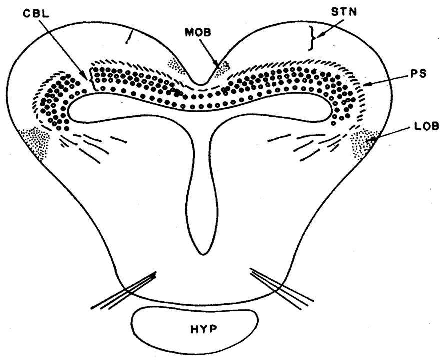

Fig. 1. Transverse section of the tectum of the frog at the level of the oculomotor nerves. CBL, cell-body layers; MOB, medial optic bundle; STN, superficial tectal neuropil; PS, palisade stratum; LOB, lateral optic bundle; HYP, hypophysis.

show position on the retina according to the cartography of Gaze (*3*).

The first layer of terminals is formed by those elements each of which is sensitive to moving or maintained contrast within its receptive field. The sharper the contrast, the better the response. These are equivalent to Hartline's (*4*) and Barlow's (*5*) "on" fibers. The second layer is made up of terminals of units each of which detects a moving or recently stopped boundary within its receptive field, provided there is a net positive curvature of the edge of the darker phase. Such a fiber will not respond, for example, to a straight-edge boundary moving across its receptive field or to a preestablished edge within that field. Both of these strata represent the endings of the unmyelinated fibers of the optic nerve.

The third layer is made up of terminal bushes from "on-off" fibers.

The fourth layer is composed of endings from "off" fibers.

The layers of endings are distinct in depth, and with the exception of the first and second layers they rarely merge at the transition zones. In this conspicuous order, both along the surface and in the depths, the area of the retina "seen" from any point in the superficial neuropil is, at most, 10° in radius. Most of the ganglion cells whose terminals appear at that point are crowded toward the middle of that area.

For the purpose of testing Sperry's hypothesis of the specific regrowth of the optic fibers after section of the optic nerve, we cut one optic nerve in several adult frogs *(Rana pipiens)*, ensuring the complete separation of the two stumps. At the end of 2 months the first signs of visual recovery were apparent, but full use of the eye did not occur for another month. When the visual recovery seemed complete, we exposed the colliculi and tested the initially deafferented colliculus for mapping of the retina. We found that the map had been regenerated along the surface, although the ganglion cells from whose terminals we were recording at any point were now spread over an area about two times as large as normal. The separation of operations in depth was also restored, and there was no sign of confusion between the operational layers.

The specific regrowth of the terminals to their proper stations cannot be explained by saying that an initial orderly array of fibers in the optic nerve crudely orders the fibers again at the time of regeneration. The fibers in the nerve simply are not in order *ab initio*. Any two contiguous fibers can come from the most widely separated points on the retina (*2, 6*).

This finding strongly supports Sperry's hypothesis that optic-nerve fibers grow back to their original destinations. They do so in an even more highly specific way than he proposed; the regrowth of the termini is also proper in depth (*7*).

Note added in proof. After this manuscript was prepared we noted that R. M. Gaze, of the University of Edinburgh, has presented to the Physiological Society similar findings in *Xenopus laevis* (*8*). He, however, has not studied the reconstitution of the distribution in depth of the optic fibers.

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5 August 1959

Lunar and Solar Perturbations on Satellite Orbits

Abstract. Calculations of the solar and lunar effects on highly eccentric satellite orbits show that the sun and the moon may cause large changes in perigee height over extended periods of time. The amplitude and sign of the perigee height variations depend on the orbit parameters and the hour of launch; for a typical orbit and various choices of launch time, the perigee height will either rise or fall at the rate of 1 km/day over the course of several months. These results may be significant in deciding the launch conditions for future satellites with highly eccentric orbits.

A refinement of earlier computations on the orbit of the Vanguard I satellite has revealed the presence of a very slow variation in perigee height, with a period of 449 days and an amplitude of about 2 km. Kozai has suggested recently that a term of this period and amplitude will result from a combination of lunar and solar perturbations on that satellite (private communication). Kozai and Whitney have extended their calculations to the case of the paddle-wheel satellite, Explorer VI (Kozai, New York *Times*, 21 Aug. 1959). Explorer VI has an apogee of 48,700 km, a perigee of 6640 km, and an orbital inclination of 47.3° to the equator. Kozai and Whitney find that the highly eccentric orbit of this satellite produces substantial lunar and solar perturbations which decrease the perigee altitude rapidly, shortening its lifetime from several decades to a probable value of 2 years.

The very interesting work of Kozai and Whitney has encouraged us to explore further the possible lunar and solar effects on perigee height for satellite orbits of large eccentricity. We find that in general both the eccentricity and the perigee height vary with time as a result of these effects. The amplitudes, frequencies, and relative phases of the variations are determined by the orbit parameters and the hour of launch. For a special set of launch conditions, and for representative orbit parameters, the perigee height may be made to rise steadily over the course of several years at a rate of approximately 1 km/day. Thus the sun and the moon may provide a substantial perigee boost for the satellite under properly chosen circumstances. For other conditions the perturbations may be minimized to obtain a relatively stable orbit. These considerations may be of importance in deciding the launch programs for future satellites with highly eccentric orbits.

As a basis for our calculations we have used a convenient series development by Musen, which is equivalent to that of Kozai to our degree of accuracy.

In Musen's results the solar and lunar potentials appear as sums of trigonometric terms, whose arguments are combinations of the angles λ, ω, Ω, defined as follows: λ = mean longitude in orbit; ω = mean argument of perigee, measured from the line of the ascending node; Ω = mean longitude of the ascending node. When these symbols appear without subscripts they refer to the satellite; otherwise they refer to the sun or moon, as indicated by the subscripts e and m.

From the perturbing potentials we find the rate of change of perigee height by the method of variation of constants.

The results of the calculation are expressed most simply, in their dependence on the orbit elements, when the latter are defined with respect to the plane of the ecliptic. In terms of these elements, we can recognize five principal effects on the perigee height. Of these, four are resonances associated with the following conditions:

$$2\dot{\omega} - 2(\dot{\lambda}_e - \dot{\Omega}) = 0 \qquad (1a)$$

$$2\dot{\omega} + 2(\dot{\lambda}_e - \dot{\Omega}) = 0 \qquad (1b)$$

$$2\dot{\omega} - (\dot{\Omega}_m - \dot{\Omega}) = 0 \qquad (1c)$$

$$2\dot{\omega} + (\dot{\Omega}_m - \dot{\Omega}) = 0 \qquad (1d)$$

where $\dot{\omega}$, $\dot{\lambda}$, $\dot{\Omega}$, are the average angular velocities of ω, λ, Ω, respectively.

These resonance conditions have a simple interpretation. For example, in case 1a $(\lambda_e - \Omega)$ represents the longitude of the sun relative to the line of nodes, and ω, the position of the perigee in the orbital plane, is also defined relative to the lines of nodes. Therefore, in a system in which the line of nodes is fixed the satisfaction of the resonance condition (case 1a) signifies that the mean angular velocities of sun and perigee are equal—that is, the line of apsides follows the sun. In this circumstance the orbital perturbation produced by the sun is clearly maximized.

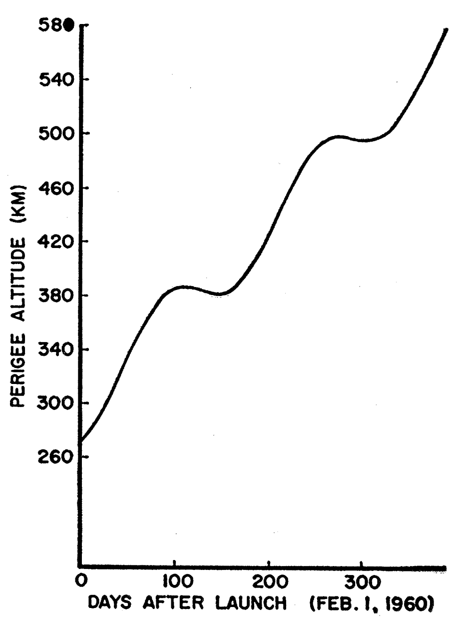

Fig. 1. Rate of change of perigee.

In case 1b the sun and the line of apsides have the same period of revolution, but opposite directions. Again it is clear that the solar perturbation will be maximized. Cases 1c and 1d represent similar resonances keyed to the motion of the moon's orbital plane. The fifth effect is produced by the perturbations of the sun and moon averaged over many periods of revolution of these bodies. This term has a period of $2\pi/2\dot{\omega}$, or approximately 800 days for the case of Explorer VI.

We return now to the quantitative treatment of the perturbations. Let q be the perigee distance from the center of the earth. The rate of change of q is then found to have the following form:

$$\frac{dq}{dt} = + A_1 \sin(2\omega + 2\Omega - 2\lambda_e) + A_2 \sin(2\omega - 2\Omega + 2\lambda_e) + A_3 \sin(2\omega + \Omega - \Omega_m) + A_4 \sin(2\omega - \Omega + \Omega_m) + A_5 \sin 2\omega$$

The coefficients A_i depend on the size and shape of the orbit and on its inclination to the plane of the ecliptic. As this inclination varies, the relative importance of each term changes.

The effects on perigee height may be maximized or minimized by choosing suitable values of the orbital inclination and the time of launch. Long period effects occur when the inclination to the equator is near 63.4°—the critical angle at which there is no motion of the argument of perigee. At this inclination the 2ω term increases steadily with time. For an orbit with an apogee of 46,550 km and perigee of 6650 km the rate of change of perigee is approximately 1 km/day, as shown in Fig. 1. The sign and precise magnitude of the rate of change depend on the initial argument of perigee. The hour of launch does not affect this result.

At angles of inclination other than 63.4°, a variety of effects may be obtained by a suitable choice of the hour of launch. Selecting the hour of launch is equivalent to selecting Ω, the longitude of the ascending node, with any value available once in 24 sidereal hours. In Fig. 2, using the same apogee and perigee as in Fig. 1, an argument of perigee equal to 135°, and an equatorial inclination of 28° for 1 Feb. 1960, we show the results of three different choices of launch time. Curve A corresponds to a launch time of 7 hours U.T. on 1 Feb., curve B to 23 hours U.T., and curve C to 13 hours U.T. Cases A and C demonstrate rapid initial variations of perigee height. Case B represents a relatively stable orbit.

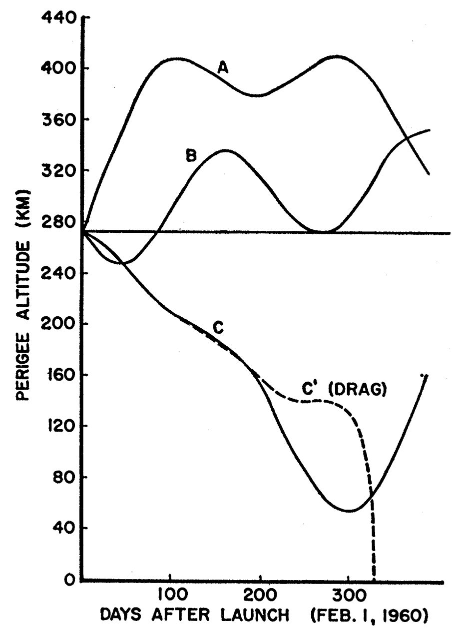

Fig. 2. Results of three different choices of launch time.

Curve C' represents the addition of drag to case C. It rises initially above the solar and lunar perturbation curve because the drag decreases the period and the eccentricity and these changes in turn decrease the solar and lunar perturbations. It is interesting to note that for a satellite with the parameters of Fig. 2, the lifetime is 25 years in the absence of lunar and solar perturbations, and approximately 1 year when they are included.

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Fat and Growth during Childhood

Abstract. Fat thickness, size, and maturity status are significantly correlated from 1.5 through 11.5 years in both sexes. Children who are fatter than their contemporaries at 8.5 to 9.5 years reach menarche earlier and complete epiphysial union sooner.

On the basis of available evidence an association would be expected between the amount of stored fat and size and maturity status in children during the growing period. Boys and girls from well-nourished populations are of greater