(wet weight 0.5 g) survived for weeks in running sea-water. The function of the egg-case for the entire 1.5-to-2 year period is protection of the embryo and the external yolk sac from injury; only when the external yolk sac is completely absorbed does the young skate hatch. In contrast to the transient existence of "embryonic hemoglobin" in the oviparous skate, the ovoviviparous shark *Squalus suckleyi* has a distinct fetal hemoglobin throughout its 23-month gestation period (*10*).

The widespread phylogenetic distribution of the ability to synthesize a fetal or embryonic hemoglobin of high oxygen affinity in egg-laying vertebrates (skate, bullfrog, terrapin, and chicken) represents a biochemical "preadaptation" (*11*) which has made possible the development of the oxygen-transfer system involved in the diffusion of oxygen from maternal to fetal blood (*1*) in the polyphyletic evolution of ovoviviparty and viviparity in many vertebrate groups.

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6. I wish to thank J. P. Baumberger and S. Gross for helpful discussion, and C. Hickman, F. L. Hisaw, F. L. Hisaw, Jr., W. S. Hoar, and P. Sund for provision of egg-cases and assistance in catching and bleeding large skates. These studies were made while I was a National Science Foundation fellow. The oxygen equilibrium of skate hemoglobin was evaluated as in a study on hemerythrin [C. Manwell, *Science* 127, 592 (1958)], a model DU Beckman spectrophotometer being used. Erythrocytes were suspended in an isotonic phosphate buffered urea-containing elasmobranch Ringer's solution, modified after the method of C. F. A. Pantin [*Notes on Microscopical Technique for Zoologists* (Cambridge Univ. Press, Cambridge, 1948)].
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9. J. P. Baumberger, *Cold Spring Harbor Symposia Quant. Biol.* 7, 195 (1939).
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11. The term "preadaptation" is being used in the sense of "prospective adaptation" [G. G. Simpson, *The Major Features of Evolution* (Columbia University Press, New York, 1953), especially pp. 188–198].

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Density of the Upper Atmosphere

An atmospheric density at an altitude of about 368 km has been inferred from the orbital behavior and physical characteristics of the American artificial earth satellite Explorer I, also denoted as 1958 Alpha. The orbital data as of 1 February 1958 were (*1, 2*): eccentricity, 0.139; inclination, 33°.2; argument of perigee, 120°.0; anomalistic period, $0^{d}.0798274$; decrease of period 3.9×10^{-7} day per period or about $0^{s}.42$ per day. From these one finds a mean distance of 1.22757 earth radii, corresponding to a perigee height above the international ellipsoid of 368 km.

The satellite is a cylinder 80 in. long and 6 in. in diameter, and it has a mass of about 14 kg (*3*). The area of such an object that is relevant to its air resistance is its area projected on a plane normal to its direction of motion. The average over all possible orientations, for random tumbling, is one fourth of the total superficial area, or 2520 cm^2. The same value is obtained if the cylinder spins about a transverse axis, randomly oriented with respect to the orbit plane. Averaged over a spin period, over orientations of the spin axis with respect to the orbit plane, and over the motion of perigee, the same projected area has been obtained as for random tumbling, and has been employed. The aerodynamic drag coefficient has been taken to be 2. The density has been inferred by a method described elsewhere (*4*) from this value, the mass, the average area, the eccentricity, the mean distance, the rate of decrease of period, and the logarithmic derivative of density near perigee given by the ARDC model atmosphere (*5*).

The density thus found, 1.5×10^{-14} g/cm^3 at a geometric altitude of 368 km (348 geopotential) is about 14 times that predicted by the ARDC model atmosphere. It falls nearly on the middle curve, No. 2, in a study (*6*) that tentatively suggested a modification of the ARDC atmosphere to satisfy a density 4.5×10^{-13} g/cm^3 at 220 km (213 geopotential) that had been inferred (*7*) from observations of the U.S.S.R. satellite 1957 Alpha 2. This value was about 9 times the ARDC density. The values 4.5×10^{-13} and 1.5×10^{-14} g/cm^3 depend somewhat on the gradients of density of the ARDC model employed in the reductions. It seems better to infer the densities at both altitudes from the observations without recourse to model atmospheres, and to proceed by successive approximations until the gradients and densities are consistent. In this way, from the observations of both satellites together, densities have been inferred of about 4.0×10^{-13} g/cm^3 at 220 km and about 1.4×10^{-14} g/cm^3 at 368 km. These values do not agree well with densities predicted by Harris and Jastrow (*8*) as extrapolations from altitudes of about 220 km and below, but they seem to be in surprisingly good agreement with curve No. 2 of reference (*6*).

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References and Notes

1. These data were kindly provided (*2*) by Dr. Charles A. Whitney of the Smithsonian Astrophysical Observatory from an analysis of Moonwatch (visual) and Minitrack (radio) observations.
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6. T. E. Sterne, G. F. Schilling, *Smithsonian Astrophys. Observatory Spec. Rept. No. 7, IGY Project No. 30.10* (1957), Fig. 2.
7. T. E. Sterne and G. F. Schilling, *Smithsonian Astrophys. Observatory Spec. Rept. No. 3, IGY Project No. 30.10* (1957).
8. I. Harris and R. Jastrow, *Science* 127, 451 (1958).

24 March 1958

Density Determinations Based on the Explorer and Vanguard Satellites

Minitrack observations on the orbits of Explorer I and Vanguard I permit us to make a rough determination of the density of the atmosphere at latitudes between 33°N and 33°S (*1, 2*). Our analysis is based on the orbit elements and rate of change of period obtained from Minitrack data for these satellites by the Vanguard Computing Center. The change in period is the direct result of the drag exerted by the atmosphere, which causes the satellite to lose energy continuously during its lifetime. As the energy of the satellite decreases, it falls towards the center of the earth,

Table 1. Orbital periods for Explorer I, derived by the Vanguard Computing Center from Minitrack data. The third column gives the average value of dP/dt, obtained from the tabular differences in the first and second columns.

Date	P (min)	dP/dt (min/day)
5 Feb.	114.95	
		0.0073
2 Apr.	114.54	
		0.0097
2 May	114.25	
		0.0150
17 May	114.13	
Weighted av. (min/day)		$(9^{+6}_{-2}) \times 10^{-3}$
M/C_dA		(24 ± 8) kg/m^2

reducing its average altitude and therefore the time required to complete each circuit. Detailed calculations, based on the equations of satellite motion, then determine the quantitative relation between the reduction in the period and the average air density in the orbit.

Since the density falls off very rapidly with increasing altitude, the average density in the orbit is heavily weighted by the contributions near perigee. Our calculations indicate that for both satellites, as also in the case of Sputnik I (*3*), the rate of change of period actually determines the density at an altitude approximately 50 km above perigee.

Tables 1 and 2 list the anomalistic periods and corresponding rates of change of period for the Explorer I and Vanguard I satellites, as issued by the Vanguard Computing Center. The tables also give the estimated values of the ballistic drag parameter, M/C_dA (M = satellite mass, A = satellite area projected along the direction of motion, and C_d = drag coefficient). We note that the observed rate of change of period determines only the ratio of the density to the ballistic drag parameter, hence a knowledge of this parameter is essential for the density analysis. The large probable error indicated in the value of M/C_dA for Explorer I represents the uncertainty in the cross-sectional area of that satellite. Explorer I has a cylindrical shape with a length of 203 cm and a radius of 7.3 cm, and the maximum and minimum values of its projected area may therefore vary by a factor of 20, depending on the orientation of the cylinder relative to the direction of motion. In our analysis the projected area is estimated by averaging over all orientations of the satellite, but a proper calculation of the effective area is extremely complicated in the present case because the motion of Explorer I about its center of mass cannot be properly described by either a random tumbling or a uniform precession about a fixed spin axis (*4*). We consider our estimate of the projected area to be uncertain by a factor of 2.

Table 3 gives the densities which we obtain from the time-weighted averages of dP/dt in Tables 1 and 2, together with the altitudes to which these densities refer. The probable errors in the average density represent the combined effects of the uncertainty in area and the variations in dP/dt during the period covered by the observations. The densities in Table 3 correspond to a mean scale height of (73 ± 10) km and a mean temperature of $1250° \pm 200°$K for the region between 400 and 700 km.

Although the density value based on Explorer I has a large probable error, this result is still of substantial interest because, when it is combined with the Vanguard I density, it gives us an indication of atmospheric conditions in a latitude region not covered by the results from Sputnik I and the earlier rocket flights. The perigee of Sputnik I was located at a latitude of $39° \pm 6°$N during the period on which the density analysis of that satellite was based, and the rocket data which we combined with the sputnik value were obtained at latitude 33°N. On the other hand, the orbits of the Explorer and Vanguard satellites are confined to the region centered on the equator and lying between 33°N and 33°S. Since perigee rotates at the rate of 6° per day in the orbital planes of these satellites, the average densities for the intervals covered in Tables 2 and 3 constitute a thorough sampling of all latitudes in this region. Thus the combination of rocket and Sputnik I data describes a temperate-zone atmosphere, while the Explorer and Vanguard results refer to a band of latitudes centered about the equator.

According to recent results of LaGow at 200 km (*5*), the summer day-time density at 59°N is 8 times the corresponding density at 33°N. We expect comparable differences between the present results and our earlier model for temperate latitudes, but in fact the densities of Table 3 are only 30 to 50 percent less than the lower limit of probable error in the temperate zone atmosphere (model *a* of reference *2*). Presumably the comparison must also allow for diurnal and seasonal variations, which are as yet very poorly determined.

As a corollary to the preceding remarks, it is interesting to note that because of the strong latitude dependence of upper atmosphere densities, we cannot compare density determinations based on the orbits of the present United States satellites with those obtained from U.S.S.R. satellites.

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Table 2. Orbital periods for Vanguard I, derived by the Vanguard Computing Center from Minitrack data. The third column gives the average value of dP/dt, obtained from the tabular differences in the first and second columns.

Date	P (min)	dP/dt (min/day)
1 May	134.277	
		$(3.0 \pm 0.5) \times 10^{-4}$
7 June	134.266	
		$(2.8 \pm 0.8) \times 10^{-4}$
25 June	134.261	
Weighted av. (min/day)		$(3.0 \pm 0.6) \times 10^{-4}$
M/C_dA		(24 ± 8) kg/m^2

Table 3. Densities derived from satellite data.

Altitude (km)	Density (g/cm^3)
405 (Explorer I)	$9^{+6}_{-4} \times 10^{-15}$
720 (Vanguard I)	$(1.2 \pm 0.3) \times 10^{-16}$

References and Notes

1. We are very much indebted to W. F. Cahill and C. Wade, Jr. for their cooperation in carrying out the necessary computations on the IBM 704 computer at the National Bureau of Standards.
2. These data have also been analyzed by J. W. Siry, in a paper to be presented at the Fifth CSAGI Assembly (Moscow, 1958), and in the IGY reports of the Smithsonian Astrophysical Observatory by T. E. Sterne (*SAO IGY Rept. 11, p.* 18), L. G. Jacchia (*SAO IGY Rept. 12,* p. 30), and G. F. Schilling and T. E. Sterne (*SAO IGY Rept. 12,* p. 37).
3. I. Harris and R. Jastrow, *Science* 127, 471 (1958).
4. The use of the average cross section is clearly appropriate for random tumbling. If the cylinder spins about a fixed axis the average will still be applicable to observations spread over a period of one or more months, because of the rapid motion of the perigee in the orbital plane. In fact, however, the spin axis of Explorer I is not fixed. This satellite is aerodynamically stable, and air drag exerts a torque about its center of mass on each passage through perigee, tending to align the spin axis with the direction of motion at perigee.
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Growth Promotion in Pea Epicotyl Sections by Fatty Acid Esters

The growth of excised pea epicotyl sections is less than that of a similar section left on the intact plant, even if optimum concentrations of indole acetic acid (IAA), gibberellic acid (GA_3) (*1*), sucrose, and cobalt (*2*) are supplied. In an investigation (*3*) of this failure of excised sections to grow optimally, fatty acid esters have been found to bring about section growth promotions much larger than any previously reported in this standard auxin bioassay material.

The peas used were the customary bioassay variety, Alaska, and the dwarf variety, Laxton's Progress. The technique utilized was essentially that of Christiansen and Thimann (*4*), except that ten 10-mm sections were employed in 20 ml of solution, a rotary shaker was employed, the *p*H was 5.5, and, in the case of the dwarf pea, sections were cut at 6 days of age. Since it is especially necessary that the dwarf pea receive a standard amount of red light during development, a continuous illumination of about 0.3 erg/cm^2/sec was supplied from a 1-watt neon bulb filtered through ⅛-inch thick pieces of No. 2444 red and No. 2082 green Plexiglas.

Pea sections so prepared showed a large increase in growth over that of con-