface of the bulb, and  $dv$  is an element of a normal to the surface.

If  $H$  is the flow of heat in unit of time from the bulb,

$$H = -K \iint \frac{d\theta}{dv} dS,$$

and if  $Q$  is the flow of aqueous vapour from the bulb,

$$Q = -\frac{D}{k} \iint \frac{dp}{dv} dS,$$

where  $k$  is the ratio of the pressure of aqueous vapour to its density.

If  $C$  is the electrical capacity of the bulb,  $E = CV_1$ ,

$$H = 4\pi CK(\theta_1 - \theta_0), \quad Q = 4\pi C \frac{D}{k} (p_1 - p_0).$$

The heat which leaves the bulb by radiation to external objects at temperature  $\theta_0$  may be written

$$h = AR(\theta_1 - \theta_0),$$

where  $A$  is the surface of the bulb and  $R$  the coefficient of radiation of unit of surface.

When the temperature becomes constant

$$LQ + H + h = 0,$$

$$p_0 = -\frac{PS}{L\sigma} \left\{ \frac{K}{D} + \frac{AR}{4\pi C D} \right\} (\theta_0 - \theta_1).$$

This formula gives the result of the theory of diffusion, conduc-

tion, and radiation in a still atmosphere. It differs from the formula of the convection theory only by the factor in the last term.

The first part of this factor  $\frac{K}{D}$  is certainly less than unity, and probably about .77.

If the bulb is spherical and of radius  $r$ ,  $A = 4\pi r^2$  and  $C = r$ , so that the second part is  $\frac{Rr}{\rho SD}$ .

Hence, the larger the wet bulb, the greater will be the ratio of the effect of radiation to that of conduction. If, on the other hand, the air is in motion, this will increase both conduction and diffusion, so as to increase the ratio of the first part to the second. By comparing actual observations of the dew-point with Apjohn's formula, it has been found that the factor should be somewhat greater than unity. According to our theory it ought to be greater if the bulb is larger, and smaller if there is much wind.

*Relation between Diffusion and Electrolytic Conduction.*

Electrolysis (see separate article) is a molecular movement of the constituents of a compound liquid in which, under the action of electromotive force, one of the components travels in the positive and the other in the negative direction, the flow of each component, when reckoned in electro-chemical equivalents, being in all cases numerically equal to the flow of electricity.

Electrolysis resembles diffusion in being a molecular movement of two currents in opposite directions through the same liquid; but since the liquid is of the same composition throughout, we cannot ascribe the currents to the molecular agitation of a medium whose composition varies from one part to another as in ordinary diffusion, but we must ascribe it to the action of the electromotive force on particles having definite charges of electricity.

The force, therefore, urging an electro-chemical equivalent of either component, or *ion*, as it is called, in a given direction is numerically equal to the electromotive force at a given point of the electrolyte, and is therefore comparable with any ordinary force. The resistance which prevents the current from rising above a certain value is that arising from the encounters of the molecules of the ion with other molecules as they struggle forward through the liquid, and this depends on their relative velocity, and also on the nature of the ion, and of the liquid through which it has to flow.

The average velocity of the ions will therefore increase, till the resistance they meet with is equal to the force which urges them forward, and they will thus acquire a definite velocity proportional to the electric force at the point, but depending also on the nature of the liquid.

If the resistance of the liquid to the passage of the ion is the same for different strengths of solution, the velocity of the ion will be the same for different strengths, but the quantity of it, and therefore the quantity of electricity which passes in a given time, will be proportional to the strength of the solution.

Now, Kohlrausch has determined the conductivity of the solutions of many electrolytes in water, and he finds that for very weak solutions the conductivity is proportional to the strength. When the solution is strong the liquid through which the ions struggle can no longer be considered sensibly the same as pure water, and consequently this proportionality does not hold good for strong solutions.

Kohlrausch has determined the actual velocity in centimetres per second of various ions in weak solutions under an electro-motive force of unit value. From these velocities he has calculated the conductivities of weak solutions of electrolytes different from those of which he made use in calculating the velocity of the ions, and he finds the results consistent with direct experiments on those electrolytes.

It is manifest that we have here important informa-

tion as to the resistance which the ion meets with in travelling through the liquid. It is not easy, however, to make a numerical comparison between this resistance and any results of ordinary diffusion, for, in the first place, we cannot make experiments on the diffusion of ions. Many electrolytes, indeed, are decomposed by the current into components, one or both of which are capable of diffusion, but these components, when once separated out of the electrolyte, are no longer ions—they are no longer acted on by electric force, or charged with definite quantities of electricity. Some of them, as the metals, are insoluble, and therefore incapable of diffusion; others, like the gases, though soluble in the liquid electrolyte, are not, when in solution, acted on by the current.

Besides this, if we accept the theory of electrolysis proposed by Clausius, the molecules acted on by the electromotive force are not the whole of the molecules which form the constituents of the electrolyte, but only those which at a given instant are in a state of dissociation from molecules of the other kind, being forced away from them temporarily by the violence of the molecular agitation. If these dissociated molecules form a small proportion of the whole, the velocity of their passage through the medium must be much greater than the mean velocity of the whole, which is the quantity calculated by Kohlrausch.

*On Processes by which the Mixture and Separation of Fluids can be effected in a Reversible Manner.*

A physical process is said to be reversible when the material system can be made to return from the final state to the original state under conditions which at every stage of the reverse process differ only infinitesimally from the conditions at the corresponding stage of the direct process. All other processes are called irreversible.

Thus the passage of heat from one body to another is a reversible process if the temperature of the first body exceeds that of the second only by an infinitesimal quantity, because by changing the temperature of either of the bodies by an infinitesimal quantity, the heat may be made to flow back again from the second body to first.

But if the temperature of the first body is higher than that of the second by a finite quantity, the passage of heat from the first body to the second is not a reversible process, for the temperature of one or both of the bodies must be altered by a finite quantity before the heat can be made to flow back again.

In like manner the interdiffusion of two gases is in general an irreversible process, for in order to separate the two gases the conditions must be very considerably changed. For instance, if carbonic acid is one of the gases, we can separate it from the other by means of quicklime; but the absorption of carbonic acid by quicklime at ordinary temperatures and pressures is an irreversible process, for in order to separate the carbonic acid from the lime it must be raised to a high temperature.

In all reversible processes the substances which are in contact must be in complete equilibrium throughout the process; and Professor Gibbs has shown the condition of equilibrium to be that not only the temperature and the pressure of the two substances must be the same, but also that the *potential* of each of the component substances must be the same in both compounds, and that there is an additional condition which we need not here specify.

Now, we may obtain complete equilibrium between quicklime and the mixture containing carbonic acid if we raise the whole to a temperature at which the pressure of dissociation of the carbonic acid in carbonate of lime is equal to the pressure of the carbonic acid in the mixed gases. By altering the temperature or the pressure very slowly we may cause carbonic acid to pass from the mix-

ture to the lime; or from the lime to the mixture, in such a manner that the conditions of the system differ only by infinitesimal quantities at the corresponding stages of the direct and the inverse processes. The same thing may be done at lower temperatures by means of potash or soda.

If one of the gases can be condensed into a liquid, and if during the condensation the pressure is increased or the temperature diminished so slowly that the liquid and the mixed gases are always very nearly in equilibrium, the separation and mixture of the gases can be effected in a reversible manner.

The same thing can be done by means of a liquid which absorbs the gases in different proportions, provided that we can maintain such conditions as to temperature and pressure as shall keep the system in equilibrium during the whole process.

If the densities of the two gases are different, we can effect their partial separation by a reversible process which does not involve any of the actions commonly called chemical. We place the mixed gases in a very long horizontal tube, and we raise one end of the tube till the tube is vertical. If this is done so slowly that at every stage of the process the distribution of the two gases is sensibly the same as it would be at the same stage of the reverse process, the process will be reversible, and if the tube is long enough the separation of the gases may be carried to any extent.

In the *Philosophical Magazine* for 1876, Lord Rayleigh has investigated the thermodynamics of diffusion, and has shown that if two portions of different gases are given at the same pressure and temperature, it is possible, by mixing them by a reversible process to obtain a certain quantity of work. At the end of the process the two gases are uniformly mixed, and occupy a volume equal to the sum of the volumes they occupied when separate, but the temperature and pressure of the mixture is lower than before.

The work which can be gained during the mixture is equal to that which would be gained by allowing first one gas and then the other to expand from its original volume to the sum of the volumes; and the fall of temperature and pressure is equal to that which would be produced in the mixture by taking away a quantity of heat equivalent to this work.

If the diffusion takes place by an irreversible process, such as goes on when the gases are placed together in a vessel, no external work is done, and there is no fall of temperature or of pressure during the process.

We may arrive at this result by a method which, if not so instructive as that of Lord Rayleigh, is more general, by the use of the physical quantity called by Clausius the Entropy of the system.

The entropy of a body in equilibrium is a quantity such that it remains constant if no heat enters or leaves the body, and such that in general the quantity of heat which enters the body is

$$\int \theta d\phi,$$

where  $\phi$  is the entropy, and  $\theta$  the absolute temperature.

The entropy of a material system is the sum of the entropy of its parts.

In reversible processes the entropy of the system remains unchanged, but in all irreversible processes the entropy of the system increases.

The increase of entropy involves a diminution of the available energy of the system, that is to say, the total quantity of work which can be obtained from the system. This is expressed by Sir W. Thomson by saying that a certain amount of energy is dissipated.

The quantity of energy which is dissipated in a given process is equal to

$$\theta_0(\phi_2 - \phi_1),$$

where  $\phi_1$  is the entropy at the beginning, and  $\phi_2$  that at the end of the process, and  $\theta_0$  is the temperature of the system in its ultimate state, when no more work can be got out of it.

When we can determine the ultimate temperature we can calculate the amount of energy dissipated by any process; but it is sometimes difficult to do this, whereas the increase of entropy is determined by the known states of the system at the beginning and end of the process.

The entropy of a volume  $v_1$  of a gas at pressure  $p_1$  and temperature  $\theta_1$  exceeds its entropy where its volume is  $v_2$  and its temperature  $\theta_2$  by the quantity

$$\frac{p_1 v_1}{\theta_1} \left\{ \frac{1}{\gamma - 1} \log \frac{\theta_1}{\theta_2} + \log \frac{v_1}{v_2} \right\}.$$

Hence if volumes  $v_1$  and  $v_2$  of two gases at the same temperature and pressure are mixed so as to occupy a volume  $v_1 + v_2$  at the same temperature and pressure, the entropy of the system increases during the process by the quantity

$$\frac{p}{\theta} \left\{ v_1 \log \frac{v_1 + v_2}{v_1} + v_2 \log \frac{v_1 + v_2}{v_2} \right\}$$

Since in this case the temperature does not change during the process, we may calculate the quantity of energy dissipated by multiplying the gain of entropy by the temperature, and we thus find for the dissipation

$$p v_1 \log \frac{v_1 + v_2}{v_1} + p v_2 \log \frac{v_1 + v_2}{v_2},$$

or the sum of the work which would be done by the two portions of gas if each expanded under constant temperature to the volume  $v_1 + v_2$ .

It is greatest when the two volumes are equal, in which case it is

$$1.386 p v,$$

where  $p$  is the pressure and  $v$  the volume of one of the portions.

Let us now suppose that we have in a vessel two separate portions of gas of equal volume, and at the same pressure and temperature, with a movable partition between them. If we remove the partition the agitation of the molecules will carry them from one side of the partition to the other in an irregular manner, till ultimately the two portions of gas will be thoroughly and uniformly mixed together. This motion of the molecules will take place whether the two gases are the same or different, that is to say, whether we can distinguish between the properties of the two gases or not.

If the two gases are such that we can separate them by a reversible process, then, as we have just shown, we might gain a definite amount of work by allowing them to mix under certain conditions; and if we allow them to mix by ordinary diffusion, this amount of work is no longer available, but is dissipated for ever. If, on the other hand, the two portions of gas are the same, then no work can be gained by mixing them, and no work is dissipated by allowing them to diffuse into each other.

It appears, therefore, that the process of diffusion does not involve dissipation of energy if the two gases are the same, but that it does if they can be separated from each other by a reversible process.

Now, when we say that two gases are the same, we mean that we cannot distinguish the one from the other by any known reaction. It is not probable, but it is possible, that two gases derived from different sources, but hitherto supposed to be the same, may hereafter be found to be different, and that a method may be discovered of separating them by a reversible process. If this should happen, the process of interdiffusion which we had formerly supposed not to be an instance of dissipation of energy would now be recognized as such an instance.

It follows from this that the idea of dissipation of energy depends on the extent of our knowledge. Available energy is energy which we can direct into any desired channel. Dissipated energy is energy which we cannot lay hold of and direct at pleasure, such as the energy of the confused agitation of molecules which we call heat. Now, confusion, like the correlative term order, is not a property of material things in themselves, but only in relation to the mind which perceives them. A memorandum-book does not, provided it is neatly written, appear confused to an illiterate person, or to the owner who understands it thoroughly, but to any other person able to read it appears to be inextricably confused. Similarly the notion of dissipated energy could not occur to a being who could not turn any of the energies of nature to his own account, or to one who could trace the motion of every molecule and seize it at the right moment. It is only to a being in the intermediate stage, who can lay hold of some forms of

energy while others elude his grasp, that energy appears to be passing inevitably from the available to the dissipated state.

DIGBY, SIR KENELM (1603-1665), an eminent English physical philosopher, born at Gothurst, Buckinghamshire, on the 11th July 1603, was descended from an ancient and illustrious family. His great-grandfather had distinguished himself at Bosworth on the side of Henry VII.; and his father, Sir Everard Digby, was one of the leading Roman Catholic gentry at the time of the Gunpowder Plot. Having risen in arms on that occasion, Sir Everard was executed at London, January 27, 1606. The young philosopher was educated by his guardians in the Protestant faith. Having finished his education at Oxford, he went abroad in 1621, and travelled in France, Spain, and Italy. On his return he was knighted, and received from Charles I. the appointments of gentleman of the bed-chamber, commissioner of the navy, and governor of Trinity House. At the head of a small squadron, which he equipped at his own expense, he sailed in 1628 against the Algerines, and afterwards defeated the Venetians near the port of Scanderoon. During a brief stay in Paris he joined the Church of Rome. Having returned to England in 1638, he espoused the cause of the king, and was imprisoned in Winchester House, by order of the Parliament. He was, however, liberated at the request of the French queen-dowager in 1643, and retired to France, where he was taken into the confidence of the court, and enjoyed the friendship of Descartes and other learned men. Here he wrote his *Treatise on the Nature of Bodies*, his *Treatise on the Soul*, *Peripatetic Institutions*, and other works. He visited England, after the defeat of the Royalist party, but the Parliament refused to allow him to remain. Banished from England upon pain of death if he returned, he resumed his residence in France, where he was treated with the highest respect, and was intrusted with an embassy to several of the courts of Italy. He returned again to his native country during the Protectorate of Cromwell, and seemed to be more zealous for the advancement of the interests of the Commonwealth than befitted a staunch royalist. He used his influence to reconcile the Catholics to the Protectorate on condition of their being secured the free exercise of their religion. With Cromwell he was on terms of intimate friendship, the bond of sympathy being probably not so much politics as a common interest in the new-born science of physics. At the Restoration he returned finally to London, where he died in 1665. He married Venetia Anastasia, the daughter of Sir Edward Stanley of Shropshire, "a lady of an extraordinary beauty and of as extraordinary a fame." His whimsical experiments to preserve her beauty by the invention of new cosmetics procured him as much notoriety as his sympathetic powder for the cure of wounds at a distance. He was appointed one of the council of the Royal Society at the time of its first establishment, and he took a very active part in its management. Besides the works already mentioned, Digby wrote *A Conference about a Choice of Religion*, Paris, 1638; *Letters on the same subject*, Lond. 1651; *Observations on Religio Medici*, Lond. 1643; *A Treatise of Adhering to God*, Lond. 1654; *On the Cure of Wounds by the Powder of Sympathy*, Lond. 1658; and a *Discourse on Vegetation*.

DIGESTIVE ORGANS. The organs of digestion, or alimentary apparatus, are for the purpose of receiving the food or aliment; of converting that portion of the food which is digestible into chyle, so that it may be absorbed and applied to the nourishment of the body; and of transmitting that which is indigestible onwards to be excreted.

In the Protozoa there is no special digestive apparatus,

but the particles of food are introduced into the general substance of the body, where they undergo digestion and assimilation. But in animals generally there is a definite digestive cavity or stomach, which communicates with the surface by a distinct opening or mouth, through which the food is introduced into the stomach. As a rule a second opening, or anus, is also in communication with the stomach, at which the indigestible parts of the food are excreted. As animals increase in structural complexity the digestive apparatus has additional parts superadded to it. In man and all the more highly organized animals it consists of an elongated tube, the Alimentary Canal, divided into various compartments, into which numerous Glands pour their secretions to be used in the digestive process. In most vertebrates, the great class of birds being excepted, the compartment of the canal called the mouth, or oral cavity, contains a hard masticatory apparatus, the Teeth, which play an important part in breaking down the food.

As the digestive organs in the human body are so constructed as to illustrate one of the most perfect forms of an alimentary apparatus, they will form the special subject of description in this article.

The ALIMENTARY CANAL is a tube about 28 feet long, which traverses almost the entire length of the axial part of the body. In man and all other vertebrates, it lies in relation to the ventral surface of the bodies of the vertebrae. It commences on the face at the orifice of the mouth, and terminates on the surface of the lower part of the trunk at the orifice of the anus. It is divided into a series of segments, or compartments, which communicate with each other, from above downwards, in the longitudinal axis of the canal. These compartments are named mouth, pharynx, cesophagus, stomach, small intestine (subdivided into duodenum, jejunum, and ileum), and large intestine (subdivided into cæcum, colon, and rectum). The canal is lined by a mucous membrane, called the alimentary mucous membrane, which is continuous with the nasal mucous membrane, with the respiratory mucous membrane, and at the anal and oral orifices with the integument. Outside this mucous membrane is the submucous coat, and external to it is the muscular wall of the canal. By the contraction of the muscular wall the food is propelled along the canal from above downwards. Opening on the surface of the mucous membrane are the orifices of the ducts of numerous glands, the secretions of which, mingling with the food, act chemically on it, so as to render it soluble and capable of being absorbed.

The *Mouth, Oral Cavity, or Buccal Cavity*, is the dilated commencement of the alimentary canal, in which the food is masticated and mingled with the secretion of the salivary and mucous glands. It is situated in the face, and extends from the lips in front to the pharynx behind. It is bounded above by the hard and soft palate, with the uvula; below by the lower jaw, the mucous membrane of the floor of the mouth, and the tongue; on each side by the cheek; and in front by the lips, between which is the aperture of communication with the surface of the face. Behind it freely communicates with the pharynx through the isthmus faucium. The muscles situated in the lips, cheeks, floor of the mouth, tongue, and soft palate enter into the formation of the walls of the mouth.

The mouth is lined by a red-coloured mucous membrane, which becomes continuous posteriorly with that of the pharynx, and at the margins of the lips with the skin of the face. The mucous membrane covering the alveolar portions of the jaws, and surrounding the necks of the teeth, is called the *gum*. From the outer surface of each jaw it is reflected to the inner surface of the cheeks and lips. From the inner surface of the lower jaw the mucous membrane is reflected to the floor of the mouth, and a broad bend,