Fur and Feathers: A Response to Falling Temperature?[1]

RAYMOND B. COWLES
University of California, Los Angeles

At the present time it seems to be generally conceded that "the appearance of fur and feathers in birds and mammals came in response to a need for some mechanism for heat conservation," and that mutations in the direction of these dermal coverings survived owing to the advantages of heat or energy conservation conferred upon the possessor of these new insulating features. Aside from the fact that necessary mutations give no evidence that they ever develop in response to a need, this Lamarckistic conclusion seems dubious for the following reasons:

(1) All the available evidence strongly suggests that the mechanism of heat regulation, which is closely associated with the warm-blooded state and is essential for that condition, has appeared as a comparatively late evolutionary acquisition. In the field of phylogeny we observe the phenomenon of a succession of steadily ascending body temperatures, culminating in what are assumed to be approximately the most specialized, warm-blooded creatures. It is interesting, and possibly no coincidence, that the morphological structures on which we base phylogenetic position in birds and mammals should also accompany the physiological trait of successively higher temperatures. The record is not perfect, that is, there are occasional exceptions to the rule, but in general there is a thermal ascent accompanying the morphological specializations in these groups.

(2) In the field of embryology as in phylogeny we find evidence which similarly suggests that thermal regulation and the development of warm-bloodedness is an apparently recent acquisition in the development of organisms. Although the interpretation of this situation might be ascribed to several possibilities, it seems most reasonable to conclude that thermal regulation and warm-bloodedness must have arrived fairly late in the evolutionary process, probably long after fur and feathers made their appearance.

The third point militating against the acceptance of the current speculations concerning the origin of fur and feathers is fairly simple.

If warm-bloodedness is of fairly recent origin, then we must assume that the early, prototypal forms which gave rise to feathered and furred creatures were probably cold-blooded. If cold-blooded, they were definitely ectothermic in nature, that is, they derived their chief source of heat from outside of the body in direct contrast to the later warm-blooded or endothermic types in which temperatures are chiefly a result of metabolic activity, often made possible by a prodigious expenditure of energy.

In so far as we know, all ectothermic animals (with the exception of colonial types, such as the bees) for all practical purposes are wholly dependent upon outside sources for their body heat and all these types become lethargic, even comatose, in the presence of falling temperatures. The naked skin of reptiles expedites the absorption of solar energy, and to interpose a barrier such as fur and feathers between the heat source and the body would seem to be impractical from the survival standpoint, except under conditions of high or increasingly great incidence of solar radiation. Survival is difficult at best, and adjustment to the environment is usually rather precisely arranged —as witness the fate of most mutants. It is true that radiant heat will penetrate through fur and feathers, and therefore that the possessor of these insulating coats could absorb some of the heat from outside of the body in spite of this barrier, but on the other hand, survival in a cold-bloded form could hardly be fostered by the development of any handicap to maximum efficiency in heat absorption, particularly if temperatures in the environment were dropping.

If fur and feathers developed under conditions that, but for their presence, would have produced injury due to increases in the intensity of solar radiation, we would expect to find the interposition of an insulating covering a highly beneficial novelty having real survival value. By high temperature or rising temperature the reference point is, of course, that of the animal's limits of thermal tolerance and not temperatures as we may know them today.

The possession of a mechanism that would slightly retard accessions of heat would extend the total number of minutes or hours of diurnal activity, especially toward mid-morning, that might be available to a foraging animal. Such a coat would also enable the animal to extend its mid-day excursions into the sunshine for longer periods of time due to this protection against rapid overheating. Toward evening, or after excursions into the open and subsequent return to shade or to burrows, the presence of this radiation excluding mechanism would have a reverse effect, that is, it would retard the loss of heat and would thus extend the animal's postwarming periods of activity.

For these reasons it seems more logical to conclude that mutations producing fur and feathers were originally retained because of their function as a device that could retard the absorption rate of excessive solar radiation. Later on, their possession permitted the gradual development of temperature control necessary for the development of warm-blooded animals.

Without an already acquired insulating coat, it is

[1] Revision of a concept originally stated in: R. B. Cowles. *Amer. Nat.*, 1940, **74**, 559.

difficult to understand how energy-expending, internally heated systems could have survived in a cooling environment. This use for insulation must be a fairly recent innovation because even the more primitive, less specialized mammals still show a tendency toward ectothermism (poikilothermism) while many of the most highly specialized thermal animals, the birds, do not acquire complete endothermism (homeothermism) until some time after hatching.

This analysis presents another example in which it can be argued that rising or high temperatures may have played a dominant part in evolution.

In the Laboratory

Semi-continuous Tap-water Aerator[1]

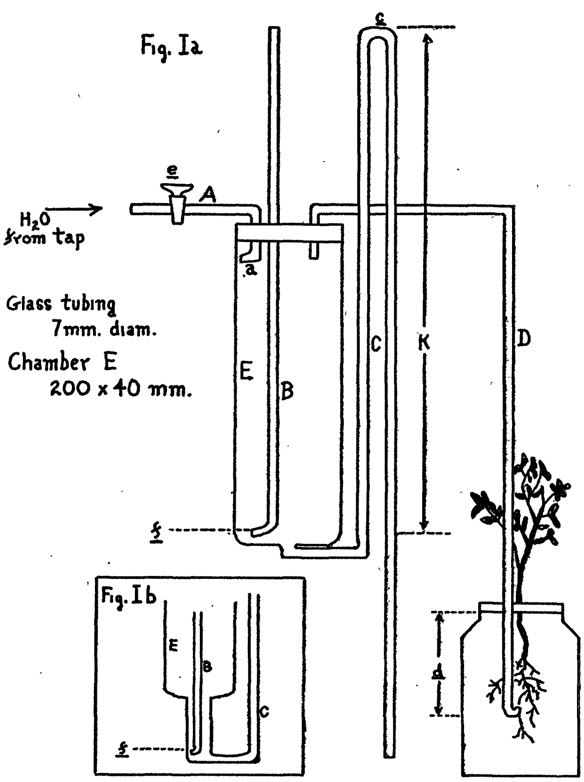
E. C. Cantino and E. D. Hatfield
University of California, Berkeley; Hercules, California

For many species, the water culture method for growing plants requires continuous aeration of the nutrient solution. By this means, the root system is maintained at an oxidative level favorable for active growth and metabolism.

In the greenhouse and in most laboratories, the source of oxygen is generally an air compressor, from which a continuous supply for the aeration process is readily obtainable. In the event that a compressor is not available, an alternative source of air is required.

The apparatus described herein has been constructed from common inexpensive glassware and requires a minimum of space. A trap or filter for oil spray and other contaminants commonly found mixed with air derived from a compressor is unnecessary because the source of such foreign material is eliminated. The quantity of water used per day for production of a moderate stream of air (approximately 10 cc. per minute) is usually in the neighborhood of four gallons or less. Results indicate that a relatively high efficiency and low cost of operation are characteristic of this equipment.

The apparatus is illustrated diagrammatically in Fig. 1a. Tap water is forced through A into chamber E, open to the atmosphere only through tubes B and C, and dropwise rate of water flow is regulated by stopcock *e*. Air is initially displaced from the chamber through B until water approaches level *f*. Subsequently, aeration of the solution commences after the pressure due to the head of water *d* has been overcome. When water has risen to level *c* in the siphon tube, it is automatically removed from chamber E by a siphon mechanism through C. During this short interval, aeration ceases. When the chamber has been emptied, the cycle is repeated and aeration continues. Water inlet tube A and tube B are bent toward the side of chamber at *a* and *f* in order to avoid spattering at the bottom of tube C during the siphoning interval and, consequently, to minimize introduction of excess air bubbles into tube C which affects the continuity of fluid in C. A highly porous, fritted glass disperson disc may be used for



more effective gas distribution at the terminal end of the aeration tube, D. However, it has been determined that a low porosity tube introduces some difficulty. The magnitude of the frictional resistance to gas flow offered by such material results in an undesirable increase in the total pressure which must be exerted by the expanding gases in E to overcome the gross resistance in the system.

The time interval between intermittent aeration can

[1] The authors wish to express their appreciation to T. C. Broyer for helpful suggestions and criticisms with this paper, which was written while the senior author was located in Pasadena, California.