

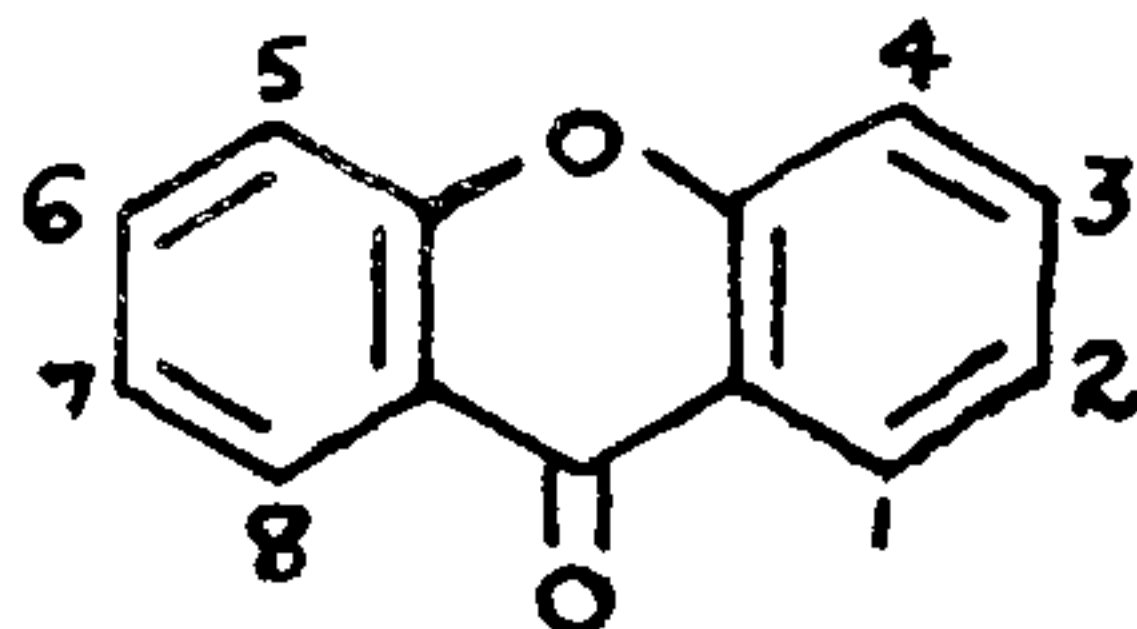
OCCURRENCE OF C<sub>8</sub> UNITS IN XANTHONES

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## NATURALLY OCCURRING XANTHONES

FOR a long time only two xanthenes of definite constitution, viz., gentisin (I) and euxanthone (II) were known to occur in Nature. Recently more xanthenes have been found as components of important vegetable drugs and also as mould and lichen products. Some of them are reported to be physiologically active. They may have uses also as analytical reagents. The following (Table I) is a list of xanthenes so far obtained from natural products. In the compounds whose structures have been more or less definitely established, an *ortho*-hydroxy carbonyl system is invariably present.



## BIOGENESIS OF XANTHONES

Structurally xanthenes are closely related to benzophenones and laboratory synthesis of the former is based on this relation (Chart 1).

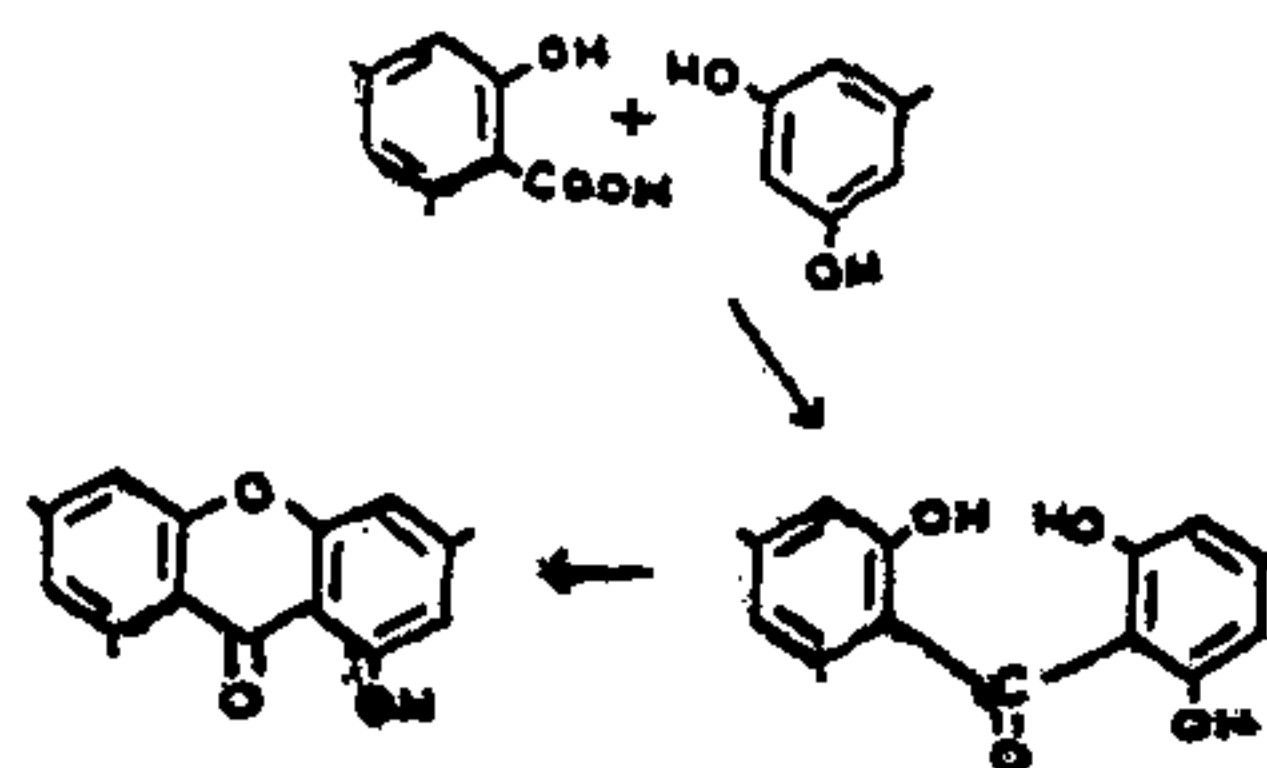


CHART 1

But with regard to their biogenesis, naturally occurring xanthenes and benzophenones seem to have different lines of evolution. This is indicated by the substitution patterns of the two benzene rings present in them. The benzophenones have been considered to be derived

TABLE I

Compound	Structure	Source
1 Lichexanthone (III)	.. 1-Hydroxy-3 : 6-dimethoxy-8-methylxanthone	<i>Parmelia formosana</i> <sup>1</sup> , <i>P. quercina</i> <sup>2</sup>
2 Demethyl-lichexanthone (IV)	.. 1 : 6-Dihydroxy-3-methoxy-8-methylxanthone	<i>Penicillium patulum</i> <sup>3</sup>
3 Ravenelin (V)	.. 1 : 5 : 8-Trihydroxy-6-methylxanthone	<i>Helminthosporium ravenelii</i> , <i>H. turticum</i> <sup>4</sup>
4 Gentisin (I)	.. 1 : 7-Dihydroxy-3-methoxyxanthone	<i>Gentiana lutea</i> <sup>5</sup>
5 Euxanthone (II)	.. 1 : 7-Dihydroxyxanthone	Urine of cows fed on <i>Mangifera indica</i> leaves <sup>6</sup> , <i>Platonia insignis</i> <sup>7</sup>
6* Norswertianol (norswerchirin) (VI)	1 : 3 : 5 : 8-Tetrahydroxyxanthone	<i>Swertia japonica</i> <sup>8</sup> , <i>S. chirata</i> <sup>9</sup>
7* Nordecussatin (norswertinin) (VII)	1 : 3 : 7 : 8-Tetrahydroxyxanthone	<i>Swertia decussata</i> <sup>10</sup>
8 Sterigmatocystin (VIII)	.. 8-Hydroxy-1-methoxyxanthone with extra dihydro-difuran (3 : 4 : 1' : 2') system	<i>Aspergillus versicolor</i> <sup>11</sup>
9 Mangiferin (IX)	.. 2-C-Glucosyl-1 : 3 : 6 : 7-tetrahydroxyxanthone	<i>Mangifera indica</i> <sup>12</sup> , <i>Salacia prinoides</i> <sup>13</sup>
10 Mangostin (X)	.. 2 : 8-Di (γγ-dimethyl) allyl-1 : 3 : 6-trihydroxy-7-methoxyxanthone	<i>Garcinia mangostana</i> <sup>14</sup>
11 Jacareubin (XI)	.. 1 : 5 : 6-Trihydroxy-(2' : 2'-dimethyl, 5' : 6' : 2 : 3-pyrano) xanthone	<i>Callophyllum brasiliense</i> <sup>15</sup>
12* Nor-rubrofusarin (norasperxanthone)	1 : 7 : 8-Trihydroxy-2-methylxanthone(?)	<i>Fusarium culmorum</i> <sup>16</sup> , <i>Aspergillus niger</i> <sup>17</sup>
13 Corymbiferin	.. Undetermined	<i>Gentiana corymbifera</i> <sup>18</sup>
14 Morellin	.. do.	<i>Garcinia morella</i> <sup>19</sup>

\* These xanthenes occur in Nature as their partial methyl ethers. For example, swertianol is a monomethyl ether; decussatin, a trimethyl ether; swertinin, a dimethyl ether; swerchirin, a dimethyl ether; rubrofusarin, a monomethyl ether; asperxanthone, a dimethyl ether. In the above compounds, the position of the methoxyl group has not been fully established.

from 4-phenylchromans or the corresponding coumarins<sup>20</sup> which are formed from a phloroglucinol ( $C_6$ ) unit (A) and a cinnamic acid ( $C_9$ ) unit (B) by the process indicated below (Chart 2). These coumarins (XII) or better the corresponding coumaric acids (XIII) seem to act as precursors and yield the benzophenones (XIV) by oxidation.

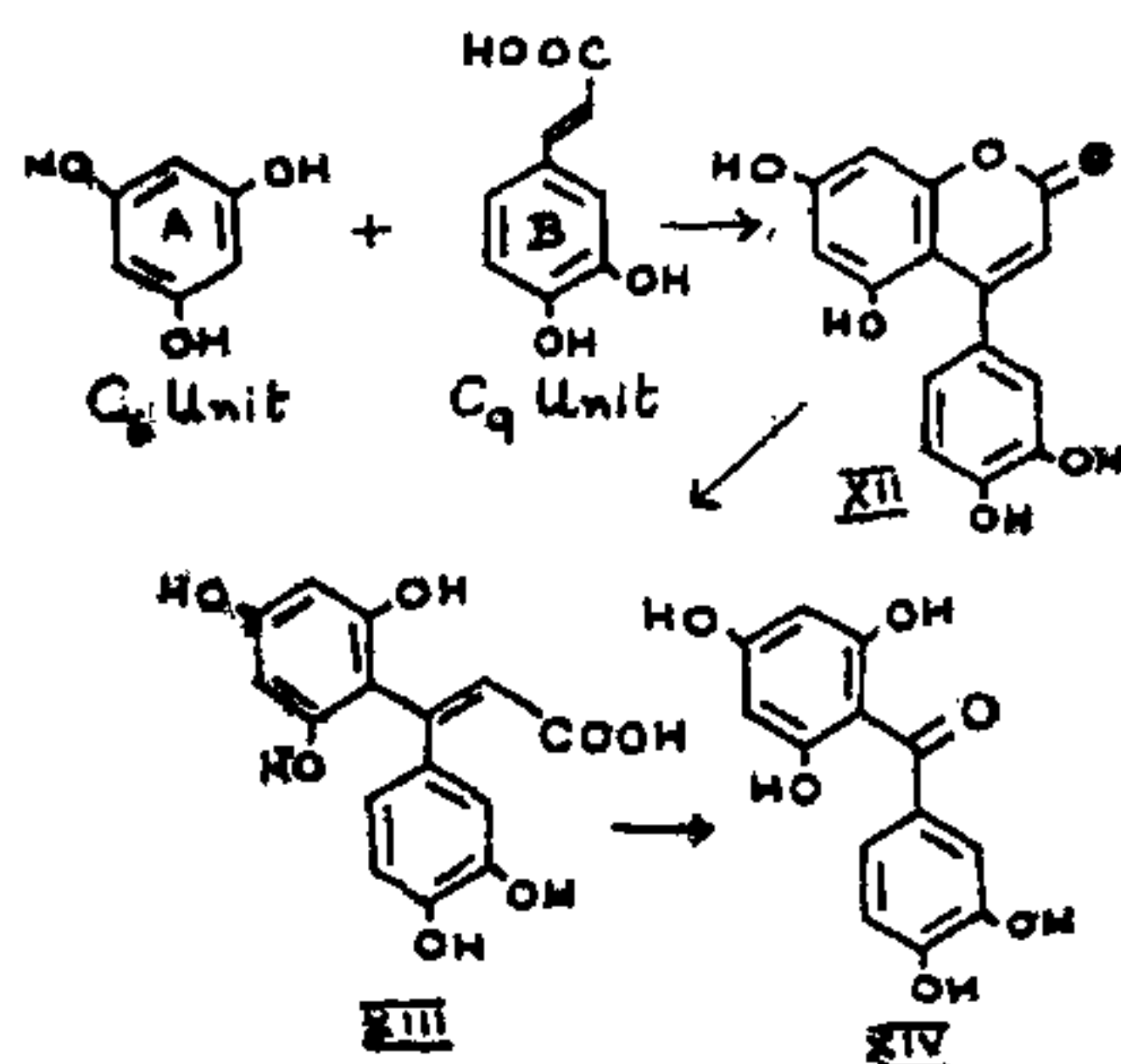


CHART 2

#### BIOGENESIS OF LICHEXANTHONE (III) AND RAVENELIN (V)

Of the various naturally occurring xanthonenes, lichexanthone (III) is a lichen product and is the simplest based on the  $C_8$  unit origin. The presence of  $C_8$  unit is obvious. Its biogenesis has already been discussed in an earlier paper.<sup>21</sup> The formation of norlichexanthone (XV) involves a  $C_8$  (orsellinic) unit (A) and a  $C_6$  (phloroglucinol) unit (B) (Chart 3). Partial methylation of the more reactive 3- and 6-hydroxyl groups leads to lichexanthone (III). The formation of demethyl-lichexanthone (IV), a mould metabolic product, from norlichexanthone (XV) seems to involve monomethylation in the 3-position. This selective methylation of the 3-hydroxyl group may be significant. Of the two reactive hydroxyl groups, viz., 3 and 6, which are not symmetrically located, the former seems to be more acidic because of the presence of the 1-hydroxyl group in the same ring. The exact reason for this is not at present clear.

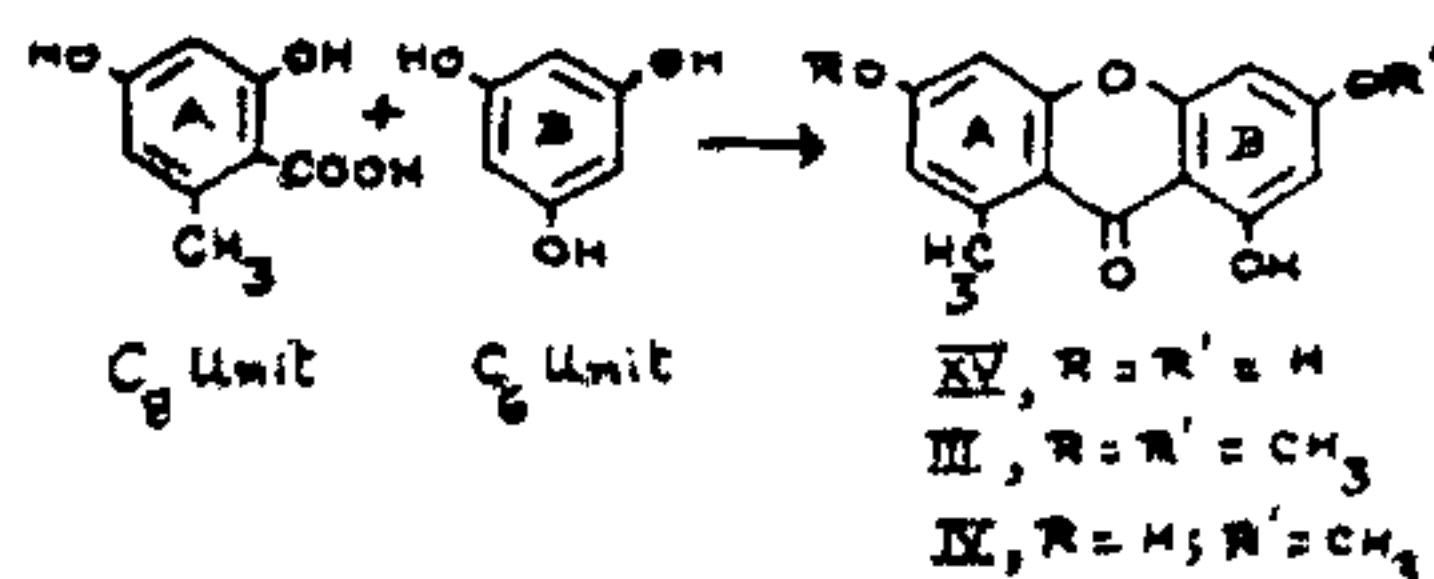


CHART 3

Though ravenelin (V), a fungal product, is isomeric with norlichexanthone (XV) and is derived from similar units, it exhibits marked difference in regard to the location of the methyl and hydroxyl groups and should, therefore, have a more complex biogenesis. As indicated in earlier papers,<sup>21,22</sup> the phloroglucinol part (B) has undergone nuclear reduction (loss of phenolic hydroxyl group) to a resorcinol (XVI) unit. Regarding the other part (A), 3-carboxyorsellinic acid (XVII) may be the modified orsellinic unit involved and it undergoes partial decarboxylation to *para*-orsellinic acid (XVIII). These two units (XVI and XVIII) could give rise to the intermediate xanthone (XIX). *Para*-nuclear oxidation in ring (A) of this xanthone would lead to ravenelin (V) (Chart 4). Based on these considerations, a convenient synthesis of ravenelin has recently been achieved.<sup>22</sup>

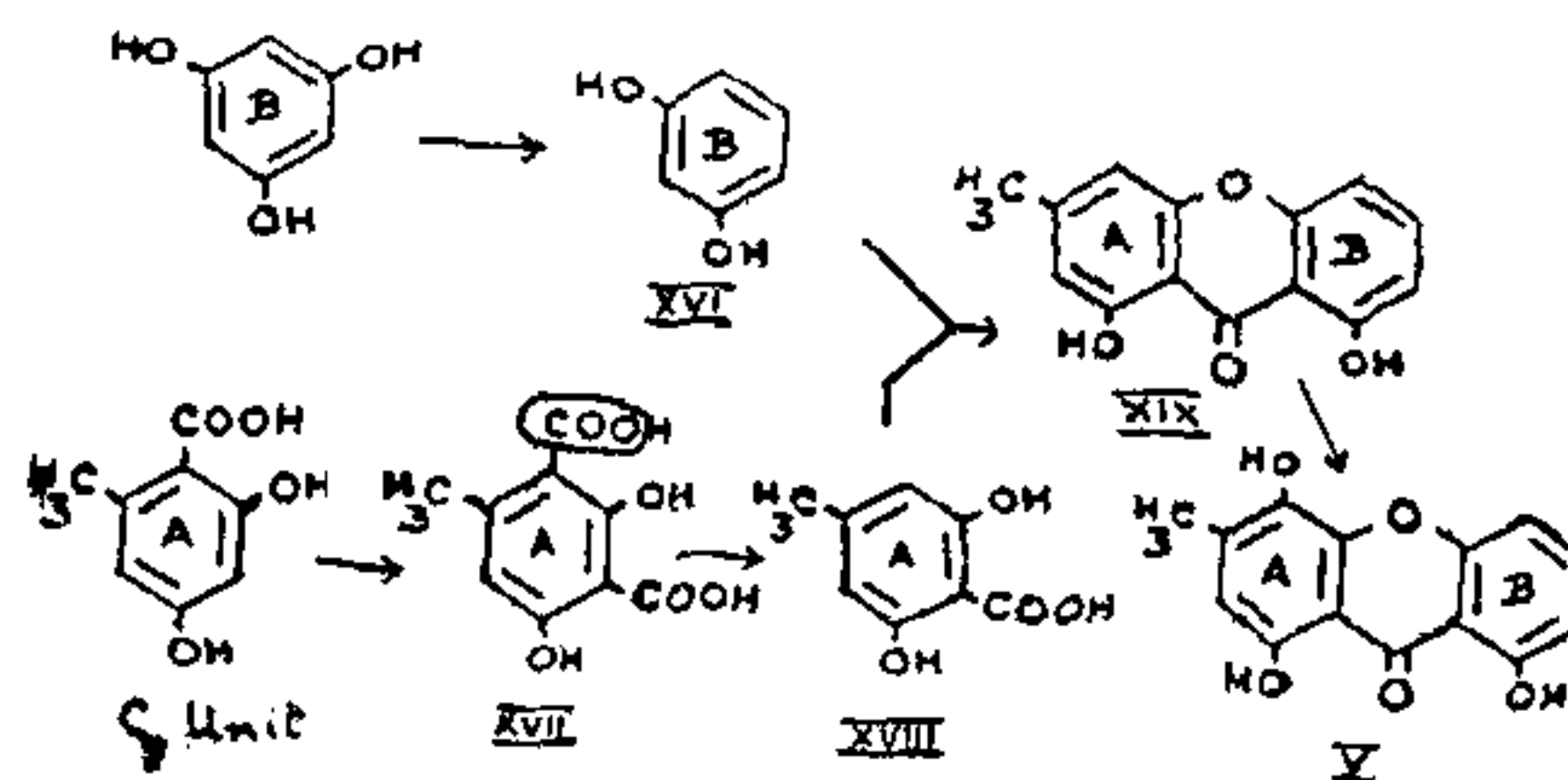


CHART 4

#### BIOGENESIS OF GENTISIN (I) AND EUXANTHONE (II)

The xanthonenes of higher plants seem to have the same evolution though their structures appear rather different. In all of them, there is a phloroglucinol ( $C_6$ ) unit or the derived resorcinol unit. But instead of a simple orsellinic ( $C_8$ ) unit, a modified one seems to be found. In the simpler members, gentisin (I) and euxanthone (II), a gentisic acid (XX) unit is present. In an earlier paper,<sup>21</sup> the origin of gentisic acid (XX), which is a metabolic product of *Penicillium* spp., was traced to  $C_8$  unit (Chart 5).

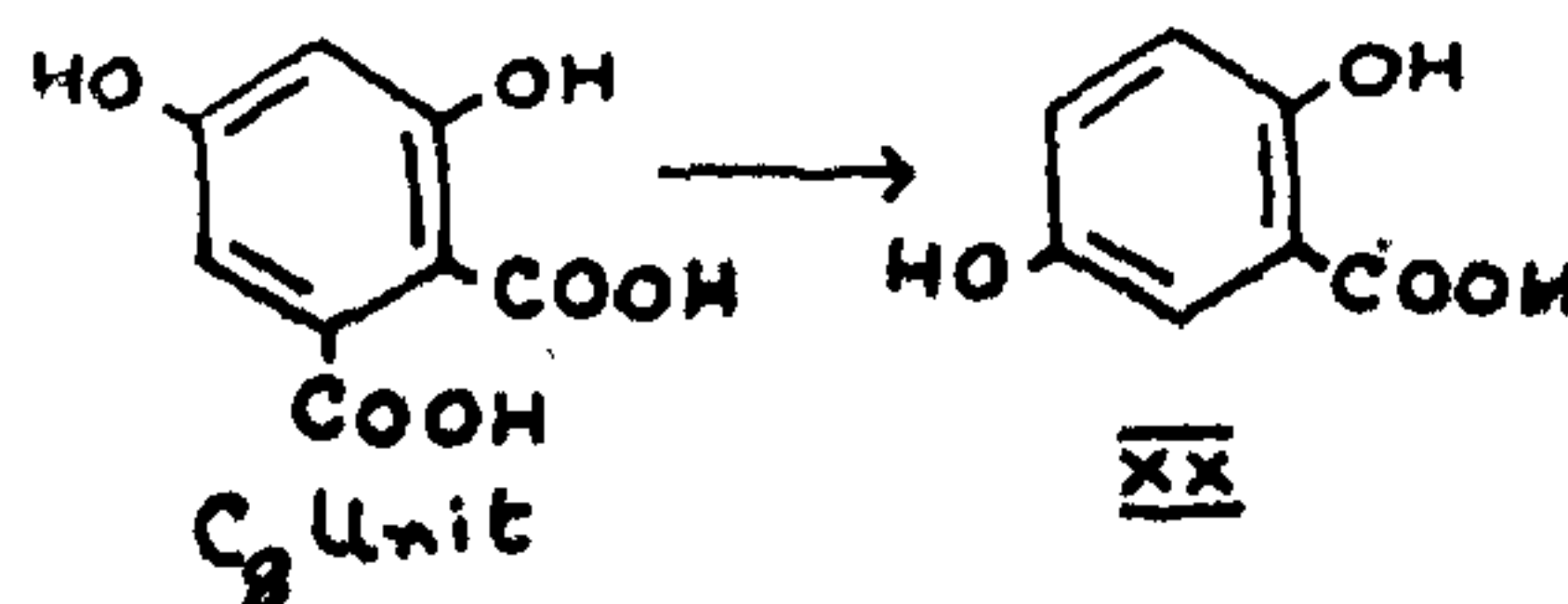


CHART 5

Gentisin (norgentisin) (XXI) may represent an earlier stage in evolution and would be the product of combination of phloroglucinol and gentisic acid (XX) (Chart 6). The formation



of gentisin (I) involves partial monomethylation of the more reactive 3-hydroxyl group.<sup>23</sup> Euxanthone (II) may arise from gentisein (XXI) by nuclear reduction. The laboratory conversion of gentisein (XXI) to euxanthone (II) follows this possible biogenetic pathway.<sup>24</sup> In this process, gentisein is monotosylated in the 3-position and the resulting tosyl ester (XXII) reduced with hydrogen and Raney nickel (hydrogenolysis).

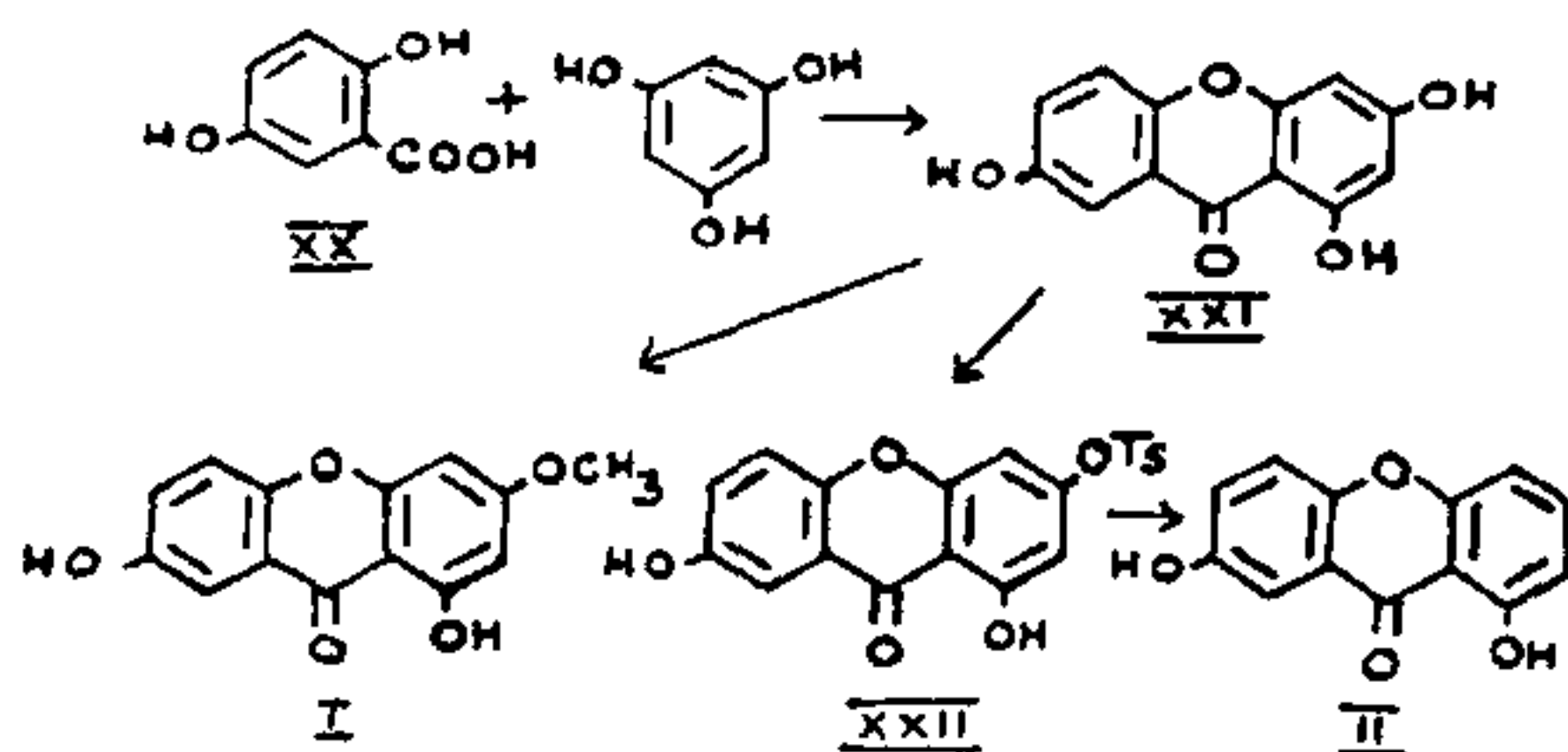


CHART 6

#### BIOGENESIS OF *Swertia* XANTHONES (VI AND VII)

The *Swertia* xanthenes are based on 1:3:5:8-tetrahydroxy-(VI) and 1:3:7:8-tetrahydroxyxanthenes (VII). In these, one of the units (B) is phloroglucinol as in the earlier cases but the other is a 6-hydroxygentisic acid unit (XXIII). The fact that these isomeric xanthenes are found in the same genera may suggest very similar origin. The following derivation of 6-hydroxygentisic acid (XXIII) from  $C_8$  unit may be suggested (Chart 7). In this, 6-formyl-2:4-dihydroxybenzoic acid ( $C_8$  unit) undergoes nuclear reduction of the 4-hydroxyl group (XXIV); subsequent *para*-nuclear oxidation would lead to 6-formyl-2:5-dihydroxybenzoic acid (XXV). Oxidation (Dakin's type) of this hydroxy aldehyde derivative would give 6-hydroxy-gentisic acid (XXIII). Similar oxidations have been shown to be important stages in the evolution of flavonoids and lichen acids and the feasibility of these under laboratory conditions has also been demonstrated.<sup>25</sup>

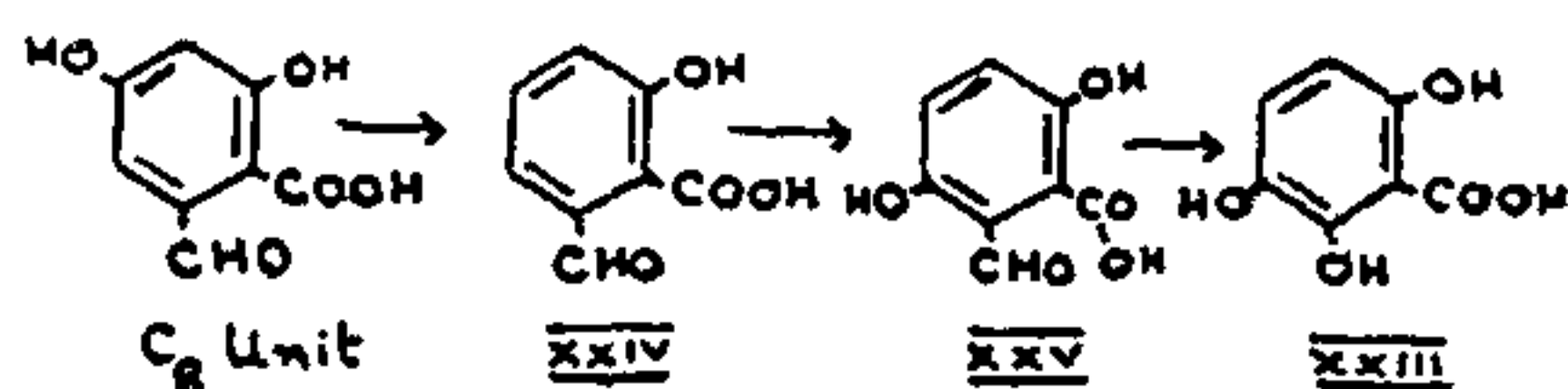


CHART 7

The isomeric tetrahydroxyxanthenes (VI and VII) may arise by ring closure in two alternative directions, the former involving the 6-

hydroxyl group and the latter, the 2-hydroxyl group, respectively, of the hydroxygentisic acid (XXIII) (Chart 8).

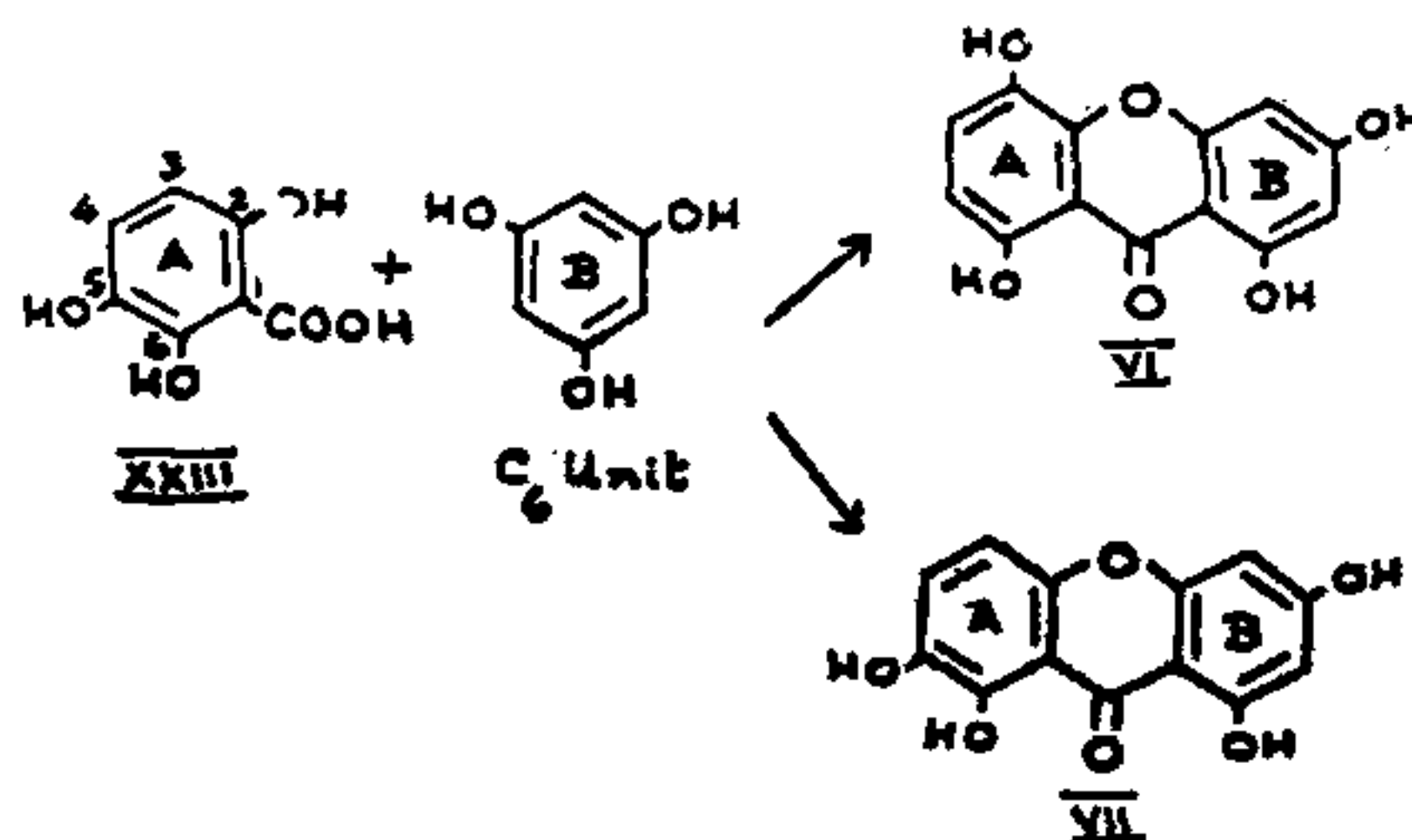


CHART 8

#### BIOGENESIS OF STERIGMATOCYSTIN (VIII)

Sterigmatocystin (VIII) is a derivative of 1:3:8-trihydroxyxanthone and thus has a phloroglucinol unit (B) as in a number of cases mentioned above. The other part is derived from 1:6-dihydroxybenzoic acid ( $\gamma$ -resorcylic acid). Further, there is a di-(dihydro)-furan system involving a  $C_4$  unit probably derived from a sugar. The 1:3:8-trihydroxyxanthone may arise from 1:3:5:8-tetrahydroxyxanthone (VI) by a process of nuclear reduction (Chart 9). Such loss of *para*-hydroxyl group in quinol systems is known, e.g., 1:2:3:5-tetrahydroxybenzene to phloroglucinol.<sup>26</sup>

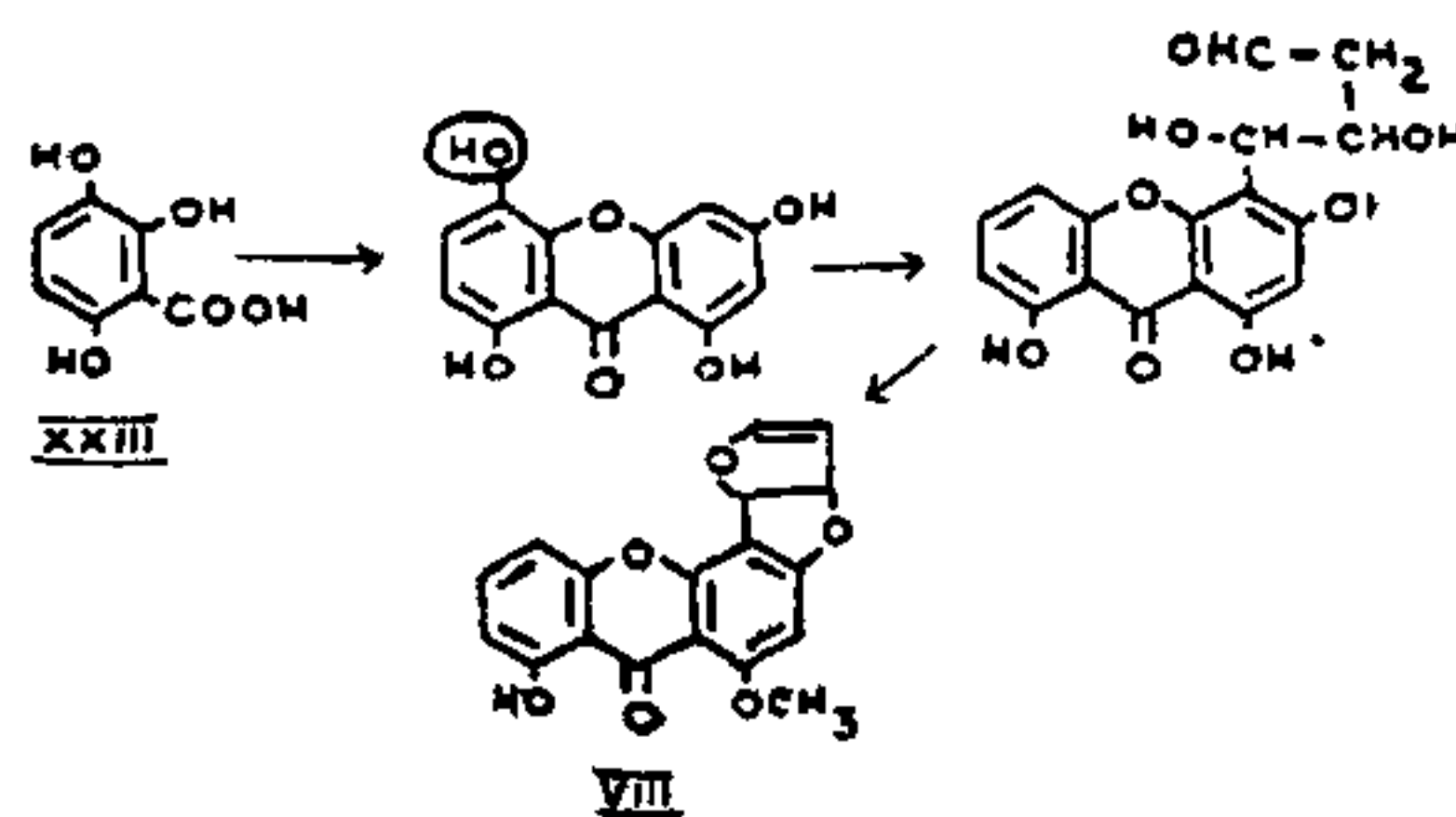


CHART 9

#### BIOGENESIS OF COMPLEX XANTHONES [MANGIFERIN (IX) MANGOSTIN (X) AND JACAREUBIN (XI)]

Under more complex types come mangiferin (IX), mangostin (X) and jacareubin (XI). The first two are derivatives of 1:3:6:7-tetrahydroxyxanthone (XXVI) and the third has a 1:3:5:6-hydroxy system (XXVII). In these two tetrahydroxyxanthenes (XXVI and XXVII) ring (B) is again phloroglucinol and the other ring (A) may again be traced to  $C_8$  units. The tentative suggestions are embodied in the formulæ of Chart 10. In the case of 1:3:6:7-tetrahydroxyxanthone system (XXVI), ring (A)

may arise from 3:5-dihydroxyphthalic acid (DHP) (XXVIII) undergoing *para*-nuclear oxidation to 3:5:6-trihydroxyphthalic acid (XXIX). For the formation of 1:3:5:6-tetrahydroxyxanthone (XXVII), the corresponding ring may result from *ortho*-nuclear oxidation of DHP (XXVIII) to 3:4:5-trihydroxyphthalic acid (XXX). Similar reactions involving *para*- and *ortho*-nuclear oxidations are frequently met with in lichen acids.<sup>25,27</sup> Further, there is loss of a single carbon atom (decarboxylation) in the 8-position of both the xanthenes to yield the final products.

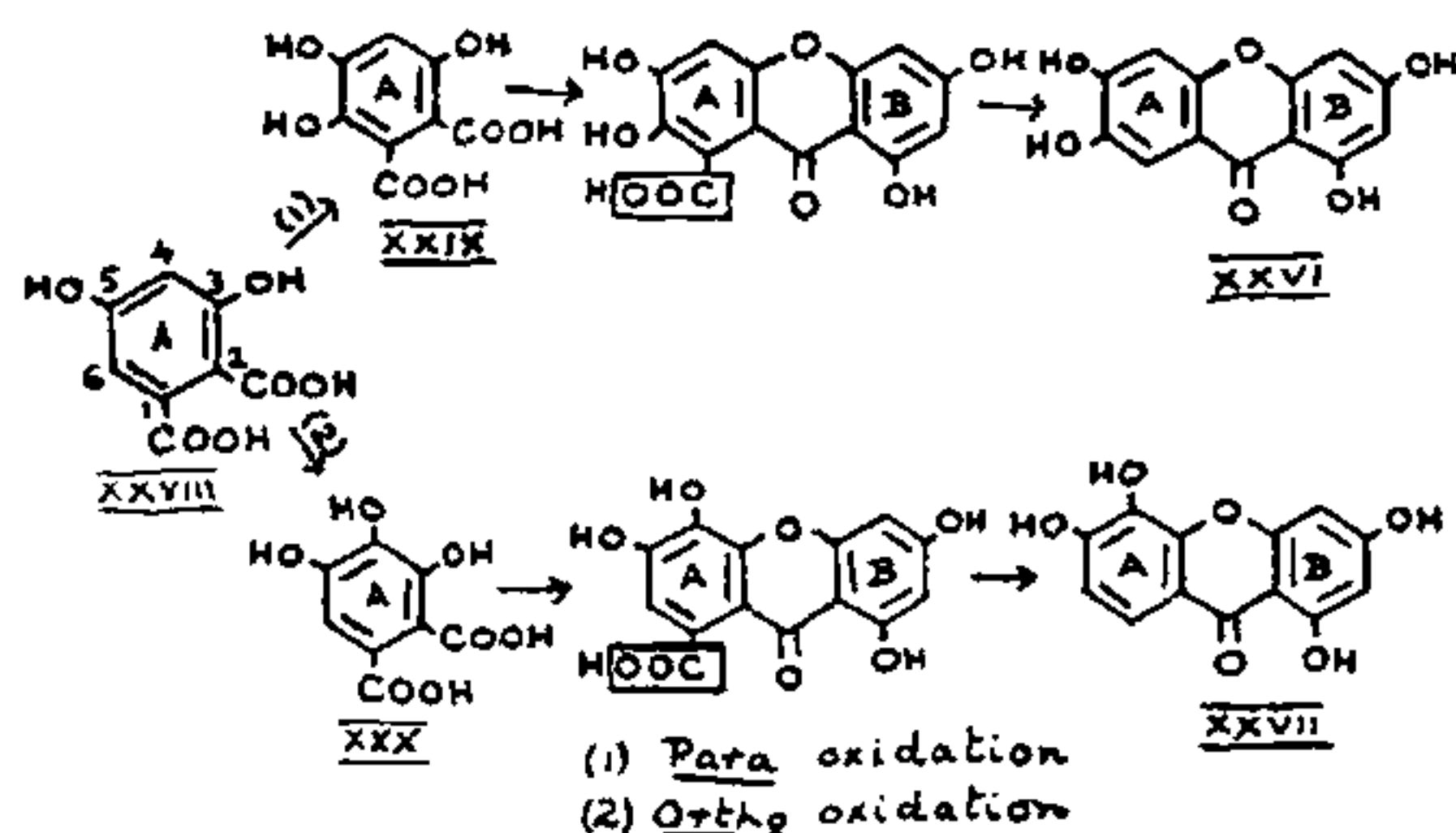


CHART 10

Mangiferin (IX) is a glucosyl derivative in which the sugar unit is linked to a carbon atom (position 2) instead of to oxygen (Chart 11). A number of examples of this type of C-glycosyl derivatives have recently been discovered.<sup>28</sup> Mangostin (X) and jacareubin (XI) are more complex and contain isoprene ( $C_5$ ) units which appear to have entered the xanthone structure at a later stage.

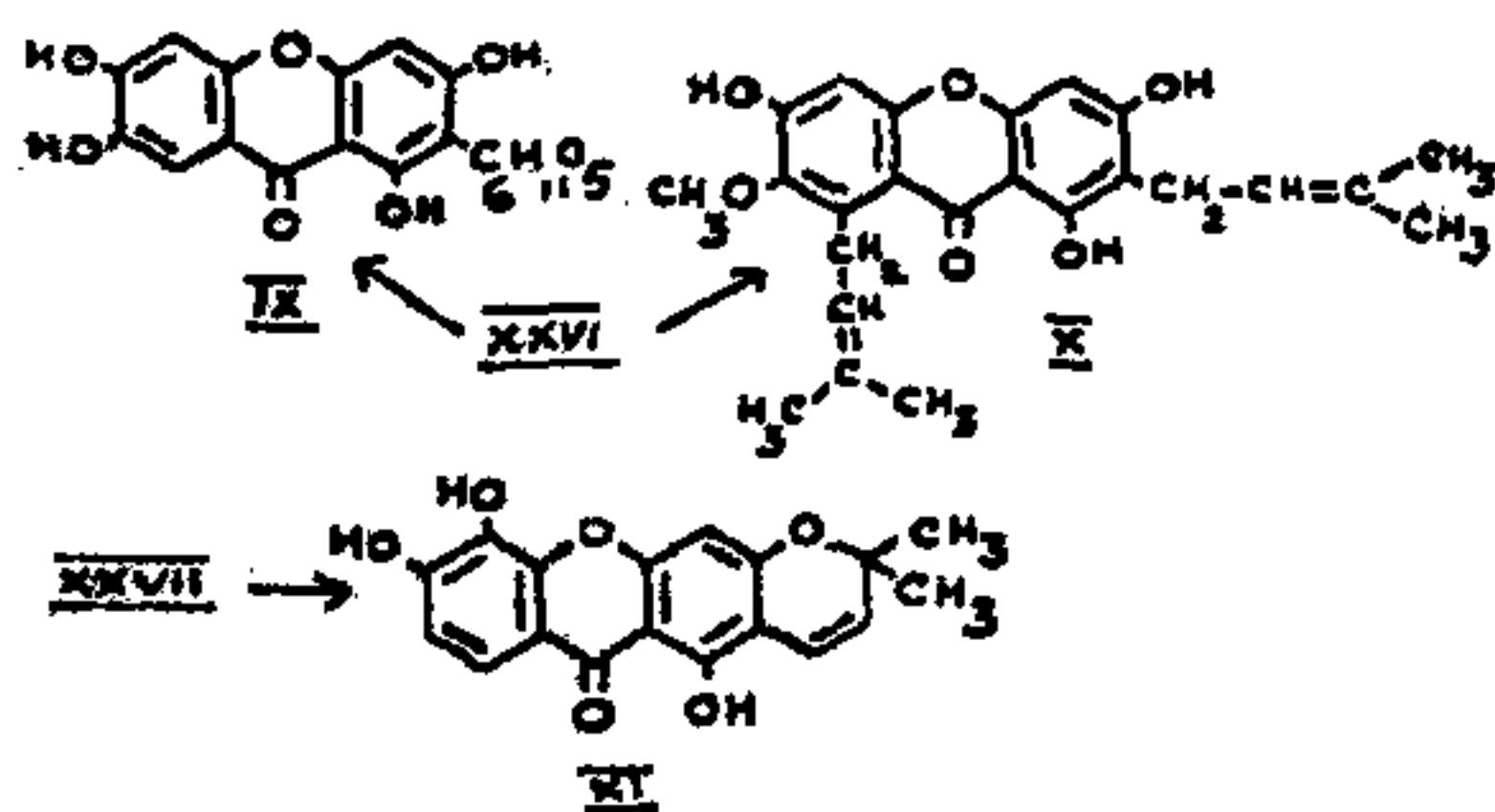


CHART 11

#### XANTHONES OF INDEFINITE STRUCTURE

The structure of nor-rubrofusarin was tentatively given as 1:7:8-trihydroxy-2-methylxanthone or its corresponding 1:6:7-hydroxyisomer.<sup>29</sup> This does not fit into the above scheme of biogenesis because the methyl group is in an unusual position, *viz.*, 2-position. However, the validity of these structures has been questioned by Robertson and co-workers<sup>17</sup> who

also found that nor-rubrofusarin was identical with non-asperxanthone. Similarly the full structures of corymbiferin and morellin have also not been established so far.

#### MODE OF XANTHONE FORMATION

At this stage should be discussed the mode of linking between the two units. The familiar synthetic method in which an *ortho*-hydroxy carboxylic acid is condensed with phloroglucinol or resorcinol (Chart 1) in the presence of a condensing agent may be an obvious suggestion, *e.g.*, the synthesis of lichexanthone<sup>30</sup> and gentisein.<sup>31</sup> Another possible method seems to be the condensation of an *ortho*-hydroxy aldehyde (XXXI) with a phloroglucinol unit leading to a fluorone derivative (XXXII). From this to the xanthone requires an oxidation stage. For the evolution of lichexanthone (III), orcylaldehyde and for the evolution of gentisein (XXI), gentisic aldehyde would be involved. But in the laboratory adoption of this course, reduction of the fluorone (XXXII) to the corresponding xanthene (XXXIII) and subsequent oxidation yield the xanthone (XV) (Chart 12). This procedure has been used for the synthesis of lichexanthone<sup>1,2</sup> (III).

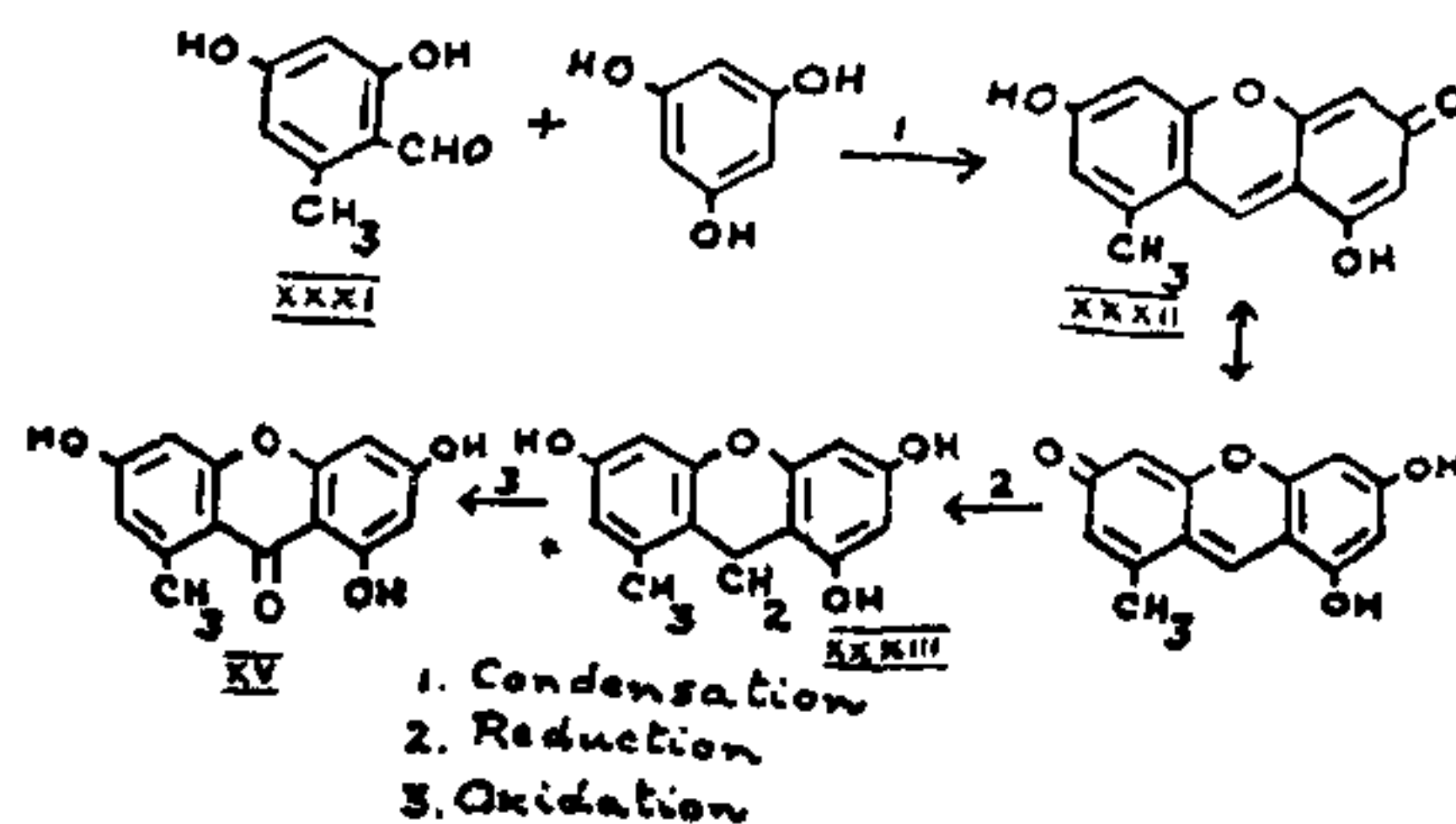


CHART 12

#### SUMMARY

A large number of xanthone derivatives have recently been isolated and characterized. All of them seem to be biogenetically capable of coming into a mixed type consisting of a  $C_0$  and a  $C_8$  unit. The simplest is represented by lichexanthone and others involve more stages of transformation. They are conveniently classified on this basis. The formation of xanthone skeleton itself could be visualized in two alternative ways involving condensation of either a carboxylic acid or an aldehyde.

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### SOLAR ENERGY

THERE are two chief methods of harnessing solar energy. The first is the direct method or the "greenhouse" method known to all horticulturists. The interior of the greenhouse heated by the sun's rays, reflects long infra-red waves to which the glass is opaque. The heat of these rays is caught as it were in a trap: it cannot escape and tends to accumulate in the glassed-in space. This method, therefore, allows the sun's rays to enter through a glass surface and prevents the radiation of bodies heated by the sun from escaping. The direct method can produce temperatures up to 150° C.—however, the practical working temperatures are kept at a lower level between 60° and 80° C.

The second method is by concentration of the solar rays on suitable collectors whereby temperatures ranging from several hundred to a few thousand degrees can be obtained. Two types of collectors are generally used: (i) The 'flat' collector consisting basically of a dark plate, insulated on the side away from the sun, and protected from the wind on the side facing the sun by a transparent pane. The plate may heat either liquid-filled pipes attached to it or air. (ii) The 'focusing collector' uses mirrors in order to concentrate the sun's rays upon a small receiving object with a dark surface. In general, the focusing collectors must be continually manoeuvred to follow the sun's movement.

The design and efficiency of the collectors have been improved in recent years by the use of new materials and of darkened selective surfaces with low radiating power, thus leading to higher operative temperatures. Glass, anodised aluminium and new plastics aluminised in a vacuum have been used for focusing collectors.

A third type of collector, suitable for very large surfaces, has been studied in France and in Israel. This is the 'solar pool', a shallow basin with a darkened bottom whose operation is based upon the principle of water density. By dissolving salts in the water at the bottom of the pool, a very salty layer is obtained while the top layer remains unsalted, the difference in density preventing them from mixing. The top layer keeps an even temperature, because it loses its heat at the same rate as it stores it, but the heat generated in the salty water at the bottom of the pool does not escape and it can be used as a source of power.

Conversion of solar heat into electricity through thermocouples has reached a high degree of development, thanks to improvements resulting from basic research in solid state physics. Progress in this field of solar converters has been particularly noteworthy in US and USSR under their programme of space research.—(UNESCO).