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This Week's Citation Classic

Zeuthen E. Oxygen uptake as related to body size in organisms.
Quart. Rev. Biol. **28**:1-12, 1953.
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Relations between body size and energy metabolism from bacteria to large poikilotherms and homoiotherms are plotted and discussed. [The *SCI*® indicates that this paper has been cited over 210 times since 1961.]

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"I received my degree in comparative physiology with August Krogh in 1939 and went to work with Kai Linderstrom-Lang and Heinz Holter on the development of the Cartesian diver. At the time, Ragnar Sparck and Gunnar Thorson debated from no data if the rate *of* oxygen uptake per unit of mass decreased to 1/100, 1/10, or not at all, when veliger larvae of marine snails and bivalves settle on the bottom. I was asked to supply the data and be King Solomon. I found no significant change in respiration intensity (O_2/body N) when the veligers settle. Unexciting.

"Interestingly, my data fell 5-10 times below natural extrapolations into the range of small zooplankton of established relations between the logarithms of oxygen uptake and body size in invertebrates. This observation triggered me into extensive studies of the relations between oxygen uptake and body size in animals from the sea with emphasis on the microscopic ones.

"In the cited review I collected my data[1] and those of others and plotted the log oxygen against log body size. The data from bacteria through protozoa, to small and large poikilotherms form a continuous band less than one decade (power of ten) broad, 14 decades on the ordinate (oxygen uptake) and 18 decades on the abscissa (weight), indicating 10_4 X rate decrease with size. With approximation, the surface law is valid for the first and third set of 6 weight decades. Over the middle set the oxygen uptake varies more nearly with body weight than with body surface.

"Basic laws of thermodynamics state that metabolic rate must decrease with body size. This counteracted evolution of size in organisms. Cells could not grow larger than present ones and produce sufficient energy. When cells stuck together *to* form the metazoa, increase in size from that of a cell to that *of* a 10^5 X larger metazoan did not result in much decrease in metabolic rate. The surface law was circumvented in this size range and small animals developed elevated rates of heat production per unit of surface. The latter was of no consequence for poikilothermic life but of highest significance for the development of ho-, moiotherms. These organisms reverted to the surface law at larger size than the poikilotherms and met evolutionary requirements for heat preservation and temperature regulation. I believe this review is much cited because few attempted to repeat my experiments, and because views *are* broad. A few reprints of 'Body size and metabolic rate in the animal kingdom' are still available."

1. **Zeuthen E.** Body size and metabolic rate in the animal kingdom. *C. R. Lab. Carlsberg Ser. Chim.* **26:**17-165, 1947.