synthesis to be completed in frogs at this temperature (*6*). Most of the 11-*cis* vitamin A therefore accumulates only *after* the opsin in the rods has been converted to rhodopsin.

The 11-*cis* isomer of retinene or vitamin A is formed from the all-*trans* isomer, probably exclusively in the eye (*4*). The present experiments show that in the frog this isomerization occurs in the dark. The same mechanism presumably operates in the light. However, in darkness the 11-*cis* isomer is initially used for rhodopsin synthesis up to the limit set by the opsin content of the eye (about 0.7 μg equivalent of vitamin A in these animals), and then an excess is stored as 11-*cis* vitamin A. In the light, on the other hand, rhodopsin bleaches, yielding all-*trans* retinene, whereas 11-*cis* retinene is continuously used for its resynthesis. This, in effect, constitutes a mechanism for converting 11-*cis* to all-*trans* retinene. The ocular content of 11-*cis* vitamin A is therefore depleted in the light, and replenished in darkness.

A specific enzyme concerned with isomerizing retinene—retinene isomerase—has been identified in the eyes of cattle and frogs (*7*). It does not act directly on vitamin A. In the dark, it catalyzes the isomerization of all-*trans* or 11-*cis* retinene to an equilibrium mixture containing both isomers in the approximate proportion 95 : 5. Light displaces the equilibrium in favor of the 11-*cis* isomer, but this probably does not occur in vivo for reasons which have been discussed elsewhere (*7, 8*).

The proportion of 11-*cis* vitamin A stored in the dark-adapted eye far exceeds what one would expect from the "dark" equilibrium catalyzed by retinene isomerase. If this is the enzyme involved, special mechanisms must be present for trapping or otherwise stabilizing the 11-*cis* isomer. Such trapping could involve the binding of 11-*cis* vitamin A by specific proteins, or its selective esterification (see *3, 9*). There is as yet no evidence that either process operates in the eye. Indeed, it is entirely possible that additional pathways exist for isomerizing all-*trans* vitamin A or retinene to the 11-*cis* configuration (*10*).

Table 2. Percentage of 11-*cis* vitamin A in eyes of frogs (groups A and B), dark or light adapted as described in Table 1. Free vitamin A was extracted as has been described, and the percentage of 11-*cis* vitamin A was determined by isomerization with iodine in the dark (*11*), or upon illumination (*3*). The percentage of 11-*cis* vitamin A in the light-adapted animals represents a steady state value, which is not changed appreciably by prolonging the light adaptation.

Exp.	Percentage of 11-*cis* vitamin A	
	Dark adapted	Light adapted
A-1	19	11.5
A-2	27	7
B-3	27.5	12
B-4	23	8
Av.	24	10

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References and Notes

1. R. Hubbard and G. Wald, *J. Gen. Physiol.* **36**, 269 (1952-53).
2. G. Wald, *ibid.* **19**, 351, 781 (1935-36).
3. N. I. Krinsky, *J. Biol. Chem.* **232**, 881 (1958).
4. G. Wald and P. S. Brown, unpublished observations.
4a. *Note added in proof:* Such an exchange of vitamin A between retina and pigment epithelium has now been demonstrated experimentally in albino rats by John Dowling in this laboratory.
5. G. Wald, *Exptl. Cell Research, Suppl.* **5**, 389 (1958).
6. M. Zewi, *Acta Soc. Sci. Fennicae* **B2**, No. 4 (1939).
7. R. Hubbard, *J. Gen. Physiol.* **39**, 935 (1955-56).
8. W. A. H. Rushton, *ibid.* **41**, 419 (1957-58).
9. N. I. Krinsky and J. Ganguly, *J. Biol. Chem.* **202**, 227 (1953).
10. This research was supported in part by grants to George Wald from the Rockefeller Foundation and the National Institute for Neurological Diseases and Blindness, National Institutes of Health (grant No. B 568 C 3, 4), and by a summer stipend to one of us (A.D.C.) from the National Science Foundation.
11. R. Hubbard, *J. Am. Chem. Soc.* **78**, 4662 (1956).

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North-South Asymmetry of the Earth's Figure

O'Keefe, Eckels, and Squires (*1*) have reported that a periodic variation of the eccentricity of the orbit of Vanguard satellite 1958β_2, which coincided in period with the revolution of the line of apsides, indicates a third zonal harmonic in the geoid—that is, a north-south asymmetry in the earth's figure; the Northern Hemisphere has a longer axial semidiameter but a smaller mid-latitudinal semidiameter than the Southern Hemisphere—that is, the earth is slightly pear-shaped. Earlier, King-Hele and Merson (*2*) had suggested that a north-south asymmetry might explain perturbations observed in the orbit of sputnik 2. O'Keefe *et al.* conclude that the asymmetry "indicates a very substantial load on the surface of the earth" and further that it is contrary to the view of Heiskanen and Vening Meinesz (*3*), and of geodesists generally, that the earth's gravitational field is very nearly that of a fluid in equilibrium.

Neither of these conclusions necessarily follows from the new figure, which can be reconciled with the Heiskanen and Vening Meinesz concept if it is assumed that the mean density of the mantle in the Southern Hemisphere is a little less than that in the Northern. Such a density variation is consistent with recent tectonic hypotheses based on an expanding earth (*4, 5*).

In an analysis of the first-order deformations of the earth's surface, I have concluded that, contrary to the commonly accepted hypothesis of contraction, the earth is an expanding body, that it has been expanding since before the Cambrian period, that the rate of expansion has been increasing with time, that since the beginning of the Mesozoic era the Southern Hemisphere has expanded substantially more than the Northern Hemisphere, and finally that the rotational consequences of the differential expansion have resulted in a first-order shear system between the Northern and Southern Hemispheres which has determined the pattern of post-Palaeozoic orogenesis.

According to the expanding earth hypothesis, less dense mantle and a geoid surface above the theoretical spheroid might be expected in areas of post-Palaeozoic orogenesis and below "new" oceans (Arctic, Atlantic and Indian oceans, the Mediterranean Sea, and the Pacific Ocean west of the Andesite line), and a geoid depressed below the spheroid and regionally denser mantle might be expected under the older continental blocks and the older oceanic segments (about half of the present Pacific Ocean). Taken collectively, these large areas of one-sign anomaly would produce a geoid which would be pear-shaped when generalized to the third zonal harmonic. They would also produce the semblance of triaxiality which has been found empirically by many

Fig. 1. Fold pattern of the Malaspina Glacier in plan (width of lobe, 25 km).

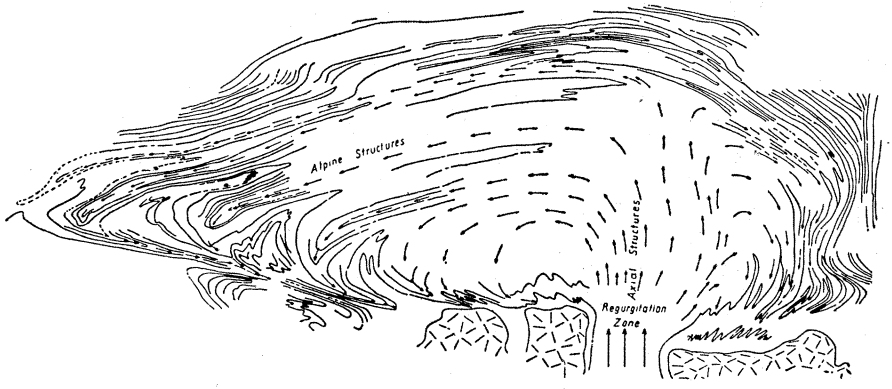

Fig. 2. Fold pattern of asymmetric orogen in cross section.

geodesists. These departures of the geoid from a rotational spheroid would still be in approximate fluid equilibrium and would not imply crustal loads of the order claimed by O'Keefe and his coauthors. They would cause a polar wandering with rheid adjustment until the rotation axis coincided with the maximum inertia axis. This also clears up the conflict reported by Munk (*6*) who found that, in the absence of such asymmetries, the pole should have migrated to Hawaii and, on accepted values for viscosity, should have arrived there within 10^5 years, whereas the palaeomagnetic data indicate that the pole has been moving slowly in the opposite direction and has not been far from its present position since the early Tertiary.

Crustal contraction has been axiomatic for so long that an expanding earth is still liable to rejection as irresponsible heresy. Originally the hypothesis of earth contraction stemmed from the idea of a cooling earth. Although this basis has long since been removed, and more recently reversed (*7*), geologists have still clung to contraction because of the false notion that the folding so universally observed in rocks necessarily indicates crustal shortening, even though I showed (*8*, p. 93) that complex folds of the type found in the hearts of orogens do not necessarily imply shortening. More recently (*4*, *5*) I have pointed out that at all but those shallow zones where the overburden load is less than the unconfined compressive strength, crustal extension yields a triaxial stress ellipsoid with all stresses positive, an environment which may produce boudins and tectonite fabrics and conjugate shears typical of orogenic zones, and further that even megastructures such as the orogens themselves do not necessarily imply crustal shortening. Figure 1 shows the fold pattern of the Malaspina Glacier, traced directly from Sharp (*9*), and Fig. 2 shows a typical cross-section of an asymmetric orogen such as the Alps, with a steep root zone and recumbent folds and nappes, with immense horizontal transport. However, Fig. 2 is drawn from Fig. 1 simply by up-ending it and reducing the ratio of the vertical and horizontal scales to simulate the flattening effect of gravity. Both the Malaspina Glacier in plan and the Alpine orogen in section exhibit similar features of fold and overthrust patterns, and in both the deformed material has developed complex tectonite fabrics, but whereas the lobe of the Malaspina Glacier has visibly increased in width tenfold during the generation of the folds, the Alpine orogen is imagined to have been reduced in width by a comparable order!

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References

1. J. A. O'Keefe, A. Eckels, R. K. Squires; *Science* **129**, 566 (1959).
2. D. G. King-Hele and R. H. Merson, *J. Brit. Interplanetary Soc.* **16**, 471 (1958).
3. W. A. Heiskanen and F. A. Vening Meinesz, *The Earth and Its Gravity Field (McGraw-Hill)*, New York, 1958), pp. 72, 73.
4. S. Warren Carey, "The tectonic approach to continental drift," *Continental Drift—a Symposium* (Univ. of Tasmania, Hobart, 1958), pp. 177–355.
5. ———, "The tectonic approach to the origin of the Indian Ocean," *Proc. 3rd Pan Indian Ocean Sci. Congr., Tananarive, Madagascar, 1957*, in press.
6. W. H. Munk, *Geophysica* **6**, 335 (1958).
7. H. A. Lubimova, *Geophys. J.*, **1**, 115 (1958).
8. S. Warren Carey, *J. Geol. Soc. Australia*, **1**, 57 (1953).
9. R. P. Sharp, *Bull., Geol. Soc. Am.*, **69**, 617 (1958).

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The hypothesis of fluid equilibrium does not seem to be consistent with Carey's suggestion that the density in the mantle in the Southern Hemisphere is less than that in the Northern.

Since the density varies with depth, the two hemispheres can be compared only at corresponding depths—that is, on corresponding geopotential surfaces. But the condition of fluid equilibrium demands that the density on a given geopotential surface be constant. If it is not, then the pressure, which is the weight of the overlying mass, will be greater in those regions where the density is greater. This will cause the heavier fluid to move out laterally and underrun the lighter fluid everywhere, until perfect stratification is brought about.

Heiskanen and Vening Meinesz point this out, remarking on the subject of fluid equilibrium:

"The condition to be fulfilled is that all equipotential surfaces be at the same time surfaces of equal density" (*1*).

Jeffreys makes the same point (*2*). The result is very well established. It is impossible to have hydrostatic equilibrium at the same time that the density is less at a given depth in the Northern Hemisphere than in the Southern Hemisphere.

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References

1. W. A. Heiskanen and F. A. Vening Meinesz, *The Earth and Its Gravity Field* (McGraw-Hill, New York, 1958), p. 55.
2. H. Jeffreys, *The Earth* (Cambridge Univ. Press, Cambridge, ed. 3, 1952), p. 137

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Instatement of Stuttering in Normally Fluent Individuals through Operant Procedures

Abstract. Normally fluent subjects were required to read from printed pages, and a recording was made of nonfluencies until a stable rate was established. A persistent shock was then introduced. Its cessation for a limited period was made contingent upon nonfluency. Chronic stuttering was instated and eliminated as a function of the change in stimulus.

In operant conditioning, the response is brought under stimulus control through the arrangement of consequences explicitly contingent upon the response (*1*). In a previous study, stuttering responses by chronic stutterers from a speech clinic were brought under stimulus control to a considerable extent by this procedure (*2*). When each stuttering response was followed by noxious stimuli, stuttering was attenuated, and when, with the same subjects, each stuttering response temporarily eliminated these stimuli, the stuttering rate rose.

Stuttering has often been considered an emotional blocking; it can, however, be regarded as a unit of verbal behavior (*3*); that is, breaks, pauses, repetitions, and other nonfluencies can be considered operant responses, having in common with other operants the characteristic of being controllable by