violent agitation of the gills by the muscle attached to the stigmatic pit would become useless, supposing an exposure of the gill-lamellæ to the atmosphere became by degrees habitual with the ancestral Arachnidan. In proportion as these hypothetical creatures acquired the habit of aërial respiration—the deepening and arching in of the stigmatic pit would be favoured, and the atrophy and final disappearance of the muscle which was attached to its inner surface, and had mechanically brought it into existence, would also be directly promoted.

A further confirmation of the view now advanced is found in the remarkable Javanese Arachnidan *Thelyphonus*. This Arachnid has not four pairs of lung-sacs like Scorpio, but only two pairs, corresponding to the two foremost lungs of *Scorpio*, and to the second and third gill-book-pairs of *Limulus*. Nevertheless, the four segments of the abdomen posterior to these are each marked by a pair of shallow stigmata placed in line with the orifices of the pulmonary sacs of the two anterior segments. When the internal structure corresponding to these parts is examined, it is found that a large muscle (similar to the similarly placed muscle of *Limulus*) is inserted into each of the four right and four left stigmata in the segments posterior to the pulmonary sacs. The two segments into which the two pairs of pulmonary sacs are sunk, have no such muscles. The pulmonary sacs are, therefore, in this case, also, to all appearance, enlarged muscular stigmata, from which their former muscles have disappeared by disuse and atrophy.

XI. "Effects of Stress on the Thermoelectric Quality of Metals. Part I." By J. A. Ewing, B.Sc., F.R.S.E., Professor of Mechanical Engineering in the University of Tokio, Japan. Communicated by Professor Fleeming Jenkin, F.R.S. Received May 31, 1881.

(Abstract.)

This investigation was undertaken, in the first instance, with the view of finding whether the gradual mechanical change which goes on with lapse of time after stretching wires (which the author described in a former paper, "Proc. Roy. Soc.," vol. 30, p. 510) is associated with a corresponding change in thermoelectric quality. But the experiments brought to light some very unexpected results with regard to the *immediate* effects of stress, and the present communication deals with these only. Part I is further limited to the effects of longitudinal pull on iron. The author is proceeding to extend the same inquiry to other metals and to other modes of stress.

The method consisted in applying load to wires by the weight of a hanging tank containing water, which could be run in and run out at any desired rate, the junction between the stressed and unstressed parts of the wire being kept at 100° C. and 18° C. approximately. The thermoelectric effects were measured by the deflections produced in a short-coil mirror galvanometer, adjusted for great sensibility.

The effect of applying a moderate amount of longitudinal pull to iron wires was found to be negative (that is to say, the position of iron in the thermoelectric series, with the given condition of temperature, was shifted towards antimony). This result was merely a confirmation of the observations of Sir William Thomson ("On the Electrodynamic Qualities of Metals," "Phil. Trans.," 1856). But, instead of increasing up to the breaking point, the effect reached a negative maximum, after which it decreased and sometimes even changed to positive before the wire broke. This result was confirmed by a large number of tests of different wires.

When loading was stopped shortly before the wire broke, and the load was gradually withdrawn, the thermoelectric effect passed back through a negative maximum, different from the first, and, finally, with no load, it reached a positive value as a consequence of the stretching which had taken place. (This positive effect due to previous stretching when the load was withdrawn had been observed before by Magnus and by Thomson.) The fact that the thermoelectric quality passed back through a negative maximum during unloading showed that the maximum which had occurred during loading was not the result of an antagonism between the influences of stress and strain.

A second loading of the same wire gave a series of thermoelectric values greatly different from those got in either of the two former processes of first loading and unloading, and showing another negative maximum long before the new limit of elasticity was reached. When that limit was passed, the subsequent drawing out of the wire was associated with a relatively rapid change in the thermoelectric quality towards positive.

When, after a wire had once been stretched, any given load was gradually applied and removed successively within the new elastic limit, the thermoelectric effects for equal intermediate amounts of stress during loading and during unloading were widely different, but passed through a cyclic series of values for each repetition of the cyclic change of stress. This effect is shown in the paper by curves which give the relation of stress to thermoelectric current. The curves got by putting on load (not exceeding the elastic limit) and by taking it off are far from coincident, but form a closed figure containing a wide area.

This cyclic phenomenon is experimentally studied at length in the paper, and the thermoelectric effects of various cycles of loads are

shown graphically in a number of diagrams. To apply a load, remove part of it, re-apply it, and continue the application, forms a wide but closed, or nearly closed, loop on the "on" curve. Similarly, to remove load, stop during the removal, and replace part, and then go on again with the removal, forms a loop of a like kind on the "off" curve.

The curves got during the gradual removal of load always show a negative maximum, even though the applied load has been less than that required to pass the negative maximum during loading.

The effect of beginning to reload a stretched wire which has been unloaded is at first feebly positive, passes a positive maximum, becomes negative, passes a negative maximum, and finally, if the wire does not break too soon, becomes once more positive before rupture takes place.

The leading characteristics of the cyclic action mentioned above are sufficiently obvious from the diagrams, but can scarcely be described verbally, except at great length. The curves show a lagging of thermoelectric effect when the stress is changed. It is proved that this lagging of effect is not a time action, for it is shown to be independent of the rate of increment and decrement of the stress. Moreover, the thermoelectric value associated with any load (not exceeding the elastic limit), arrived at in any manner, is constant so long as the load is constant.

One very remarkable feature of the curves is that *the first effect of reversal from loading to unloading, or from unloading to loading, is to continue the same kind of thermoelectric change which has been going on just before the reversal takes place.* For example, if the wire had been becoming negative when loading was stopped and unloading began, it continued to change towards negative during the very first part of the subsequent unloading. This law appears to be general.

As a consequence of the cyclic action it follows that there may exist between a stress and its associated thermoelectric effect any relation which can be expressed by a point within the wide area enclosed between the most distant "on" and "off" curves. To attempt, therefore, to assign a relation irrespective of the preceding states and changes of stress would be altogether futile.

Instances are given of "molecular reminiscences" of previous stress-actions, exhibiting themselves by modifying the form of the curves in the next succeeding experiments with the same wire.

It is shown that *mechanical vibration greatly reduces, if it does not wholly destroy, the distinction between the "on" and "off" curves of thermoelectric quality and stress*, if the wire be kept in a state of vibration during the application and removal of the load.

It is also shown that two widely different values of thermoelectric quality, got by reaching the same stress in two different ways (namely by addition of load from zero and by partial removal of load from a high value), become almost equal to each other when the wire is

vibrated, not during, but after, the changes of load through which the given state has been reached.

It is also shown that this approximate equality produced by vibration continues after the vibration ceases. Also, that when a cycle of loads is gone through afterwards, without vibration, the old difference between the "on" and "off" curves reasserts itself.

It is suggested that the cyclic phenomenon so conspicuous in this investigation is not peculiar to the thermoelectric effects of stress, but is probably present in other effects of stress, and may perhaps be found to occur in the changes of any quality of matter which is a function of another variable quality (such as temperature) when the latter quality is subjected to increment and decrement.

Lastly the results of certain independent experiments made by others in other branches of physics are referred to in confirmation of this suggestion.

XII. "On the Reversal of the Lines of Metallic Vapours. No. VIII. (Iron, Titanium, Chromium, and Aluminium.)" By G. D. Liveing, M.A., F.R.S., Professor of Chemistry, and J. Dewar, M.A., F.R.S., Jacksonian Professor, University of Cambridge. Received June 2, 1881.

In our last communication on this subject we observed ("Proc. Roy. Soc.," vol. 29, p. 405) that iron introduced as metal, or as chloride, into the electric arc, in a lime crucible, in the way which had proved successful in the case of many other metals, gave us no reversals. We succeeded, however, in reversing some ten of the brightest lines of iron, mostly in the blue and violet, by passing an iron wire through one of the carbons, so as to keep up a constant supply of iron in the arc. Considering the great number of iron lines, and that so many of them are strongly represented amongst the Fraunhofer lines, it seemed somewhat surprising that it should be difficult to obtain a reversing layer of iron vapour in the arc inclosed as we use it in an intensely heated crucible. A like remark might be made respecting titanium, which is almost as well represented as iron in the Fraunhofer lines, but has heretofore given us no reversals. Almost the same might be said of chromium, except that the number of chromium lines is so much less than that of either of the other two metals.

We have since found that most, if not all, of the strong lines of these three metals may be reversed by proper management of the atmosphere and supply of metal in the crucible. Indeed, with regard to iron we have found that the method employed with other metals was successful so far as the ultra-violet rays were concerned, though it