land 57¾, Italy 10½, Russia 4⅓, Sweden 46⅓, Switzerland 82½, the United States 11½. In this list Switzerland is highest, with 82½ scientists per million of population. Holland is second; Germany third; the United States is eighth, with only two of the ten countries below her. In proportion to the population, Switzerland had over seven times more scientists than the United States, Holland had five times more, Germany over four times more, and Sweden four times more. This statistical study gives forceful answer to the question regarding the need of organizations like the Sigma Xi, 38 years ago, in the United States.

Florian Cajori

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ENLARGED PARATHYROIDS IN RACHITIC CHICKENS

In truly rachitic chickens, enlargement of the parathyroid glands occurs with remarkable constancy. Similar enlargement of the parathyroids of rachitic mammals—particularly rats and the human—has been reported by several investigators, such as Erdheim, Ritter and Pappenheimer and Minor.

This enlargement of the parathyroids in rachitic chickens is a very useful means for differentiating between rickets and various other morbid conditions that occur in birds used in nutrition investigations. For instance, in the pathologic condition commonly known as "legweakness," it frequently becomes necessary to differentiate between rickets and some other condition that may give rise to leg symptoms in chickens.

The ease with which the chickens' parathyroids may be found and their remarkable responsiveness to the rachitic process make them a valuable criterion for judging the presence or absence of rickets.

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FALL OF A METEORITE IN BRITISH COLUMBIA

A meteorite was heard and seen to fall, and the incandescent pieces were seen to splash from the top of the mountain on the north side of the water supply creek of Manitou cannery, on the west side of Dean channel, British Columbia, between nine and eleven o'clock in the evening of August 3. This place is about opposite the mouth of Dean River. It was both heard and seen by Mrs. Harlan I. Smith, of Ottawa, Ontario, Mr. Milo Fougner, of Bella Coola, B. C., Mr. Andrew Widsten, Dominion Fishery Patrol officer, of Bella Coola, B. C., and Mrs. Humphrey, wife of the cannery caretaker. Mr. Smith and Mr. Humphrey heard but did not see it. Some passengers on the steamship *Camosun,* of the Union Steamship Line of Vancouver, then at the cannery wharf, also possibly saw or heard this meteorite. The sound was heard almost simultaneously with the sight.

Harlan I. Smith

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SPECIAL ARTICLES

ON THE UPPER CRITICAL CONCENTRATION OF OXYGEN IN ROOT GROWTH

The writer has shown that in event of a deficiency of oxygen in the atmosphere of the soil the rate of root growth varies inversely with change of temperature[1] and that the "minimum" oxygen supply is not a fixed supply but that it also varies, but directly, with temperature change.[2] Such concentration has been termed the lower critical concentration.[3] The lower critical concentration of oxygen is thus the least concentration at which growth will take place at any temperature.

In considering the relation of root growth to available oxygen it will be apparent that there are four cardinal concentrations. Of these, one, the lower critical, has already been defined. Another concentration is that at which growth is "normal." This is termed the upper critical concentration. Between the lower and the upper critical concentration exists an oxygen deficiency, as will be seen. But above the upper critical concentration an increase in the amount of oxygen does not apparently induce change in the growth rate until a certain and possibly high concentration is reached, when the rate may fall. And, finally, the concentration may apparently be so great as to bring about entire cessation of growth. Such would be the maximum concentration. Of the upper optimal concentration, the range of the optimal or of the maximal concentration or the range of the supraoptimal, this note has nothing to do. Attention, however, should be called to certain apparent characteristics of the upper critical concentration of oxygen in root growth.

The upper critical concentration of oxygen, as above defined, is such partial pressure as will just permit a "normal" rate of root growth at any given temperature. For the reason that the oxygen requirement of roots varies with temperature changes, the actual concentration for the upper critical is greatest at the highest temperatures and least at the lowest temperatures. A test of what the upper critical con-

[1] "The influence of the temperature of the soil on the relation of roots to oxygen," W. A. Cannon, Science, n.s., 58: 331, 1923.

[2] "A note on the relation of root growth in the soil to the oxygen supply: The growth ratio," W. A. Cannon, *Ecology*, 5: 319, 1924.

[3] In a study on roots and aeration, unpublished.

centration may be is had by maintaining the temperature and other environmental conditions as constant as possible, while at the same time the amount of oxygen is varied. If, upon increasing the concentration, the rate of growth is increased, the partial pressure tested was less than the upper critical; but, on the other hand, if the rate remains unaffected, the concentration either is that of the upper critical or above. By varying the oxygen partial pressure in such fashion a point will at length be found at which a decrease in the oxygen supply will decrease the rate, but an increase will not accelerate growth. Such concentration will be the upper critical. Whether, in practice, the actual upper critical can be closely determined, can, perhaps, be questioned. However, this is not especially important; one or two per cent. either way, in face of so great partial pressure, does not affect the matter greatly. The point to be made is that the upper critical concentration is a cardinal concentration of oxygen for growth of the root and is related to the temperature. Like the lower critical, the partial pressure of oxygen necessary to effect a certain rate of root growth, other factors being constant and equal, varies, as suggested, with the temperature.

Little is now known relative to the range of the upper critical concentration of oxygen for root growth, either as to its possible range with temperature changes, or as regards different species. Work touching the general subject is now in progress. Enough has been done, however, to give an idea of both of these features for two or three species. And some of these results can be mentioned in the present note.

It has been found that in such species as Pisum and Zea, under "normal" conditions of soil aeration, an added amount of oxygen, such as would be had by passing atmospheric air through the soil, may increase the rate of growth. This, however, apparently occurs only at high temperatures of the soil. Be this as it may, it has been determined experimentally, in a tentative way, that under the conditions of the experiment, and with relatively low air temperatures, a soil atmosphere containing 10 per cent. oxygen induces about normal growth of the root at a soil temperature of 30° C. At soil temperatures 10 degrees, or so, below, however, a rate normal for the temperature will go on in about 4 per cent. oxygen, the air temperature remaining about as before. The range of the upper critical concentration of oxygen in root growth is therefore approximately 6 per cent. in Zea. Apparently about the same range of the upper critical concentration is to be had in the cotton, which also requires a good oxygen supply for root growth.

The upper critical concentration in such species as are relatively tolerant to oxygen deprivation, however, such as the orange and willow, is apparently of another order than that for Zea. Although the matter has not been sufficiently investigated so as to speak with surety, it appears possible that normal growth of the root will take place in the orange at 27° C. soil temperature when about 1.2 per cent. oxygen is present in the atmosphere of the soil, but apparently more than this amount is required in the willow to bring about a normal growth rate of the root at 30° C. In both species relatively active growth at low temperature of the soil will take place in about .5 per cent. oxygen. In such species, therefore, the range of the upper critical concentration as associated with temperature change, is relatively small. And as the upper critical concentration is not large and the lower critical concentration is small the range of oxygen deficiency in such species as orange and willow is likewise small. In either it may not exceed 1.5 per cent. Very possibly the lower critical concentration for the high temperatures, in such species, is about the same as the upper critical concentration for low temperatures. This will be seen to be very different from the condition which obtains in Zea and Pisum, in which the difference is relatively great, as indicated above.

It has been known for some time that different species may have unlike relations to oxygen, but such possible differences have been based on observations of the least amount of oxygen consistent with root growth. Temperature has not been taken into account until recently. When comparisons have been made to the known oxygen content of the soil it has been difficult to associate such findings with those from the experiments for the reason that the soil usually contains more oxygen than would be called for in the lower critical concentration. Hence an ecological application has not been clear. However, there is now known to be a relation between the amount of oxygen held in solution and the partial pressure required for the lower critical, in all species, and for the upper critical concentration in such as occur in substrata which are saturated with water. From what has been said above relative to normal rate of root growth and the oxygen supply, it appears possible that the ecological application must be sought rather in the oxygen requirement of the root for a normal rate of growth for any temperature. But in referring to the temperature as a limiting factor it is also recognized that other factors, especially those associated with the shoot, may also be associated factors, possibly of as great importance as temperature, but not likely. However, nothing is known as to this, and the striking relation remains between the supposed oxygen content of most soils and the known oxygen content necessary to produce normal growth at any temperature in a few species. There remains one difficulty, however, which should be bridged. No direct work correlating the results of field studies on oxygen content and those in the laboratory on oxygen requirement have been carried out, although it will have been seen from what has been suggested above that such would be required before the ecological application of physiological findings is possible. In other words, we are now beginning to learn that plants require different and determinable amounts of oxygen for root growth, but we are as far as ever from making use of this knowledge either in the field or in cultural practices.

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THE SEED-CORN MAGGOT AND POTATO BLACKLEG[1]

ON account of the lack of evidence to the contrary plant pathologists in general have assumed that "infected seed tubers are the sole source of infection and distribution" of potato blackleg.[2] Since all experiments have indicated that the pathogene does not hibernate in the soil,[3] it has been assumed also that the pathogene hibernates only in partly decayed tubers. The writer has obtained evidence recently which shows that the seed-corn maggot, *Phorbia fusciceps* Zett., is a common agent of dissemination as well as inoculation of potato blackleg in Minnesota. Preliminary experiments indicate also that the pathogene may be biologically transmitted by the insect, thus providing another important means of hibernation.

Eggs of the insect are deposited on the seed pieces before planting. It has been demonstrated that the eggs may be contaminated with pathogenic bacteria when deposited. The larvae have been found in a very large percentage of seed pieces under diseased plants and have never been observed in the seed pieces of plants not affected with blackleg. The larvae leave the decayed seed pieces and enter the soil to pupate before or shortly after the symptoms of the disease first appear on the shoots. This probably explains why they have not been observed more frequently.

The larvae of the insect act as agents of inoculation by burrowing into the seed piece, introducing the bacteria and at the same time aiding the development of the disease by inhibiting the normal tendency of the seed piece to cork off the decay. In experiments extending over three years, more than five hundred seed pieces, partly decayed by *Bacillus phytophthorus* Appel, have been planted in both wet and dry soils. Every seed piece, with the exception of a few that decayed completely before sprouts could develop, successfully warded off the decay and produced a healthy plant. The seed tubers were handled so that no flies could have gained access before planting and no larvae were found in the seed pieces. On the other hand, when nine sound seed pieces, each bearing one or more eggs, were planted, two cases of blackleg developed. Larvae were found in the seed pieces of these two plants but not in the remaining seven. Most of the eggs used were of unknown age and therefore of doubtful viability. If all the eggs had been freshly deposited, in all probability a larger number of diseased plants would have been obtained.

Phorbia fusciceps is known by entomologists to be parasitic on a large number of crop plants. It has been reported as attacking beans, corn, peas, turnips, cabbage, radish, onion, beets, tomatoes and "seed potatoes." It is widely distributed throughout the United States. In descriptions of the injury done by the insect, invariably mention is made of the decay which follows it. Its life history and means of hibernation are imperfectly known.[4]

These discoveries have a very important bearing on the application of control measures for potato blackleg. In numerous cases investigated by the writer in which high percentages of blackleg had developed in spite of seed disinfection, almost invariably the tubers had been disinfected several days before planting and had been left exposed. The usual seed treatment methods would kill any eggs on the tubers at the time, and as larvae were found in the seed pieces of diseased plants, eggs must have been deposited after treatment and without doubt were the source of infection. Where seed tubers have been disinfected and planted *immediately*, very little blackleg has been observed. If seed disinfection is to control blackleg, it appears that the treated tubers must be planted immediately after treatment or else stored in a place inaccessible to flies.

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1 Published with the approval of the director as Paper No. 495 of the Journal Series of the Minnesota Agricultural Experiment Station.

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