same order of magnitude as that indicated by our results. If sulfate is converted to hydrogen sulfide under equilibrium conditions, then the calculated enrichment factor for S^{34} would be $1.088/1.015 = 1.072$. However, if it is a unidirectional process, then the enrichment factor will depend largely on the 1.088 factor above.

Controlled laboratory experiments are being carried out in collaboration with H. Kleerekoper of our Zoology Department to determine the extent of sulfur isotope fractionation that occurs when anaerobic sulfur bacteria attack and reduce sulfate to hydrogen sulfide. This process occurs at the bottom of the sea and in swamps under anaerobic conditions and is part of the natural sulfur cycle. On the other hand, certain aerobic sulfur bacteria act on organic matter and H_2S to produce free sulfur and sulfate. Sulfur isotope fractionation may occur in these processes as well. It is known from our previous results that free sulfur from the Gulf of Mexico, which is considered to be of bacterial origin, is low in S^{34} as compared to free sulfur from Italy and Sicily, which are of volcanic origin. These bacterial processes are being investigated in this laboratory also.

TABLE 2

ISOTOPIC CONSTITUTION OF SULPHUR FROM CYSTINE

Sample No.	Source	180° Mass spectrometer* S^{32}/S^{34} ratio
1	Commercial cystine (Eastman Kodak)	22.32 ± 0.01
2	Human hair†	22.35 ± 0.01
3	"	22.27 ± 0.01
4	"	22.18 ± 0.02
5	"	22.21 ± 0.01
6	"	22.20 ± 0.01
7	"	22.23 ± 0.01
	Average	22.25 ± 0.02
8	H_2S from eggs	22.27 ± 0.02

* Each sample ratioed to pyrite from Park City, Utah, having an S^{32}/S^{34} ratio equal to 22.12.

† Each sample of hair was taken from a different individual.

Sulfur samples from cystine, obtained from human hair, have also been investigated. The S^{32}/S^{34} ratios obtained are given in Table 2. Fig. 1 shows that these isotopic ratios for organic material, and for cystine in particular, fall between the values obtained for sulfates and hydrogen sulfides, although for the most part the organic sulfur is low in S^{34} content.

Since amino acid and protein sulfur are synthesized by plants which utilize sulfates in the soil (a part of the sulfur cycle), it is possible that some fractionation of the sulfur isotopes occurs in photosynthesis. Experiments are in progress using *Chlorella* to investigate this possibility.

References

1. THODE, H. G. Paper presented at the Roy Soc. Canad. meeting, Vancouver, B.C., June 1948.
2. THODE, H. G., MACNAMARA, J., and COLLINS, C. B. *Canad. J. Res.*, 1949, **B27**, 361.
3. TRAFIMOV, A. *Doklady Akad. Nauk. U. S. S. R.*, 1949, **66**, 181.

Weight and Body Temperature[1]

Simon Rodbard

Cardiovascular Department,[2] Medical Research Institute, Michael Reese Hospital, Chicago, Illinois

Although it is generally stated that the normal body temperature of birds is higher than that of mammals, examination of the literature shows the temperature of some birds to be as low as 39° C (*10*), whereas many mammals have temperatures as high as 39.5° C (*3*). An analysis of available data (*2, 3, 10–12*) shows that the body temperature of large birds is approximately of the same order as that of mammals of the same size.

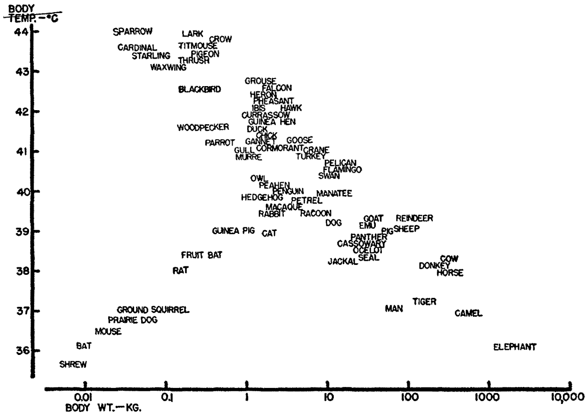

FIG. 1.

A plot of the body temperatures of birds against the logarithm of the average weight of the adult of the species gives a linear relationship (Fig. 1). Birds of 1 kg have a body temperature of about 41.5° C. For each tenfold decrease in weight, the body temperature increases about 1.5° C. A similar plot of data on large mammals gives approximately the same slope with perhaps a slightly lower intercept. However, for the small mammals weighing less than 1 kg, a line of different slope is obtained. In these, each tenfold decrease in weight is accompanied by a decrease in body temperature of about 1.5° C.

Since body temperature varies somewhat with the diurnal and reproductive cycles, age, exercise, excitement, depth of insertion of the thermometer, and environmental temperatures, the plotted data are considered as so many areas having a range of ± 0.5° C, rather than as points. The weight of mature animals of a species also varies within a range, as indicated. Because of the extreme variability of data on the body temperature of mammals with poor temperature regulation, such as monotremes and edentates, these are not included in the present analysis.

In small animals, the small amount of metabolizing

---

[1] Aided in part by a contract from the Department of the Army to the Michael Reese Hospital.

[2] The Department is supported in part by the Michael Reese Research Foundation.

mass compared to surface area available for heat loss results in a precarious juggling between the production of heat and its dissipation to the environment. This is manifested in the wide diurnal variations in body temperature seen in the small birds. In the small mammals, with a less efficient insulation, a body temperature as high as that of the small birds apparently cannot be maintained. This is evidenced in the hypothermic response of small rodents to infection or to the injection of foreign proteins (*6*), which in larger animals leads to a febrile response. This poorly developed homeothermism is also seen in the facility with which the body temperature of small mammals falls and a state of hibernation ensues on exposure to cold. By contrast, animals such as the bear with a large ratio of mass to surface area have only a slight fall in body temperature on entering the hibernating state (*1*).

A number of physiological measurements such as heart rate, cardiac output, and oxygen consumption have been correlated with weight (*4*). However, body temperature also play a significant role in the determination of these functions. This is illustrated by the fact that the mouse has a heart rate of about 670, while the canary, also weighing about 20 g, has a heart rate of 1000 per min. The mouse has a normal body temperature of about 37° C, while the body temperature of the canary is about 44° C. We have recently shown that in some species, the blood pressure and the level of the blood sugar are related to the body temperature (*7–9*). The blood pressures and blood sugars of birds are generally higher than those for mammals, in accord with their higher body temperatures. That these effects are related to body temperature rather than to weight is shown by the fact that small mammals (*4*) have much lower blood pressures than do birds of the same weight (*13*).

Studies on the metabolic rates of animals have been based on a calculated surface area based upon approximately the 0.7 power of the weight (*5*). However, since weight of the animal appears to affect the body temperature, which in itself plays a significant role in the metabolic rate of the animal, simple conversion of weight to surface area may lead to considerable error. This is apparent upon consideration of the fact that a variation of only 1° C in body temperature may increase the resting metabolism by 10%. It would therefore appear that comparisons of the metabolic activity of various species on the basis of surface area alone, without regard to weight and body temperature, are likely to be misleading.

Individuals of a given species may all have approximately the same body temperature, despite fairly large variations in body size. Adequate data on this point are not available. The weight-body temperature relationship may, however, appear in the fact that young animals have slightly higher body temperature than adults of the same species.

It is noteworthy that closely related species may have fairly deviant body temperatures in accordance with their body weights. Since the setting of the normal body temperature determines the lethal level in fever, a bird of large size with a normal temperature of 40° C will have lethal body temperature of about 44° C, while a very small but closely related species with a normal temperature of 44° C may have a lethal temperature of 47° C. This difference in lethal thermal levels suggests that the mechanisms leading to death in pyrexia devolve upon disturbances in specific physiological adjustments induced by change in body temperatures, rather than upon the absolute temperature level itself.

The fact that various unrelated species of large size have body temperatures in the same range indicates the independent achievement of these thermal levels. This may be dependent upon survival factors related to the size of animal. It suggests that for large homeotherms of a given weight, a particular level of body temperature is optimal for survival. In small homeotherms, other factors predominate, resulting in a marked disparity between the body temperatures of birds and mammals of the same size.

References

1. BENEDICT, F. G. and LEE, R. C. *Carnegie Instn. Publ.* #497, 1938.
2. BERNARD, R., CAYOUETTE, R., and BRASSARD, J. A. *Rev. Canad. Biol.*, 1944, **3**, 251.
3. BRITTON, S. W. and KLINE, R. F. *Amer. J. Physiol.* 1939, **125**, 730.
4. CLARK, A. J. *Comparative physiology of the heart.* New York: Macmillan, 1927.
5. KLEIBER, M. *Physiol. Rev.*, 1947, **27**, 511.
6. OLIZKI, L. and AVINERY, S. *Brit. J. exp. Path.*, 1937, **18**, 316.
7. RODBARD, S. *Amer. J. Physiol.*, 1947, **150**, 67.
8. *Ibid.*, **151**, 509.
9. RODBARD, S. *Science*, 1948, **108**, 413.
10. SUTHERLAND, A. *Proc. zool. Soc. Lond.*, 1899, 787.
11. WETMORE, A. *Smithsonian misc. Collection*, 1921, **72**, 1.
12. WISLOCKI, G. B. *Quart. Rev. Biol.*, 1933, **8**, 385.
13. WOODBURY, R. A. and HAMILTON, W. F. *Amer. J. Physiol.*, 1937, **119**, 663.

On the Amendment of the Nomenclature of the Rh-CDE System

Edward F. Ducey and Robert I. Modica

Laboratory Service of St. Mary's Hospital,
Grand Rapids, Michigan

The recent article by Castle, Wintrobe, and Snyder on the nomenclature of the anti-Rh-CDE typing serums (*1*) has served to clarify the situation but poorly, and has brought out into the open the confusion that exists in the terminology of the Rh-CDE factor. The Wiener classification (*6, 7, 10*) using the Rh and Hr terms is unwieldy. Anyone who has tried to learn (and teach) the terminology of Wiener, with the hat, arm, and glove symbols (*5*), has soon become lost in flights of fantastic conjectures. The steps taken by Race (*2*), and later elaborated and expanded (*3*), have pointed a path through the forest of the Wiener complexity.

But the recommendation of the Review Board (*1*) that both systems be used concurrently has done the field of immunology an unintentional disservice. The Rh-CDE