connection, if any, between the dwarfing factors and those responsible for other abnormalities has not been determined. It will be necessary to observe, mark, rear and test large numbers of animals before these points can be settled.

The observations made on this group of animals point to an incomplete recessive mutation, which is characterized by a dwarfing effect and by functional disorders in both heterozygous and homozygous individuals. The reduction in size is of a measured order so that a unit size factor becomes operative in the determination of the weights of affected individuals in relation to the weights of normal members of the population. The unit factor is represented by a homozygous, lethal dwarf which is one third the weight of its normal sibs and one half the weight of its heterozygous sibs. It is possible that factors operating in this manner may be concerned in other types of size inheritance.

The combination of abnormalities presented suggests a primary pituitary disorder which affects both the acidophilic and the basophilic elements of the anterior pituitary with secondary disturbances of other endocrine glands.[4] This possibility is further supported by the occurrence in another group of rabbits of a hereditary condition which simulates over-function of the acromegalic type. This will be reported in another paper.

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[4] Harvey Cushing, *Harvey Lectures*, 28: 90, 1932–33.

THE BIOLOGICAL AND CHEMICAL NOMENCLATURE FOR THE CAROTENOIDS

THE class of natural pigments known as carotenoids has attracted the attention of botanists, zoologists and chemists for nearly a century. The past decade has witnessed the nearly complete clarification of the chemical constitution and molecular configuration of almost all the known members of this class of substances. It is now definitely established that the true carotenoids, *i.e.,* those members which have the same number of carbon atoms as carotene are either hydrocarbons of definite configuration or alcohols or ketones of these same hydrocarbons. The hydrocarbons appear to fall into two groups, the carotenes, containing ionone rings and the lycopenes, aliphatic isomers of carotene. The existence of several isomeric carotenes has been established, but so far only one lycopene. The nomenclature now employed for the different carotenes, *i.e.,* α-, β-, etc., is fairly satisfactory both from a biological as well as a chemical standpoint. However, the nomenclature at present prevailing for the ketonic and alcoholic carotenoids is both unsatisfactory and also confusing.

According to the prevailing nomenclature for the alcoholic carotenoids it is necessary to choose between the following alternatives: (a) Retain the term xanthophyll as a term of historical value to designate the crystalline pigment mixture with the composition $C_{40}H_{56}O_2$, isolated by Willstätter[1] from green leaves; (b) employ the term xanthophyll in the future only in the plural, *i.e.,* xanthophylls, to designate the isomeric carotenoids having the composition $C_{40}H_{56}O_2$, analogous to the term carotenes for the isomeric carotenoids with the composition $C_{40}H_{56}$, and employ only specific names for various xanthophylls as isolated, as has already been done in the case of lutein and zeaxanthin, the two major and minor fractions so far isolated from the crystalline mixture from leaves, formerly called xanthophyll; new specific names could be given for any additional isomers which may be discovered in the future; (c) employ the old term xanthophyll for the major component of the crystalline mixture from green leaves, and give new names to the various isomers as isolated or discovered, as has been done in the case of the carotenoid zeaxanthin; this alternative would require the abandonment of the term lutein, the name given by Kuhn to the major xanthophyll-like pigment of green leaves.

In the main the first and second alternatives are favored by Kuhn[2] and the third alternative by Karrer.[3] The situation is analogous to that which developed when it became definitely known that vitamin B is composed of more than one component. In view of the fact that the discovery of isomeric forms of carotene was followed by the adoption of the more logical scheme of designating them as α- β- γ- and δ-carotene, respectively, instead of giving them specific names, and furthermore in view of the fact that xanthophyll (lutein) appears to be structurally related to α-carotene and zeaxanthin to β-carotene (as pointed out by Karrer[4]), another, more logical alternative of the present systems of xanthophyll nomenclature would be as follows: Employ the term xanthophyll as a generic term for the $C_{40}H_{56}O_2$ carotenoids, analogous to the generic term carotene and designate the specific xanthophylls as α-, β-, etc., to indicate their structural relationship to the corresponding α-, β-, etc., carotenes as their structure is elucidated. The "lutein" of Kuhn and the "xantho-

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[1] R. Willstätter and W. Mieg, *Liebigs Ann.*, 355: 1, 1907.

[2] R. Kuhn, A. Winterstein and E. Lederer, *Z. f. physiol. Chem.*, 197: 141, 1931.

[3] P. Karrer, H. Wehrli and A. Helfenstein, *Helv. chim. Acta*, 13: 268, 1930.

[4] P. Karrer and H. Wehrli, *Nova Acta Leopoldina*, n. s., 1: 175, 1933.

phyll" of Karrer thus would become α-xanthophyll, and "zeaxanthin" would become β-xanthophyll. The likelihood of other xanthophylls occurring in nature is indeed rendered very probable by the discovery of γ-[5] and δ-carotene.[6]

Rhodoxanthin, for a number of years classified with the xanthophylls and whose empirical formula $C_{40}H_{50}O_2$ seems at first sight to justify such a classification, is now shown to be a ketonic carotene.[7] Therefore it can not be classed properly with the xanthophylls but must be grouped with the carotenes, not, however, as carotene with a new Greek letter prefix but as di-keto-β-carotene, which it appears to be.

Of course, there can be no serious objection raised to the use of specific names for the various esterified forms of the xanthophylls, such as "helenien" and "physalien," but if the nomenclature suggested above is used it would seem much better from a biochemical standpoint to designate them α-xanthophyll-dipalmitate (helenien) and β-xanthophyll-dipalmitate (physalien), respectively, since such names clearly indicate their chemical nature as well as their carotenoid affiliations.

The writer appreciates fully that the terms carotene and xanthophyll are not strictly chemical terms but originated from botanical taxonomic terms. In fact, the names which have been given to almost all the known polyene pigments have had a taxonomic origin either in botany or zoology. For this reason the name "lutein" is out of place in a system of nomenclature for pigments of plant origin. Nevertheless, a chemical influence has already been felt in connection with the spelling of the name carotene, which was formerly most frequently spelled "carotin," the name suggested by Wachenroder (1826). Arnand (1886) suggested "carotene" in keeping with the hydrocarbon structure, and the recent establishment of the polyene structure fully justifies this spelling, provided it be accepted that chemical structure should influence nomenclature and spelling of terms of botanical and zoological taxonomic origin. If this be accepted, then the logical spelling of the term xanthophyll should be xanthophyol or xanthophyllol to indicate the alcohol nature and provide for suitable euphony.

The idea of employing Greek letter designations for the different xanthophylls is not new but was proposed by both Tschirch[8] and Tswett[9] although each on different grounds and thus without any correspondence between the individual components of their respective systems. It is most interesting, however, to note that Tswett's xanthophyll-α turns out to be the pigment now known as "xanthophyll" or "lutein" which, as already mentioned, is related structurally to α-carotene and therefore should be called α-xanthophyll or α-xanthophyol (xanthophyllol). In fact, the writer some time ago[10] expressed the belief that the crystalline "lutein" of Willstätter and Escher[11] from egg yolk is the pure xanthophyll-α of Tswett, and this belief has been shown by Kuhn[12] to be about 70 per cent. correct.

A still more logical system of nomenclature for the alcoholic xanthophyll-like carotenoids would be one which could include all those structurally related to the isomeric carotenes, including those with three and four OH groups as well as the xanthophylls. With this idea in view the author suggests that the name xanthophyll be dropped entirely and that the generic name xanthin be adopted, which, as a matter of fact, is now used as a terminal ending for the names of all the C_{40} oxygen-containing carotenoids except xanthophyll (lutein) itself and the esters "physalien" and "helenien." In order to indicate the number of alcohol groups present the specific xanthins of this system would be given the terminal endings -ol, -diol, -triol, -tetrol, etc., and the structural relationships to the corresponding carotene would be indicated by the proper Greek letter, as soon as this relationship is established. Only in the case of special products such as the "cryptoxanthin" of Kuhn,[13] which possesses the β-carotene structure for one carbon ring and the zeaxanthin structure for the other, would a new compound name be necessary. It could be called β-carotene-β-xanthinol. If other such compounds are discovered, as they are likely to be, they could be named according to the structural relations of the carotene and xanthin portions of the molecule. For example, there could be conceivably an α-carotene-β-xanthinol, a β-carotene-γ-xanthinol, etc. Esters would be indicated by naming the acid involved after the xanthinol.

As indicated in a previous paragraph rhodoxanthin would not be generically one of these new xanthins, inasmuch as it is not an alcohol, but should be called di-keto-β-carotene. Although only one lycopene is known at the present time, its structural relation to the optically inactive β-carotene should be designated by the same prefix, *i.e.,* β-lycopene.

As regards the carotenoids with less than 40 C atoms, capsanthin, the paprika pigment, astacin, the red crustacean pigment and azafrin, the pigment of "azafran," can undoubtedly be made to fit into the proposed scheme as soon as their structure is known,

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[5] R. Kuhn and H. Brockmann, *Ber.,* 66B: 437, 1933.

[6] A. Winterstein, *Z. f. physiol. Chem.,* 219: 249, 1933.

[7] R. Kuhn and H. Brockmann, *Ber.,* 66B: 828, 1933.

[8] A. Tschirch, *Ber. botan. Ges.,* 5: 128, 1887.

[9] M. Tswett, *Ber. botan. Ges.,* 29: 630, 1911.

[10] L. S. Palmer, "Carotinoids and Related Pigments." Chemical Catalog Co., New York, 1922.

[11] R. Willstätter and H. H. Escher, *Z. physiol. Chem.,* 76: 214, 1912.

[12] R. Kuhn and A. Smakula, *Z. physiol. Chem.,* 197: 161, 1931.

[13] R. Kuhn and Ch. Grundmann, *Ber.,* 66B: 1746, 1933.

for they apparently contain at least one ionone ring as well as an aliphatic conjugated polyene chain. Bixin and the safran pigments (crocetin and crocin) should probably be dropped from the true carotenoid classification, since it seems doubtful whether structural relationships to carotene will ever be established for them. As a matter of fact their polyene chain is all they have in common with the true carotenoids so far as chemical structure is concerned. Perhaps the designation pseudo- or secondary carotenoids would be better for them and their chemical classification based on the adoption of a generic name to indicate a common relationship, if that should prove possible, and a suitable terminology to show that they are carboxy acids.

The scheme proposed above is admitted to be a compromise with established practise of designating the oxygen-containing carotenoids by a distinct group name. However, attention may be called to the fact that it now seems entirely feasible to have a strictly chemical nomenclature for all the true carotenoids, based entirely on the terms carotene and lycopene or a combination of these terms. In this nomenclature the specificity of the true carotenes would be retained by use of the Greek letter prefixes which have already been assigned to them, except that "α" would specifically indicate the presence of optically active carbon atoms in the left- or right-hand ionone rings (or their open chain forms as they occur in lycopene), "β" will specifically represent the occurrence of only optically inactive carbons in the rings (or open forms of the rings). The order of naming the "α" and "β" rings (closed or open) would be from left to right. All the alcohol or ketone or combined alcohol-ketone (such as taraxanthin and fucoxanthin may be) derivatives of the carotenes would be given such designations as would indicate their respective relationships to the carotenes, and, in addition, the terminal endings -ol, -diol, -triol, -tetrol, etc., depending on the number of -OH groups; furthermore, such carotenes as possess the ketone structure would be indicated by the proper prefix, *i.e.*, keto-, diketo-, etc. The position of the various -OH and (or) $>C:O$ groups may also be indicated according to the usual organic chemistry nomenclature, as soon as this is determined.

The accompanying table shows the schemes for both the suggested new generic nomenclature for the C_{40} oxygen-containing carotenoids, and also for the proposed new strictly chemical nomenclature so far as the structural relationships to the carotenes are known.

CAROTENOID NOMENCLATURE

Old name	Formula	Proposed new generic name	Proposed new chemical name
α-carotene	$C_{40}H_{56}$	α-carotene	βα-carotene
β-carotene		β-carotene	ββ-carotene
γ-carotene		γ-carotene	β-lyco-β-carotene
δ-carotene, etc.		δ-carotene, etc.	β-lyco-α-carotene, etc.
Lycopene	$C_{40}H_{56}$	β-lycopene	ββ-lycopene
Rhodoxanthin	$C_{40}H_{50}O_2$	diketo-β-carotene	5, 5′-diketo ββ-carotene
Xanthophyll Lutein	$C_{40}H_{54}(OH)_2$	α-xanthin-diol	βα-carotene-5, 5′-diol
Zeaxanthin	$C_{40}H_{54}(OH)_2$	β-xanthin-diol	ββ-carotene-5, 5′-diol
Flavoxanthin	$C_{40}H_{53}(OH)_3$	α-xanthin-triol	βα-carotene-(?)-triol
Taraxanthin	$C_{40}H_{53}O(OH)_3$	α-keto-xanthin-triol	(?)-keto-βα-carotene(?)-triol
Violaxanthin	$C_{40}H_{53}O(OH)_3$	β-keto-xanthin-triol	(?)-keto-ββ-carotene-(?)-triol
Fucoxanthin	$C_{40}H_{52}O_2(OH)_4$	(?)-diketo-xanthin-tetrol	(?)-diketo-(?)-carotene-(?)-tetrol
Cryptoxanthin	$C_{40}H_{55}OH$	β-carotene-β-xanthinol	β5′β-carotenol
Helenien	$C_{72}H_{116}O_2$	α-xanthin-diol-dipalmitate	βα-carotene-5, 5′-diol-dipalmitate
Physalien	$C_{72}H_{116}O_2$	β-xanthin-diol-dipalmitate	ββ-carotene-5, 5′-diol-dipalmitate
Capsanthin	$C_{35}H_{50}O_3$	?	?
Azafrin	$C_{27}H_{38}O_4$	hemi-α-xanthin-diol	di-α-1, 2-carotene-diol-(?)
Astacin	$C_{27}H_{32}O_3$	?	?

NOTE: The question mark indicates either (a) lack of information regarding the position of the known ketonic or hydroxyl group or (b) the group suggested has not been proved or (c) the structure is partly or wholly unknown.

The writer hopes that these suggestions will prompt discussion which will lead to the adoption of some logical biochemical nomenclature and prevent the accumulation of more confusion of names for these interesting and important substances while their chemistry is new and before long-established usage makes such adoption difficult if not impossible to secure.

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BOOKS RECEIVED

MARTIN, ERNEST G. and H. NEWELL MARTIN. *The Human Body.* 12th Edition. Pp. xv + 701. 167 figures. Holt. $4.00.

SWINGLE, DEANE B. *A Textbook of Systematic Botany.* Second Edition. Pp. xv + 270. McGraw-Hill. $2.25.