conchiolin in the outer calcareous layer of the valves has almost the same composition as that in the inner layer, and consequently differs completely in character from that in the outer ligament layer. Nevertheless, in both these bivalves, the inner layers of the shell exhibit properties comparable with those of their counterparts in *Anodonta*, similarity between the inner ligament layers being particularly close.

In considering the evolution of Gastropoda in fresh waters, an account was given by Dr. W. Russell Hunter of work largely carried out at the field station maintained on Loch Lomond by the Zoology Department of the University of Glasgow. The snails of fresh waters are either prosobranchs, retaining the typical molluscan ctenidium and closely related to marine gill-breathing forms, or pulmonates with no ctenidium and the mantle cavity modified as a 'lung'. In both groups different degrees of adaptation to life in fresh waters co-exist, forming functional and morphological series. The ecological and physiological work reported upon was largely concerned with certain species of pulmonate snails, including *Lymnaea peregra*, *Physa fontinalis* and *Planorbis albus*. Some populations of these snails have to migrate periodically to the surface of the water to breathe[11]. Other populations of the same species can live in deeper offshore water, and a variety of conditions are found in their mantle cavities. In some the 'lung' is water-filled, the snails respiring by some other means, while in others it contains a gas-bubble, which may be used to obtain dissolved oxygen from the water, or merely to give buoyancy[12]. Similar variations between different populations within each species of snail are found in their reproduction: the breeding periods, the numbers of eggs produced, and the survival of the young vary from one population to another. Adaptive plasticity in their methods of breathing, feeding and reproduction is characteristic of freshwater molluscs as a whole. The process of evolution in animals like snails living in fresh waters has been markedly different from evolution in similar animals living in the sea or on land[13]. Freshwater environments are characterized by the high degree of small-scale, short-term isolation which can occur within them. Thus, it seems likely that both the adaptive plasticity found in several aspects of the physiology of freshwater snails, and the co-existence of different degrees of adaptation to limnic life, are associated with the discontinuity in space and the impermanence in time of most fresh waters[13].

A. E. Henderson described his experimental work on the mantle cavity mainly of the larger freshwater pulmonates, *Lymnaea stagnalis* and *Planorbarius corneus*. The use of the 'lung' as an air store for respiratory purposes during submergence has been at least partially supplanted by other functions. Some snails undoubtedly bring the gas-bubble in the cavity into contact with the water during submergence, and can extract sufficient oxygen by diffusional processes to prolong the period of submergence. But other animals, even of the same species, do not do this, and in such cases (perhaps in all) the hydrostatic function of the gas-filled cavity may dominate in determining the behaviour of the animal. In these larger species, the time taken for the bubble to be used up (by the extraction of oxygen to the point where the snail loses its buoyancy) is of the same order as the normal duration of a dive, suggesting that loss of buoyancy may determine the frequency of surfacing. Further, the loss of buoyancy caused by pressure at depth, and the fact that the snails are not found with gas in their cavities at just those depths where they lose their buoyancy, seems to indicate that the hydrostatic can be more important than the respiratory function in some species.

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# TIME-SPAN OF DISCRETION IN JOB ANALYSIS

A BOOK by Dr. Elliott Jaques* described a new approach to problems of payment for work involving, among other things, a new way of analysing the work content of roles and a suggested means of measuring responsibility. For the past eighteen months, J. M. M. Hill has been engaged in examining some of the concepts put forward in this book, in testing their validity, and in recommending if and how they should be used for the solution of problems experienced by the Glacier Metal Company, of which he is the policy research officer. In a recent paper† he describes some of the preliminary results of his examination.

* "Measurement of Responsibility" (Tavistock Publications, Ltd., 1956).

† Tavistock Pamphlets No. 1: The Time-Span of Discretion in Job Analysis. By J. M. M. Hill. Pp. 29. (Reprinted from *Human Relations*, Vol. 9, No. 3.) (London: Tavistock Publications, Ltd., 1958.) 3*s*. 6*d*. net.

The kernel of Jaques's approach may be described as follows. The work activities (or duties) which, under normal conditions of industrial contract employment, a man performs in return for pay may be divided into those that are prescribed (laid down for him so that he has no authorized choice in the matter) and those that are discretionary (in that judgment or the making of choices is called for from him). All jobs—even the most apparently 'routine'—call for some exercise in discretion, and no discretion is allowed to continue indefinitely without being subject to review by a superior. Jobs differ in the maximum length of time that discretion will be allowed to continue before a review takes place, and this maximum length of time—the time-span of discretion—is of fundamental theoretical and practical importance.

The time-span of discretion is a measure of level of work and of responsibility. That time-span of discretion is related to salary, inasmuch as there exists an ascending scale of monetary salaries corresponding to ascending time-spans of discretion. An individual doing a job in industry may be receiving remuneration at, above or below the level appropriate to the time-span of discretion of the job in question. Each of these three possibilities will be associated with different characteristics as regards the satisfaction and behaviour of those concerned. In particular, payment at the appropriate level will be experienced by the individual as satisfactory—he will not actively press for increase and will not express disruptive disaffection.

If Dr. Jaques's hypothesis is correct, it is a matter of fundamental importance to industry and may even provide a basis on which the apparently intractable problems of differentials may be settled. Before such notions and other economic implications of the idea may be investigated, Dr. Jaques's findings must be checked by observation and experiment and the actual time-span of discretion of jobs must be determined.

In the course of his work, Mr. Hill has been concerned with assessing the time-span of jobs and with the communication of the means of such assessment. In his paper the dependence of the existence of a clear time-span of discretion of a job on the existence of a clearly structured work situation is described, and some of the implications of this examined. Problems of assessing time-span in situations of unclarity are also discussed. The meaning of the term discretion is then described, expanded and exemplified, and reference made to some of the difficulties that may be met in discovering the discretionary aspects of a job. A review mechanism is then defined as any systematic means by which a manager becomes aware of the quality of his subordinates' use of discretion, and this definition is expanded and exemplified. Three kinds of review mechanisms discovered are described as:

Direct review, in which a subordinate hands back a completed piece of work to his manager for full inspection.

Indirect positive review, in which a manager deliberately seeks information about the way in which his subordinate has been using discretion, from sources outside that subordinate's control.

Indirect negative review, in which a manager relies on the fact that he will hear of the matter should his subordinate use discretion inadequately.

Jobs are then grouped as 'single aspect' or 'multiple aspect' according to whether only one or many different kinds of work activities are carried out. The boundaries between the different aspects of a multiple-aspect job are termed either 'permeable' or 'impermeable' according to the extent to which a review of discretion in one aspect leads to review of other aspects.

Within the framework given, a job may be set up in reality with a range of possible time-spans of discretion, and that within discoverable limits managers have choice concerning the time-span of discretion that they will allow a subordinate.

A description is also given of the means by which information about jobs may be elicited in order that the time-span of discretion may be assessed. Three examples of time-span analysis are presented and discussed. In each case the analysis concerns a particular kind of work, namely—the work of a draughtsman, a manual operator's work, and research work.

In future papers it is hoped to present an analysis of line management jobs, to examine the relationship of time-span with salary, to describe the use of the time-span instrument for organizational design, and to examine the implications that the use of such an instrument has for personnel management and for work study in industry.

# EVIDENCE FOR PERMEABILITY MINIMA IN LOW-PRESSURE GAS FLOW THROUGH POROUS MEDIA

By Dr. D. M. GROVE and M. G. FORD

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FOR a gas flowing in a porous medium at a pressure such that $\lambda$, the mean free path of the gas molecules, is much less than $2r$, the mean pore diameter, it is well established[1] that there is a linear relationship between $K$, the permeability (cm.²/sec.), and $\bar{p}$, the mean pressure of the gas in the porous medium. Among the various equations put forward to represent such flow is that developed from the Kozeny equation by Carman and Arnell[2,3], which may be written as:

$$K = \frac{\varepsilon^3 \bar{p}}{k\eta A^2} + \frac{8}{3}\,\frac{\delta\varepsilon^2}{k'A}\sqrt{\frac{2RT}{\pi M}} \qquad (1)$$

where $\varepsilon$ = porosity (cm.³/cm.³) of the porous medium; $A$ = specific surface area (cm.²/cm.³) of the porous medium; $k$ = Kozeny constant (5·0); $k'$ = shape factor (2·0 to 2·5 for most porous media); $\eta$ = viscosity of the gas; $M$ = molecular weight of the gas; and $\delta$ = a coefficient of the order of unity.

All equations for slip flow are of the form[4]:

$$K = K_p\bar{p} + \delta K_k \qquad (2)$$

where $K_p$ is the Poiseuille (viscous) flow and $K_k$ is the contribution due to slip of the gas molecules at the pore walls[5]. The slip term is of the same form as the expression for Knudsen (molecular) flow, which for a porous medium may be written as[6]:

$$K_k = \frac{8}{3}\,\frac{\varepsilon^2}{A}\sqrt{\frac{2RT}{\pi M}} \qquad (3)$$