None of them shows a cone reaching as high as the outer rim. Further, these cones are usually craterless, and more of the nature of a central peak. In nearly all the craters the rim is complete. In the few good examples of terrestrial volcanic explosion craters, formed by the blowing away of the cone of a typical volcano, the rim is always broken. The Monte Somma rim extends only half-way round the new Vesuvius, and the rim of Krakatoa is very irregular. The quiescent type of the Hawaiian volcanoes have craters of irregular outline. Photographs of a model of Vesuvius and the volcanoes of the Phlegrean Fields have been given to show an apparent similarity to the lunar craters; but the photographs, being taken in plan, are misleading, for these volcanoes are actually cones rather than depressed craters. Terrestrial volcanoes are distributed along lines of weakness in the earth's crust; whereas the craters on the moon are scattered about promiscuously, as if from a pepper-pot.

A point that perhaps invalidates the meteorite theory is that there is no evidence of the formation of craters on the moon at the present time. An apparent variation in the size and brightness of the small crater mapped as Linné affords the only doubtful evidence of any change. Nevertheless, meteorites are still falling on the earth, in spite of the protecting atmosphere; and presumably they must also be falling on the moon. In earlier periods it is evident that the meteoritic bombardment must have been much more intense. Maybe the larger stray masses of the solar system have already been gathered up. On the earth during historic times there has been no catastrophic fall, except perhaps that on June 30, 1908, at a spot in central Siberia, almost as inaccessible to us as the moon itself, and of which precise information is still lacking.

[1] Details are given in recent papers in the *Mineralogical Magazine*, and abstracts of recent literature in *Mineralogical Abstracts*.

[2] NATURE, **129**, 781 (1932).

[3] NATURE, **129**, 932 (1932).

[4] Gifford, A. C., "The Mountains of the Moon." *New Zealand J. Sci. Tech.*, **7**, 129–142 (1924); and recapitulation in **11**, 319–327 (1930). See NATURE, **126**, 379 (1930).

[5] Mohorovičić, S., "Experimentelle Untersuchungen über die Entstehung der Mondkrater: ein neuer Beitrag zur Explosionshypothese." (Croatian with German summary.) *Archiv za Hemiju i Farmaciju, Zagreb*, **2**, 66–76+4 plates (1928).

[6] Wegener, A., "Die Entstehung der Mondkrater." (Sammlung Vieweg, Heft 55, Braunschweig, 1921).

Pigments Associated with the Fatty Tissues of Plants and Animals*

By Prof. I. M. Heilbron, F.R.S., and A. E. Gillam

TURNING now to a brief consideration of the question of the biogenesis of the carotenoids, their structure reveals an obvious connexion with isoprene

$$CH_2=C(CH_3)-CH=CH_2,$$

a hydrocarbon that may be regarded as the fundamental unit from which numerous important plant products are elaborated, as a result of the regular combination of individual units. The fact that the carotenoids are symmetrical necessitates, however, the assumption that they are built up in the plant, not on this simple plan alone, but by the union of two molecules of an intermediate compound containing twenty carbon atoms. According to Karrer, this may be the alcohol phytol, $C_{20}H_{39}OH$, which constitutes approximately one third of the chlorophyll molecule. Condensation of two phytyl residues could thus theoretically give rise to lycopene from which, by simple ring closure, the carotenes would be produced.

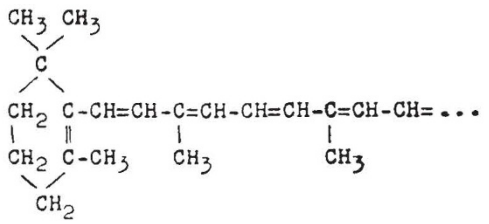
In conclusion, the physiological importance of these pigments in the economy of life must be considered. So early as 1919, Steenbock advanced evidence of a possible connexion between carotene and vitamin A, the physiologically important substance found in all liver oils, notably those of the cod and halibut. This is essential for growth, for in its absence young animals cease to grow, and ultimately die. More specific effects due to vitamin A deficiency are the eye disease, xerophthalmia, decreased resistance to respiratory infections and night-blindness. This latter affection is completely curable in a few days by the absorption of food rich in vitamin A; its cause appears to be related to the fact observed by Wald that the vitamin plays an essential role in the visual perception which occurs on the retina of the eye. The vitamin itself forms an almost colourless highly viscous oil which is notable for its intense absorption band at 328 mμ, and the characteristic blue colour which it gives with antimony trichloride. It is thus clear that the pigment carotene cannot itself be vitamin A, but, as established by von Euler in 1929, it can nevertheless replace the typical vitamin in the animal organism. Complete clarification of this apparent anomaly was reached when Moore conclusively

* *Continued from p.* 615.

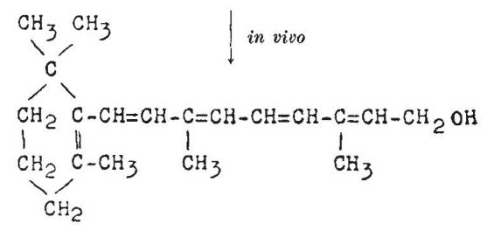
demonstrated that if carotene is fed to rats suffering from vitamin A deficiency, it is converted into the colourless vitamin, which appears in the liver.

The structure of vitamin A has been established, and its formation from carotene may be represented by the following equation, although the exact mechanism of conversion is still obscure :

$$C_{40}H_{56} + 2H_2O = 2C_{20}H_{30}O$$



½ β-Carotene



Vitamin A

Arising from the foregoing, it follows that animals are primarily dependent upon the carotene of grass for their supply of vitamin A. The full appreciation of this fact opens up interesting problems for mankind, and much experimental work is being carried out in order to make use of this new knowledge.

Of the many studies which have been made of the variations in the carotene and vitamin A content of milk as affected by the diet, breed, age, etc., of the cows, I need only mention a few carried out notably by Steenbock in America, by Messrs. Imperial Chemical Industries, Ltd., at their experimental farm in Berkshire, as well as in our own laboratory.

Palmer and Eccles were the first to prove that the yellow colour of butter is mainly due to carotene. The further discovery that butter also contains vitamin A and that the two pigments can be quantitatively evaluated by spectroscopic methods opened the way to the investigation of the factors controlling the quantities of these substances in milk and butter. The actual amounts normally present in milk fat are extremely small, namely, carotene 1–20 parts and vitamin A 2–20 parts per million. In collaboration with Prof. J. C. Drummond of University College, London, Dr. R. A. Morton of Liverpool University, and Dr. S. J. Watson of I.C.I. Agricultural Research Station, we have, during the past few years, been examining the possibility of maintaining the high vitamin content of summer milk throughout the winter. We have ascertained that by employing grass, artificially dried in specially designed driers, in place of part of the concentrates usually given to stall-fed cattle in the winter, both the vitamin A and carotene content of milk (and hence of butter) can be maintained at nearly the level usually regarded as peculiar to summer samples. In a particular experiment, one group of Shorthorn cows was stall-fed on a normal diet throughout a whole winter, whilst another group had a dried grass supplement replacing part of the concentrates. Vitamin A and carotene were determined in the milk fats once a month and the results, expressed graphically in Figs. 1 and 2, leave no doubt as to the efficacy of the dried grass supplement.

Similar experiments have been carried out with A.I.V. silage instead of dried grass. This particular silage is made by storing the fresh grass in a silo and conserving it by sprinkling with dilute acid, the process being due to A. I. Virtanen of Finland.

The following results are typical of those obtained with this fodder. A group of thirteen pure-bred South Devon cows were stall-fed for five weeks on an ordinary winter ration of hay and concentrates. They were then placed on a diet containing 40 lb. of A.I.V. silage per cow per day for five weeks, and afterwards transferred back to the control ration for another five weeks. The colour, carotene, and vitamin A values of the resulting butters are shown in Table 4 and clearly demonstrate—from the vitamin A angle—the value of A.I.V. silage.

TABLE 4

EFFECT OF A.I.V. SILAGE IN THE RATION, ON COLOUR, CAROTENE AND VITAMIN A CONTENT OF MILK FAT. (SOUTH DEVON COWS.)

	Ration	Date of sample	Yellow Colour (Lovibond units)	Carotene (mgm. % fat)	Vitamin A (mgm. % fat)
1st Period	Control 5 weeks	Jan. 25, 1933	4·0	0·10	0·18
2nd „	A.I.V. silage 5 weeks	March 1, 1933	8·4	0·27	0·41
3rd „	Control 5 weeks	April 7, 1933	2·8	0·11	0·24

Although the vitamin A activity of a butter can in general be roughly correlated with its yellow colour, we have found that this is only strictly true when comparing butters from the same breed of cow. Thus when Shorthorn or Ayrshire cows were fed on a ration rich in carotene, the yellow colour rose to a maximum above which the further addition of carotene in the diet would not increase it. The Shorthorn butter was, however, always somewhat more yellow than that

obtained from the Ayrshire cows. The traditionally high yellow colour of the milk in Jersey and Guernsey cattle is due to their having a higher 'ceiling value' for carotene in their milk-fat than any of the other breeds. Experimental results indicate, however, that although Shorthorn milk-fat is normally paler than that from the Guernsey cow, the gross vitamin A activity is about the same; this is due to the fact that the milk of the Shorthorn has a slightly higher proportion of the true vitamin A.

The figures in Table 5 were obtained by spectrophotometric examination of the milk fats of pure-bred Shorthorn and Guernsey cows kept on the same diet at the National Institute for Research in Dairying. Parallel biological tests for gross vitamin A potency carried out by Dr. S. K. Kon showed that the butters of the two breeds were indistinguishable at each of the three seasons.

The differences in carotene and vitamin A content of the milk of different species of animals are exemplified by the Guernsey cow and the goat; for the latter, in striking contrast to the former, gives a butter which is almost dead-white in colour. Despite the almost total absence of carotenoids in goat's butter, it nevertheless contains vitamin A in amount only slightly lower than that of an average cow's butter.

Although the seasonal variations in the colour and vitamin A content of milk and butter are actually directly due to the presence or absence of carotene in the diet, that is, fresh green grass is necessary to produce good yellow butter, there is one exception to this generalization. Whatever the breed of cow or the season of the year, the colostrum is usually 10–20 times richer in both vitamin A and carotene than is the normal milk. The quality falls rapidly from the first day after calving and reaches normality again in about a week. This richness in vitamin A is therefore quite consistent with the traditional belief in the high food value of colostrum, and furnishes another remarkable example of the way in which biological processes provide for special circumstances in the life of the organism. These phenomena have been shown to be exactly parallelled in the human subject.

Examples of the relative vitamin A values of ordinary and colostrum milk are given in Table 6, the results having been obtained in the course of the experiments described above.

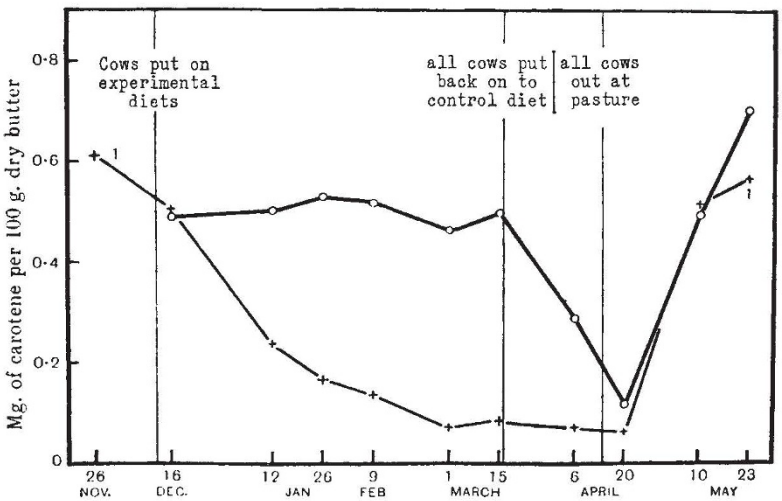


Fig. 1. CAROTENE OF THE BUTTERS
+ — +, control ration. o — o, artificially dried grass ration.

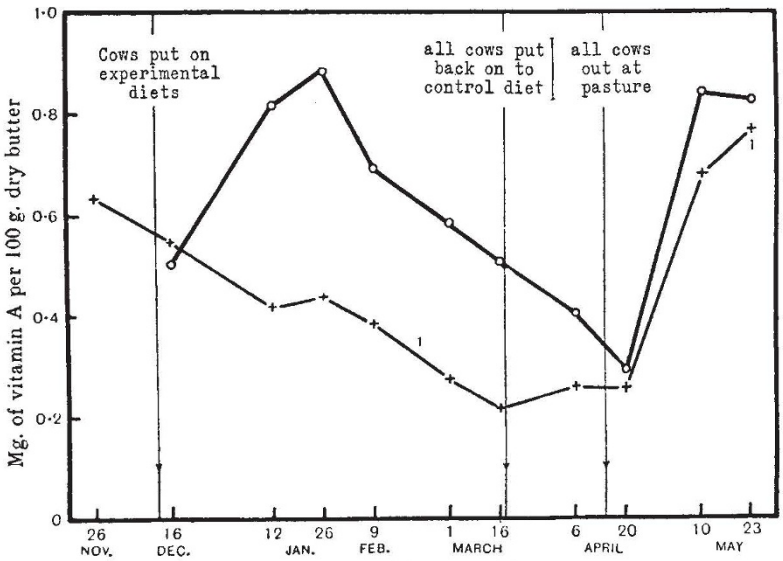


Fig. 2. VITAMIN A* OF THE BUTTERS
+ — +, control ration. o — o, artificially dried grass ration.

Examination of the carotene and vitamin A values of milk-fat leads to a consideration of the vehicle by which the carotene of the food is transported to the udder of the cow, namely, the blood serum. Studies of bovine blood sera have shown that the carotene and vitamin A

* Results expressed here and throughout this article are based on the assumption that pure vitamin A has an intensity of absorption of $E^{1\%}_{1cm.}$ 328 mμ = 1600.

vary with the amount of carotene in the food, thus being richer in summer than in winter. It

TABLE 5
CAROTENE AND VITAMIN A VALUES OF SHORTHORN AND GUERNSEY BUTTER FATS UNDER IDENTICAL CONDITIONS OF FEEDING

	Shorthorn		Guernsey	
	Carotene	Vitamin A	Carotene	Vitamin A
Summer	0·78	1·10	2·24	0·89
Autumn	0·67	0·93	1·80	0·70
Winter	0·19	0·39	0·50	0·34

(Values as mgm. per 100 gm. fat).

TABLE 6
COMPARISON OF THE CAROTENE AND VITAMIN A VALUES OF THE FAT OF ORDINARY AND COLOSTRUM MILK (INDIVIDUAL COWS CHOSEN AT RANDOM)

Breed	Date of sample	Carotene (mgm. % fat)	Vitamin A (mgm. % fat)
Friesian	Oct. 20	3·40	1·24
	Nov. 20	0·38	0·52
Ayrshire	Nov. 22	4·60	2·96
	Dec. 22	0·18	0·37
Guernsey	Oct. 28	3·61	1·13
	Nov. 28	0·91	0·67
Shorthorn	Oct. 13	2·90	3·51
	Nov. 13	0·28	0·48

is also interesting to note that the serum of cows is distinctly richer than is that of bulls, but whether this is due to a genuine sex difference or to different conditions of management has yet to be ascertained (cf. Table 7 due to Gillam and El Ridi).

TABLE 7
CAROTENE AND VITAMIN A IN COW'S BLOOD SERA (AVERAGE VALUES)

	Cows		Bulls	
	Carotene	Vitamin A	Carotene	Vitamin A
Winter	0·40	0·13	0·08	0·05
Summer	1·11	0·29	0·42	0·14

(All values as mgm. per 100 ml. of serum.)

We have attempted in the foregoing to trace the stages in the development of our knowledge of the lipochrome pigments and to show how, by the application of the elegant methods now used by the organic chemist, the constitution of the more important of these natural polyenes has been elucidated. Apart from the intrinsic interest of this work, it has led to the fundamental discovery of the close interrelation between carotene and vitamin A, one of the indispensable key substances of life.

Fire-Walking: Scientific Tests

EIGHTEEN months ago, the University of London Council for Psychical Investigation arranged a demonstration of fire-walking, with the view of obtaining precise information upon its scientific aspects. Descriptions of the condition of the feet of the performer, Kuda Bux, before and after the walk, and results of some physical observations, were given in NATURE of September 21 and 28, 1935 (**136**, 468, 521). As the observations were not altogether conclusive, two more demonstrations were arranged by the University of London Council for Psychical Investigation through Mr. Harry Price, honorary secretary of the Council, in the grounds of Mr. Alex. Dribbell at Carshalton, Surrey, on April 8 and 10.

The professional fire-walker was Ahmed Hussain, a Moslem from Cawnpore. In the first experiment, the trench containing the charcoal on oak-ash was 12 ft. long. The temperatures were measured by special thermocouples with the co-operation of the Cambridge Scientific Instrument Co., Ltd., and were shown to be 575° C. on the surface and 700° C. inside. After examination and tests for chemical treatment, Hussain walked the trench in 1·3 sec., showing no signs of injury. He then repeated the walk leading three amateur volunteers with the claim that they would be immune from burning. They were, however, all burned to a varying but slight degree. A further two volunteers then performed the walk separately and unaided. They were also slightly burned, and where the number of steps had been uneven, the foot that had been down most often was most affected. This indicated that the injurious effect was cumulative, although Hussain claimed that he could walk any distance. As he refused to retrace his steps, the trench was increased to 20 ft. for the second experiment.

In the second experiment, the surface temperature was 740° C. and the inside 750° C. Hussain took six steps in 2·3 sec., and this produced five blisters on one foot and marked erythema on the other, a condition closely resembling that of the amateurs after four steps. The effect was therefore cumulative in his case also. One of the former volunteers covered the distance in four steps and 1·4 sec., and then later, in rope-soled shoes, took seven steps in 3·6 sec. The frayed portions of the rope were slightly scorched at the edges only. The feet sank into the ash to a depth of between two and three inches, and it seems clear that its poor thermal conductivity prevents damage to normal skin if the contact-time is less than about half a second, although the small flames within it will produce singeing of the hairs. This time corresponds with that of one quick step: two steps with the same foot could only be done without injury by the practised professional, and three steps was beyond his limit.

This small difference between amateur and professional, together with observations made during the experiment, make it very unlikely that any hypothesis of a special induced mental state is required, such as is, of course, maintained by the Indian performers.