condition of the globe. It is manifest that the fusion of the eyes in cyclopia is a pathological condition consequent on an arrest of development in other and adjacent parts; and the state of the chorioid and other internal structures depends on the greater or less amount of fusion of the corneæ and sclerotics.

ART. VI.—*On Carbonic Acid in Mineral Waters.* By JULIUS ALTHAUS, M.D., Member of the Royal College of Physicians of London, &c.

ONE of the most important and interesting constituents of mineral waters is carbonic acid, the “spirit of the springs,” which not only greatly contributes to the solubility of certain salts contained in such waters, but also renders them more palatable and more agreeable to the stomach. It is especially important for chalybeate waters, which, when devoid of carbonic acid, soon lose the iron which was in solution, and also become heavy and unpalatable. There are some very strong chalybeates in England, as, for instance, the springs of Sandrock, in the Isle of Wight, those of Dorton, in Oxfordshire, and those of Tunbridge, which, if they only contained carbonic acid gas, would no doubt attract a large number of patients from this and other countries, who now resort to the waters of Spa, Driburg, Pyrmont, Schwalbach, and other continental places. The strongest chalybeate known in the whole world is the Aqua Ferrata di Rio, in the island of Elba; but as it does not contain any carbonic acid, it is entirely useless for medical purposes.

In mineral waters, carbonic acid is found in three different states. It is either “*bound*” to certain bases, with which it forms carbonates; from these the gas does *not* escape, when the water is heated; or it is “*half-bound*,” forming sesquicarbonates and bicarbonates, from which compounds part of the gas is disengaged as soon as the water comes in contact with the air, and still more rapidly when it is heated; so that, since certain salts are only soluble as bicarbonates, and insoluble as carbonates, they are precipitated as soon as the surplus atoms of carbonic acid are gone; finally, it is contained in the waters *free*, as gas, which escapes at the ordinary temperature, as soon as the water rises out of the earth, and the pressure under which it was in the interior ceases. This escape is more rapid and powerful when the water is hot or artificially heated. Carbonic

acid is found almost entirely pure in the neighbourhood of the Lake of Laach, in Meinberg, and Driburg, while in other places it is found mixed with nitrogen, sulphuretted hydrogen, and oxygen.

The tension with which the gas escapes, shows considerable variations in the several mineral waters. Where there are many outlets for it in a certain locality the tension is, generally speaking, not considerable; but if borings are made in places where there has been no previous exit of gas, the pressure is sometimes so powerful, that as soon as an opening is made, it rises twenty or thirty feet into the air, carrying with it large stones from the boring hole. This has often been observed in boring for artesian wells. The same is the case, if the escape of the gas is accidentally or intentionally impeded. Thus, some time ago, the tube connected with the acidulated spring at Pymont, had become obstructed, whereupon the gas heaved up not only the large metal funnel, which, at its upper end, is eight feet in diameter, but also the whole cottage that had been built over it.

The quantity of carbonic acid contained in the spas is very variable. It is well known, that common spring water contains a certain amount of carbonic acid (from one-sixth to one-fourth of a cubic inch in the pound). River water is also slightly impregnated with this gas, and a little more of it is found in sea-water than in fresh water. The small quantity contained in drinking water is sufficient to impart to it a refreshing taste, which no water has that is quite devoid of carbonic acid. But the amount of this gas contained in springs, rivers and the sea, is very trifling when compared with the quantity found in certain spas. It varies from one to seventy cubic inches in the pound, and such waters as contain ten cubic inches or more are called acidulated springs.

The amount of carbonic acid found in mineral waters is dependent upon several conditions, of which the chief are, hydrostatic pressure, and temperature. According to Lersch, one ounce of water at a temperature of from about 40° to 60° Fahrenheit, absorbs at the ordinary pressure of air, one grain of carbonic acid. If the pressure increases, more gas is absorbed, but not in the same ratio, as by a pressure equivalent to seven atmospheres, not seven, but only five times the ordinary amount of gas is dissolved. As soon as this pressure ceases, gas-bubbles are set free from the mineral spring, in the same way as on opening a bottle of Champagne.

The escape of carbonic acid from the springs, is considerably influenced by the variations of atmospheric pressure. When the

barometer rises, less gas is set free; but if it falls, as, for instance, before a storm, the amount of gas evolved is very large, the bubbles rise more rapidly, the surface of the springs appears more agitated than usual, the water has a more refreshing taste, and, where baths of this gas are given, the bathers find it impossible to bear the powerful effects of it; a circumstance which has been more especially noticed by M. Bertrand, in the gas-baths of the Auvergne. The carbonic acid discharged by the Racoczi of Kissingen, varies, according to the atmospheric pressure, from 110 to 170 cubic inches of gas in a minute. These gas springs may, therefore, serve as indicators of an impending change in the weather, and only seldom deceive the observer. In consequence of a diminished amount of gas in some springs, oxide of iron, which is only kept in solution by carbonic acid, is precipitated, and imparts to the water a red colour, which mostly indicates the approach of heavy rains. It is from such and similar natural phenomena that weather-wise persons draw their prophecies.

The *temperature* of the water has also an important bearing upon the amount of carbonic acid contained in it. The capability of water to absorb carbonic acid, decreases in an inverse proportion to its temperature. Accurate calculations have shown, that 1,000 volumes of water will, when heated from 40° to boiling point, expand to 1,043 volumes, while 1,095 volumes of carbonic acid, which are absorbed by 1,000 volumes of water, expand to 1,417 volumes; therefore, if acidulated water is heated, the gas expands much more largely than the water, and for this reason alone part of it must escape. But there are other influences at work, which carry off a still larger quantity of gas from heated water, namely, the diminution of affinity which exists between hot water and other gases, but its own; the more steam there is present in water, the less of foreign gases can be kept in solution; besides, the steam bubbles, which rise from water when heated, mechanically carry the carbonic acid away with them. At boiling point carbonic acid is entirely expelled, as are in fact all foreign gases; but gentle heat is not sufficient to drive the gas entirely out. Thus water used for bathing, at a temperature of 86° to 88° Fahrenheit, may still be so much saturated with the gas, that, if the patients enter the tubs, the whole surface of the body becomes thickly covered with bubbles of carbonic acid, and if wiped off they immediately re-appear. A low temperature enables the springs to retain a large quantity of carbonic acid, and, consequently, to keep in solution a comparatively larger

quantity of the carbonate of lime and magnesia, oxide of iron, and other substances which are insoluble in the absence of this gas. If the latter escapes, the salts just named are at once precipitated.

The more or less intimate connexion of carbonic acid with certain mineral waters, has been the subject of much mystical misrepresentation. Thus it was observed that the gas is more loosely bound to the acidulated springs of Silesia than to those of Pyrmont, Spa, Selters, and Driburg; that the gas seemed only to travel through some of the springs, while others were very firmly impregnated with it; and such and similar observations were adduced to prove that physical laws were not sufficient for explaining the wonderful phenomena connected with the "spirit of the springs." But if we analyse the actual state of things, it is not difficult to account for it in a scientific manner. Thus, for instance, we should naturally expect that the water of Reinerz, in Silesia, would lose its carbonic acid sooner than that of Driburg, in Westphalia, as the former has a temperature of 66°, and the latter of 51° only. But it is true that the temperature and pressure are not in all cases sufficient to account for the more or less intimate connexion of carbonic acid with water; in such instances, however, we can always trace other physical or chemical influences at work. Thus, if water saturated with a certain gas, comes in contact with other gases which it does not yet contain, it will dissolve a certain amount of these latter; but, with the loss of a certain quantity of the former. If water, which, when rising from the earth, contains no other gas than carbonic acid, comes in contact with the atmosphere, it at once absorbs nitrogen and oxygen, whereby carbonic acid is driven out; but when water is already impregnated with nitrogen and oxygen, before it rises, carbonic acid will be the more firmly bound to it. Finally, we have to consider that water keeps gases less easily in solution, in proportion to the increase of its own specific gravity. Carbonic acid, therefore, escapes more rapidly from strongly concentrated saline waters than from such as contain only a small quantity of solid ingredients. If these circumstances are borne in mind, we shall almost always be able to explain the relations of carbonic acid to water, and may, in fact, often determine, *à priori*, whether a certain spa is likely to contain much or little of this gas. Thus, for instance, the brines and bitter waters which contain from 80 to 2,000 grains of salines in the pound of water, will not contain much carbonic acid; the bitter water of Friedrichshall, in which 193 grains of salines are dissolved, does not contain any carbonic acid.

Thermal springs will also contain very little of it, on account of their high temperature, while such waters as are rather cold and contain only a moderate quantity of salines, present the most favourable conditions for absorbing a large amount of this gas, and keeping it in solution for a considerable time. In some spas it is contained in such large quantities that it constitutes their chief element; while in others carbonic acid is not the characteristic feature of the water, although it essentially modifies the composition and the effects of the same.

The sources from which mineral waters derive carbonic acid are of various kinds, and where they are abundant, waters which have a high specific gravity and a comparatively high temperature may contain more gas than others of, perhaps, less gravity and temperature, but which are in a neighbourhood where the sources of it are sparing. Small quantities of carbonic acid are absorbed by the springs from the upper strata of the earth, which attract it from the atmosphere, and in which it also accumulates by putrefaction of organic bodies. Fossil remains of plants contain a large amount of carbonaceous matter; and if water runs through such strata their substance is decomposed by the oxygen, which is always present in it; and thus carbonic acid is formed, which is then generally found together with sulphuretted hydrogen. That free oxygen is lost in this way, and oxygenation of carbon takes place, is evidenced by the circumstance that common spring water contains less oxygen than rain water (respectively 16 and 7 volumes of it in 1,000 volumes of water).

But the sources of carbonic acid I have just enumerated only hold good for a limited number of acidulated springs, most of which are, no doubt, connected with active or extinct volcanoes. Exhalations of carbonic acid, either in its free state as gas or united with water, are generally the last remnants of Plutonic catastrophes. The carbonic acid can at present only rise where disruptions of the crust of the earth exist, and its upper strata do not offer an impediment to the exit of the gas. Such rents we find, for instance, in Germany, at Pyrmont, where the well-known Grotto of Dogs is filled with pure carbonic acid; and powerfully acidulated chalybeate springs issue from the fissures in perpendicular layers of sandstone. Carbonic acid also rises from the basalt formation which we find extending through Germany from the Eifel to the Riesengebirge. In the neighbourhood of the Lake of Laach there are more than a thousand acidulated springs close to each other. In some of them

the bubbles which escape from the water are as large as the head of an adult, and a noise as of hissing, whizzing, and gurgling is heard at a great distance. Within a few miles of Marienbad we find 124 acidulated springs, and the quantity of carbonic acid developed in them is something prodigious. From an approximative calculation the springs of Meinberg furnish about one million of cubic feet annually, and those of Nauheim eleven millions. In France we have exhalations of carbonic acid in the cave of Montjoly, in the Auvergne, and the Puits de Nérac, in the Vivarais. In Italy we find the gas-springs of Sciacca and Latera, at the foot of the Etna; the famous Grotto del Cane near Vesuvius; the Lake of Amsanctus, near Naples, in which the carbonic acid is mixed with sulphuretted hydrogen; and the Guada Mortale, in the neighbourhood of that lake, which contains pure carbonic acid, and where sheep, hares, and rabbits are often found suffocated. In Greece there were and are still many places where escapes of this gas occur; such was the steaming cave in Apollo's Oracle at Delphi, where the Pythia pronounced her prophecies, and of which no remains are left; also the gas-springs in the sacred forest of Dodona, near Epirus, the most ancient oracle of the Greeks; the springs of Thermopylæ, and many others. The phenomena observed in such places are so remarkable that we cannot be surprised at finding an uneducated age and people looking upon them as manifestations of supernatural powers. In fact, the hissing and gurgling sounds, occasioned by the discharge of the gas, were, by the ancients, believed to be the voices of demons. It was in places like those just mentioned, which were called the "*spiracula Orci*," that, according to Homer and Virgil, Odysseus and Æneas went to the lower world to meet the spirits of the departed; that oracles were founded which were used by a cunning priesthood to deceive the vulgar; and it was into the awful lake of Amsanctus that, according to Virgil, the fury Alecto, in her anger, precipitated herself from the summit of the mountain.

Volcanic agency does not, however, *produce* carbonic acid; it merely provides it with an outlet, tearing asunder the crust of the earth, and taking away the obstruction to the free escape of the gas from the interior of the globe. The most abundant source of carbonic acid is, no doubt, the decomposition of carbonates, such as the carbonate of lime, of iron, of magnesia, which enter into the composition of the solid crust of the earth. The common limestone alone exists in such quantities in it as to be able to give out inexhaustible

streams of carbonic acid from every point of the earth's surface, of which this salt, together with silica, forms the greatest part; its geognostical distribution extending from the newest tertiary deposit to the oldest primitive rocks. From its combination with lime, carbonic acid is evolved partly by sulphuric and hydrochloric acids, which exist in the interior of the earth, sulphate and chloride of lime being thus formed; and partly by a simple process of calcination which is continually carried on at a certain depth, in consequence of the heat inherent to the interior. Berzelius believed that the action of the heat, and, therefore, a continued evolution of carbonic acid from limestone, ceased at the depth of two or three fathoms from the surface, in consequence of the very bad conducting power of the stone. But Bischof has proved that if limestone is exposed to a high degree of heat it cannot retain its cohesion and firmness; in fact, under such circumstances, the rock soon cracks in every direction, is disintegrated into fragments, and thereby affords ample room for the continued influence of the heat, which is, of course, assisted by the presence of a large amount of aqueous vapours. This is, only on a larger scale, the very same process which we may every day observe in our artificial lime-works.

In a subsequent communication I intend entering into the physiological effects and the therapeutical action of carbonic acid, both as gas and when dissolved in water.

ART. VII.—*Observations on Encysted Tumours*. By HENLEY THORP, M.D., F.R.C.S.I., L.K. & Q.C.P.I., Letterkenny.

DURING the last ten years I have been called on to operate upon several cases of encysted tumours, and as my experience of these growths, at least as they occur in the orbital region, does not correspond in some respects with Mr. Hamilton's, as published in his memoir in the last number of this journal, I am induced to give a brief account of a few cases, out of many others, which have come under my notice, and to append a few remarks upon encysted tumours generally, as well as upon those which occur in the neighbourhood of the orbit in particular.

CASE I.—In the summer of 1853, a farmer, aged 30, consulted me respecting a swelling that occupied the outer part of the left