Physiology.—As in the case of other plants, we are here concerned with the functions of the Schizomycetes and their relations to the environment ; for convenience, the subject may be treated under various headings. Limitation of space prevents our doing more than touch lightly upon such matters as the action of the Schizomycetes as ferments, and their relations to disease, though both subjects belong strictly to the physiology of their nutrition and actions on the environment.

*Nutrition.—*Having no chlorophyll, the Schizomycetes of course depend on other organisms for their carbonaceous food, and are either saprophytes—*i.e.,* live on the remains of dead organisms— or parasites—*i.e.,* obtain their food direct from living organisms. Pasteur, Nägeli, and others have shown that these organisms can derive their carbon from very numerous and widely different organic substances, *e.g.,* sugars of all kinds, mannite, glycerine, tartaric and other vegetable acids, &c., and even from ethylalcohol, benzoic, salicylic, and carbolic acids to some extent. Carbonic, formic, and oxalic acids, cyanogen, urea, and oxamide are, however, useless for this purpose. The nitrogen and carbon together may be obtained from leucin, asparagin, methylamine, &c., or the nitrogen alone from these or urea, and compounds of ammonia with vegetable acids or phosphorus. The best nutritive substances are proteids (peptones) and sugars (glucoses) ; others must be passed over here. The nature of the particular Schizo­mycete has to be studied as well as the solution, and external agents affect the matter also. Certain minerals are of course necessary,—sulphur, phosphorus, potassium (or rubidium or cæsium), and calcium (or magnesium, barium, or strontium) being indispensable. As one of many suitable nutritive solutions we may select the following :—

Di-potassium phosphate 0·20 gramm.

Magnesium sulphate 0·04 ,,

Calcium chloride 0·02 „

Peptone 1·00 ,,

Water 100·00 ,,

For other solutions, particulars as to changes of concentration, &c., and the peculiarities of different Schizomycetes in this connexion, special works must be consulted.

The chief sources of error in cultures of these very minute forms are the introduction of spores, &c., from without into the vessels, and on the instruments, &c., and the difficulty of continuously observing a developing individual with the necessary high powers. Numerous errors have arisen from inferences being employed to fill up gaps in life-histories which have only been partly observed. The first object of the cultivator, then, is to guarantee the purity of his materials, instruments, &c., and then to keep one form (or even a single specimen) under observation for a sufficiently long period and under suitable conditions. The practical difficulties are enormous, of course, and are very rarely entirely overcome for periods at all long. Here again we must refer to the special works for details as to the beautiful and refined methods now devised or employed by De Bary, Cohn, Koch, Brefeld, Lister, Nägeli, and others, calling special attention to the gelatine method devised by Vittadini and Brefeld and so successfully used and improved by Koch. Thoroughly conducted cultivations should decide in what medium the Schizomycete flourishes best, and how it behaves in others,—what vegetative forms it presents normally, and how changes in the environment affect these. They should also decide the characters of the aggregates or colonics ; at what temperatures germination, growth, division, spore-formation, &c., take place or cease, and so on ; the necessity or otherwise of free oxygen ; the effects of the organism on its substratum or medium—whether it cause fermentation, or putrefaction, or excrete soluble ferments, and so on. Moreover, the products of these actions should be examined in detail. Where the particular Schizomycete is a parasite (wholly or partially) the methods of culture are even more refined. Here the fluids or tissues of the host must be regarded as a soil in which (by means of “infection,” “inoculation,” &c.) the observer sows the spores or vegetative cells of the parasitic organism. It is impossible to go more into details in the limits of this article, however, and we must dismiss the subject with the remark that, having regard to the complexity of the medium *(e.g.,* blood) and the organization of the host, the difficulties of manipula­tion become greater than ever.

*Temperature.—*As with other plants, so with the Schizomycetes, their various functions, *e.g.,* germination, growth, division, forma­tion of spores, &c., can only be carried on at certain temperatures : the best average temperature is about 35° C., but the optimum may differ for each species and for each function. The same is generally true for the minimum and maximum temperatures, which have to bo determined separately also. Remarkable phenomena are con­nected with the death-points of certain *Bacilli,* &c. The spores of some of these forms have been frozen for days or weeks without injury, and some are said to have resisted temperatures as low as —100° C., or even lower: it appears to be all but impossible to kill such spores by cold. High temperatures are more fatal ; but the

spores of *Bacilli* have germinated after the fluid containing them was boiled for an hour, and even a temperature of 110° C. and higher has been withstood. The vegetative states are less re­sistent ; nevertheless the bacilli of anthrax were not killed by heating the fluid to 75-80° for an hour or more. Speaking generally, ripe spores are most resistent and germinating ones least so ; dry cells or spores resist extreme temperatures better than normally saturated ones. Of course time is an important factor ; and other conditions also affect the matter, *e.g.,* slightly acid media are more fatal than neutral or feebly alkaline ones, denser less so than thin ones *(caeteris paribus),* and so on.

To illustrate the importance of these facts we may note Tyn­dall’s method of “discontinuous heating”: by boiling the solu­tions containing the spores for 5-10 minutes daily all the life was destroyed in two or three days, though an exposure of an hour or more to a temperature of 100° C. did not kill the spores if not repeated. The explanation is that the spores which resist the first or second short boiling have time to begin germinating in the interval, and they then succumb at once when the liquid is again boiled. @@1

*Light, Electricity, Gravitation,* &c.—The relations between these and the functions of Schizomycetes have been partly investigated, but the results must be passed over here. A few of the higher genera show polarity—or at any rate difference between base and apex. @@ 2

*Effects of Chemical Agents. —Oxygen. —*Pasteur showed that, while some Schizomycetes require free oxygen like other plants, there are some which need none, or at most very little—the extreme case is perhaps still doubtful ; but “ anaerobiotic ” forms like *Bacillus butyricus* stand in sharp contrast to such exquisitely “ aerobiotic ” ones as *Bacterium aceti, Bacillus subtilis,* &c. A few are known to flourish best—or at any rate they are more active—when supplied with oxygen in proportion less than that in the atmosphere. Engelmann showed that, while some species congregated close to a bubble of air, others collected at a certain distance from it, and came nearer when the bubble contained less oxygen. The same is true for the same species when brought near an *Alga* which is evolving oxygen—the aerobiotic forms collect where the oxygen is being evolved (in the yellow-red, &c., of the spectrum). Some Schizomycetes are powerful deoxidizing and reducing agents : it has already been stated that *Beggiatoa* deposits pure sulphur in its filaments. *Bacterium aceti* and others, on the contrary, transfer oxygen in large quantities to the medium in which they live, and the carbon in that may be entirely consumed. Fermentation once started may go on without free oxygen or not (according to the particular Schizomycete, &c. ), but it is necessary at the commence­ment. Oxygen is of course necessary for the respiration of the growing Schizomycete. @@3

Water is absolutely necessary for the life and growth of the Schizomycetes, but the spores (and to a less extent the vegetative cells) of some can resist desiccation for long periods ; others (*e.g*., *Bacterium zopfii)* soon die. Those of *Bacillus subtilis* have been kept air-dry for years ; and those of *B. anthracis* were not killed after several weeks in absolute alcohol. A year in water failed to kill the spores of *B. subtilis.* Zooglœa and vegetative cells of some resist drying for some time—how long is uncertain. In the dry state spores and cells are disseminated by currents of air : how far spores may be buried and still retain life (carried down by rain, &c.) is uncertain. The importance of these facts, however, is obvious. @@4

*Acids, Poisons,* &c.—The reader must be referred to the literature for details as to the quantities of acids and other products of their own decomposition which can be endured by given Schizomycetes (see especially the literature on fermentation and cultivation, and also respecting the action of poisons, antiseptics, &c.). @@5

*Attraction towards Proteid Food-Substances.—*Bacteria have long been known to swarm around pieces of organic food-materials, but although Ehrenberg and Cohn noticed the fact it was not investi­gated in detail until quite recently. Pfeffer finds that *Bacteria* and *Spirilla* are attracted in a definite manner towards minute tubes containing extract of meat or solution of asparagin, just as he finds antherozoids and zoospores of various kinds attracted by definite substances into tubes designed to imitate archegonia. For Pfeifer’s proofs that the substances mentioned exert a specific

@@@1 See Cohn, *Βeitr. zur Biol. d. Pfl.,* i. Hft. 2, 1872, 11. Hft. 2, 1876 ; Eidam, *Beitr. zur Biol.,* i. Hft. 3, 1875 : Brefeld, *Unters, über Schimmelpilze,* iv. ; Tyndall, *floating Matter of the Air,* 1881; Roberts, *Phil. Trans.,* 1874; Pasteur, *Ann. de Chimie,* 1862.

@@@2 See Engelmann, *Unters, aus d. Physiol. Lab. zu Utrecht,* 1882 ; Cohn and Mendelssohn in *Beitr. zur Biol. d. Pfl.,* iii. Hft. 1, 1879 ; Pfeffer, *Pflanzen· physiologie,* ii. p. 156, 1881.

@@@3 See Pasteur, *Comptes Rendus,* 1861-62 ; Nägeli, *Theorie der Gähring ,* 1879 ; Schützenberger, *Fermentation,* 1876; Engelmann, *Bot. Zeitung,* 1881 and 1882; Pfeffer, *Pflanzenphysiologie,* 1881.

@@@4 See Pasteur, *Comptes Rendus,* 1883; Kurth, “Bacterium zopfli,” in *Bot. Zeitung,* 1883; Brefeld, *Schimmelpilze,* iv. ; see also the literature on distribu­tion and occurrence of Schizomycetes.

@@@5 See Woodhead and Hare, *Pathological Mycology,* i., 1885. Further literature is there quoted.