lines could be obtained. For checking the accuracy of the pulse counter, an additional set of precordial electrodes was applied and connected by long lead wires to a direct-writing electrocardiograph. The *R*-wave counts on the electrocardiogram have been compared with 3000 heart beats recorded by the pulse counter. Check periods include 15 minutes of vigorous exercise, 15 minutes lying in various positions, and the remaining time sitting and walking. During three consecutive 24-hour counts on one of us (D.A.R.), check electrocardiograms were obtained eight times at 8- to 12-hour intervals. The differences between pulse counter counts and electrocardiogram *R*-wave counts ranged from 0.1 to 3.8 percent with a mean of 1.3 percent. (The error in reading the pulse counter dial is up to ± 5 heart beats at the beginning and at the end of a test period. A difference up to 0.3 percent between the two methods for counting 3000 heart beats could, therefore, be expected.) Similar results have been obtained during 24-hour counts on one other man and on two women, all between the ages 32 and 36. During many additional check periods, the pulse counter has functioned with a similar degree of accuracy in men and women in other age groups.

When the pulse counter was used for 24-hour counts, a log of standard time, pulse counter time, and activity was kept, with entries made at about hourly intervals during waking hours. The three consecutive 24-hour counts noted above were 117,000, 115,000 and 122,000. Average minute rates calculated from the logs were 65, 68, and 66 while asleep and 88, 91 and 92 while awake. Average minute rates calculated from hourly counts while awake ranged from 70 to 110. By keeping a log, much additional information about pulse rates during different activities can be obtained.

In our studies we are concerned with the effect of factors such as age, sex, and occupation on pulse rates of apparently healthy people in whom differences in minute rates obtained by the usual means are probably small. A pulse count per 24 hours of usual activity, integrating the amplitude, duration, and frequency of variations in rate over a reasonable physiological cycle, may reveal larger differences among individuals. The pulse counter may also be used for other measurements of heart rate—for example, during work, physical training, disease, or therapy.

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Note

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Vitamin-A Content of the Frog Eye during Light and Dark Adaptation

Abstract. Rhodopsin is synthesized from 11-*cis* retinene (vitamin A aldehyde), but releases all-*trans* retinene when bleached by light. In the frog, both isomers of vitamin A are stored in the eye. Total ocular vitamin A, including that bound as retinene in rhodopsin, remains constant during light and dark adaptation. Stores of 11-*cis* vitamin A, however, diminish in the light and are replenished in darkness.

The bleaching and synthesis of rhodopsin involve a cycle of stereoisomerization of retinene (vitamin A aldehyde). Rhodopsin is synthesized from 11-*cis* (neo-*b*) retinene, but releases all-*trans* retinene when bleached by light. Each of these isomers is reduced reversibly by alcohol dehydrogenase and diphosphopyridine nucleotide to the corresponding isomer of vitamin A (*1*).

Vitamin A is stored in the retina and pigment layers (pigment epithelium and choroid) of the eye, and may thence exchange via the blood with stores in other tissues (*2*). However, ocular vitamin A is not in equilibrium with other stores. For example, in cattle up to 65 percent of the vitamin A in the eye may have the 11-*cis* configuration (*3*), whereas this isomer has not been found in other tissues (*4*).

Several years ago, Wald showed that in frogs the bulk of the vitamin A released upon bleaching rhodopsin, leaves the retina during light adaptation, and re-enters during dark adaptation to re-form rhodopsin (*2*). However, he did not decide whether the vitamin A leaves the eye altogether, or is merely transferred from the retina to the pigment layers.

Table 1 shows that *Rana pipiens* has more vitamin A in its eye (retina and pigment layers) when light adapted than when dark adapted. However, if one includes the retinene bound in rhodopsin, the total remains essentially constant in light and darkness. It seems, therefore, that during light adaptation there is a flow of vitamin A from retina to pigment layers, which is reversed during dark adaptation (*4a*). This process is no doubt facilitated by the close anatomical contact between these tissues (see *5*).

The proportion of 11-*cis* vitamin A fluctuates in light and darkness as shown in Table 2. In the light, about 10 percent of the vitamin A has the 11-*cis* configuration, but the concentration increases to about 25 percent during 6 hours of dark adaptation.

Taken together, Tables 1 and 2 show that the frogs of group A, which contained about 1.7 μg of vitamin A per eye, stored about 0.17 μg (that is, 10 percent) as the 11-*cis* isomer when light adapted. After 6 hours of dark adaptation, however, the eye contained about 0.94 μg of the 11-*cis* isomer: 0.24 μg (24 percent of 1 μg) as 11-*cis* vitamin A, and 0.7 μg bound in rhodopsin. During this period in darkness, therefore, 0.7 to 0.8 μg per eye, or about half the vitamin A, was isomerized to the 11-*cis* configuration. Similar computations for the frogs of group B show that during the dark period about 0.9 μg of vitamin A per eye—about one-third of the total—was isomerized to 11-*cis*.

The percentage of stored 11-*cis* vitamin A begins to rise after about 3½ hours of dark adaptation, which is roughly the time it takes for rhodopsin

Table 1. Vitamin A content of the frog eye (*R. pipiens*) following light or dark adaptation in vivo. Temperature 22° to 23°C. In each experiment, three frogs were either light adapted 1 hour in a white pan, illuminated with two 75-watt lamps with reflectors, or dark adapted 6 hours. Following light adaptation, the eyes contained no detectable rhodopsin; after dark adaptation, their rhodopsin content was maximal. The retina and pigment layers were dissected and extracted together. Dark-adapted eyes were dissected in dim red light, light-adapted eyes in diffuse room light. To determine free vitamin A, tissues were ground with anhydrous sodium sulfate and extracted with petroleum ether. Rhodopsin was determined as follows: the tissues were ground with anhydrous sodium sulfate under red light, and vitamin A was extracted as above. The powder was then bleached in white light to convert rhodopsin to retinene and opsin, and retinene was extracted with acetone containing 0.5 percent water. All extracts were transferred to chloroform, and vitamin A and retinene were determined by the antimony chloride reaction. Experiments were performed with two groups of frogs (A and B), which differed as shown.

Exp.	Vitamin A (μg per eye)		
	Free	Bound in rhodopsin	Total
	Group A: dark adapted		
1	1.2	Not measured	
2	1.1	Not measured	
3	1.0	0.7	1.7
	Group A: light adapted		
3	1.8	Negligible	1.8
4	1.7	Negligible	1.7
	Group B: dark adapted		
2	1.9	Not measured	
3	2.6	0.7	3.3
4	1.9	0.7	2.6
	Group B: light adapted		
1	2.8	Negligible	2.8
3	3.25	Negligible	3.25
4	2.6	Negligible	2.6

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

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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

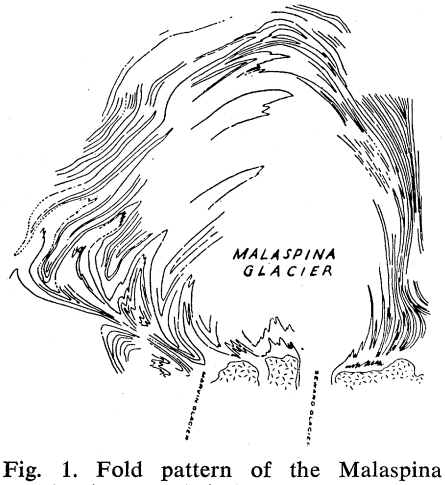

Fig. 1. Fold pattern of the Malaspina Glacier in plan (width of lobe, 25 km).