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Whole-body calorimetry in the 1990s and beyond ☆

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Lavoisier and Laplace carried out, arguably, the most important experiments in the history of biological thermodynamics. Nevertheless, results from studies on whole-body calorimetry carried out some 200 years later and presented at the 9th ISBC Conference were of an exceptionally high standard and illustrated the vast range of topics which are now open to investigation using this technique. Not only did the meeting highlight current developments but it also suggested the way forward to the next century.

The ISBC is probably unique in bringing together biologists with such a wide range of backgrounds but with a unifying common interest. Exchange of ideas was commonplace, for example between clinicians and marine biologists, or scientists working on development of insects or mammals. There were over 30 presentations in which whole-body calorimetry played a major role. Current areas of interest include problems associated with specific stages of development, mechanisms of thermoregulation, and the impact of the environment on metabolism. Species being studied range from humans and other large mammals, to birds, fish, insects and polychaetes; with a correspondingly wide range of habitats. It is impossible and inappropriate to summarize all the presentations, and attention will therefore focus on specific points raised at the Conference.

1. Methodology

The meeting provided an excellent forum for discussing the use of whole-body calorimetry, as either direct calorimetry (heat loss) or indirect calorimetry (gas exchange/heat production), for answering a wide variety of questions. Clearly there

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are different problems associated with the particular environment in which the animal lives. Thus, with aquatic species there are specific problems of direct calorimetry associated with the high heat capacity of water, which results in a high time constant of the system, while examination of birds in flight raises equally difficult problems. Problems of size, at both ends of the scale, are also being overcome in ingenious ways, and the method of choice is undoubtedly a compromise between the questions being asked and the most practical approach to the subject.

2. Development

A theme running through many presentations was the stage of development of the individual, and this area of research is likely to increase in importance. Apart from furthering our understanding of biological processes, studies will undoubtedly have applications in many fields, including ecology, nutrition, and both clinical and preventative medicine. Particularly important, for example, is the extent to which the early environmental experience of the individual, both pre- and post-natally, affects subsequent development.

3. Locomotor activity

The contribution made by activity to total energy expenditure represents a critical part of the overall energy budget. Although not easy to assess, significant advances are now being made in this field and are providing new insight into a wide range of problems. These include obesity in humans and the specific problems of migration in birds, especially in relation to the importance of energetics and dehydration on long flights.

4. Nutrition and substrate utilization

Not only is whole-body calorimetry invaluable for assessing the energetic response of the individual to nutritional status, but it also allows an estimate of the metabolism of specific substrates. This is a rapidly expanding area of investigation and has important applications in assessing the sequence of substrate oxidation during different stages of development, and under different conditions of energy and nutrient intake.

5. Environment

A particularly important challenge for the 1990s is the extent to which pollution is affecting the ecology and energy metabolism of different organisms in a wide

range of habitats. Whole-body calorimetry is tackling this problem at many levels, especially in relation to the responses of individuals to different temperatures, salinities and oxygen partial pressures. In many instances, it has been necessary to develop appropriate field methods, and these are now being applied successfully to a wide variety of species.

6. Mechanisms of thermogenesis and thermoregulation

A key area involves determining the mechanisms by which the individual responds to environmental challenge during critical stages of development. It is being tackled using a multidisciplinary approach which combines results from direct and indirect calorimetry with investigations at the tissue, cellular and molecular levels. Focus is on the role of endocrine and growth factors, and the mechanisms by which the differential responses of specific tissues regulate the overall response of the individual.

7. The future

In summary, crucial areas for investigation into the next century are concerned with:

(1) The development of field methods of whole-body calorimetry which, nevertheless, retain a very high degree of accuracy.
(2) The roles of nutrition and other environmental factors in regulating energy balance.
(3) The partition of total energy expenditure into the specific contributions made at the organ, cellular and subcellular level.
(4) The mechanisms by which energy metabolism is regulated during critical stages of development.

Results from such studies will significantly advance our fundamental understanding of animal energetics, growth and development. Furthermore, a detailed understanding of the efficient regulation of energy exchange will be of particular relevance in producing adequate food supplies in a world with an increasing population and limited resources; the use of lower vertebrates and invertebrates for the production of protein could be especially important in this respect. Results will have many other important applications, particularly with respect to optimizing the quality of the environment and the health of humans and other animals.