external rotation, and extension by internal rotation; adduction never occurs.

To minimize abduction, an appropriate value for α needs to be selected by setting the derivative of φ_z with respect to x equal to zero, which leads to the condition

$$\tan^2 \alpha = \cos \theta$$

For small values of θ, $\cos \theta$ is almost unity and, ignoring the negative root, $\alpha = \pi/4$. With this value of α, equation (4) for the angular displacement becomes

$$\left.\begin{aligned} \varphi_x &= \tan^{-1} \frac{\sqrt{2} \sin \theta}{1 + \cos \theta} = \tan^{-1} \sqrt{2} \tan \frac{\theta}{2} \\ \varphi_y &= \tan^{-1} \frac{1 - \cos \theta}{\sqrt{2} \sin \theta} = \tan^{-1} \frac{1}{\sqrt{2}} \tan \frac{\theta}{2} \\ \varphi_z &= \tan^{-1} \frac{1 - \cos \theta}{1 + \cos \theta} = \tan^{-1} \tan^2 \frac{\theta}{2} \end{aligned}\right\} \quad (5)$$

Using these expression, φ_x, φ_y and φ_z are plotted against θ in Fig. 5.

In practice, a swing of $\pm$ 15° should be associated with $\pm$ 5°–10° of rotation, while abduction or adduction should be negligible. The graph (Fig. 5) shows that with the axis of rotation angled downwards and outwards by 45°, a 15° swing produces 8° of outward rotation, and a $-$15° swing 8° of inward rotation, whereas abduction, being minimal for low values of φ_x is only 2° during the same amount of movement. The practical value of such joints is at present being investigated using assessment techniques evolved at the Cerebral Palsy Physical Assessment Centre, Guy's Hospital.

A polyplanar joint, the movement of which approximates more closely to that of a hip joint, should show a number of advantages over the conventional simple hip joint currently used in long leg braces. The application

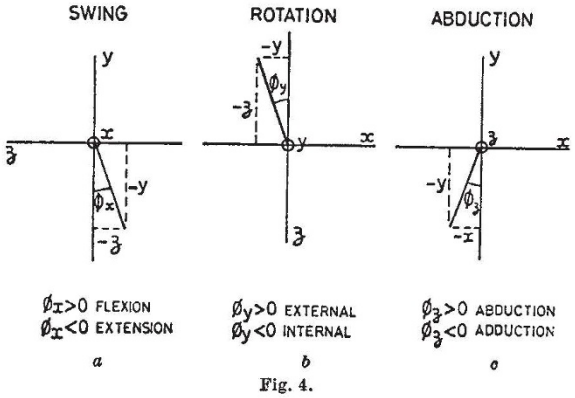

Fig. 4.

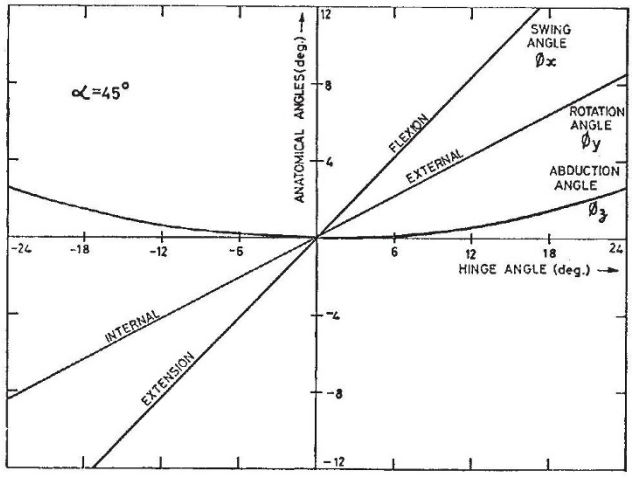

Fig. 5.

of engineering theory to the problem demonstrates how valuable co-operation between university departments can be in reducing the time spent on physical trials of such apparatus.

D. R. Scrutton
P. Robson
Cerebral Palsy Physical Assessment Centre,
Paediatric Research Unit, Guy's Hospital.
R. M. Davies
Department of Mechanical Engineering,
University College, London.

Negentropy, Information and the Feeding of Organisms

In a recent reply to Büchel, concerning entropy and information in the universe, Popper[1] persists in the use of a biological example which appears to be incorrect. This concerns the developing birds' eggs which "appear to produce structural negentropy by increasing their structural organization; they are, as far as we know, "fed", in Schrödinger's sense, exclusively on heat (that is, on entropy)". This does not constitute a counter example to Schrödinger's views[2] because the developing embryo in the egg "feeds" on the negentropy of the yolk; this conversion process, in common with most biological energy conversion processes, is not very efficient and in the course of it entropy (as heat) is generated. The purpose of incubation is to reduce the rate of flow of heat away from the egg which is poorly insulated, no doubt inevitably so as a consequence of the structural requirements for gas exchange. Thus over the whole period of incubation there is a net loss of radiant energy from the egg and it is therefore misleading to suggest, as Popper does, that the egg has fed on entropy. To have asked of Schrödinger (as Popper requires) that he say something of organisms which distinguishes them from heat engines was scarcely possible in the strictly thermodynamic context of Schrödinger's famous remark, because it would have required going beyond the then available limits of thermodynamics to say something about the form or information content of the received energy.

Photosynthetic autotrophic organisms are entropy feeders which canalize the entropy of sunlight into the thermodynamic and structural negentropy of their own structures. The entropy feeding of these organisms can be said to be achieved ultimately by the agency of the informational (that is, structural) negentropy represented in the replicative and renewal templates within their cells. Büchel[3], however, makes extravagant claims about the relationships of this structural negentropy to the thermodynamic entropy increase of a system, raising to the level of a general principle the proposition that "whenever structural negentropy is produced, the thermodynamic entropy must increase by at least the same amount". Even if it is accepted as proved that in the chosen example of a watchmaker assembling a watch, putting in as he does so n bits of information, the attendant increase in thermodynamic entropy will be at least Kn log 2 cal/grad, there is no evidence that a similar relationship will hold for the structural negentropy generated by a living organism. Taking the case of even the simplest organisms growing on defined media we do not have sufficient knowledge of the direction and magnitude of radiation and chemical energy exchange with the environment or of how to approach the problem of a valid estimate of their information content, even to embark on the measurement of this relationship, much less to claim its probable general validity.

Harold W. Woolhouse
Department of Botany, University of Sheffield,
Western Bank, Sheffield.

Received January 25, 1967.

[1] Popper, K., *Nature*, 213, 320 (1967).
[2] Schrödinger, E., *What is Life?* (Cambridge University Press, 1944).
[3] Büchel, W., *Nature*, 213, 319 (1967).