RELATION BETWEEN TEMPERATURE GROWTH RANGE AND SIZE IN THE GENUS BACILLUS

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In the course of a three-year study of 105 cultures of aerobic, non-thermophilic, spore-forming bacteria, a growth-range-temperature cell-size relation was incidentally noted, and on two separate occasions at a one-year interval, the rather definite consistency of this concomitancy was observed.

Body size of the organisms was always measured in gentian-violet-stained dry preparations with an ocular filar micrometer.

The author was impressed with one fact, which seems of ecological significance: Those cultures having lower minimum and maximum growth temperatures are as a rule larger in cell size than those having higher minimum and maximum growth temperatures. A corollary is that those cultures isolated from material incubated at 45°C. and 50°C. are usually members of smaller sized species than those isolated from materials kept at room temperature.

In this connection it is interesting to note that many cytological investigations of the nuclear phenomena of bacteria have used spore-forming species isolated from cold-blooded animals such as earthworms, insects, frogs, fish and shellfish. The species isolated are large-celled organisms.

Table 1 summarizes data collected for those cultures to which species names have been assigned at the time of writing. Thirty-four other cultures included in the study show the same tendency. Those that resemble the *Bacillus megatherium* or *Bacillus mycoides* groups have lower optimum and maximum growth temperatures and show larger sizes than others having higher temperature limits of growth.

Unfortunately data in the literature that can be analyzed in this respect are almost non-existent. Measurement of cell size involves so many variables that comparisons only within the work of a single author can be made, rather than the more desirable ones involving the work of several authors.

TABLE 1

Temperature growth ranges and cell sizes of some members of the genus Bacillus

SPECIES	NUMBER OF CULTURES	TEMPERATURE		CELL SIZE		
		Minimum	Maximum	Width	Length	Median
		°C.	°C.			
Bacillus subtilis	16	15	55–60	0.47–0.83μ	1.77–2.77μ	0.62 x 2.27μ
Bacillus vulgatus	3	10–15	55–60	0.46–0.66μ	2.16–2.50μ	0.56 x 2.33μ
	9	10–15	50–55	0.46–0.98μ	1.69–3.95μ	0.68 x 2.80μ
Bacillus mesentericus	2	10–15	55–60	0.62μ	2.00–3.08μ	0.62 x 2.40μ
	5	10–15	50–55	0.58–1.00μ	1.52–3.08μ	0.70 x 2.40μ
Bacillus agri	5	15–20	50–60	0.46–0.58μ	2.62–3.32μ	0.53 x 2.45μ
Bacillus cereus	20	10–15	40–50	0.70–1.41μ	3.15–5.85μ	1.00 x 3.60μ
	11	5–10	40–50			

TABLE 2

	FORD'S GROUPS ARRANGED ACCORDING TO:	
	Size	Decreasing minimum and maximum growth temperatures
Group I. *Subtilis*	0.375μ by 1.5 to 2.5μ	Group I
Group II. *Mesentericus*	0.5μ by 1 to 1.125μ	Group II
Group IV. *Mycoides*	0.5μ by 3 to 6μ	Group V Group VI
Group V. *Cereus*	0.75μ by 2.25 to 4μ	Group IV
Group VI. *Megatherium*	0.75μ to 1.25μ by 3 to 9μ	

Ford and associates (1916), working with over 1700 cultures isolated from air, milk, water and soil, differentiated nine groups of species in the genus *Bacillus*. However, they included no data on temperature relations. If it is permissible to use the

data here reported regarding temperature limits of growth together with their data recording size, we can arrange five groups. The results obtained follow in table 2.

It is of course realized that the data presented are meagre. But the conclusion has justification from theoretical considerations. Adolph (1931) states that "adult body size is the quotient of assimilation rate and fission rate. A smaller size obviously means that fission rate increased relatively more than assimilation rate. The consequences to the population, expressed as rates of growth at various temperatures, may thus be calculated from the mean sizes and fission rates which have been measured.... In this particular clone of *Colpoda* it follows from the measurements of fission rate and of adult size that assimilation rate per individual is very little increased by temperature compared with fission rate. A change of ten degrees in temperature multiplies the assimilation rate 1.2 times and the fission rate 2.3 times." He continues, "Since mechanisms of assimilation differ among diverse types of unicellular organisms, some species may yet be found in which size increases with temperature." Apparently the genus *Bacillus* is not composed of such species. In the author's experience *Bacillus mycoides, Bacillus megatherium* and *Bacillus cereus* have slower fission rates than *Bacillus subtilis, Bacillus vulgatus* and *Bacillus mesentericus.*

Zoologists have recognized for some time Bergmann's rule which states that body size of races of species is in part a function of temperature. Races living in cooler climates are larger in body size than those races of the same species living in warmer zones. This rule has been found applicable not only to mammals and birds, with which it originally dealt, but also among some invertebrates.

It is obvious that the conclusion presented in this paper can stand much investigation. It is hoped that calling attention to what may be an ecological fact will stimulate bacteriologists to turn their attention to the problem. Time, observation and experiment will prove the worth of the present contention, and show whether or not it is a phenomenon general to all genera or limited merely to the genus *Bacillus.*

CONCLUSION

The large-celled species of the genus *Bacillus* have lower minimum and maximum temperatures of growth than do small-celled species.

REFERENCES

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