Meaning of 'Turnover' in Biochemistry

Hevesy[1] considers the determination of the rate of renewal, or turnover, as one of the most important applications of tracers. A clear definition of the term 'turnover' is therefore of obvious interest. In the present literature the term 'turnover' is used with two different meanings. This leads to confusion.

Zilversmit, Entenman and Fishler[2], and later other workers in Chaikoff's laboratory[3,4], use 'turnover-rate' as a synonym of rate of disappearance. According to this definition, turnover-rate has the dimension: amount/time. Siri[5], on the other hand, uses 'turnover-rate' as the reciprocal of turnover-time. According to his definition, therefore, turnover-rate has the dimension 1/time, that is, it is Zilversmit's rate divided by pool content.

Even though it may not have chronological seniority, Siri's terminology is preferable because it is more logical. We may speak of transfer-rate or exchange-rate from one pool to another, or rate of disappearance from one pool, and can say, for example, how many atoms (or grams) of phosphorus are exchanged per unit of time or disappear from a pool per unit of time; and the rate of turnover is the number of times a given pool of, say, phosphorus atoms is turned over, or is renewed, per unit of time. As the rate of turnover of a wheel (presumably the original for the analogy) is the linear velocity of the car divided by the circumference of the wheel, so the rate of turnover of a metabolic pool is the transfer-rate divided by the pool content.

If the concentration of tracer changes as a first-order process:

$$\frac{d\alpha}{dt} = k\alpha,$$

where α is concentration of tracer (that is, specific activity) and t is time, then k stands for the 'rate constant' in the terminology of chemical kinetics.

If the change in tracer concentration is the result of a transfer process with a constant rate of transfer, a (amount per unit time), from a constant pool content, A, then:

$$k = \frac{a}{A},$$

where a/A is the relative rate of transfer. Then,

$$\frac{\text{amount/time}}{\text{amount}} = \frac{1}{\text{time}}.$$

This relative rate of transfer tells what fraction of the pool content, A, is transferred per unit of time or, if a is larger than A, how often the pool content A is turned over per unit of time. This relative rate of transfer is therefore properly called 'turnover-rate'. Its reciprocal A/a shows how much time is required for one turnover of a pool of content A. This is the 'turnover-time'.

'Renewal-rate' is a synonym of 'turnover-rate', and a similar argument applies for its definition. In tracer work we do not study renewal of atoms but of pools, and the renewal-rate should show how many times a pool is renewed per unit of time.

It is suggested that for the sake of clarity in terminology, the term 'turnover-rate', or its synonym 'renewal-rate', be used exclusively as an index for the number of times the content of a pool turns over or is renewed, which is the reciprocal of time of turnover.

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Feulgen-negative Nuclear Division in *Habrobracon* Eggs after Lethal Exposure to X-Rays or Nitrogen Mustard

The females of the parasitic wasp *Habrobracon juglandis* (Ashmead) when well fed will store eggs in the first meiotic metaphase (metaphase-1) and retain them until the female is placed with the host[1]. The unfertilized eggs develop into viable haploid males. When the untreated egg is oviposited, meiosis proceeds and the pronucleus is formed 30 min. after oviposition at 30° C. The nuclei divide synchronously at the rate of approximately one division every 15 min. At the ninth or tenth cleavage stage (2½–3 hr. after oviposition) most of the nuclei migrate to the egg periphery. After two or three more divisions, cell membranes slowly form between the nuclei, and tissue differentiation begins. The embryo hatches about thirty hours after oviposition and feeds on the paralysed host.

In the present experiments, well-fed females were treated with X-ray exposures of 10 kr. (1·5 kr./min.) or an equivalent dose of nitrogen mustard (prophase-1 hatchability was criterion[2]). This exposure is approximately five times the lethal dose for metaphase-1 oocytes. The X-rays were delivered by a G. E. Maxitron-250 unit operating at 250 kVp., with a tungsten target and 1 mm. aluminium inherent and 3 mm. of aluminium added filtration (half-value layer, 0·55 mm. copper); the nitrogen mustard (kindly supplied by Merck and Co.) was delivered in the form of an aerosol. The subsequent development of eggs which were in metaphase-1 during the time of treatment was studied; the eggs were fixed in Kahle's fluid at various times after oviposition and were stained according to the Feulgen procedure after optimum hydrolysis in 1 *N* hydrochloric acid.

More than 95 per cent of the eggs treated with X-rays and all eggs treated with nitrogen mustard were identical in their developmental pattern. Meiosis proceeds at a normal rate, even when chromosome bridges are present. The first cleavage is partially inhibited, particularly but not specifically at metaphase, for one to two hours after oviposition—nuclear division then slowly proceeds until two to eight Feulgen-positive interphase or prophase nuclei are present, usually near the anterior end of the egg. At approximately the eighth hour after oviposition, ooplasmic areas can be seen within the yolky egg interior. These areas are ordinarily diagnostic for cleavage nuclei; but nothing definite can be recognized within them except for occasional spindle-like structures. By the ninth or tenth hour, Feulgen-