Table 1. Inhibition of HeLa cell growth by inclusion of tritium in culture medium. In all experiments with thymidine, the cells were grown for 24 hours in the presence of H^3TDR, and then in cold medium for an additional 48 hours. In the experiment with $H^3{}_2O$, the cells were merely grown for 48 hours in the tritium-containing medium. Each control medium was same as treated except that the tritiated thymidine was replaced by an equal amount of nonlabeled thymidine.

Expt. No.	H^3 vehicle	Medium (μc/ml)	Total cell counts* at end of expt. (cell/μl)		
			Control	Treated	p†
1	Thymidine	2.5	170 ± 12	90 ± 17	< .01
2A	Thymidine	2.5	662 ± 38	357 ± 19	< .01
2B	Thymidine	1.25	662 ± 38	406 ± 43	< .01
3A	Thymidine	5.0	1333 ± 191	747 ± 60	< .05
3B	Thymidine + carrier‡	5.0	1333 ± 191	1124 ± 51	> .3
4A	$H^3{}_2O$	5000	696 ± 15	328 ± 65	< .01
4B	$H^3{}_2O$	1000	696 ± 15	633 ± 68	> .3

* Indicated values are means ± standard errors.
† Significance level for difference between means of treated and controls.
‡ 17.5 μg of additional unlabeled thymidine per milliliter.

μc) was incorporated. There were about 2.5×10^5 cells per milliliter at zero time in this experiment. The HeLa cell nucleus does not appear to exceed 15 μ in diameter, so that the maximum volume of the nucleus is 2×10^3 μ^3. Therefore, the concentration of H^3TDR would be

$$1\ \mu c/2 \times 10^3 \times 2.5 \times 10^5\ \mu^3$$

or about 2×10^{-9} $\mu c/\mu^3$. In the experiment with $H^3{}_2O$, the concentration was 5 mc/ml, or 5×10^{-9} $\mu c/\mu^3$. This twofold difference is less than the error in our estimate of nuclear volumes. Therefore, the inhibition in this case, as in the case of external irradiation, can be reasonably attributed to nuclear damage caused by the β-radiation, and it is unnecessary to postulate special "hot atom" effects as used to explain the toxicity of P^{32} incorporated into the DNA of bacteriophage (5) or bacteria (6). It is of interest that 5 mc/ml of $H^3{}_2O$ (the concentration of $H^3{}_2O$ required for growth inhibition of HeLa cells) was found to reduce the mitotic index in regenerating liver by about 50 per cent (7). Water containing 5 mc/ml of tritium irradiates itself at the rate of 65 rep/hr.

These results imply upper limits of labeling for tracer applications of tritium. At the moment these limitations do not appear to be too stringent, for cells labeled at an inhibitory level reduce hundreds of silver grains per week, whereas a few grains per month are quite satisfactory for autoradiography. Nevertheless, the fact that the other radiobiological phenomena, such as chromosome breaks, mutations, and cancerogenesis, occur at much lower radiation levels than needed for gross inhibition of cell division should be borne in mind when interpreting results. The fact that tritium-labeled thymidine concentrates radioactivity in radiosensitive regions where it may remain a long time also demands extra caution in its handling. The radiotherapeutic possibilities of tritium incorporated within the nucleus are being further pursued (8, 9).

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Formula for Inferring Atmospheric Density from the Motion of Artificial Earth Satellites

A simple formula for inferring air density from satellite motion may be useful to workers in the field (1). To find such a formula, the density, ρ, is approximated near perigee by $\rho_\pi e^{-Kz}$, where ρ_π is the density at perigee, z is the altitude above perigee, and K is the logarithmic gradient of density

$$K = -2.3026\ (d/dz)\ \log_{10}\rho \qquad (1)$$

at perigee. An integral that appears in a basic analysis (2) of orbital effects of drag is then evaluated in terms of Bessel functions $I_0(Kae)$ and $I_1(Kae)$, where a is the orbital mean distance and e the eccentricity. The Bessel functions are expanded asymptotically, and there finally results an approximate formula by which ρ_π may be inferred from the rate of change, $\dot{P}$, of the period P and from certain other data. In practical units the formula is

$$\rho_\pi = -4.826 \times 10^{-15} \times \dot{P}\frac{m}{AC_D}\frac{c^{1/2}}{af(c,e)}\ \text{g/cm}^3 \qquad (2)$$

where $\dot{P}$ is in seconds per day; m is the satellite's mass in grams; A is the satellite's area in square centimeters projected on a plane normal to the direction of motion; C_D is the dimensionless aerodynamic drag coefficient, believed to be approximately 2; a is measured in earth radii of 6378 km; c is 6378 Kae if z, in Eq. 1, is in kilometers; and $f(c,e)$ is a function given approximately by

$$f(c,e) = 1 + 2e + (3e^2/2) + \frac{1 - 6e - 10.5e^2}{8c} + \frac{9 + 30e + 85.5e^2}{128c^2} + \ldots \qquad (3)$$

The first two terms alone in Eq. 3 appear to furnish the function to within an accuracy of about 10 percent, and the whole expression, to within a few percent, if e lies between 0.02 and 0.20 and K exceeds 0.01. The mean distance a may be inferred from P, and e and ae from a and r_π, the geocentric perigee distance in earth radii, by the equations:

$$a = (P/84^m.49)^{2/3}$$
$$e = 1 - r_\pi/a$$
$$ae = a - r_\pi$$

The numerical coefficient in Eq. 2 is the reciprocal of $3(\pi/2)^{1/2}$ times the number of seconds in a day times the earth's radius in centimeters. An average value of the A of a nonspherical satellite should be used in Eq. 2, and if all orientations are equally frequent and the satellite is convex, its average A is one-fourth of its total superficial area. The value of K, somewhat dependent on perigee height, can be approximated by applying Eq. 1 somewhat above perigee to a model atmosphere like the ARDC (3). Alternatively, K may be determined without reference to assumed models by applying Eq. 2 to two or more satellites with different perigee heights and adjusting K until it is consistent with the resulting perigee densities.

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