Now, by the formulas of § 7 (p. 305),

$$\phi = t - p_0 \frac{r^{-2} + r_3^{-2}}{r_0^{-2} - r_3^{-2}},$$

$$\varpi = p - p_0 \frac{r^{-2} - r_3^{-2}}{r_0^{-2} - r_3^{-2}}$$

$$= (p_2 + t) r_2 r^{-1} - t - p_0 \frac{r^{-2} - r_3^{-2}}{r_0^{-2} - r_3^{-2}},$$

where

$$p_2 = p_0 \frac{r_2^{-2} - r_3^{-2}}{r_0^{-2} - r_3^{-2}},$$

so that

$$\varpi = t(r_2 - r)/r - p_0 \frac{r^{-2} - r_2^{-2}}{r_0^{-2} - r_3^{-2}};$$

and the expression for the winding tension, $\theta$, finally reduces to the form—

$$\theta = \mathrm{A} + \frac{\mathrm{L}}{r} + \frac{\mathrm{M}}{r - r_0} + \frac{\mathrm{N}}{r + r_0},$$

where

$$\mathrm{A} = \frac{p_0 r_0^2 (r_3^2 - r_2^2)}{r_2^2 (r_3^2 - r_0^2)} = p_0 \frac{r_2^{-2} - r_3^{-2}}{r_0^{-2} - r_3^{-2}} = p_2,$$

$$\mathrm{L} = -t r_2,$$

$$\mathrm{M} = t(r_2 - r_0) - p_0 r_0 \frac{r_0^{-2} - r_2^{-2}}{r_0^{-2} - r_3^{-2}},$$

$$\mathrm{N} = t(r_2 + r_0) + p_0 r_0 \frac{r_0^{-2} - r_2^{-2}}{r_0^{-2} - r_3^{-2}},$$

after considerable algebraical reduction.

(55) A great simplification is introduced if we put $r_3 = r_2$, equivalent to supposing that the jacket C fits loosely over the coil B, so that the firing stresses do not extend into the jacket C, which, therefore, now contributes nothing to the strength of the gun; and now $\mathrm{A} = 0$, $\mathrm{L} = -tr_2$, $\mathrm{M} = tr_2 - (t + p_0)r_0$, $\mathrm{N} = tr_2 + (t + p_0)r_0$; and we thus obtain the formula (51) of Longridge's "Treatise," or formula (50) of Moch's article.

With the numbers of Fig. 10, we find $\theta_1 = 34$, while obviously we always have $\theta_2 = \phi_2$, as the winding tension of the last layer of wire is the same as the tension in repose.

Having plotted out by points the curve $\theta_1\theta_2$ for the winding tension $\theta$, a curve of the fourth degree, it will be found practically correct enough to replace it by the most approximate straight line; and now in winding the coil, the difference of the tension weights destined for two consecutive layers of wire remains constant.

(56) We have now finished the theory of the wire gun, so far as the circumferential strength is concerned; and for its experimental verification, an interesting article in Note No. 38, on the Construction of Ordnance, "On Winding and Dismantling an Experimental Wire-wound Gun Cylinder," by Lieutenant W. Crozier (Washington, June 1886), may be consulted; and according to recent reports a 10-inch gun has been recently constructed in America by Captain Crozier, on designs based upon his experimental results.

The theory of the longitudinal stresses in the wire gun has not been touched upon, because it is still a point of dispute as to whether the tube alone should provide the longitudinal strength, or whether it should be partly borne by the outside jacket, the wire coil being obviously unable, except in Canet's double coning system, of giving any assistance in this direction.

Mr. Longridge's principle of strengthening a tube with wire, wound with appropriately varying tension, will be found useful in peace and in war: he can claim credit that a gun strengthened on this principle, the 9·2-inch wire gun, was chosen from its great strength to test the extreme range of modern artillery in 1888, with what were called the "Jubilee rounds"; when, with an elevation of about 40°, a range of 21,000 yards, or 12 miles, was attained, the projectile weighing 380 pounds, and the muzzle velocity being about 2360 f.s.

The dimensions in the diagrams have been purposely taken in round numbers, so as not to represent invidiously any particular gun; in some cases, inappropriate stresses have made their appearance; and now it is the art of the gun-designer to modify slightly the dimensions of the parts of his first rough sketch, so as to attain to more uniformity of strength and a better theoretical result.

There is no claim to originality in the theory that has been given above, and we fear that due credit has not always been properly assigned to the right investigator; but the attempt has been made to present the essential points of the theory in as simple a form as possible, with a minimum recourse to algebraical formulas. The subject has been written about so much of late years that the reader is apt to be confused with the variety of notation and treatment; and it is hoped that the graphical method presented here will enable the theorist to present his results to the practical gun-maker in a more intelligible and convincing form.

A. G. GREENHILL.

## *ON PUTREFACTIVE ORGANISMS.*[1]

THE author said his difficulty was to decide in which way to treat his subject. He might summarize the investigations of twenty years, and endeavour to show the original motives which led to their being undertaken, and then contrast this with the new meaning which has been derived from the investigations founded on recent methods and instruments; or, secondly, he might show the results of a series of continuous observations on certain saprophytic organisms placed under increasingly adverse environments, so as to endeavour to discover their behaviour in regard to the great Darwinian law. He inclined to this last as the view of his work that might have the broadest interest to a Society like that he was addressing; but the value of the improvements in recent lenses led him to give the priority to the results so obtained. In the case of larger animals, it was well known that a change of environment produced changes in the organism; but that these changes were hard to follow up, owing to the few generations that come under the notice of the student or observer. But in the case of micro-organisms the generations succeed each other so rapidly that it is easy to follow the changes produced by environment. He could show the effect on certain micro-organisms of a gradual change of temperature, and how in from seven to eight years an organism arose which lived and multiplied at a temperature of 157° F., whose ancestors had lived at a temperature of 65° F., and would have died if exposed to temperatures above 100°. He said there was nothing harder than to carry an audience to a just appreciation of the lower forms of life, but nevertheless he hoped to point out some of the practical results due to the improvements in modern microscopes. If they took a glass of drinking-water and put in it some shreds of fish, or any other organic substance, it soon became turbid and charged with the minutest organisms. To illustrate the number of these organisms, Dr. Dallinger said that visible to the human eye in the heavens there were in all probability with our most powerful modern telescopes 100,000,000 stars; and if they supposed that each of these, like our sun, was attended by eight primary bodies and twenty secondary planets, there would be two thousand eight hundred millions of bodies in space accessible to human research. The same number of these minute organisms to which he had referred would lie in a space equal to one ten-thousandth of a cubic inch. Any such a molecule of even dead matter must arrest the attention of the human mind; but when we remembered that these were complex *vital* forms, they had a significance of a high order, and their inconceivably rapid multiplication would make the mind pause and think. A decomposing mass of matter was a mass of beings endowed with life, and producing definite products. The life of the organism was not even an incidental product, the organisms were there for a purpose. They break up the decomposing organic matter into its elements, and so make it ready again for the purposes of life. Dr. Dallinger went on to describe some of the organisms which he has observed and examined. He said, that if they took some putrescent fluid from different putrefactive material, and mixed them, then put a very minute quantity of sterilized fluid on the microscope slide, and put into this the point of a needle which had been inserted into the mixture of putrefaction, and examined it with a sufficiently powerful microscope, the field of view in the microscope became, as it were, charged with life in an instant. There were many kinds of organisms, and they had many movements. There were rod-shaped organisms, spiral forms, a perfect oval form with two flagella, or whips. Another would be like the calyx of a papilionaceous flower, and have four flagella. Another would have a delicate egg-shape, and another be shaped like a double convex lens, and move with a beautiful wave motion. The fluid speck seen under the microscope was densely peopled. What were these organisms, and what their functions amid the denizens

[1] Abstract of an Address delivered before the Bristol Naturalists' Society, by the Rev. W. H. Dallinger, F.R.S.

of earth? They were extremely small, and the largest of them so small that one hundred millions could be packed within a cube whose side was equal to the diameter of a coarse human hair, and there were from ten to twenty less than this. This group were amenable only to the most powerful microscopes. It was known long ago that they carried on putrefaction; now they knew that the process was a fermentation. Dr. Dallinger then went on to contrast ordinary saccharine fermentation, like that of yeast, producing carbonic acid and alcohol, with the fermentation produced by these saprophytic organisms, and showed that both could be prevented by taking care to keep away any of the germs of the fermentation, that both could be arrested by the action of heat, and that both tended to break up the organic matter into simpler forms. In the case of the saprophytes, water and carbonic acid were produced eventually from the decaying mass on which they dwell, and thus by the vital functions of these organisms the chemical elements in the animal body were restored to nature, to become once more part of the protoplasm of living things. There were, however, two things in which these saprophytic ferments were different from ordinary ferments; in the latter a special organism produces a special product, whereas in the former there was no such definite product, and in the saprophytic ferment the final process was produced, not by one definite organism, but by a series of organisms. He did not think that these ferments destroyed one another; but between the beginning and the end of the putrefaction there was a definite incoming and disappearance of many forms. In from 50° to 60° north latitude, he believed these organisms were limited to ten forms, and of these eight were definitely determined, and their life-history made out. There were some present everywhere, and they acted at once. Dr. Dallinger said the object of his study was biological, and not pathological. Some of the results he discovered some time ago, but the large progress of recent years was due to the great improvements in our instruments. These organisms were all different, no two of them behaved alike. He said that if they added a very small quantity of putrescent fluid to a speck of water on a slide kept at 65° F., it was very easy to find some of these organisms almost directly, using a lens magnifying 1000 diameters; and they would be found to increase with a rapidity that no description could suggest. He then showed on the screen the first kind of organism that appears, and mentioned that when seen in reality, they were in a constant state of movement, and that the saprophytic ferment begins to split up and break down the organic tissues. This first organism, *Bacterium termo*, would produce profound changes in the putrefying tissues, and prepare the way for other organisms. It would be seen that this organism would be densest round the mass that was being broken up, forming a felt-like covering or garment to it; soon a new organism of a spiral form would make its appearance (this was shown on the screen), while *Bacterium termo* would become less abundant, and be diffused over the entire fluid. The new one, like *Bacterium termo*, would be densest next to the putrid matter, and would form a covering to it. The decaying tissue would now rapidly change, and would give off noxious gases. This form would continue for an indefinite time, and be succeeded by one or two new forms. (These were shown on the screen.) One of these new forms would have a single flagellum, and the other would have two; and they would move rapidly about and glide continuously over the decomposing matter. They increased very rapidly, one method of increase being by a process of division. In another method two bodies would unite together, and an amœboid condition ending in the *fusion* of two forms resulting in a sac from whence spore was produced, giving rise to new generations. Their rate of increase was inconceivably rapid, and it was not surprising that the putrid tissue was surrounded by a garment of these organisms. They had in all probability their food and suitable conditions for their life produced by the functions of their predecessors. Then a time came when this form died out, and a very remarkable organism appeared which also invested the putrid matter with a garment of living organisms; they stuck to the mass and waved to and fro. These were shown on the screen as they would be seen in the microscope, clustering round the matter. With this was shown the next organism—a most wonderful one. It has a rigid flagellum armed with a hook and a long trailing flagellum. The animal swims about, and when it comes to a piece of decaying tissue, it often anchors itself by the trailing flagellum, which is coiled into a spiral; then it darts up and down upon the decaying matter. The action of this was shown by a mechanical slide, the up-and-down motion and the coiling and uncoiling of the flagellum being seen. These were succeeded by a group which had a free flagellum without any hook, and which fastens itself down by means of its trailing flagellum, and hammers the decomposing tissue by throwing itself against it. This process was also shown on the screen by means of a mechanical slide. Dr. Dallinger said that this occurred at about the middle of the putrefactive action, the greater part of which is accomplished by this. The mass now gradually broke up. The next kind, which was also shown on the screen, and its process explained by a mechanical slide, has two trailing flagella by which it anchors itself; it then springs up and darts down, and further promotes the decomposition. At the close of this stage there is little left of the original tissue but some water charged with carbonic acid, and a slight deposit of fragments. Dr. Dallinger said that four years ago he found a new organism which acts as a gleaner, and gathers up the fragments of the *débris* left by the others. It is armed with six flagella, and swims about in the liquid, and when it comes within a certain distance of the solid remnants twists its middle flagella together, and springs up and down on the *débris*, removing entirely tiny particles. They move in a most beautifully rhythmic manner up and down. He showed a picture of these on the screen, and also a mechanical slide of a group of three, with their pretty rhythmic action. And thus the organic tissues were broken up into their ultimate elements. Dr. Dallinger mentioned that the last form was comparatively rare, and was more frequent in warm countries. It was clear, he said, that different climates had somewhat different forms. In conclusion, he said that twenty years ago, when in a state of ill-health, he took to this research, and found all these beauties and a thousand times more; and he urged those present to take up some field of microscopical research, and seek for the hidden beauties of Nature. They would find much pleasure in the doing of it. They need not be appalled by the high powers he had used; there were many facts to be found by the help of far lower powers. If they did this they would find that life would have a pleasure it had never known before.

## HIGHLAND PLANTS FROM NEW GUINEA.

AS we have already noted, Baron von Mueller contributes to the Transactions of the Royal Society of Victoria (vol. i., Part 2) some important records of observations on Sir William MacGregor's highland plants from New Guinea. The following are his general conclusions:—

"The memorable expedition, so valiantly and circumspectly carried out by His Excellency Sir William MacGregor, the Governor of British New Guinea, for the ascent and exploration of the Owen Stanley's Ranges, has for the first time brought also the flora of the temperate and the sub-Alpine zone of that great island within the reach of elucidation. In a brief preliminary report, written in July last, attention was drawn to the extraordinary commigration, by which plants of Asiatic, of far southern and even of sub-Antarctic types had mingled together in the Papuan highlands. From the material thus brought together only a commencement could be made to study the vegetation of the higher mountains regarding geographic points of view; in order to obtain a full insight into the Papuan Alpine flora, it would require to explore the hitherto inaccessible more central culminations in the island, where on tiers still some few or perhaps several thousand feet higher in yonder latitudes, according to varied physical conditions, a glacier flora would be more fully reached. To form extensive conclusions on the nature of the Papuan Alpine flora would at present be premature; but from what we have now seen, it promises to be eminently interesting. On this occasion I shall merely group these highland plants on geographic principles, with a hope that it may yet fall to my own share to carry on these comparisons more amply at some future time from fuller material, the total sub-Alpine and Alpine flora of New Guinea in all likelihood comprising several hundred species of vascular plants. Such future researches will be to myself all the more fascinating, as from 1853 to 1855 the whole flora of the Australian Alps became elucidated by field-work of my own, it being utterly unknown before. In these pages is alluded only to those plants, which Sir William MacGregor gathered in altitudes between 8000 and 13,000 feet, therefore in the region above the mountain zone, involved in almost permanent clouds.

"Of the 80 plants, specifically and distinctly recorded in these