pounds, added to the observation (*1*) that both are mutagenic in an *Escherichia coli* T4 bacteriophage system, make it even more desirable that a persuasive explanation be found for the qualitative difference between them in mutagenicity for *Salmonella*.

ERICH HIRSCHBERG
Department of Biochemistry, College of Medicine and Dentistry of New Jersey, Newark 07103
I. BERNARD WEINSTEIN
Institute of Cancer Research, Columbia University, New York 10032

References

1. P. E. Hartman, K. Levine, Z. Hartman, H. Berger, *Science* **172**, 1058 (1971).
2. E. Hirschberg, I. B. Weinstein, R. Carchman, S. Archer, *Proc. Amer. Ass. Cancer Res.* **9**, 30 (1968); R. A. Carchman, E. Hirschberg, I. B. Weinstein, *Biochim. Biophys. Acta* **179**, 158 (1969); I. B. Weinstein and E. Hirschberg, in *Progress in Molecular and Subcellular Biology*, F. Hahn, Ed. (Springer-Verlag, Heidelberg, 1971), vol. 2, p. 232.
3. M. J. Waring, *Humangenetik* **9**, 234 (1970); *Studia Biophys.* **24/25**, 257 (1970); *J. Mol. Biol.* **54**, 247 (1970); in *Progress in Molecular and Subcellular Biology*, F. Hahn, Ed. (Springer-Verlag, Heidelberg, 1971), vol. 2, p. 216.
4. M. Wittner, H. Tanowitz, R. M. Rosenbaum, *Exp. Mol. Pathol.* **14**, 124 (1971).

21 June 1971

Height, Weight and Age at Menarche and the "Critical Weight" Hypothesis

Frisch and Revelle (*1*) have concluded that menarche occurs at a critical body weight, perhaps triggered by a feedback from the metabolic mass of the body to appropriate regulatory systems. They based their conclusions on the lack of differences in mean weight at menarche among girls when divided into four menarcheal age groups, as opposed to a steady increase in mean height from the youngest (< 12.0 years) through the oldest (> 13.9 years) age category.

We have investigated this more intensively in 70 normal girls, 42 of Caucasian ancestry from Philadelphia, and 28 of mixed European (largely Spanish), and American Indian background from Guatemala City. All of the subjects were well nourished and free of disease at related clinical examinations; they were taking part in longitudinal growth studies and had attained menarche in the interval between successive annual examinations. We estimated height and weight at menarche by interpolation.

The Philadelphia girls attained menarche at a mean age of 12.4 years and at an estimated mean height of 153.5 cm and weight of 47.1 kg. For the Guatemalan girls, the corresponding means were 12.3 years, 146.1 cm, and 39.8 kg. These means differed significantly between the two samples ($P < .001$). The range of variation in weight was a striking 22 kg for each group if one Guatemalan and one Philadelphia girl with weights of 60 and 61 kg, respectively, are excluded.

These data were standardized around their subsample means for age, height, and weight by converting to T-scores (*2*) and treated as a single sample. Multiple regression analysis expressed age (A_m) as a function of height (H_m) and weight (W_m) at menarche, as given in the equation

$$A_m = 39.3 + 0.38\,H_m - 0.17\,W_m$$

The regressions of age on both height and weight are significant, the former at the .01 and the latter the .05 level. The coefficients of partial correlation are, for height and age at a constant weight, +.68, and for weight and age at a constant height, −.26; both coefficients are statistically significant.

The results indicate that, far from a critical and unvarying weight at menarche, there is not only a striking range of absolute variation, but also a significant regression of age upon weight if height is held constant. At a constant height girls who menstruate earlier are heavier than those menstruating later. At a constant weight, the early maturers are shorter. When considered together, therefore, early menarche is associated with shorter, heavier girls, and later menarche with taller and lighter girls.

The rather complex interrelation among the height, weight, and age at menarche, and the failure to consider them, could very well lead one to suspect the weight and age to be unrelated. For our sample, the regression of age upon weight, without considering height, is, at +.13 (T-score units), not significantly different from zero. On the other hand, the relationship between height and weight at menarche ($r = +.64$) is significant and positive.

Thus, weight at menarche is related to height, as is obvious, since taller girls weigh more than shorter ones. Taller girls also reach menarche later. But, at a constant height, weight and age at menarche are significantly related in a negative direction. Weight is therefore related to height and to age in opposite directions.

The results of the directionally opposite relationships of weight to the height and age at menarche are to obscure the latter, unless the height covariance is accounted for. By merely comparing mean weights at menarche of various age groups, Frisch and Revelle have been led to conclude that the weight is constant over age. The more detailed analysis of our data in contrast reveals that the two are related and that the "critical weight" hypothesis is an artifact arising from failure to consider the interrelationships of all three variables.

FRANCIS E. JOHNSTON*
ROBERT M. MALINA
MARTHA A. GALBRAITH
Department of Anthropology, University of Texas, Austin 78712

References and Notes

1. R. E. Frisch and R. Revelle, *Science* **169**, 397 (1970).
2. M. W. Tate, *Statistics in Education* (Macmillan, New York, 1955), pp. 219–21.
3. Supported in part by PHS grant DE 00087 and by NSF grants USDP GU-1598 and GS 3038.
* Present address: Department of Anthropology, Temple University, Philadelphia, Pa., 19122.

24 June 1971; revised 17 September 1971

The mean weight at menarche found recently by Johnston, Malina, and Galbraith for Caucasian girls from Philadelphia is about the same, 47.1 kg, as we found (47.8 ± 0.51 kg) for Caucasian girls from Berkeley, Boston, and Denver who had menarche three decades ago (*1*). However, the mean age of menarche of the Philadelphia girls, 12.3 years, is 7 months earlier than the mean age of menarche, 12.9 ± 0.1 years, of the girls of three decades ago. This appears to support our critical weight hypothesis and our explanation of the secular trend to an earlier menarche (*1*, *2*). (We assume that standard errors of Johnston *et al.*, which are not given, are in a similar range as ours.)

Different racial groups have different weights and heights at menarche, as was found by Johnston *et al.* for the Philadelphia and Guatemalan girls, and as we noted from the significant difference in weights and heights at the time of maximum rate of growth, which precedes menarche (*3*); for example, the mean weight for Japanese girls is 33 kg (*4*), and that for American girls is 39 kg (*5*).

Table 1. Weight (mean ± S.E.) at various heights (mean ± S.E.) with increasing age of menarche, and at all ages of menarche. Categories of height are by rounded standard deviation (6 cm) from the rounded mean, 158 cm.

Height category (cm)	Menarche ⩽ 12.9 years			Menarche ⩾ 13.0 years			All ages of menarche		
	No.	Height (cm)	Weight (kg)	No.	Height (cm)	Weight (kg)	No.	Height (cm)	Weight (kg)
⩽ 152.0	17	148.6 ± 0.56	40.9 ± 0.84	8	146.0 ± 1.8	38.8 ± 1.1	25	147.8 ± 0.72	40.2 ± 0.69*
152.1–158.0	32	155.2 ± 0.32	48.5 ± 1.2	26	155.1 ± 0.37	44.8 ± 1.2†	58	155.1 ± 0.24	46.9 ± 0.87
158.1–164.0	37	161.2 ± 0.24	50.6 ± 0.96	27	160.7 ± 0.30	48.0 ± 1.2	64	161.0 ± 0.19	49.5 ± 0.75
⩾ 164.1	9	165.9 ± 0.64	53.4 ± 2.2	25	167.9 ± 0.74	51.4 ± 1.1	34	167.4 ± 0.59	51.9 ± 0.98*
All subjects	95	157.4 ± 0.57	48.4 ± 0.71	86	159.7 ± 0.78	47.2 ± 0.72	181	158.5 ± 0.48	47.8 ± 0.51

* Differs from mean for all subjects at $P < .01$. † Differs from ages up to 12.9 at $P < .05$.

We question whether the T-score method, which is normally used to combine different test scores of the same population, is a valid way to combine menarcheal data of two different racial groups. Assuming the method is applicable, the results of Johnston *et al.* are difficult to interpret. For example, their multiple regression equation gives an age of menarche of 91 years if the mean height and weight of American girls at menarche is substituted in the equation. Apparently the equation is in terms of T-scores, but the standard deviations of the means are not given, so the T-scores cannot be decoded.

Using our homogeneous data of 181 American girls, we find, contrary to the results of Johnston *et al.*, that the partial correlation coefficient for weight and age at a constant height is $r = -.09$, which is not significant. Table 1 shows that, when grouped by height, the difference between the mean weights of early and late maturing girls is an insignificant 2 to 2.6 kg, except for one height group, 152 to 158 cm, in which the difference is 3.7 kg. It is well known that early maturing girls are fatter than later maturers (*6*). At the same height therefore, the earlier girls should weigh somewhat more than the later maturers. However, both groups could have equivalent lean body weights, which would be in accord with our hypothesis that a critical weight is related to a critical metabolic rate.

Our data confirm the relation found by Johnston *et al.* between height and weight at menarche, but we find a much less strong association: the partial correlation coefficient for height and age at a constant weight is $r = .24$, rather than .68. The correlation of weight with height is $r = .50$ rather than .64.

With our sample of American girls, the multiple regression equation for age at menarche A_m on height H_m and weight W_m is:

$$A_m = 6.7 + .044\ (\pm .014)\ H_m - .016\ (\pm .014)\ W_m$$

The regression coefficient of height on age is significant at $P < .01$. The regression coefficient of weight on age is not significant. This is our basic finding of an invariant mean weight and a signficantly increasing mean height with increasing age of menarche (*1*).

Our data confirm the observation of Johnston *et al.* that, over all ages, taller girls weigh more than shorter ones (Table 1). However, as Table 1 shows, the difference in mean weight as height increases is not significant in the height range within ± 1 S.D. from the height mean, that is, 68 percent of the girls. The significant difference of 4.1 kg from the mean of the very tall girls can be explained in part, and perhaps entirely, by increased skeletal weight. The significantly lower weight of the very short girls (below 152.0 cm) may be too large to be explained only by decreased skeletal weight; they seem to be an exceptional group in some other way.

We thus find that for all but one small group of very short girls (14 percent of the girls) the differences in weight as height is kept constant, or with increasing height over all ages, are small and easily explainable in terms of the three components of a critical weight—lean body mass, fat, and skeleton.

In an effort to reduce the variability of weight at menarche, we have estimated lean body weight at menarche by the equations of Mellits and Cheek (*7*) which estimate total water from height and weight. We found a reduction of 35 percent in the variability of weight at menarche (coefficient of variation = 9.1 percent compared to 14 percent) when weights are converted to lean body weights.

We are puzzled by the statement of Johnston *et al.* that the critical weight hypothesis resulted from concluding that the age and weight at menarche are unrelated. The critical weight hypothesis is that age and weight at menarche *are* related. The same phenomenon observed in animals has been termed the weight-dependency of sexual maturation (*8*).

ROSE E. FRISCH
ROGER REVELLE, SOLE COOK
Harvard University Center for Population Studies, Cambridge, Massachusetts 02138

References and Notes

1. R. E. Frisch and R. Revelle, *Science* **169**, 397 (1970); *Arch. Dis. Child.* **46**, 695 (1971).
2. ———, *Hum. Biol.* **43**, 140 (1971).
3. ———, *ibid.* **41**, 185 (1969).
4. Maximum increments calculated from growth data [*Nutrition in Japan, 1964* (Ministry of Health and Welfare, Tokyo, 1965)].
5. R. E. Frisch and R. Revelle, *Hum. Biol.* **41**, 537 (1969).
6. J. M. Tanner, *Growth at Adolescence* (Blackwell, Oxford, ed. 2, 1962), pp. 101–02; B. T. Donovan and J. J Van Der Werff Ten Bosch, *Physiology of Puberty* (Arnold, London, 1965), p. 31.
7. E. D. Mellits and D. B. Cheek, *Monogr. Soc. Res. Child Develop.* **35**, 12 (1970).
8. L. S. Monteiro and D. S. Falconer, *Anim. Prod.* **1**, 145 (1959).

12 October 1971