

—even better without, perhaps. The next alternative is between isolated vascular bundles, and vascular bundles in a cylinder, connected with other characters, entailing previous teaching and study, which should largely consist of acquiring a knowledge of natural orders. Nevertheless this book may prove useful, especially to the collector desirous of determining the natural orders of his plants in the field or at home. So far as we have tested it, it is carefully compiled and edited, and we can conscientiously recommend it to those who know the characters of many natural orders in advance.

W. B. H.

LETTERS TO THE EDITOR.

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Attempt to Liquefy Helium.

I HAVE received a letter from Prof. Olszewski, of Krakau, in which he informs me that having exposed a sample of helium which I sent him to the same treatment as was successful in liquefying hydrogen—namely, compressing with a pressure of 140 atmospheres, cooling to the temperature of air boiling at low pressure, and then expanding suddenly—he has been unable to detect any sign of liquefaction.

The density of helium being, roughly speaking, twice that of hydrogen, it is very striking that its liquefying point should lie below that of hydrogen. It may be remembered that argon, which has a higher density than oxygen, liquefies at a lower temperature than oxygen; and it was pointed out by Prof. Olszewski that this behaviour was not improbably connected with its apparently simple molecular constitution. The similar fact now recorded for helium may therefore be regarded as evidence of its simple molecular constitution. I use the word "its" instead of "their," although further research may corroborate Prof. Runge's contention that what is termed helium may in reality be a mixture of two, if not more than two elements. If this contention is true, both, or all, must have extraordinarily low boiling-points.

WILLIAM RAMSAY.

September 23.

Helium and the Spectrum of Nova Aurigæ.

IN the paper on the constituents of the gas in cleveite that we read before the British Association, we said that in the first spectrum of Nova Aurigæ the principal lines 5016 and 4922 of the lighter constituent were far more intense than those of the other constituent. But we were puzzled at the line 6678 not having been observed, as it is also a strong line in the spectrum of the lighter constituent. On inquiry, Dr. and Mrs. Huggins were kind enough to give us better information. Dr. Huggins writes: "I think there is no doubt that we did see the red line at 6678 in Nova Aurigæ. We were unable to measure in that part of the spectrum, but on three nights we saw a bright line a little below C. This was a pure estimation under difficult circumstances. In the map we put the line, as a mere guess, at a little over 6700. On the first night we put the line in a rough diagram, made at the time, a little nearer C, almost exactly at 6678. On a subsequent night, we made the estimation a little below 6700, but the line was not then so bright."

London, September 27. C. RUNGE AND F. PASCHEN.

Latent Vitality in Seeds.

THERE is no doubt, as M. Casimir de Candolle has recently shown in his paper on latent life in seeds, that all the functions of seeds can remain completely quiescent for a long period; probably in some cases this period may be indefinitely long. In 1878 I published a paper¹ on the resistance of seeds,

¹ Italo Giglioli. "Resistenza di alcuni semi all'azione prolungata di agenti chimici, gassosi e liquidi," *Gazzetta Chimica italiana*, ix., 1879, p. 199; and *Giorn. delle staz. sper. ital.* viii., 1879, p. 199.

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especially of *Medicago sativa*, or lucerne, to the action of gaseous and liquid chemical reagents. An abstract of my experiments was published in NATURE, vol. xxv., 1882, p. 328.

Recently I have examined portions of the seeds used in the experiments of 1877 and 1878, to see if after the lapse of so many years, during which the seeds have remained constantly surrounded by special gases, or immersed in different solutions, they had retained their vitality. The results have been remarkable, for in some cases a large proportion of the seeds have maintained their vitality after a lapse of 15, 16, and nearly 17 years of special external chemical conditions. I summarise the results of some of my experiments.

(a) Experiments in Gases.

In all these experiments the gases were *dry*, for in these conditions moisture is rapidly fatal to the seeds. The seeds were introduced into small bulbed tubes, into which the dry gas was made to pass for some time, after which the tubes were rapidly sealed at a spirit-lamp flame. The tubes were then kept in the dark.

In the following summary I give the dates of the sealing and opening of the tubes:—

Hydrogen.—Lucerne seeds, from September 15, 1877, to August 5, 1894, a period of 16 years, 10 months, and 20 days. Out of 51 seeds sown, none germinated. Seeds of wheat, vetch, *Cynara cardunculus* and coriander, kept in hydrogen, gave the same negative results. There is some suspicion that the hydrogen had not been originally well dried.

Oxygen.—Lucerne, from May 19, 1878, to August 4, 1894, 16 years, 2 months, and 15 days. Out of 293 seeds sown, 2 germinated, or 0.68 per cent. The seeds were not thoroughly dry.

Nitrogen.—Lucerne, from April 12, 1878, to August 21, 1894, 16 years, 3 months, and 22 days. Out of 320 seeds, 181 germinated, or 56.56 per cent.

Chlorine and Hydrochloric Acid Gas.—Lucerne, from April 28, 1878, to August 3, 1894, 16 years, 3 months, and 5 days. Out of 342 seeds, 23 germinated, or 6.72 per cent. Originally these seeds had been put into pure chlorine; but the gas had acted on the seeds, carbonising a portion of them, so that at the end of the experiment the seeds were in an atmosphere composed chiefly of hydrochloric acid gas, mixed with carbon dioxide.

In a second experiment with lucerne seed, kept in chlorine, and then hydrochloric acid, during the same period, out of 167 sown, 10 germinated, or 5.98 per cent. In this experiment the tube was carefully opened *in vacuo*, to protect the seeds from the moisture condensed by the hydrochloric acid gas at the moment when it is brought into contact with common air.

Sulphuretted Hydrogen.—From October 14, 1877, to August 5, 1894, 16 years, 9 months, and 22 days. After the opening of the tube, filled with the strongly smelling gas, the seeds were left in contact with the air for 24 hours, before sowing them in the moist sand of the germinator. Out of 101 lucerne seeds, one germinated, or 0.99 per cent. Out of 50 seeds of wheat, none germinated.

Arseniuretted Hydrogen.—From April 4, 1878, to August 4, 1894, 16 years and 4 months. On opening the tube the garlic smell of AsH₃ was strongly evident. Out of 255 lucerne seeds sown, 181 germinated, or 70.98 per cent. In a second experiment with seeds kept in arseniuretted hydrogen, out of 247 lucerne seeds 170 germinated, or 68.82 per cent.

Carbon Monoxide.—From April 3, 1878, to August 4, 1894, or 16 years and 4 months. Out of 266 lucerne seeds, 224 germinated, or 84.2 per cent.

Carbon Dioxide.—From September 8, 1877, to August 5, 1894, or 16 years, 11 months, and 27 days. The same tube contained seeds of lucerne, wheat, vetch, *Cynara*, and coriander. None germinated. Perhaps the large number of seeds contained in a relatively small tube rendered the carbon dioxide damp, and therefore noxious.

Nitric Oxide.—From May 2, 1878, to August 4, 1894, or 16 years, 3 months, and 2 days. On opening the tube, abundant red fumes were produced by contact with air. Before sowing, the seeds were left dry for 24 hours. Some of the seeds were brownish, the rest retained their natural colour. Out of 309 lucerne seeds, 3 germinated, or 0.97 per cent. In a second experiment, the tube containing the lucerne seeds was opened *in vacuo*: out of 320 seeds, 2 germinated, or 0.62 per cent.

(b) *Experiments with Liquids and Solutions.*

I give only the results obtained with alcohol and alcoholic solutions. In other liquids, such as ether and amyl alcohol, the liquids had gradually evaporated, so that the exact period of their action could not be ascertained, and the seeds, covered with a moist oily varnish, had lost all vitality. Lucerne seeds kept in chloroform for 16 years and 4 months, were completely lifeless. In all the recorded experiments the seeds were completely immersed in a relatively large volume of liquid.

Strong Alcohol.—From March 26, 1878, to August 6, 1894, or 16 years, 4 months, and 13 days. The alcohol was originally absolute, but in contact with the seeds, and during so many years must have absorbed a small proportion of water. Before being sown, the lucerne seeds were carefully air-dried on a filter for 12 hours. Out of 60 seeds sown, 40 germinated, or 66·6 per cent.

Concentrated Alcoholic Solution of Corrosive Sublimate.—The alcoholic solution was originally prepared with alcohol nearly absolute, and saturated with mercuric chloride. From May 23, 1878, to August 17, 1894, or 16 years, 2 months, and 25 days. On taking the seed from the mercuric solution, they were very carefully washed with alcohol at 97 per cent. until every trace of the mercuric compound was washed away. The seeds were dried at the ordinary temperature, and then sown. Out of 79 lucerne seeds, 16 germinated, or 20·2 per cent.

Alcoholic Solution of Sulphur Dioxide.—From November 10, 1878, to August 24, 1894, or 15 years, 9 months, and 14 days. Originally the alcohol was of 93 per cent. strength; the solution preserved a suffocating odour of sulphurous acid. The lucerne seeds were mixed with minute sulphur crystals; the seeds were well washed with strong alcohol, dried and sown. Out of 645 lucerne seeds, one alone germinated, or 0·15 per cent.

Alcoholic Solution of Sulphuretted Hydrogen.—From November 10, 1878, to September 4, 1894, or 15 years, 9 months, and 15 days. The alcohol, originally 93 per cent. strength, had been repeatedly saturated with sulphuretted hydrogen gas. The liquid emitted a marked mercaptan smell. Sulphur crystals were formed, and sedimented with the lucerne seeds. The latter were washed with 97 per cent. alcohol, and then air-dried. Out of 583 seeds, 41 germinated, or 7·03 per cent.

Alcoholic Solution of Nitric Oxide.—From November 10, 1878, to September 4, 1894, a period equal to that of the last described experiment. The alcohol, 93 per cent. strength, had been repeatedly saturated with NO. Before sowing, the seeds were washed with alcohol and dried. Out of 288 seeds, 12 germinated, or 4·16 per cent.

Alcoholic Solution of Phenol.—The lucerne seeds preserved in the solution for over 15 years, showed no signs of vitality. In washing the seeds, previous to sowing, with alcohol, they could not be completely purified from the phenol.

Many of the germinating lucerne plants developed from the seeds used in these experiments, were transplanted from the germinator into flower-pots. The plants grew well, and have flowered and seeded normally.

At the beginning of these experiments, in 1877 and 1878, I was not aware of the noxious action of even small proportions of moisture. It is probable that if in all these experiments special care had been taken at the beginning to exclude as much as possible moisture, both from the seeds and from the gases or liquids, a much larger proportion of seeds would have retained their vitality. The difficulty of preserving the vitality of large seeds must be chiefly caused, in all probability, by the difficulty of thoroughly drying them.

These experiments are of interest in showing that seeds may retain their vitality in conditions when all respiratory exchange is completely prevented for a long series of years. They fully confirm the results of the late G. J. Romanes, who proved that seeds may preserve their vitality for 15 months when kept *in vacuo*, or when transferred from the vacuum tubes to other tubes, charged with sundry gases or vapours.¹

My experiments encourage, moreover, the suspicion that latent vitality may last indefinitely when sufficient care is taken to prevent all exchange with the surrounding medium. There is no reason for denying the possibility of the retention of vitality in seeds preserved during many centuries, such as the mummy-wheat, and seeds from Pompei and Herculaneum, provided that these seeds have been preserved from the beginning in conditions unfavourable to chemical change. The original

dryness of the seeds, and their preservation from soil moisture or moist air, must be the very first conditions for a latent secular vitality.

In experimenting with seeds from Pompei and Herculaneum, I have not as yet been able to find among them any living grain. The greater part of these seeds are too much carbonised and changed to permit the entertaining of much hope as to their possible vitality. Especially among the seeds of Pompei, the carbonisation must have been caused by the slow action of moisture, which would speedily destroy all life in the seeds. Among the Pompeian wheat the destruction of organic matter has been so great as to leave in the seed, in its present condition, a proportion of ash as high, in some cases, as 4·2 per cent., and even 8·4 per cent.

On the other hand, some of these seeds, as those found in the granaries of the *Casa dell' Argo*, at Herculaneum, in 1828, seem to have been in conditions favourable to a prolonged preservation of latent vitality; the millet seeds, especially, were found unchanged in outer aspect. Unfortunately, no test was made at the time of their discovery, and since then the action of moist air, and exposure to changes of temperature and to light, must have impaired fatally any remnant of vitality still lurking amongst the seeds.

All researches on latent life are of great interest in ascertaining the nature of living matter. The present researches have established that, for some seeds at least, respiration, or exchange with the surrounding medium, is not necessary for the preservation of germ-life. It is a common notion that life, or capacity for life, is always connected with continuous chemical and physical change. The very existence of living matter is supposed to imply change. There is now reason for believing that living matter may exist, in a completely passive state, without any chemical change whatever, and may therefore maintain its special properties for an indefinite time, as is the case with mineral and all lifeless matter. Chemical change in living matter means active life, the wear and tear of which necessarily leads to death. Latent life, when completely passive, in a chemical sense, ought to be life without death.

It may be finally remarked that the proof of the resistance of seeds to vacuum, of the non-necessity of a respiratory exchange with outer air, together with the proof of the resistance in some seeds to very low temperatures, are facts encouraging the belief that the origin of life on our globe may be due to the introduction of germs that have travelled, embedded in aerolites, from other planets where life is older than upon the earth.

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To Friends and Fellow Workers in Quaternions.

SINCE the publication of Hamilton's "Elements of Quaternions," in which the great mathematician developed his new calculus with admirable skill and clearness, more than thirty years have passed away, without it finding the adequate recognition which it so highly deserves. The circumstance is still the more deplorable as the calculus has since been further developed by Prof. Tait and others.

There is, in truth, no question as to the importance of the use of vectorial quantities in physics, but on account of their apparently preponderating importance, various physicists have been led to invent new forms of vector-theory excluding the idea of quaternions. But, as far as we see, they are founded on definitions which are established by quaternions, and are systems of notation rather than logical developments of a mathematical idea.

On the other hand, many who are prejudiced against the calculus of quaternions maintain the opinion that it is hard to understand, and that it contains a great deal which is useless in addition to things immediately applicable. To the latter charge there need be no answer, since all forms of mathematics are exactly alike in this respect, and since in the very combination of the pure and the applied lies the potentiality of further development. In regard to the former objection, quaternionists need only say that if the objectors approach the calculus of quaternions with proper care and meekness, they will ere long assuredly rejoice in having at their disposal an instrument of research mightier far than they had the slightest notion of so long as they were in the domain of cartesian coordinates. Certainly it would be a blessing to science if they could accept these assertions, and their endeavours would find a

¹ NATURE, December 7, 1893, p. 140.