

New structures of carotenoids in marine animals

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Abstract - A review is presented on progress made since the 6th International symposium on carotenoids, Liverpool, UK, 1981, in the following areas:

- Sponges (Porifera)
- Molluscs (Mollusca)
- Echinoderms (Echinodermata)
- Tunicates (Protochordata)
- Fishes (Pisces)

1. INTRODUCTION

The world's trend during the past decade in exploiting the sea for resources and the discovery of a new antibiotic cephalosporin in a marine organism prompted investigation of marine life under the slogan of "drugs from the sea." The discovery of the antitumor activity (Refs. 1-3) of vitamin A and β -carotene encouraged interest in marine carotenoids which occur in great diversity.

Marine carotenoids have been reviewed by Scheuer (Ref. 4), Baker and Murphy (Ref. 5) and Liaaen-Jensen (Ref. 6). In this lecture an attempt is made to describe new carotenoids from marine animals with emphasis on structural aspects since 1981.

2. SPONGES (PORIFERA)

The recent developments in this field are reviewed by Yamaguchi (Ref. 7) and Liaaen-Jensen (Ref. 6). The discovery of a series of unique aryl carotenoids with 1, 2, 5- or 1, 2, 3-trimethyl phenyl end groups widely differing from those in other marine animals have encouraged the interest of bio-organic chemists in sponges. Tanaka et al. have isolated new marine carotenoids, isoagelaxanthin A and isoclathriaxanthin from Acanthella vulgata and Agelas mauritiana, respectively. These structures have been determined to be (1) (Ref. 8) and (2) (Ref. 9).

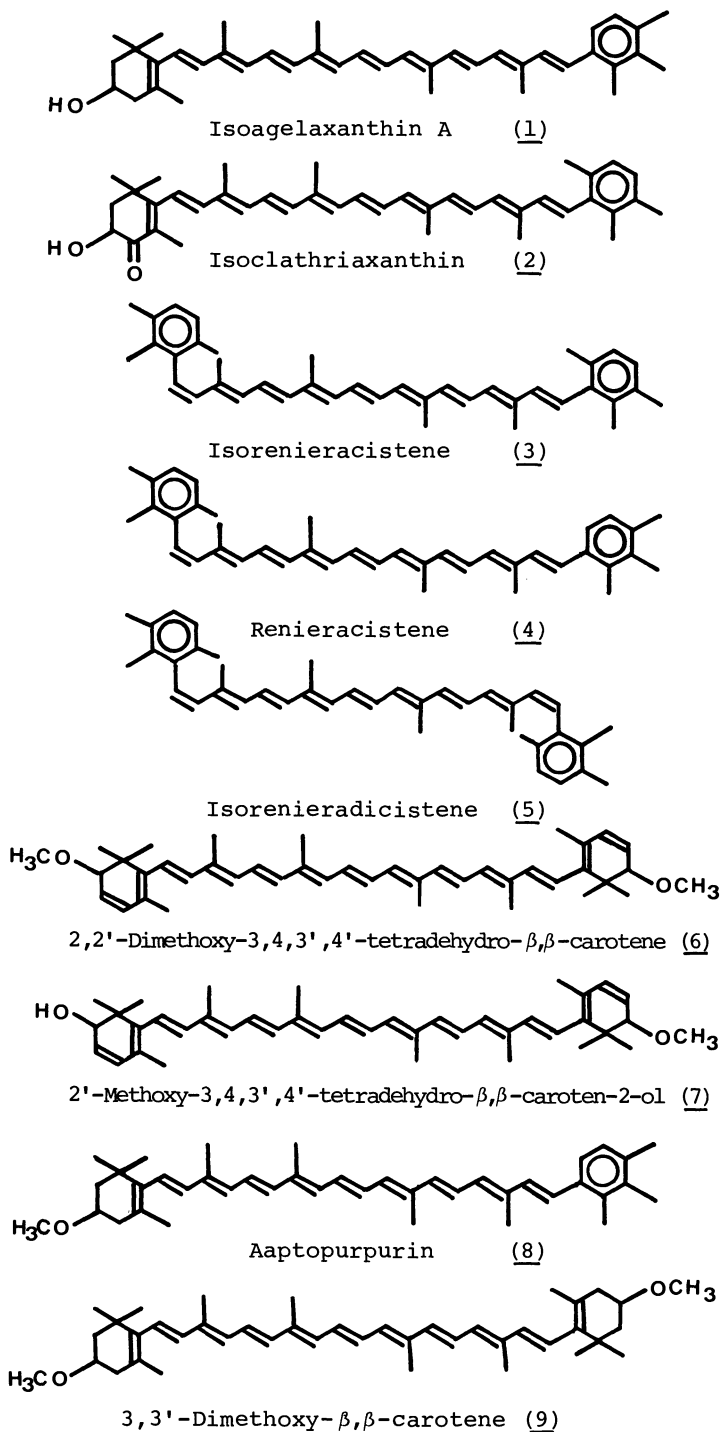
Novel cis aromatic carotenoids, isorenieracistene and renieracistene were isolated from the sponge Tethya amamensis and their structures have been established to be 7-cis- ϕ, ϕ -carotene (3) and 7-cis- ϕ, χ -carotene (4) on the basis of their spectral data and iodine catalyzed isomerization (Ref. 10). Another new 7,7'-di-cis aromatic carotenoid, isorenieradicistene (5) has been isolated by our group from the marine sponge Suberites sericeus (Ref. 11).

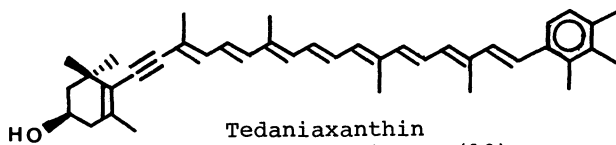
Until recently, methoxylated carotenoids appeared to be restricted to photo-synthetic bacteria (Ref. 12) but new methoxylated carotenoids have been isolated, (6) and (7) from Rhaphidophylus typicus by Liaaen-Jensen's research group (Ref. 13), and (8) and (9) from Aptos aptos by Tanaka et al. (Ref. 14).

The first isolated tedaniaxanthin (Ref. 15) from the marine sponge Tedania digitata was identified with allopurpurin (Ref. 16) isolated from the sponge Microciona prolifera, and the structure has been elucidated as (10) (Ref. 17).

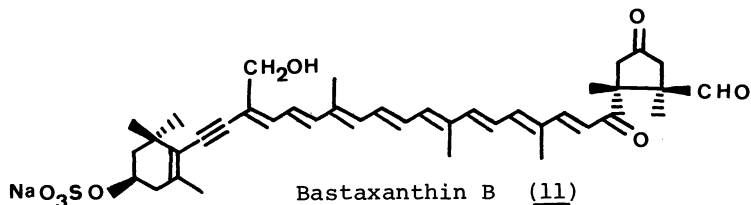
Furthermore, an interesting series of carotenoid sulfates, bastaxanthin B, B₂, C, C₂, D, E, F, and desulfated carotenoids, bastaxanthol B and C have

been isolated by Liaaen-Jensen's research group from *Ianthella basta* (Refs. 13 & 18). The structure of the major sulfate bastaxanthin C has been shown to be the sodium 3-O-sulfate of 3,19,17'-trihydroxy-7,8-didehydro- β,κ -carotene-3',6'-dione (13). The absolute configuration of the three chiral centers has been assigned to be (3R,1'R,5'R)-configuration (Ref. 19). This is the first naturally occurring carotenoid sulfate. Plausible structures have been assigned to other bastaxanthins [B (11), B₂ (12), C₂ (14), D (15), E (16) and F (17)] on the basis of spectral data, electrophoretic behaviour, chemical derivatization and enzymatic or acid-catalysed hydrolysis (Ref. 20). These minor sulfates represent structural variation in the cyclopentane end group with different oxidation levels.

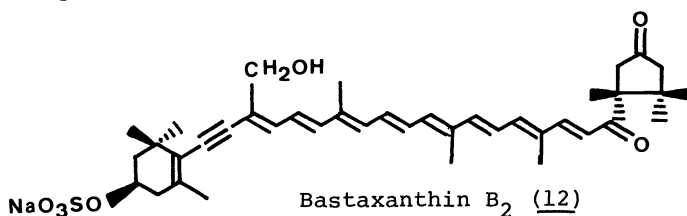




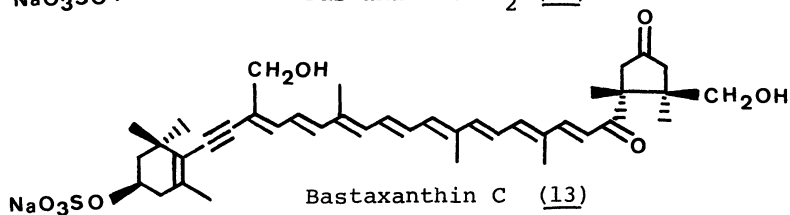
Tedaniaxanthin
= Alloporpurin (10)



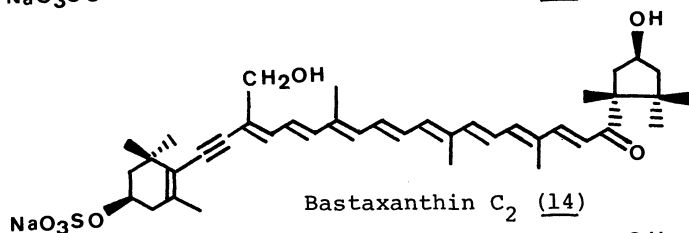
Bastaxanthin B (11)



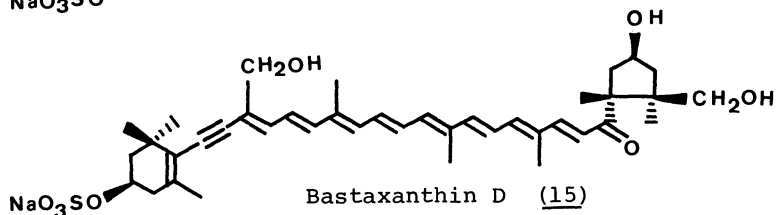
Bastaxanthin B₂ (12)



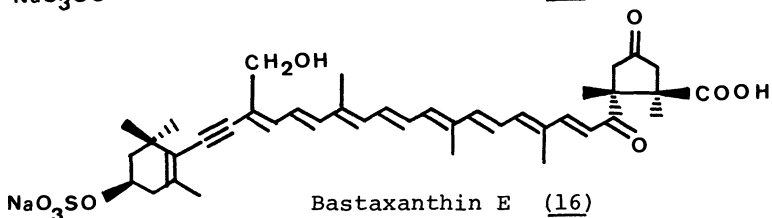
Bastaxanthin C (13)



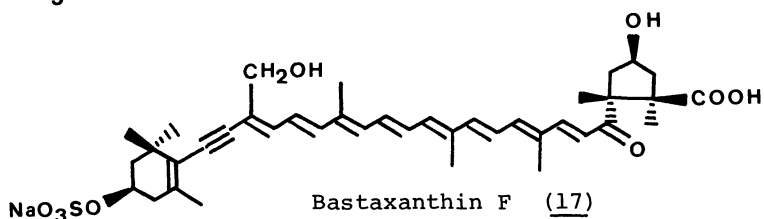
Bastaxanthin C₂ (14)



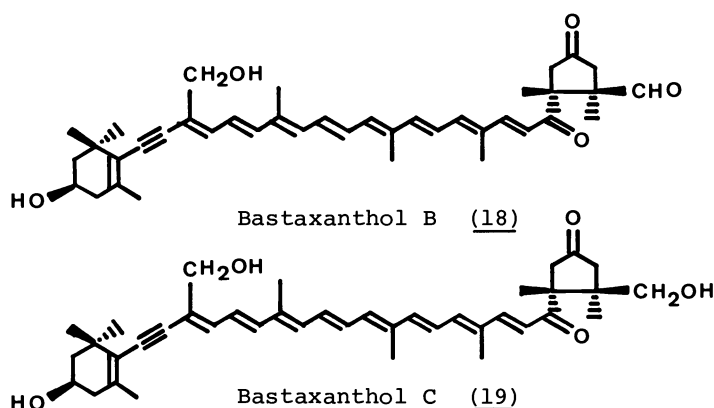
Bastaxanthin D (15)



Bastaxanthin E (16)



Bastaxanthin F (17)



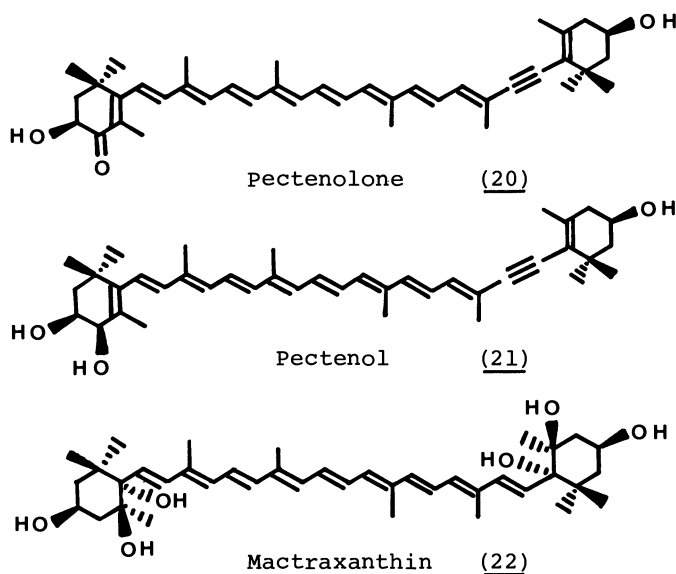
3. MOLLUSCS (MOLLUSCA)

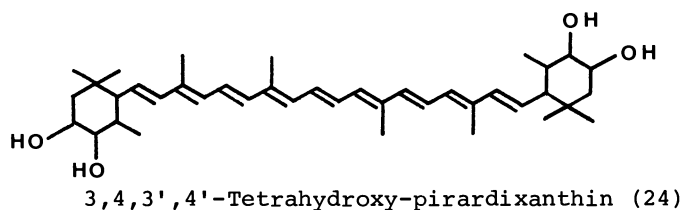
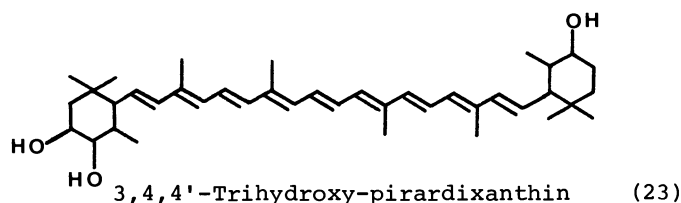
In an earlier study, pectenolone was isolated from the gonad of the scallop *Pecten maximus* and the planar structure (Ref. 21) was proposed, though its stereochemistry remained uncertain. Recently we have determined the absolute configuration of the two asymmetric centers in the structure of pectenolone (20) (Ref. 22).

Furthermore, a new marine carotenoid pectenol has been isolated from orange-red muscle of the Japanese sea mussel *Mytilus coruscus* (Ref. 23) and the structure has been determined to be (3*S*,4*R*,3'*R*)-7',8'-didehydro- β,β -carotene-3,4,3'-triol (21) (Ref. 24). Natural pectenol is completely identical with one of the two diastereomers obtained by NaBH₄ reduction of pectenolone (20) isolated from the Japanese scallop *Patinopecten yessoensis* (Refs. 24 & 25).

Another novel marine carotenoid mactraxanthin has been isolated from the Japanese edible surf clam *Mactra chinensis* and the structure of mactraxanthin has been established to be (3*S*,5*S*,6*S*,3'*S*,5'*S*,6'*S*)-5,6,5',6'-tetrahydro- β,β -carotene-3,5,6,3',5',6'-hexaol (22) (Ref. 26). This is the first report of a naturally occurring hexahydroxy carotenoid.

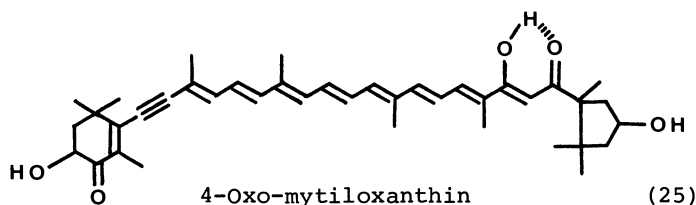
Recently we have isolated new marine carotenoids along with 4,4'-dihydroxy-pirardixanthin (Refs. 27 & 28) from the spindle shell *Fusinus perplexus* and the structures have been elucidated as 3,4,4'-trihydroxy-pirardixanthin (23) and 3,4,3',4'-tetrahydroxy-pirardixanthin (24), respectively (Ref. 29).





4. ECHINODERMS (ECHINODERMATA)

A recent investigation of *Asterias rubens* has revealed the presence of a new marine carotenoid, 4-oxo-mytiloxanthin (25) (Ref. 30) considered to be an oxidative metabolic product of mytiloxanthin which originated from shellfishes on which starfishes feed. It is interesting from the biosynthetic point of view.



5. TUNICATES (PROTOCHORDATA)

Our research group isolated new marine carotenoids, halocynthiaxanthin (28) (Ref. 31) and mytiloxanthinone (30) (Ref. 32) from the sea squirt *Halocynthia roretzi* along with eleven known carotenoids (Ref. 33). Astaxanthin had been reported as principal keto-carotenoid in the sea squirt (Refs. 34 & 35) but the principal keto-carotenoid was not astaxanthin but mytiloxanthinone (30). Mytiloxanthinone (30) shows a remarkable lability toward base, therefore, it might have been overlooked till now. The structure has been determined to be (3R,5'R)-3,8'-dihydroxy-7,8-didehydro- β,κ -carotene-3',6'-dione by spectral data, chemical evidence and biosynthetic point of view. It is assumed to be an oxidative metabolic product of mytiloxanthin (29).

The structure of halocynthiaxanthin has been determined to be (28) by means of spectral and chemical evidence (Ref. 31). In order to establish the absolute configuration of halocynthiaxanthin, conversion of naturally occurring (3S,5R,6S,3'S,5'R,6'R)-fucoxanthin (26) isolated from brown algae into semi-synthetic (3S,5R,6S,3'R)-5,6-epoxy-3,3'-dihydroxy-7',8'-didehydro-5,6,7,8-tetrahydro- β,β -caroten-8-one was performed. The resulting semi-synthetic compound was identical with naturally occurring halocynthiaxanthin (28). Thus the structure of halocynthiaxanthin has been established to be (28) (Ref. 33). Fucoxanthin (26) in phytoplankton and sea weeds on which the sea squirts feed seems to be metabolized to fucoxanthinol (27), halocynthiaxanthin (28), mytiloxanthin (29) and eventually to mytiloxanthinone (30) as shown in Fig. 1 (Ref. 36). The presence of halocynthiaxanthin (28) has also been demonstrated by our group in many species of shellfishes (Ref. 37) and tunicates (Ref. 36).

An extensive search for carotenoids from the Japanese tunicate *Amaroucium pliciferum* led to the isolation of two novel carotenoids, amarouciaxanthin A (31) and B (32). By the spectral data and chemical properties, the structures of amarouciaxanthin A and B have been determined to be 6,3',5'-trihydroxy-4,5,6',7'-tetrahydro-7,8,5',6'-tetrahydro- β,β -carotene-3,8-dione (31) and 6,3'-dihydroxy-4,5,7',8'-tetrahydro-7,8-dihydro- β,β -carotene-3,8-dione (32), respectively (Ref. 38). Furthermore, treatment of each of (31) and (32) with 10% KOH/MeOH gave paracentrone (Ref. 39) and triophaxanthin

(Ref. 40) along with 6-oxo-isophorone, respectively. Therefore, the validity of the proposed structures (31) and (32) for amarouciaxanthin A and B, respectively, has been established by the experimental results mentioned above (Ref. 39). These (31) and (32) are presumed to be metabolic products in another metabolic pathway of fucoxanthin (26) as shown in Fig. 1. Further studies on the stereochemistry of the chiral centers are under way.

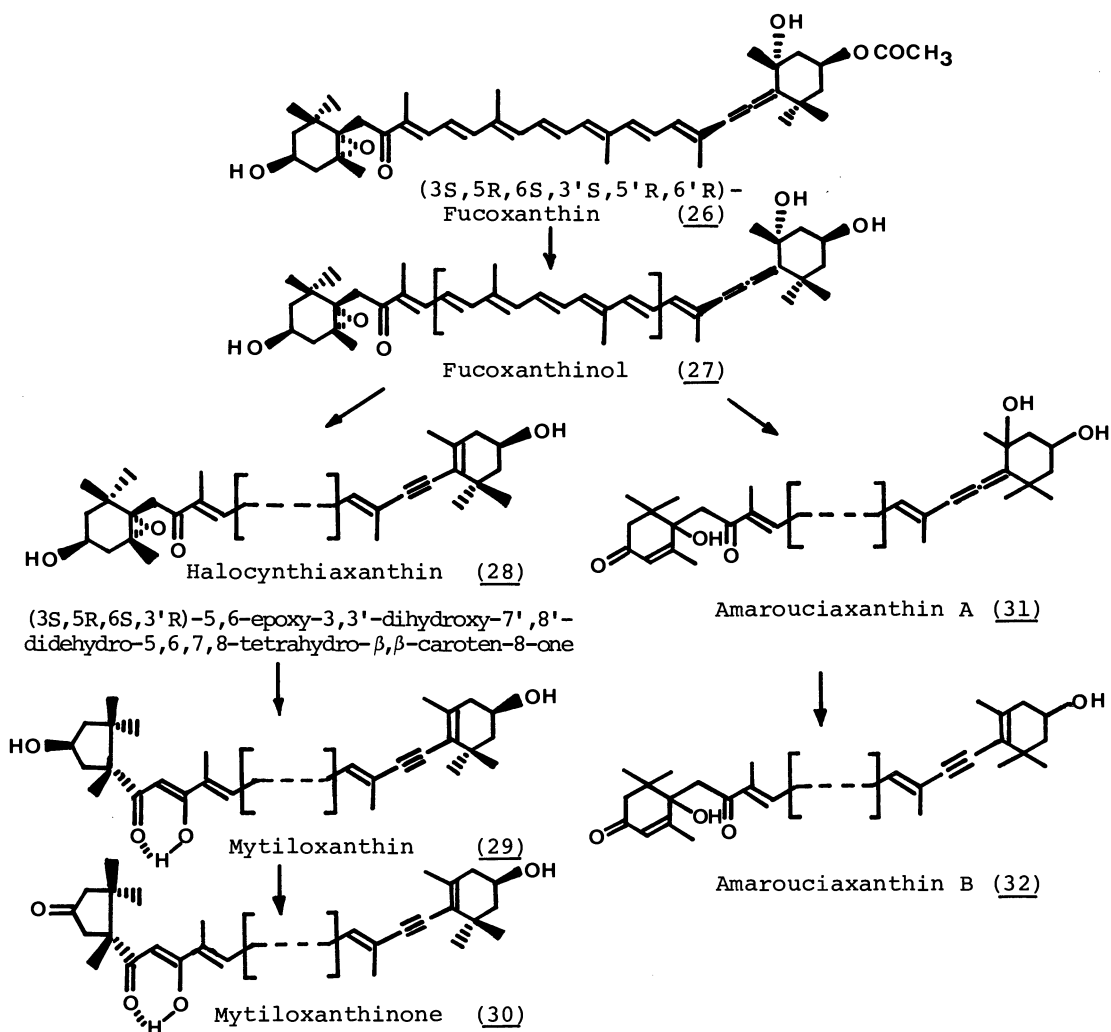


Fig. 1. Possible metabolic pathways of fucoxanthin in marine animals.

6. FISHES (PISCES)

The presence of idoxanthin in the ovaries of marine fishes was shown by Miki *et al.* (Ref. 41). Recently the absolute configuration of idoxanthin (33) has been determined to be (3S,3'S,4'R)-configuration by means of $^1\text{H-NMR}$ and CD measurement by our group (Ref. 42).

As far as we are concerned with the eight possible stereoisomers in lutein, so-called lutein and 3'-epilutein (Refs. 43-45) were isolated from natural sources and four of them were synthesized by Mayer's research group (Ref. 46)

Our group has isolated other new lutein isomers (35) and (36) beside (34) from the integuments of marine fishes (Refs. 47 & 48). Lutein and 3'-epilutein (Refs. 49 & 50) possessing 6'R chirality have been isolated from fresh water fishes, while (34), (35) and (36) having 6'S chirality have been isolated from marine fishes (Ref. 47 & 48). It is interesting from the comparative biochemical point of view.

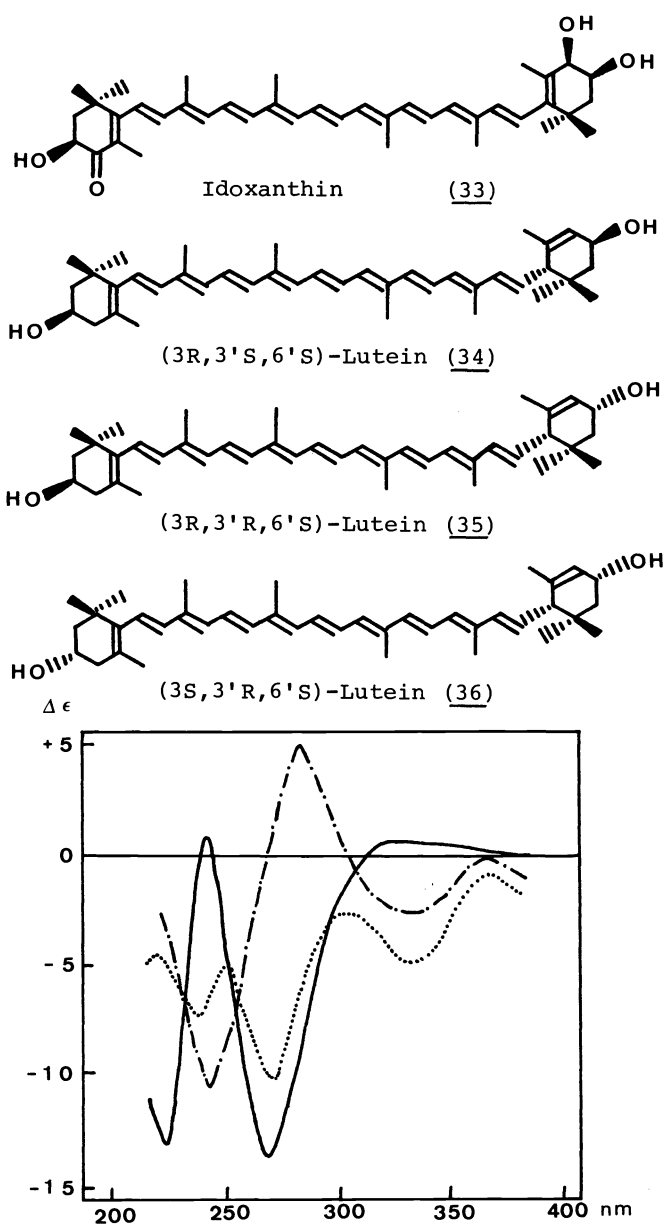


Fig. 2. CD spectra of (34)——, (35)..... and (36)--- in EPA (ether-isopentane-EtOH=5:5:2) solution at 20°C.

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