Treatment by Oral Administration. Six adults harboring enterobius were each given 1.0 gm. of hexylresorcinol pills. The drug was given early in the morning and breakfast omitted and no food was taken until 6 hours later. Three weeks after treatment, stool examinations were made and all 6 contained enterobius or its eggs.

Conclusion. 1. Hexylresorcinol is very active on *Enterobius* vermicularis, a 1-1000 suspension killing them in 2 minutes. 2. Five out of 6 people treated with hexylresorcinol pills by mouth and enemas became free of their enterobius. Two out of 3 people treated by enema only became free of enterobius. Although this is not sufficient data to judge which method is the best, the life history of the worm indicates need of both oral and enema treatment. 3. Suggested outline of treatment. Treat twice a week in the morning as follows: (a) Omit breakfast; no food until noon. (b) Hexylresorcinol pills orally, 0.1 gm. per year of age up to 10 years of age, maximum dose after this age 1.0 gm. Drink plenty of water. (c) Soapsuds enema and after its evacuation an enema of 1 part crystalline hexylresorcinol in 1000 cc. of water; this enema to be given high and retained 5 minutes. (d) Bed sheets to be boiled at least twice weekly to destroy eggs or worms passed on them.

6435

On the Motion of Growth. I. Introduction to the Energetics of Growth and Metabolism.

NORMAN C. WETZEL.

From the Babies and Childrens Hospital, Cleveland, and the Department of Pediatrics, School of Medicine, Western Reserve University.

It is proposed in this and in a few succeeding papers briefly to present the major results of an extensive investigation into the general nature and mechanism of growth, a problem which has now occupied our attention for the past eight years. It is clearly impossible, accordingly, to do more here than to sketch in the barest fashion such features as are of primary interest to those working in this field. A detailed description whereby all steps in the argument are properly and fully justified has already been prepared for early publication elsewhere.

Previous workers as described by Scammon[1] have contributed

[1] Scammon, R. E., Report of National Research Council Committee on Child Development, Washington, 1929, Part I, pg. 1.

greatly in diverse ways to our knowledge of the outward, graphical characteristics of growth in various biological forms, but it needs to be pointed out that no analyses have been brought to the point where the intrinsic properties or perhaps better, the special mechanisms of growth as such are thereby satisfactorily clarified, and further, that there is nowhere a hint as to the real connections of this fundamental process with other biological processes as, for example, that of metabolism. In the present instance we have founded our entire procedure upon the general, and indeed, almost obvious concept that all growth must be viewed as a process of biological energy exchange. Primary stress is therefore to be laid upon the importance of dealing with this entire subject from the standpoint of what may be called the energetics of growth. The *dynamical* association of growth with metabolism comes thus as a natural result of this principal postulate.

A General Concept of the Energetics of Growth.

With due respect to various possibilities in the task, we begin with a broad definition of growth and take this in the biological as well as in the dynamic sense to refer primarily to a *change* in cell number. Such a change, however, need not always be an increase in cell number, although under ordinary circumstances, obviously, the characteristic change will be that associated with, and due to, cellular reduplication. It is next assumed that any biological entity undergoing growth is in suitable contact with an appropriate source of energy; and that the chief products, daughter cells, may find agreeable accommodations in their immediate surroundings. Thus, source, cells, and environment when properly adapted with respect to subsidiary physical conditions,* will constitute for simplicity a system wherein growth proceeds in accordance with these several adjustments. It is further assumed that the energy so withdrawn from the source becomes transformed in part into daughter cells, this fraction comprising the *"Internal Work of Growth,"* and in part into other fractions which together compose the *"External Work"* of this process. Thus, by the conservation law we have schematically,

$$\begin{bmatrix}\text{Energy of the}\\ \text{Source}\end{bmatrix} \rightarrow \underset{\text{(Daughter Cells)}}{\begin{bmatrix}\text{Internal Work}\\ \text{of Growth}\end{bmatrix}} + \underset{\substack{\text{(Loss by Dissipation,}\\ \text{Energy of Storage,}\\ \text{Synthesis, etc.)}}}{\begin{bmatrix}\text{External Work}\\ \text{of Growth}\end{bmatrix}} + \begin{bmatrix}\text{Work of}\\ \text{Maintenance}\end{bmatrix}$$

---

* Temperature, [$\overset{+}{H}$], etc., etc.

where provision has also been made for cell nutrition or maintenance. The proper mathematical representation of the foregoing concept, ought accordingly, to include all cases of growth—and, if appropriate solutions can be obtained, ought also to lead to a clearer understanding of processes hitherto considered unrelated to the main event itself.

Our own studies have shown that the general relationship given above can be expressed, when the quantities have been properly chosen, by the equation,

$$S - \underbrace{\int V_c(t)dq}_{\text{Internal Work}} = \underbrace{\int [E_c(t)dq + \rho \left(\frac{dq}{dt}\right)^2 dt] + \frac{q^2}{2\kappa} + \frac{\lambda}{2}\left(\frac{dq}{dt}\right)^2}_{\text{External Work}} + \underbrace{A't}_{\text{Maintenance}} + C_o \quad (1)$$

wherein the various factors are defined as follows:

- q, the dependent variable, and referred to as the "charge of growth" later to be shown equal to $\mu \int \frac{1}{z}\frac{dz}{dt}dt$, z being a function of cell number, and μ a constant of proportionality herein taken as unity;
- S, Energy at the Source;
- $V_c(t)$, Energy appearing in the cells themselves;
- ρ, a constant accounting for the true irreversibility of any finite growth process, and termed the Resistance to Growth;
- κ, a constant to be known as the Permittance of Growth;
- λ, a constant pertaining to the momentum of growth;
- E_c, a constant representing the Energy of cellular synthesis per unit charge;
- A', the unit rate of maintaining cells;
- C_o, the arbitrary constant of integration.

Due to the ever increasing complexity of the subject, spatial relations in any of the three dimensions are neglected as unimportant in a first approach to the problem. With this restriction the foregoing relation represents the full expression of the fundamental agencies which together accomplish the work of growth. We refer to it as the equation of energy, and each of its terms will be separately justified and developed in another series of forthcoming papers.

Results—Equation (1) leads directly, when the functions S and $(V_c, E_c)(t)$ are known[2] to a solution of an integral in t for the change in weight of the human being from the 100th day of gestation to full adult life, a longer period than heretofore embraced in

[2] Wetzel, N. C., PROC. SOC. EXP. BIOL. AND MED., 1932, **30**, 227.

any single analytical or "rational" expression for weight. It leads next by way of the numerical evaluation of ρ to a description of the course of human basal metabolism throughout the same period of life,[3] in terms either of unit or total heat production. Some insight is thus gained into the curious succession of critical points shown in growth and metabolism respectively. This expression for the normal alterations in human metabolism as age proceeds through the period of growth will also serve to define the course of heat production during starvation.[4] In addition, equation (1) may be so arranged to account, at least dynamically, for the nature of the change in weight incident to prolonged fasting, the human case being considered briefly in a succeeding paper.[5] Lastly, equation (1) has been applied to numerous other examples of growth including that displayed by tissue cultures, yeast cells, plants and animals, and in all of these it has succeeded in agreeing with experimental observations. A special example, where, fortunately, simultaneous data on heat production are also available, is considered for the case of bacteria in the final paper of this series.[6]

6436

On the Motion of Growth. II. Human Growth in Weight from Early Fetal to Adult Life.

NORMAN C. WETZEL.

From the Babies and Childrens Hospital, Cleveland, and the Department of Pediatrics, School of Medicine, Western Reserve University.

The equation of energy previously set forth[1] has been applied to the case of human growth in weight but the steps necessary for this can only be briefly outlined here. We need first to know the nature and relations of the functions $S, (V_c, E_c)\ (t)$, which as already explained, pertain to energy at the source, to that in the form of cells, and to the energy of synthesis respectively. It can be shown that these several factors are connected in the case of "average" human weight by the relation,

[3] Wetzel, N. C., PROC. SOC. EXP. BIOL. AND MED., 1932, **30**, 233.

[4] Wetzel, N. C., to be published.

[5] Wetzel, N. C., to be published.

[6] Wetzel, N. C., to be published.

[1] Wetzel, N. C., PROC. SOC. EXP. BIOL. AND MED., 1932, **30**, 224.