

Balfour Stewart, and Loewy. Recognizing the sun as the governor of our system and the source of terrestrial heat and light, it appears certain that at least some of the circumstances attending our globe are directly or indirectly the results of solar conditions, of which we can read but too few, and interpret still fewer rightly. In the present instance we see that, as in other curves, a certain rainfall maximum may be *less* than minima not immediately preceding or succeeding; and this alone suggests the desirability of comparison with actual magnitudes of sun-spot areas; but the introduction of this more accurate test would doubtless prove a waste of time, unless the approximate relation at present under view can be maintained.

III. "Studies on Biogenesis." By WILLIAM ROBERTS, M.D., Manchester. Communicated by HENRY E. ROSCOE, F.R.S.
Received March 3, 1874.

(Abstract.)

The object of the investigation is to inquire into the mode of origin of *Bacteria* and toruloid vegetations. The inquiry is divided into three sections.

SECTION I. *On the sterilization by heat of organic liquids and mixtures.*—When beef-tea or a decoction of turnip is boiled for a few minutes and afterwards preserved from extraneous contamination, it passes into a state of "permanent sterility."

This state is characterized by loss of power to *originate* organisms with conservation of the power of *nourishing and promoting the growth* of organisms.

All organic liquids and mixtures seem capable of being brought to this state by exposure to the heat of 212° F.; but the length of time during which exposure to this heat is necessary to induce sterilization varies greatly according to the nature of the materials. Ordinary infusions and decoctions were sterilized by boiling for five or ten minutes; but milk, chopped green vegetables in water, pieces of boiled egg in water, and other mixtures were not sterilized unless the heat was continued for twenty to forty minutes. Hay-infusion was sterilized, like other infusions, by boiling for a few minutes; but when the infusion was rendered alkaline with ammonia or liquor potassæ, it was not sterilized except after an exposure to the heat of boiling water for more than an hour. Sometimes it germinated after two hours, and once after three hours of such exposure.

There appeared to be two factors of equal importance in the induction of sterilization—namely, the *degree* of heat and the *duration* of its application. These two factors appeared to be mutually compensatory in such fashion that a longer exposure to a lower temperature was equivalent to

a shorter exposure to a higher temperature. For example, speaking roughly, an exposure for an hour to a heat of 212° F. appeared to be equivalent to an exposure for fifteen minutes to a heat of 228° F.

SECTION II. *On the capability of the normal tissues and juices to generate Bacteria and Torulæ without extraneous infection.*—The following substances were examined :—egg-albumen, blood, urine, blister-serum, milk, grape, orange- and tomato-juice, turnip and potato. These substances were conveyed into previously prepared sterilized bulbs and tubes, which were hermetically sealed at one end and plugged with cotton-wool at the other end. When the several steps of the experiment were quickly and dexterously performed, the risks of extraneous contamination, although not altogether avoided, were reduced to small proportions. The bulbs and tubes thus charged were afterwards maintained at a temperature ranging from 60° to 90° F., and were finally examined at periods varying from four to ten weeks. Out of 90 experiments performed in this way, 67 preparations remained barren and 23 became fertile. When the ideal conditions of the experiment could be carried out in approximative perfection, as with urine, blister-serum, orange-, grape-, and tomato-juice (34 experiments), the preparations, all save one, remained barren; but when the risks of extraneous infection were (from the mechanical difficulties) obviously greater, as with blood, milk, turnip, and potato, the proportion of fertile preparations was considerable, though even with these (except in the case of milk) the barren preparations were in a large majority.

The experiments seemed clearly to lead to the conclusion that the normal tissues of plants and animals were incapable of breeding *Bacteria* and *Torulæ* except under the stimulus of extraneous infection.

SECTION III. *On the bearing of the facts adduced in the preceding sections on the origin of Bacteria and Torulæ, and on the real explanation of some of the alleged cases of Abiogenesis.*—Seeing that organic liquids and mixtures sterilized by heat, and the normal juices and tissues, continued permanently barren under the most favourable conditions of air, moisture, warmth, and light, so long as they were preserved from extraneous contamination, and seeing that the admission of ordinary air or water into contact with them was invariably followed by germination, it was impossible to avoid the conclusion that ordinary air and water contain, in addition to their proper elements, multitudes of particles capable of provoking germination. The exact nature of these particles may be a matter of dispute, but the reality of their existence is not doubtful; nor is it doubtful that the ordinary and common development of *Bacteria* and *Torulæ* is directly due to their agency.

The greatest difficulty hitherto encountered to the general acceptance of the panspermic theory has been the appearance of *Bacteria* (without the possibility of fresh infection) in certain liquids which have been exposed for a considerable time to a boiling heat. Only two explanations

of this fact seem possible—either germs preexisting in them have survived the heat, or the organisms have arisen in them abiogenically. These alternatives were subjected to two series of test experiments. In the first series it was proved directly that there exist in ordinary air and water particles which preserve their germinal activity after being boiled for five minutes in previously sterilized liquids. The second series of experiments showed that, in the extraordinary increase of resistance to sterilization by heat exhibited by alkalized hay-infusion, the action of the alkali is to heighten the surviving power of preexisting germs, and not to exalt the abiogenic aptitude of the infusion itself.

The issue of the whole inquiry has been to fully confirm the main propositions of the panspermic theory, and to establish the conclusion that *Bacteria* and *Torulæ*, when they do not proceed from visible parents like themselves, originate from invisible germs floating in the surrounding aërial and aqueous media.

Nevertheless the author is unable to withstand the impression that this general and common mode of origin is possibly supplemented, under rare conditions, by another and an abiogenic mode of origin. The facts on which this impression rests are comparatively few. They consist in certain instances of greatly retarded germination of *Bacteria* in liquids which had been exposed to a boiling heat, and in two very remarkable instances of the growth of fungoid vegetations (not identical with those usually developed after air infection) in plugged bulbs which had been boiled in a can of water.

If it should be hereafter established that *Bacteria* and fungoid vegetations do, under exceptional circumstances, arise abiogenically, this would not overturn the panspermic theory, it would merely limit the universality of its application.

April 23, 1874.

JOSEPH DALTON HOOKER, C.B., President, in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

The following Papers were read :—

- I. “On some Points connected with the Circulation of the Blood, arrived at from a study of the Sphygmograph-Trace.”
By A. H. GARROD, B.A., Fellow of St. John’s College, Cambridge; Prosector to the Zoological Society. Communicated by Prof. A. B. GARROD, M.D., F.R.S. Received March 12, 1874.

(Abstract.)

The author commences by giving a table containing a fresh series of