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IUPAC–IUB Revised Tentative Rules for Nomenclature of Steroids*†

Contents

Introduction

The rules of steroid nomenclature originate from a discussion held at the Ciba Foundation in London, England, in 1950 between the representatives of many schools. These were published in *Chemistry & Industry*, Jan 23, pp SN 1–11 (1951), and also in French and German. They were subsequently taken over by the International Union of Pure and Applied Chemistry and published in an official form in the *Comptes rendus* of the Zurich meeting in 1952 (also IUPAC Nomenclature of Organic Chemistry, Sections A & B, 1957, Butterworths Scientific Publications, London, 1st ed, 1958; 2nd ed, 1966, pp 71–82; and numerous reprints and translations), including *J. Am. Chem. Soc. 82*, 5577–5581 (1960)).

In 1960 a group of specialists under the chairmanship of Professor T. Reichstein, including representatives of the IUPAC Commissions of the Nomenclature of Organic Chemistry and of Biochemical Nomenclature, met in Basle, Switzerland, for discussions of amendments and additions to the rules. Agreement was not reached on all the points discussed, and the results of this meeting were therefore published in discussion form in the IUPAC *Information Bulletin*, No. 11. They have generally been referred to as the "Basle Proposals."

Since then, many points in the Basle Proposals have become almost universally accepted in the literature. In 1965 the two International Commissions concerned, namely, the IUPAC Commission of the Nomenclature of Organic Chemistry and the Commission on Biochemical Nomenclature (now jointly responsible to IUPAC and IUB), decided that the time had come for as many as possible of the Basle Proposals to be formulated as rules.

The present rules include: all the original rules, mostly renumbered (with additions and amendments arising from the Basle proposals or from current practice in the literature); and most of the Basle Proposals, namely, those that have been generally accepted. Further, adoption of the sequence-rule procedure‡ for general stereochemical descriptions in much of the chemical literature has permitted its introduction now also for some sections of steroid nomenclature that were previously in dispute or intractable. Decisions on a few of the Basle Proposals have, however, been postponed; it is hoped that further experience will indicate the most appropriate ways of dealing with them.

General Application

Although these rules are called "Rules for Nomenclature of Steroids," many of the principles therein have become almost universally accepted also in diterpene and triterpene chemistry; also to some extent for sesquiterpenes and for several groups of alkaloids. It is suggested that the same principles may be applied to a number of other specialized groups of natural products, perhaps without the need for further official rules, so long as the basic ideas are followed. These principles include: (i) clear definition of stem names and the stereochemistry implied in them; (ii) systematic application of the rules of general organic chemical nomenclature, with modifications where special considerations make this necessary; (iii) application of the methods of skeletal modification given in these rules, *viz.*, the use of homo and nor for, respectively, stepwise expansion and contraction of ring systems, the use of seco for reductive fission of ring systems, and the use of *abeo* for formal bond migrations (this flexible concept was first proposed by D. H. R. Barton at an informal meeting of terpene chemists convened by the Chemical Society in London, England).

* These rules shall be known as the IUPAC–IUB 1967 Revised Tentative Rules for Steroid Nomenclature.

† These rules are issued by the IUPAC Commission on the Nomenclature of Organic Chemistry [P. E. Verkade (Chairman), L. C. Cross, G. M. Dyson, G. Kersaint, K. L. Loening, N. Lozac'h, H. S. Nutting, S. Veibel; associate members, R. S. Cahn, J. Rigaudy; observers, K. A. Jensen, W. Klyne], and by the IUPAC–IUB Commission on Biochemical Nomenclature [O. Hoffmann-Ostenhof (Chairman), A. E. Braunstein, W. E. Cohn, J. S. Fruton, P. Karlson, B. Keil, W. Klyne, C. Liébecq, E. C. Slater, E. C. Webb; corresponding member, N. Tamiya; observer, S. Veibel], and are published by permission of the IUPAC, the IUB, and the official publishers to IUPAC, Butterworths Scientific Publications. Reprints of these Revised Tentative Rules may be obtained from the NAS–NRC Office of Biochemical Nomenclature (Dr. Waldo E. Cohn, Director), Biology Division, Oak Ridge National Laboratory, Oak Ridge, Tenn. 37830.

‡ Cahn, R. S., Ingold, C. K., and Prelog, V. (1966), *Angew. Chem. Intern. Ed. Engl. 5*, 385; *Angew. Chem. 78*, 413 (in German). For a partial simplified account see Cahn, R. S. (1964), *J. Chem. Educ., 41*, 116.

Comments

Comments on and suggestions for future revisions of these Tentative Rules should be sent to: Professor P. E. Verkade, 's-Gravenhage, Ary Schefferstraat, 217, The Netherlands, or Professor O. Hoffmann-Ostenhof, Biochemische Abteilung, Organisch-Chemisches Institut der Universität Wien, 1090 Vienna, Währinger Strasse 68, Austria, or to any member of the Commissions named in the footnote on p 2227.

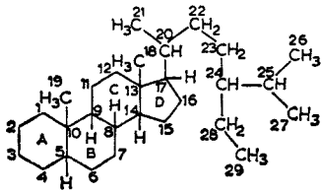
Rules

Rules are numbered 2S-1, 2S-2, 2S-3, etc., the first "2" denoting that this is the second or revised set of rules. The numbers of the corresponding previous rules (see Introduction), where they exist, are included for comparisons.

General

Rule 2S-1 (Expanded from Rules S-1 and S-2)

1.1. Steroids are numbered and rings are lettered as in formula 1 If one of the two methyl groups attached to C-25 is substituted,



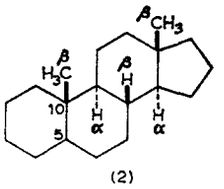
(1)

it is assigned the lower number (26); if both are substituted, that carrying the substituent cited first in the alphabetical order or order of complexity is assigned the lower number (*cf.* IUPAC 1965 Rule* C-15.11(e)). For trimethyl steroids see Rule 2S-2.3, Note 3.

1.2. If one or more of the carbon atoms shown in (1) is not present and a steroid name is used, the numbering of the remainder is undisturbed.

1.3. For a steroid, the name, including stereochemical affixes, and its structural formula (see Rule 2S-1.4) denote the absolute configuration at each asymmetric center (see also Rule 2S-1.5). When the configuration at one or more centers is not known, this is indicated by Greek letter(s) ξ (xi) prefixed by the appropriate numeral(s).

1.4. When the rings of a steroid are denoted as projections onto the plane of the paper, the formula is normally to be oriented as in (2). An atom or group attached to a ring depicted as in the orientation (2) is termed α (alpha) if it lies below the plane of the



(2)

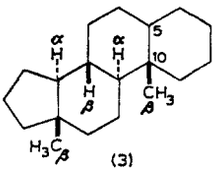
paper or β (beta) if it lies above the plane of the paper. In formulae, bonds to atoms or groups lying below the plane of the paper are shown as broken (- - -) lines, and bonds to atoms or groups lying above the plane of the paper are shown as solid lines (preferably thickened). Bonds to atoms or groups whose configuration is not known or is unspecified are denoted by wavy lines (∿∿).

Notes. (1) Projections of steroid formulae should not be oriented as in formulas 3, 4, or 5 unless circumstances make it obligatory.

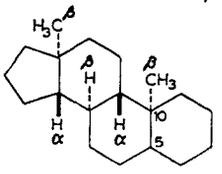
(2) With the preferred orientation (2), and with (3), α bonds appear as broken lines and β bonds as solid (thickened) lines. The reverse is true for (4) and (5). Wavy lines denote ξ bonds for all orientations of the formula.

(3) A perspective representation of the stereochemistry of formula 2 as in (2a) or (2b) may also be used.

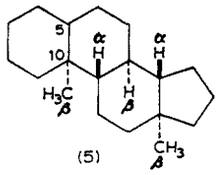
* IUPAC (1965), Nomenclature of Organic Chemistry, Section C, Butterworths Scientific Publications, London; also *Pure Appl. Chem.* *11*, No. 1 and 2.



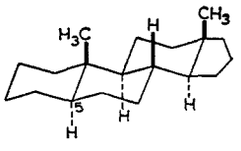
(3)



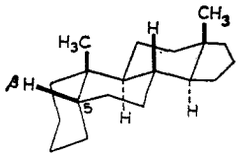
(4)



(5)



(2a)
A 5α-steroid



(2b)
A 5β-steroid

(For the significance of the prefixes 5α- and 5β- see Rule 2S-I.5.)

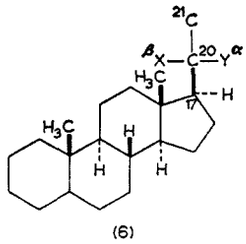
When steroid formulae are drawn in this way, bonds pointing upward are, by convention, drawn bold and bonds pointing downward are drawn broken; these representations correspond to the β and α bonds of projection formulae such as (2) and do not conform to the general practice that bold and broken lines denote bonds projecting respectively above and below the plane of the paper. Note, however, that the general practice is followed with chair and boat forms of spirostans (see Rule 2S-3.3).

(4) All hydrogen atoms and methyl groups attached at ring-junction positions must always be inserted as H and CH_3, respectively (Me may be used in place of CH_3 if editorial conventions require it). The practice, sometimes followed, of denoting methyl groups by bonds without lettering is liable to cause confusion and should be abandoned. This is essential in view of customs in other fields and applies also to other groups of compounds such as cyclic terpenes and alkaloids for which steroid conventions are commonly used.

1.5. Unless implied or stated to the contrary (see Rules 2S-3, 2S-4.3, 2S-5, and 2S-11), use of a steroid name implies that atoms or groups attached at the ring-junction positions 8, 9, 10, 13, and 14 are oriented as shown in formula 2 (*i.e.*, 8β, 9α, 10β, 13β, 14α), and a carbon chain attached at position 17 is assumed to be β oriented (see Notes below). The configuration of hydrogen (or a substituent) at the ring-junction position 5 is always to be designated by adding α, β, or ξ after the numeral 5, this numeral and letter being placed immediately before the stem name. The configuration of substituents attached at other centers of asymmetry in the tetracyclic system A–D is stated by adding α, β, or ξ after the respective numerals denoting their position.

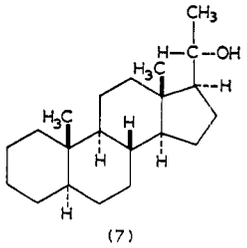
Notes. For the purpose of this rule a carboxyl group at position 17 is not considered to constitute a carbon "chain" (for the nomenclature used, see Rule 2S-4.3). For pent a-and hexacyclic derivatives, see Rule 2S-3, and for stereochemical modifications, see Rule 2S-5.

1.6. When the configuration at position 20 in the side chain of a pregnane derivative is as depicted in the projection formula 6 (*i.e.*, a Fischer projection but with the highest number at the top), substituents shown to the right of C-20 are termed α and those to the left are termed β.



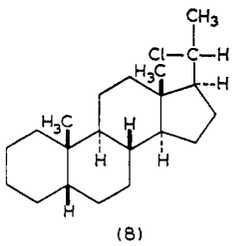
(6)

Examples



(7)

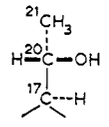
5α-Pregnan-20α-ol*



(8)

20β-Chloro-5β-pregnane*

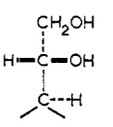
Notes. (1) The 20α/20β nomenclature is continued because of long tradition. When a longer side chain is present at C-17, the sequence-rule procedure (see Cohn *et al.*, 1966) is more generally convenient (see Rule 2S-1.7), and it may also be used to designate stereochemistry at C-20 in pregnanes, being particularly useful for C-20 substituents that may cyclize with a substituent at another position [*e.g.*, carboxylic acids as in example 12]. For 20-hydroxy, 20-alkoxy, 20-acyloxy, 20-amino, and 20-halogeno derivatives of pregnane without a substituent on C-17 or C-21, 20α is equivalent to (20*S*), and 20β to (20*R*); however, these equivalences are sometimes reversed when additional substituents are present, *e.g.*, on C-17 or C-21, and in such cases ref 1 should be consulted.



(9)

20α-ol (20*S*)

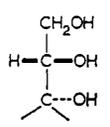
but



(10)

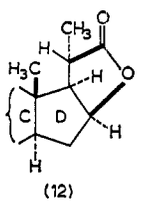
20α,21-diol (20*R*)

although



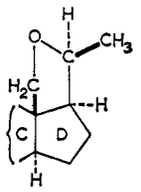
(11)

17,20α,21-triol (20*S*)



(12)

(20*S*)-16β-Hydroxypregnane-20-carboxylic acid lactone (≡ 20α)



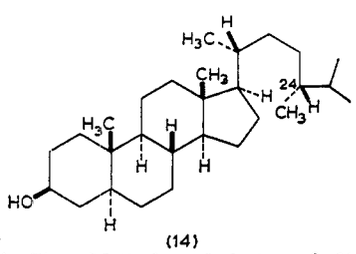
(13)

(20*S*)-18,20-Epoxypregnane (≡ 20α)

(2) When stereochemistry at C-20 is denoted by a Fischer-type projection, as in (6)–(11) or for cardenolides as (37) or bufanolides as (43), the 17,20 bond is preferably denoted by an ordinary line; the stereochemistry at C-17 is then adequately denoted by a thick or a broken bond to the H or to the other substituent (*e.g.*, OH) at position 17. In such formulae, representing the 17,20 bond by a thick or a broken line cannot be correct for both C-17 and C-20; this has, however, frequently been done, then involving the additional convention that the way in which this bond is written is neglected when considering the stereochemistry at C-20.

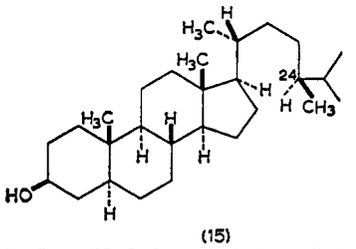
1.7. The stereochemistry at C-20 and other positions in steroid side chains longer than ethyl is described by the sequence-rule procedure.**

Examples



(14)

(24*R*)-24-Methyl-5α-cholestan-3β-ol*
(formerly 24α-methyl)
(trivial name: campestanol)



(15)

(24*S*)-24-Methyl-5α-cholestan-3β-ol*
(formerly 24β-methyl)
(trivial name: ergostanol)

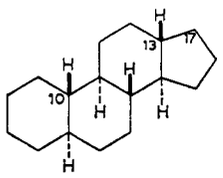
Notes. (1) The sequence-rule procedure is also used when the side chain is cyclized (see Rules 2S-3.3 and 2S-3.4).

(2) The backbone of a C-17 side chain is best denoted as in the plane of the paper (lines of ordinary thickness), the 17,20 bond being similarly denoted. Except for pregnane derivatives, stereochemistry due to substituents on the chain is then indicated by the customary thick or broken lines denoting bonds that project, respectively, above and below the plane of the paper.

Fundamental Carbocycles

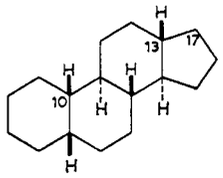
Rule 2S-2 (Expanded from Rules S-3.1 to S-3.5)

2.1. The parent tetracyclic hydrocarbon without methyl groups at C-10 and C-13 and without a side chain at C-17 is named "gonane."



(16)

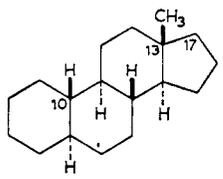
5α-Gonane



(17)

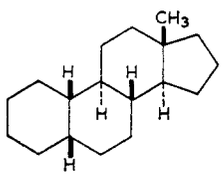
5β-Gonane

2.2. The hydrocarbon with a methyl group at C-13 but without a methyl group at C-10 and without a side chain at C-17 is named "estrane."



(18)

5α-Estrane

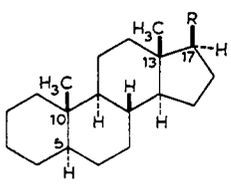


(19)

5β-Estrane

Note. Names of compounds having a methyl group attached to C-10 and a hydrogen atom attached to C-13 are to be based on 18-norandrostane (see Rules 2S-2.3 and 2S-7.1) and not on 10-methylgonane.

2.3. The names given in Table I are used for the hydrocarbons 20 and 21 with methyl groups at both C-10 and C-13.



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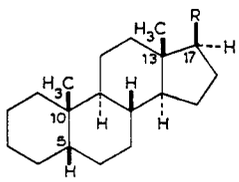
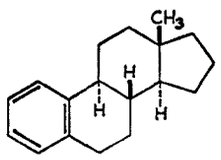


(21)

Notes. (1) Unsaturation and substituents are denoted in the names of steroids by the usual methods of organic chemistry (*cf.* Rule 2S-4). Examples (22)–(25) illustrate some simple cases.

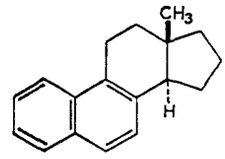
* For the names "pregnane" and "cholestane," see Rule 2S-2.3.

** See Cahn *et al.* (1966).



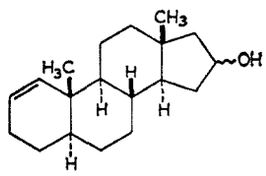
(22)

1,3,5(10)-Estratriene



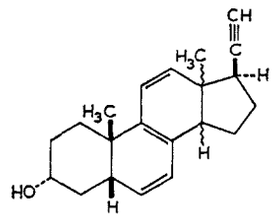
(23)

1,3,5(10),6,8-Estrapentaene



(24)

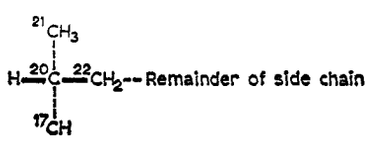
5α-Androst-1-en-16ξ-ol



(25)

5β,13ξ,14ξ-Pregna-6,8,11-trien-20-yn-3α-ol

(2) The names "cholane," "cholestane," "ergostane," and "stigmastane" imply the configuration at C-20 shown in partial formula 26; this is 20*R* except for some derivatives containing additional substituents (*cf.* Note to Rule 2S-1.6).

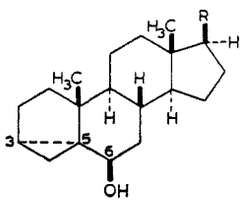


(26)

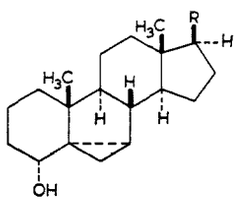
(3) Tetracyclic triterpenoids may be regarded as trimethyl steroids, the three additional methyl groups being numbered 30 (attached to C-4 with α configuration), 31 (attached to C-4 with β configuration), and 32 (attached to C-14); for example, 5α-lanostane (27) is 4,4,14α-trimethyl-5α-cholestane, the former name implying 14α,20*R* configuration. Trivial names are common in this series of compounds, and some are illustrated in examples (27)–(31).

2.4. When an additional ring is formed by means of a direct link between any two carbon atoms of the steroid ring system or the attached side chain, the name of the steroid is prefixed by "cyclo"; this prefix is preceded by the numbers of the positions joined by the new bond and the Greek letter (α, β, or ξ) denoting the configuration of the new bond, unless that designation is already implicit in the name.

Examples



(32)

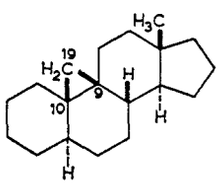


(33)

R = $CH(CH_3)CH_2CH_2CH_2CH(CH_3)_2$

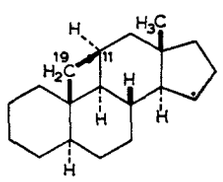
3α,5-Cyclo-5α-cholestan-6β-ol

5,7α-Cyclo-5α-cholestan-4α-ol



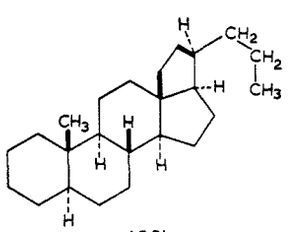
(34)

9,19-Cyclo-5α,9β-androstane



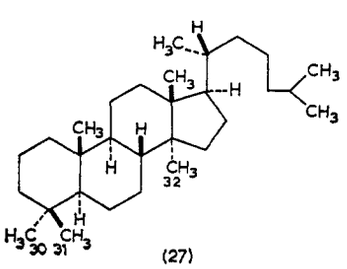
(35)

11β,19-Cyclo-5α-androstane



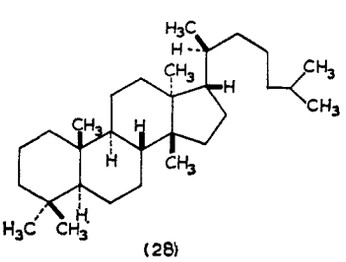
(36)

(20*R*)-18,21-Cyclo-5α-cholane



(27)

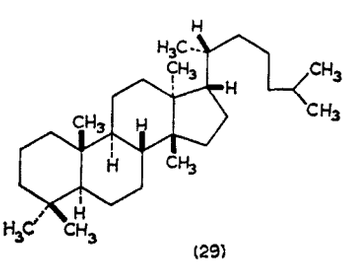
5α-Lanostane



(28)

5α-Tirucallane

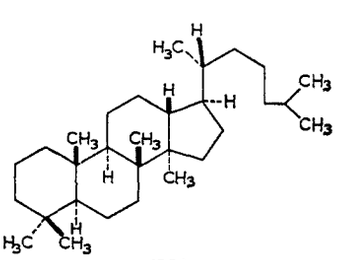
5α,13α,14β,17α,20*S*-Lanostane



(29)

5α-Euphane

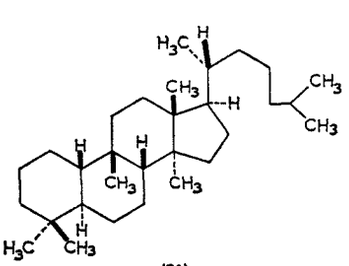
5α,13α,14β,17α-Lanostane (20*R* implied in the name)



(30)

5α-Dammarane

8-Methyl-18-nor-5α-lanostane (all configurations except 5α are implied in the name)



(31)

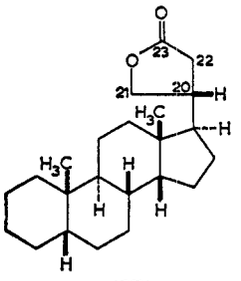
5α-Cucurbitane

19(10→9β)*abeo*-5α-Lanostane (for the *abeo* nomenclature see Rule 2S-9)

TABLE I

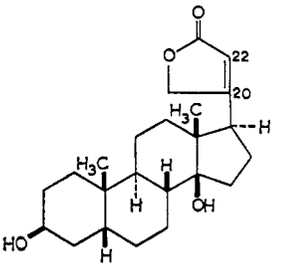
R	(20) 5α Series	(21) 5β Series
H	5α-Androstane	5β-Androstane (*not* testane)
C_2H_5	5α-Pregnane (*not* allopregnane)	5β-Pregnane
[a]$CH(CH_3)CH_2CH_2CH_3$	5α-Cholane (*not* allocholane)	5β-Cholane
[a]$CH(CH_3)CH_2CH_2CH_2CH(CH_3)_2$	5α-Cholestane	5β-Cholestane (*not* coprostane)
[a]$CH(CH_3)CH_2CH_2\overset{24b}{C}H(CH_3)CH(CH_3)_2$	5α-Ergostane	5β-Ergostane
[a]$CH(CH_3)CH_2CH_2\overset{24c}{C}H(C_2H_5)CH(CH_3)_2$	5α-Stigmastane	5β-Stigmastane

[a] 20*R* configuration. [b] 24*S* configuration. [c] 24*R* configuration.



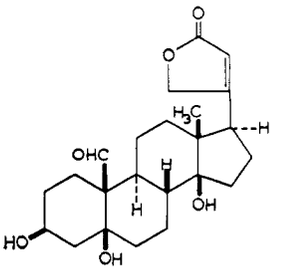
(37)

5β,14β-Cardanolide



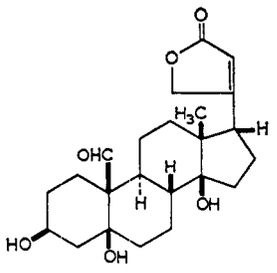
(38)

3β,14-Dihydroxy-5β,14β-card-20(22)-enolide (= digitoxigenin*)



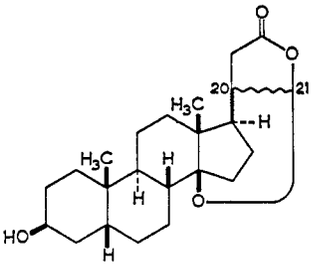
(39)

3β,5,14-Trihydroxy-19-oxo-5β,14β-card-20(22)-enolide (= strophanthidin*)



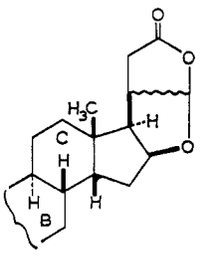
(40)

3β,5,14-Trihydroxy-19-oxo-5β,14β,17α-card-20(22)-enolide (= 17α-strophanthidin*) (also, allostrophanthidin**)



(41)

3β-Hydroxy-14,21ξ-epoxy-5β,14β,20ξ-cardanolide (= isodigitoxigenin**)



(42)

A 16β,21ξ-epoxy-14β,20ξ-cardanolide

Penta- and Hexacyclic Modifications

Rule 2S-3 (Amended Versions of Rules S-3.6 to S-3.9)

3.1. (a) The name "cardanolide" is used for the fully saturated system (37) of digitaloid lactones whose configuration is as illustrated (the configuration at position 20 is shown as a Fischer-type projection‡ and is the same as that in cholesterol, *i.e.*, 20*R*). Notwithstanding Rule 2S-1.5, the configuration at position 14 must always be stated as an affix to the names of these compounds.

(b) Names such as "20(22)-cardenolide" are used for the naturally occurring unsaturated lactones of this type.

(c) The names "14,21-" and "16,21-epoxycardanolide" are used for the compounds containing a 14,21 or a 16,21 oxygen bridge, respectively.

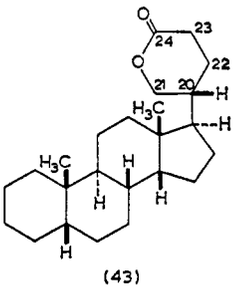
Note. Statement of the configuration at C-14 for all cardanolides is a change from the earlier steroid rules and is in line with current practice.

Examples are given in (37)–(42) above.

3.2. The name "bufanolide" is used for the fully saturated system (43) of the squill–toad poison group of lactones, with the configuration at position 20 shown (this configuration is drawn as a Fischer-type projection (see Note to Rule 2S-3.1(a)) and is the same as in cholesterol, *i.e.*, 20*R*. Notwithstanding Rule 2S-1.5, the configuration at position 14 must always be stated as an affix to the names of these compounds. Unsaturated derivatives are named by replacing the suffix -anolide by -enolide, -adienolide, etc.; thus, the name "20,22-bufadienolide" is used for the naturally occurring doubly unsaturated lactones.

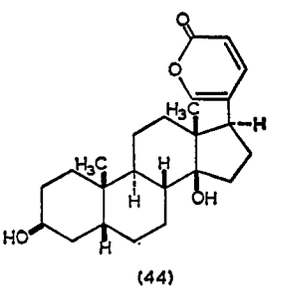
Note. Statement of the configuration at C-14 for all bufanolides is a change from the earlier steroid rules and is in line with current practice.

Examples



(43)

5β,14β-Bufanolide



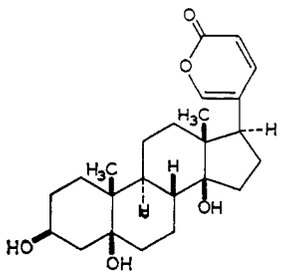
(44)

3β,14-Dihydroxy-5β,14β-bufa-20,22-dienolide (= bufalin*)

* Denotes a trivial name; the systematic name is preferred.

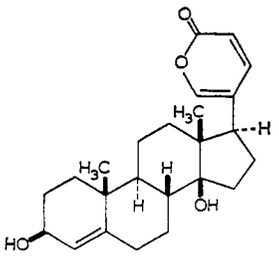
** Denotes a previous trivial name now considered unacceptable.

‡ This method of drawing is customary for the steroids. Since the highest numbered atom is at the top, the usual Fischer projection has been rotated in the plane of the paper through 180°.



(45)

3β,5,14-Trihydroxy-5β,14β-bufa-20,22-dienolide (= telecinobufagin*)

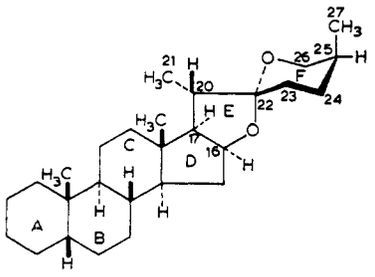


(46)

3β,14-Dihydroxy-14β-bufa-4,20,22-trienolide (= scillarenin*)

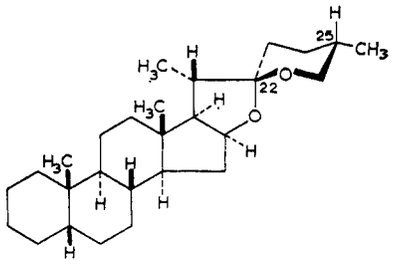
3.3. The name "spirostan" is used for the compound of structure 47;** this name specifies the configurations shown for all the asymmetric centers except positions 5 and 25. A prefix 5α or 5β is added in the usual way (see Rule 2S-1.5). Configurations at C-16 and C-17, if different from those shown in formula 47, are designated as 16β(H) and 17β(H). Configurations at C-20 and C-22, if different from those shown in formula 47, are designated by the sequence-rule procedure‡ or, if unknown, by ξ. Steric relations of substituents at C-23, C-24, C-25, or C-26 are in all cases designated by the sequence-rule procedure‡ or, if unknown, by ξ.

Examples



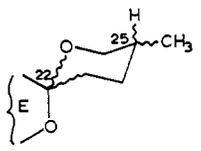
(47)

(25S)-5β-Spirostan



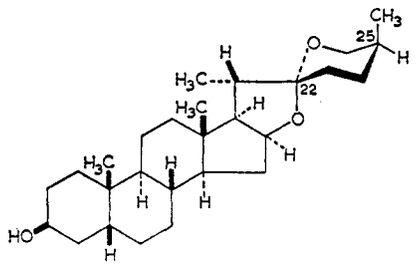
(48)

(22S,25S)-5β-Spirostan



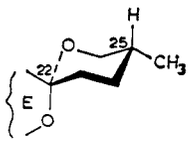
(49)

22ξ,25ξ-



(50)

(25S)-5β-Spirostan-3β-ol (= sarsasapogenin*)



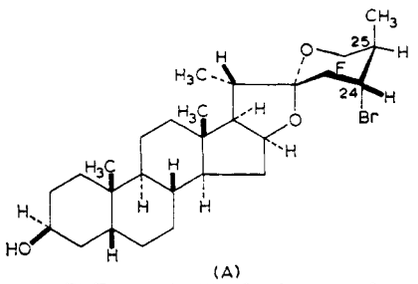
(51)

(25R)-

Notes. Several other methods have been used in the past for designating stereochemistry at C-22 and C-25 in the spirostans and related series; all involve serious difficulties (*cf.* the Basle Proposals, IUPAC *Information Bulletin*, No. 11; also L. F. Fieser and M. Fieser, "The Steroids," Reinhold Publishing Corp., New York, N. Y., 1959, Chapter 21). The sequence-rule procedure is adopted in these rules because it gives an unequivocal symbolism.

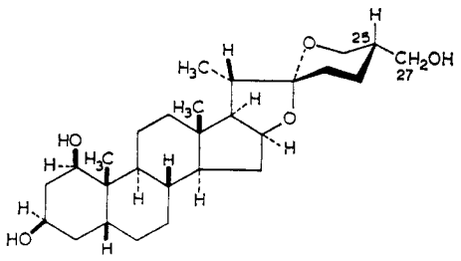
It is to be noted that, although ring E, like rings A, B, C, and D, can conveniently be shown by projection onto the plane of the paper, ring F cannot be adequately represented in this way since the oxygen atom, C-26, C-24, and C-23 lie in one plane that is perpendicular to the plane of the paper. Ring F is conveniently drawn as in formulae 47–51; in formula 47, for instance, the broken line from C-22 to oxygen denotes that the oxygen atom and C-26 of ring F lie behind the plane of the paper and that consequently C-23 and C-24 lie in front of the plane of the paper (configuration *R* at C-22). In formula 48, the configuration at C-22 is reversed and must be stated in the name (*S*). It is conventional to draw ring F as a chair, but this conformation is not implied in the name "spirostan"; whatever the conformation of ring F, C-27 and the 25-hydrogen atom both lie in the plane of the paper and so cannot be denoted by broken or thickened lines or designated α or β. In (47), the methyl group is axial (above the general plane of ring F), and in (48) it is equatorial (in the general plane of ring F); in both cases the configuration at C-25 is *S*, but this identity of *R,S* designation arises only because the configuration at C-22 has also been reversed between (47) and (48); a 25*R* configuration is shown in (51). The wavy lines in (49) denote unspecified or unknown configurations at both C-22 and C-25.

The *R,S* specification may also be affected by substitutents attached to ring F or C-27, as in compounds A and B.



(A)

(24R)-Bromo-(25R)-5β-spirostan-3β-ol



(B)

(25S)-5β-Spirostan-1β,3β,27-triol

3.4. The name "furostan" is used or the compound of structure 52 (16β,22-epoxycholestane); this name specifies the configurations at all the asymmetric centers except positions 5, 22, and (if position 26 is substituted) also 25. Configuration at C-5 is designated by use of α or β in the usual way (see Rule 2S-1.5), and configurations

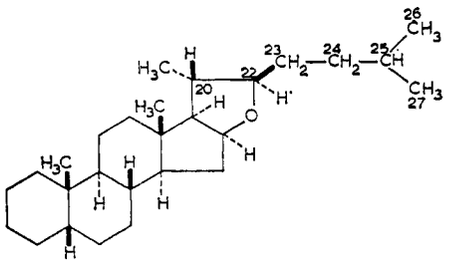
* Denotes a trivial name; the systematic name is preferred.

** This is a 16,22:22,26-diepoxycholestane.

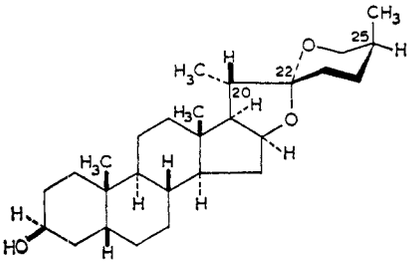
‡ See Cohn *et al.* (1966).

at C-22 and, if necessary, C-25 by the sequence-rule procedure, or in all these cases by ξ if unknown.

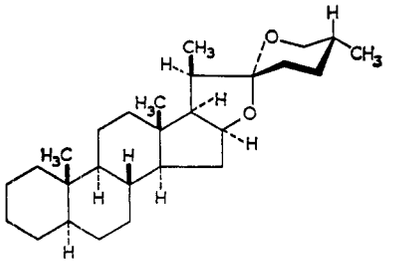
Example



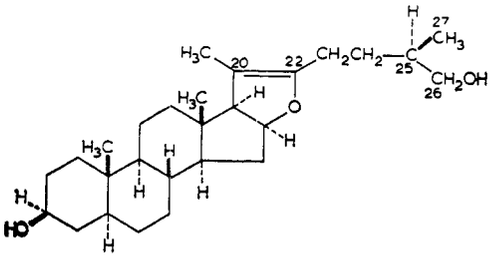
(52)
(22*R*)-5β-Furostan



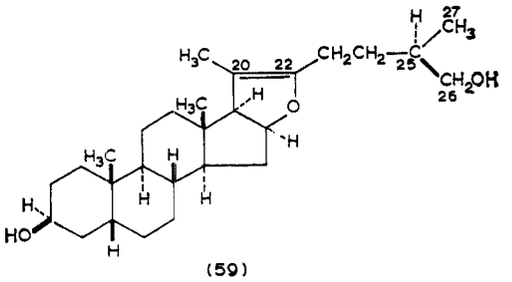
(53)
(25*S*)-5β-Spirostan-3β-ol
(Sarsasapogenin*)



(55)
(20*R*,22*R*,25*R*)-5α-Spirostan
(Cyclopseudoisogenin*)



(57)
(25*R*)-5α-Furost-20(22)-en-3β,26-diol
(Pseudotigogenin*)



(59)
(25*S*)-5β-Furost-20(22)-en-3β,26-diol
(Pseudosarsasapogenin*)

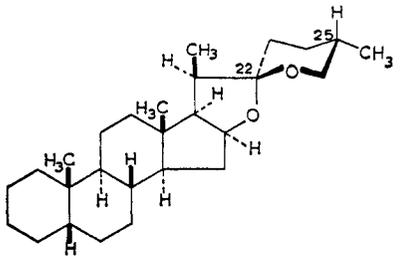
Note. Representative examples of the new standard names and old names** for some common types of spirostan, furostan, and derived structures are given in Table II and formulae 53–59.

Derivatives

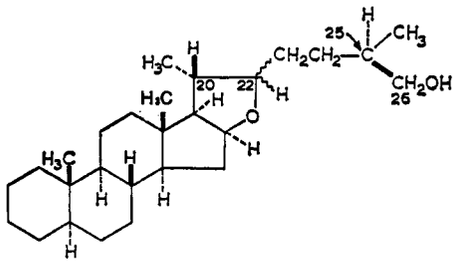
Rule 2S-4 (Extended Version of Rule S-4)

4.1. Steroid derivatives that can be considered to be formed by modification of, or introduction of substituents into, a parent compound are named by the usual methods of organic chemistry (see IUPAC Nomenclature of Organic Chemistry, Sections A & B (1957), *J. Am. Chem. Soc. 82*, 5545–5574 (1960), and Section C (1965), Butterworths Scientific Publications, London, *Pure Appl. Chem. 11*, No. 1 and 2 (1965)).

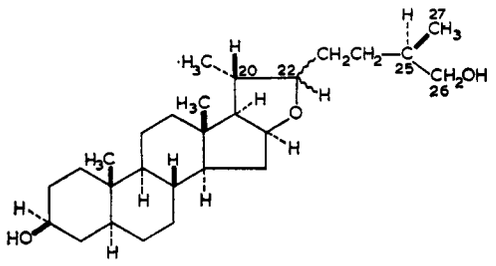
Notes. For the benefit of the specialist, those rules of general substitutive nomenclature that apply most often to steroids are outlined here. For full detail, the IUPAC rules cited above should be consulted.



(54)
(20*R*,22*S*,25*S*)-5β-Spirostan
(Cyclopseudoneogenin*)



(56)
(20*S*,22ξ,25*S*)-5α-Furostan-26-ol
(Dihydrogenin*)



(58)
(20*S*,22ξ,25*R*)-5α-Furostan-3β,26-diol
(Dihydropseudotigogenin*)

I. Unsaturation is indicated by changing terminal "-ane" to "-ene," "-adiene," "-yne," etc., or "-an" to "-en," "-adien," "-yn," etc.; *e.g.*, 5α-cholest-6-ene, 5β-cholesta-7,9(11)-diene, 5-spirosten; see also the names of examples (22)–(25).‡

* Denotes a trivial name; the standard name is preferred.

** Standard names are preferred.

‡ For uniformity with the IUPAC rules cited above, the conventions of *Chemical Abstracts* are used also in the present rules for the position of locants (positional numerals) and designation of unsaturation. In such matters, and in use of Δ (Greek capital delta) to designate unsaturation (which is not recommended by IUPAC), authors should

TABLE II: Spirostans and Furostans

Formula Type	Standard Name	Configurations Implied in Standard Name	Old Names (with trivial names for particular compounds in brackets)[a]
47	(25*S*)-Spirostan	20*S*,22*R*	Sapogenin (without prefix) Neogenin 25-L-Genin [Sarsasapogenin is (53)]
51	(25*R*)-Spirostan	20*S*,22*R*	Isogenin 25-D-Genin [Smilagenin is (25*R*)-5β-spirostan-3β-ol Tigogenin is (25*R*)-5α-spirostan-3β-ol]
54	(20*R*,22*S*,25*S*)-Spirostan		Cyclopseudoneogenin
55	(20*R*,22*R*,25*R*)-Spirostan		Cyclopseudoisogenin
56	(22*R*) (or *S* or ξ), (25*R*) (or *S* or ξ)-Furostan	20*S*	Dihydrogenin (26-ol) and dihydropseudogenin (26-ol) [Dihydrosarsasapogenin is 5β,22ξ,25*S*-furostan-3β,26-diol Dihydropseudotigogenin is (58); *cf.* (57)]
57	(25*R*) (or *S* or ξ)-Furost-20(22)-en		Pseudogenin [Pseudotigogenin is (57) Pseudosarsasapogenin is (59) Pseudosmilagenin is (25*R*)-5β-furost-20(22)-en-3β,26-diol]

[a] The standard name is preferred.

II. Most substituents can be designated either as suffixes or as prefixes; a few can be named only as prefixes, the commonest of these being halogens, alkyl, and nitro groups. When possible, one type of substituent must be designated as suffix. When more than one type is present that could be designated as suffix, one type only may be so expressed and the other types must be designated as prefixes. Choice for suffix is made according to an order of preference that is laid down in the rules cited above; the most important part of this order, for steroids, is as follows, in decreasing preference: 'onium salt, acid, lactone, ester, aldehyde, ketone, alcohol, amine, ether. Suffixes are added to the name of the saturated or unsaturated parent system, the terminal "e" of "-ane," "-ene," "-yne," "-adiene," etc., being elided before a vowel (presence or absence of numerals has no effect on such elisions). The following examples illustrate the use of these principles.

(a) Acids
Suffix for $-CH_3 \rightarrow -COOH$: -oic acid
Suffix for $CH \rightarrow C-COOH$: -carboxylic acid
Examples: 11-oxo-5α-cholan-24-oic acid
(20*S*)-3α-hydroxy-5-pregnene-20-carboxylic acid

(b) Lactones, other than cardanolides and bufanolides.
The ending "-ic acid" or "-carboxylic acid" of the name of the hydroxy acid is changed to "-lactone" or "-carbolactone," respectively, preceded by the locant of the acid group and then the locant of the hydroxyl group, and the prefix "hydroxy" is omitted for the lactonized hydroxyl group.
Examples: 3β-hydroxy-5α-cholano-24,17α-lactone
(20*R*)-3β-hydroxy-5-pregnene-20,18-carbolactone

(c) Cardanolides and bufanolides.
The -olide ending of these names denotes the lactone grouping, and substituents must be named as prefixes.

(d) Esters of steroid alcohols.
Special procedures are used.
For esters of monohydric steroid alcohols, the steroid hydrocarbon radical name is followed by that of the acyloxy group in its anionic form. The steroid radical name is formed by replacing the terminal "e" of the hydrocarbon name by "yl" and inserting before this the locant and Greek letter, with hyphens, to designate the position and configuration.
Example: 5α-cholestan-3β-yl acetate
For esters of polyols the name of the polyol (*cf.* g below) is followed by that of the acyloxy group(s) in its anionic form, with locants when necessary.
Examples: 5β-cholestane-3α,12α-diol diacetate
5β-cholestane-3α,12α-diol 3-acetate 12-benzoate
estradiol-17β 17-monoacetate
When an acid, lactone, or spirostan group is also present, the ester group is designated by an acyloxy prefix.
Example: (25*S*)-3β-acetoxy-5β-spirostan

(e) Aldehydes.
Suffixes: -al (denotes change of $-CH_3$ to $-CHO$, *i.e.*, without change in the number of carbon atoms)
-aldehyde (denotes change of $-COOH$ to $-CHO$, *i.e.*, without change in the number of carbon atoms; name derived from that of the acid)
Prefix: oxo- (denotes change of $>CH_2$ to $>CO$, thus also of $-CH_3$ to $-CHO$, with no change in the number of carbon atoms)
Examples: 5α-androstan-19-al
5α-cholan-24-aldehyde
19-oxo-5α,17(αH)-etianic acid
Other methods are used for introduction of additional carbon atoms as $-CHO$ groups.

(f) Ketones
Suffix: -one
Prefix: oxo-
Examples: 5β-androstan-3-one
5-pregnene-3,20-dione
11-oxo-5α-cholan-24-oic acid

(g) Alcohols
Suffix: -ol
Prefix: hydroxy-
Examples: 5β-cholestane-3α,11β-diol
3α-hydroxy-5α-androstan-17-one

Notes. (1) Composite suffixes -olone and -onol, to denote simultaneous presence of hydroxyl and ketonic groups, are not permitted by IUPAC rules and should not be used.
(2) A few trivial names exist for hydroxy ketones, such as testosterone for 17β-hydroxy-4-androsten-3-one (see Rule 2S-4.2).

(h) Amines
Suffix: -amine
Prefix: amino-
The suffix may be attached to the name of the parent compound or of its radical.
Examples: 5-androsten-3β-ylamine
or 5-androsten-3β-amine
3β-(dimethylamino)-5α-pregnan-20α-ol

(i) Ethers are named as alkoxy derivatives when another group is present that has priority for citation as suffix.
Examples: 3β-ethoxy-5α-cholan-24-oic acid
17β-methoxy-4-androsten-3-one

When no such other group is present, ethers of steroid monoalcohols may be named by stating the name of the steroid hydrocarbon radical, followed by the name of the alkyl (or aryl, etc.) radical, and lastly by "ether"; in English these three parts of the name are printed as separate words, for example, 5α-androstan-3β-yl methyl ether. For ethers of steroid polyols, the same system may be used but with the name of the steroid hydrocarbon radical replaced by the name of the polyol; for partially etherified polyols, locant(s) precede the names of the alkyl (or aryl, etc.) group(s); for example, 5α-pregnane-3β,17α,20α-triol trimethyl ether, 5α-pregnane-3β,17α,20α-triol 3,17-dimethyl ether, cortisol 21-methyl ether.

respect the house customs of the journals to which their papers are submitted.

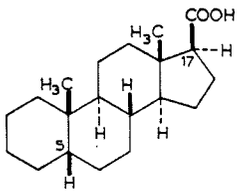
4.2. The following are examples of trivial names retained for important steroid derivatives, these being mostly natural compounds of significant biological activity.

Aldosterone	18,11-Hemiacetal of 11β,21-dihydroxy-3,-20-dioxo-4-pregnen-18-al
Androsterone	3α-Hydroxy-5α-androstan-17-one
Cholecalciferol*	9,10-Seco-5,7,10(19)-cholestatrien-3β-ol (for seco see Rule 2S-8)
Cholesterol	5-Cholesten-3β-ol
Cholic acid	3α,7α,12α-Trihydroxy-5β-cholan-24-oic acid
Corticosterone	11β,21-Dihydroxy-4-pregnene-3,20-dione
Cortisol	11β,17,21-Trihydroxy-4-pregnene-3,20-dione
Cortisol acetate	Cortisol 21-acetate
Cortisone	17,21-Dihydroxy-4-pregnene-3,11,20-trione
Cortisone acetate	Cortisone 21-acetate
Deoxycorticosterone	21-Hydroxy-4-pregnene-3,20-dione (*i.e.*, the 11-deoxy derivative of corticosterone)
Ergocalciferol*	9,10-Seco-5,7,10(19),22-ergostatetraen-3β-ol (for seco see Rule 2S-8)
Ergosterol	5,7,22-Ergostatrien-3β-ol
Estradiol-17α	1,3,5(10)-Estratriene-3,17α-diol
Estradiol-17β	1,3,5(10)-Estratriene-3,17β-diol
Estriol	1,3,5(10)-Estratriene-3,16α,17β-triol
Estrone	3-Hydroxy-1,3,5(10)-estratrien-17-one
Lanosterol	8,24-Lanostadien-3β-ol
Lithocholic acid	3α-Hydroxy-5β-cholan-24-oic acid
Progesterone	4-Pregnene-3,20-dione
Testosterone	17β-Hydroxy-4-androsten-3-one

Note. If these trivial names are used as a basis for naming derivatives or stereoisomers, the derived trivial name must make the nature of the modification completely clear and is preferably accompanied at first mention by the full systematic name. For example, in steroid papers "epi" is often used with trivial names to denote inversion at one center; the name "11-epicortisol" defines the compound fully since cortisol is already defined as the 11β alcohol; but the name "epicortisol" does not define the compound and is inadequate.

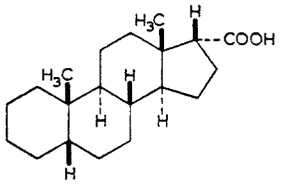
4.3. Androstane-17-carboxylic acids may be called "etianic acids," although the former (systematic) name is preferred. The orientation of the hydrogen atoms at positions 5 and 17 must in all cases be indicated as 5α or 5β, and 17(αH) or 17(βH), respectively.

Examples



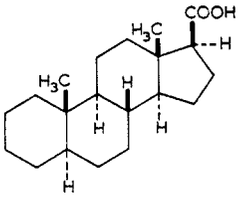
(60)

5β-Androstane-17β-carboxylic acid (systematic) or 5β,17(αH)-etianic acid (trivial)



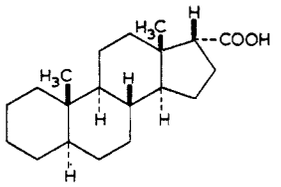
(62)

5β-Androstane-17α-carboxylic acid (systematic) or 5β,17(βH)-etianic acid (trivial)



(61)

5α-Androstane-17β-carboxylic acid (systematic) or 5α,17(αH)-etianic acid (trivial)



(63)

5α-Androstane-17α-carboxylic acid (systematic) or 5α,17(βH)-etianic acid (trivial)

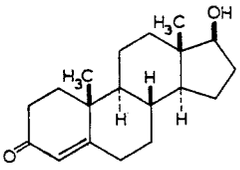
* Included in the List of Trivial Names for Miscellaneous Compounds of Biochemical Importance published by the IUPAC–IUB Commission of Biochemical Nomenclature; see, for example, IUPAC Information Bulletin No. 25, 19 (1966), or *J. Biol. Chem. 241*, 2987 (1966), or *Biochim. Biophys. Acta 107*, 1 (1965).

Stereochemical Modifications

Rule 2S-5 (Extended Version of Rule S-5)

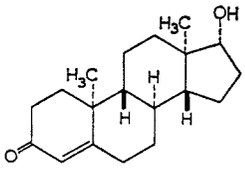
5.1. If, as for instance in a synthetic compound, there is stereochemical inversion at all the asymmetric centers whose configurations do not require to be specified in a name, the italicized prefix *ent-* (a contracted form of *enantio-*) is placed in front of the complete name of the compound. This prefix denotes inversion at all asymmetric centers (including those due to named substituents) whether these are cited separately or are implied in the name.

Examples



(64)

17β-Hydroxy-4-androsten-3-one (Testosterone)



(65)

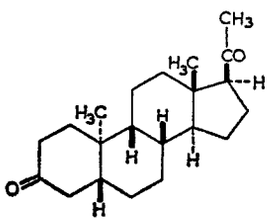
ent-17β-Hydroxy-4-androsten-3-one (*ent*-Testosterone)

Note. When roman or arabic numerals are used to enumerate formulae, the prefix *ent-* may be used to indicate the enantiomer. Thus, *e.g.*, (65) above may be designated (*ent*-64).

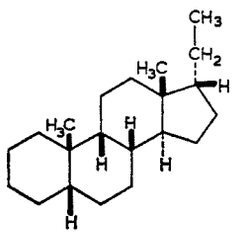
5.2. If there is stereochemical inversion at a minority of the asymmetric centers whose configurations do not require to be specified in a name, the configuration of the hydrogen atoms or substituents at the affected bridgeheads, or the carbon chain (if any) at position 17, are stated by means of a prefix or prefixes α or β, each with its appropriate positional numeral, placed before the stem name laid down in the preceding rules

Examples of Rule 5.2 are given in structures 66 and 67.

5.3. The enantiomer of a compound designated as in Rule 5.2 is given the same name preceded by *ent-*.



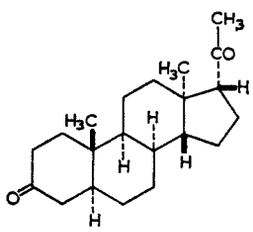
(66)
5β,9β,10α-Pregnane-3,20-dione



(67)
5β,9β,17α-Pregnane

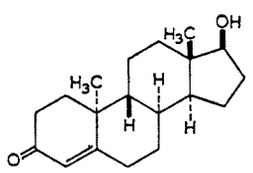
Note. This rule covers the compounds in which there is inversion at a majority, but not all, of the asymmetric centers that do not require to be specified in the name.

Examples



(68)=(*ent*-66)

ent-5β,9β,10α-Pregnane-3,20-dione
(not 5α,8α,13α,14β,17α-pregnane-3,20-dione)



(69)

ent-17α-Hydroxy-13α,14β-androst-4-en-3-one
(not 17β-hydroxy-8α,9β,10α-androst-4-en-3-one)

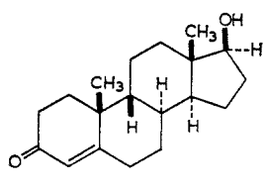
5.4. If there is stereochemical inversion at half of the asymmetric centers whose configurations are implied in the stem name of a "normal" steroid (*e.g.*, (70)), the prefixes to be specified in the name of the stereoisomer are that set that includes the number occurring first in the series 8,9,10,13,14,17 without or with the prefix *ent-* as appropriate.

5.5. Racemates, as for instance obtained by synthesis, are named by use of an italicized prefix *rac-* (an abbreviation of *racemo-*), placed before the complete name of the compound, the enantiomer chosen for naming being that required by Rules 2S-5.1 to 2S-5.4.

Example: A racemate composed of (64) and (65) (= *ent*-64) is named *rac*-17β-hydroxy-4-androsten-3-one or *rac*-testosterone.

5.6. (a) When the relative, but not the absolute, configuration of two or more asymmetric centers in a steroid derivative is known, as for instance for a compound obtained by synthesis, the 10β configuration is taken as basis for the name; or, if C-10 is not asymmetric or is absent, the lowest numbered asymmetric bridgehead is designated α (or *R*); the other asymmetric centers are then considered as α or β (or *R* or *S*) relative to that one; and the whole name is prefixed by *rel-* (italicized). Individual asymmetric centers may be referred to as α*, β*, *R**, or *S** (spoken as alpha star, R star, etc.), but these symbols are not used in the name of the compound.

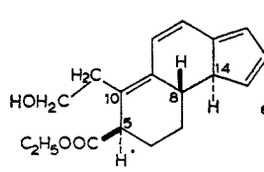
(b) When both enantiomers of known relative, but unknown absolute, configuration are prepared, they are distinguished by a prefix (+)-*rel-* or (−)-*rel-*, where the plus or minus sign refers to the direction of rotation of plane-polarized light (the wavelength, solvent, temperature, and/or concentration must be added when known to affect this sign).



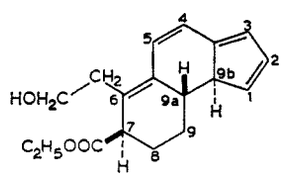
(73)

The dextrorotatory form having either this or the enantiomeric configuration would be named:

(+)-*rel*-17β-Hydroxy-8α,9β-androst-4-en-3-one

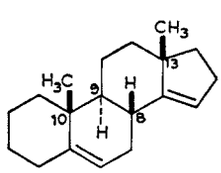
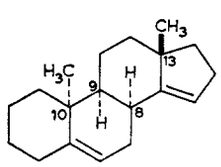
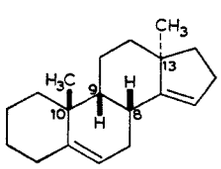


equal to



(74A) (74B)

(74A) *rel*-(Ethyl 2-hydroxy-2,3-seco-*A*-nor-5α-gona-9,11,13(17),15-tetraen-3-oate) (for seco see Rule 2S-8 and for nor see Rule 2S-7); or (74B) *rel*-[(7*R*,9a*S*,9b*S*)-Ethyl 8,9,9a,9b-tetrahydro-7*H*-cyclopenta[*a*]naphthalene-7-carboxylate]

		Configuration at asymmetric centres	Name
(70) "Normal" steroid		8β,9α,10β,13β	5,14-Androstadiene
(71) Steroid inverted at 8 and 10; "normal" at 9 and 13		8α,9α,10α,13β	8α,10α-Androsta-5,14-diene
(72) (*ent*-71) Steroid inverted at 9 and 13; "normal" at 8 and 10		8β,9β,10β,13α	*ent*-8α,10α-Androsta-5,14-diene

Note. (72) could also logically be named "9β,13α-androsta-5,14-diene"; this name might seem simpler, but it has the disadvantage that it does not indicate that (72) is the enantiomer of (71).

Note. At some stage in synthetic work on steroids, names of intermediates have to be changed from a system used in general organic chemistry to the steroid system. The names of (74A)

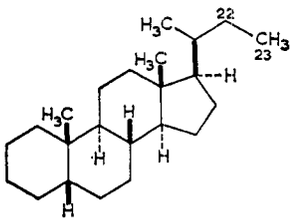
and (74B) illustrate such a change and it should be noted (i) that not merely the name but also the numbering are usually changed and (ii) that the steroid name usually avoids the need to specify the configuration at each asymmetric center. The latter factor will often indicate at what point in a synthesis the change of nomenclature is desirable.

Shortening of Side Chains and Elimination of Methyl Groups

Rule 2S-6 (Expanded from Rule S-6)

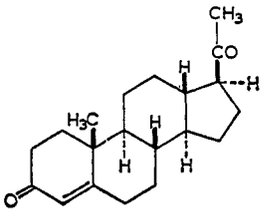
6.1. Elimination of a methylene group from a steroid side chain (including a methyl group) is indicated by the prefix "nor," which in all cases is preceded by the number of the carbon atom that disappears. When alternatives are possible, the number attached to nor is the highest permissible. Elimination of two methylene groups is indicated by the prefix "dinor."

Examples



(75)

24-Nor-5β-cholane



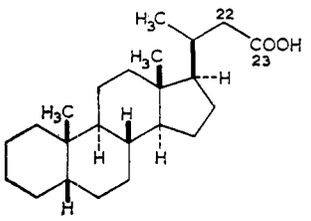
(76)

18-Nor-4-pregnene-3,20-dione

Exceptions. By Rules 2S-2.1 and 2S-2.2 the names gonane (for 18,19-dinorandrostane) and estrane (for 19-norandrostane) constitute exceptions to the above Rule 2S-6.1. The names gonane and estrane are used also as parent names for their derivatives.

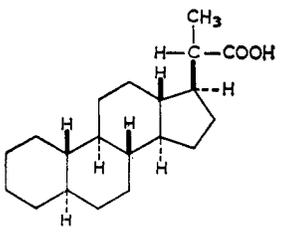
However, 18-nor- and 19-nor- are used with other trivial names, as in 19-norpregnane, 18,19-dinorspirostan, 18-norestrone.

The compound produced by shortening the C-17 side chain of pregnane is named 17-methylandrostane rather than 21-norpregnane. See also Note to Rule 2S-2.2.



(77)

24-Nor-5β-cholan-23-oic acid



(77a)

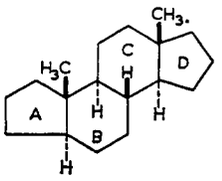
18,19-Dinor-5α-pregnane-20α-carboxylic acid

Ring Contraction or Expansion

Rule 2S-7 (Amended Version of Rule S-7)

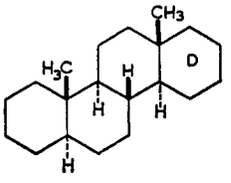
7.1. Ring contraction and ring expansion (other than insertion of atoms between directly linked bridgeheads or, when a steroid side chain is present, between C-13 and C-17) are indicated by prefixes "nor" and "homo," respectively, preceded by an italic letter indicating the ring affected. For loss or insertion of two methylene groups, "dinor" and "dihomo" are used. "Homo" and "nor," when occurring in the same name, are cited in alphabetical order.*

Examples



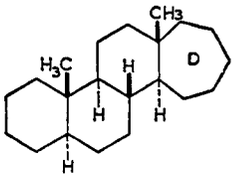
(78)

A-Nor-5α-androstane



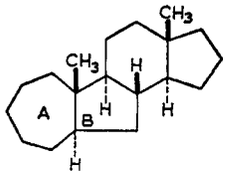
(79)

D-Homo-5α-androstane



(80)

D-Dihomo-5α-androstane



(81)

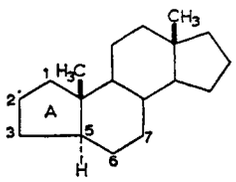
A-Homo-*B*-nor-5α-androstane

Notes. (a) By too extended use, this nomenclature can be applied to compounds whose steroid character is excessively modified. It is recommended that it be confined to steroids containing at least one angular methyl group, or a steroid C-17 side chain, or a steroidal group on ring D (*e.g.*, a spirostan); also that no more than two of the steroid rings may be altered by any combination of the operations denoted by "nor" and "homo." When these conditions are not met, general systematic nomenclature should be used.

(b) Names incorporating "homo" and "nor" are normally preferred to alternatives incorporating "cyclo" and "seco" [*cf.* example (86)].

7.2. On ring contraction, the original steroid numbering is retained, and only the highest number(s) of the contracted ring, exclusive of ring junctions, is deleted.

Example

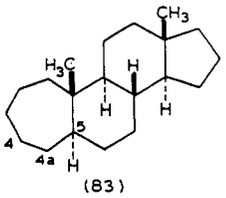


(82)

A-Nor-5α-androstane (Number 4 is omitted)

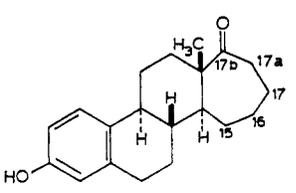
7.3. On ring expansion (other than insertion of atoms between directly linked bridgeheads or, when a C-17 side chain is present, between C-13 and C-17), the letter a (and b, etc., as necessary) is added to the highest number in the ring enlarged exclusive of ring junctions, and this letter and number are assigned to the last peripheral carbon atom in the order of numbering of the ring affected.

Examples



(83)

A-Homo-5α-androstane



(84)

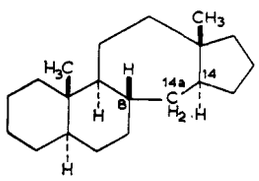
3-Hydroxy-*D*-dihomo-1,3,5(10)-estratrien-17b-one

* Alphabetical order is used for any combination of cyclo, homo, nor, and seco; they are placed immediately before the stem name and after any prefixes denoting substituents.

7.4. Ring expansion by formal insertion of a methylene group between directly linked bridgeheads is indicated as shown below. The italic capital letters denote the ring(s) affected; the locants in parentheses (which are included in the name) are those of the inserted methylene groups.

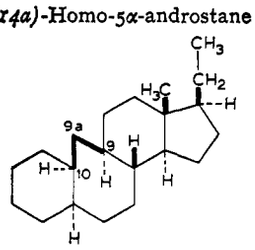
CH_2 added between	Prefix used
C-5 and C-10	*AB(10a)*-Homo
C-8 and C-9	*BC(8a)*-Homo
C-8 and C-14	*C(14a)*-Homo
C-9 and C-10	*B(9a)*-Homo
C-13 and C-14	*CD(13a)*-Homo

Examples



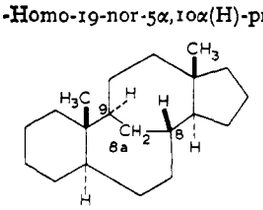
(85)

***C(14a)*-Homo-5α-androstane**



(86)

B(9a)*-Homo-19-nor-5α,10α(H)-pregnane

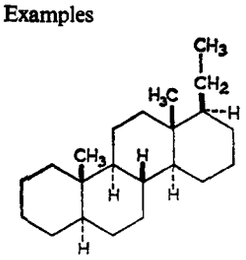


(87)

BC(8a)-Homo-5α-androstane

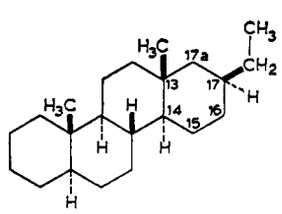
7.5. Expansion of ring D by insertion of atoms between C-13 and C-17: the names "*D*-homopregnane," "*D*-homocholane," etc., are used only for the isomer with the side chain at position 17a [*cf.* example (88)]. Isomers with the side chain at position 17 (formed by formal insertion of a methylene group between C-13 and C-17) are named as derivatives of androstane, estrane, or gonane [*cf.* example (89)]. As exceptions, furostans and spirostans into which a methylene group has been formally inserted between C-13 and C-17 are given these names with an added prefix "*D(17a)*-homo" [*cf.* example (90)].

Examples



(88)

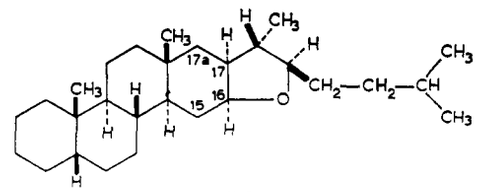
D-Homo-5α-pregnane



(89)

17β-Ethyl-*D*-homo-5α-androstane

* This name is preferred to 9β,19-cyclo-9,10-seco-5α,10(αH)-pregnane (see note b to Rule 2S-7.1). This skeleton is contained in some *Buxus* alkaloids.



(90)

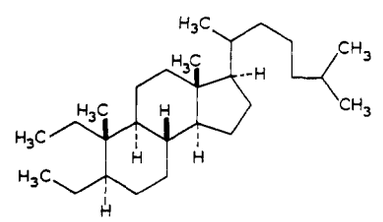
(22*R*)-*D(17a)*-Homo-5β-furostan

Ring Fission

Rule 2S-8 (Unchanged from Rule S-7.4)

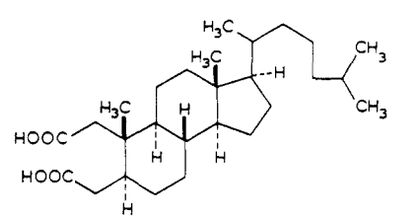
8.1. Fission of a ring, with addition of a hydrogen atom at each terminal group thus created, is indicated by the prefix "seco-," the original steroid numbering being retained.*

Examples



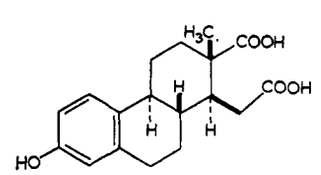
(91)

2,3-Seco-5α-cholestane



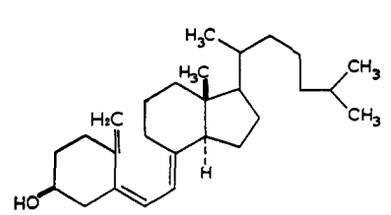
(92)

2,3-Seco-5α-cholestane-2,3-dioic acid



(93)

3-Hydroxy-16,17-seco-1,3,5(10)-estratriene-16,17-dioic acid



(94)

9,10-Seco-5,7,10(19)-cholestatrien-3β-ol (trivial name: cholecalciferol**)

* If more than one ring is opened, general systematic nomenclature may be preferable. The principles of note a to Rule 2S-7.1 apply also to seco steroids.

** This trivial name is retained (see Rule 2S-4.2).

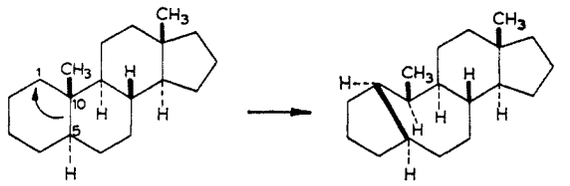
Modification by Bond Migration (*abeo* system)

Rule 2S-9 (New)

9.1. A compound that does not possess a steroid skeleton but may be considered formally to arise from a steroid by bond migration may be given the name laid down in the preceding rules for the steroid in question, to which is attached a prefix of the form *x*(*y*→*z*)-*abeo*-. This prefix is compiled as follows: A numeral denoting the stationary (unchanged) end of the migrating bond (*x*) is followed by parentheses enclosing (i) the number denoting the original position (*y*) from which the other end of this bond has migrated, (ii) an arrow, and (iii) the number (*z*) denoting the new position to which the bond has moved. The closing parenthesis is followed by *abeo*- (Latin, I go away) (italicized) to indicate bond migration. The original steroid numbering is retained for the new compound and is used for the numbers *x*, *y*, and *z*. Such of the customary letters as are necessary are added to specify the resulting stereochemistry.

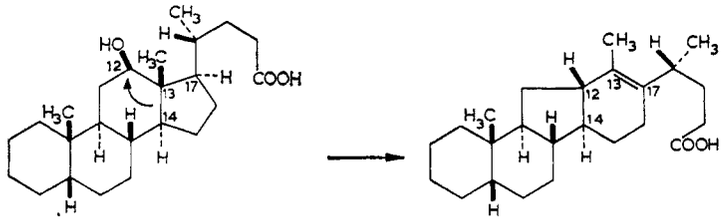
Note. The *abeo* nomenclature described in this rule is permissive, not compulsory. It is most suitable for use in discussions of reaction mechanism and biogenesis. For registration in a general (nonsteroid) compendium the general systematic names may be preferable, particularly when names of steroid type can be conveniently assigned by the homo–nor method. Differences in numbering between *abeo* names and other systematic names should be particularly noted [*cf.* example (96)].

Examples



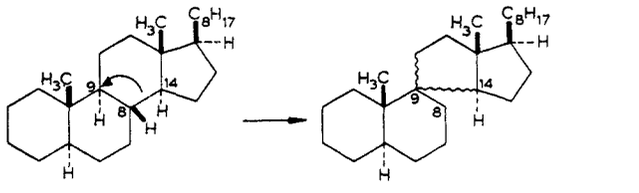
(95)

5α-Androstane — 5(10 → 1αH)*abeo*-5α-Androstane**



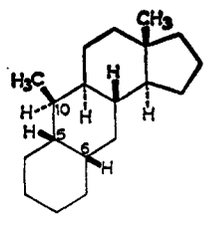
(96)

12β-Hydroxy-5β-cholan-24-oic acid — 14(13 → 12βH)*abeo*-5β-Chol-13(17)-en-24-oic acid*



(97)

5α-Cholestane — 14(8 → 9ξ)*abeo*-5α-Cholestane‡



(98)

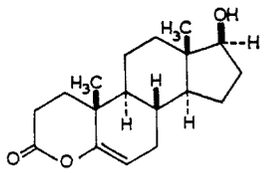
1(10 → 6βH)*abeo*-5β-Androstane (an anthrasteroid)

Hetero Modifications

Rule 2S-10 (Unchanged from Rule S-7.5)

10.1. If hetero atoms occur in the ring system of a steroid the replacement ("oxa–aza") system of nomenclature is used with steroid names and numbering (*cf.* IUPAC Rule B-4; also Introduction to IUPAC Rules C-0.6).

Example



(99)

17β-Hydroxy-4-oxa-5-androsten-3-one

Steroid Alkaloids

Rule 2S-11 (New)

11.1. When readily possible, systematic names for steroid alkaloids are derived from pregnane or some other steroid parent name. Trivial names for other steroid alkaloids are chosen so that the name for the saturated system ends in "-anine." In names for unsaturated compounds this ending is changed to "-enine," "-adienine," etc., as appropriate. When asymmetry exists at positions 8, 9, 10, 13, 14, 16, 17, 20, or 23, it is implied in the name, as set out in Table III and formulae, and divergences are designated as laid down in Rule 2S-5. Configurations at positions 5, 22, and 25 must be specified with the name. Sequence-rule symbols are used for positions numbered 20 or higher.

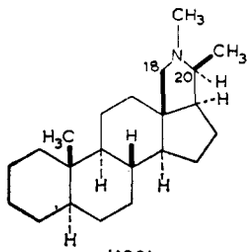
Examples

Typical examples of parent names for groups of alkaloids are given in Table II and the formulae therein. It must be noted that substitution or unsaturation may alter the *R*,*S* designations for derivatives.

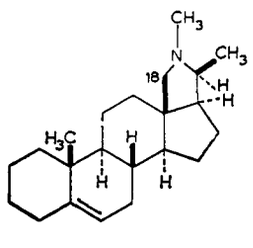
* Name according to Rules 2S-2.4 and 2S-8.1: 12α,14β-cyclo-13,14-seco-5β-chol-13(17)-en-24-oic acid.

** Name according to Rule 2S-7.4: 9αβ-methyl-*B*(9*a*)-homo-*A*-nor-5α,10α-estrane.

‡ The configuration at C-9, if known, is assigned by the sequence-rule procedure (Cahn *et al.*, 1966).



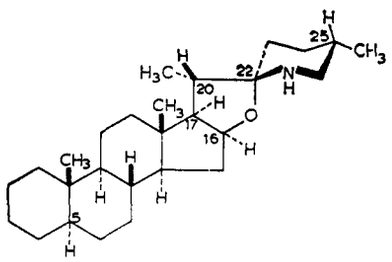
(100)
5α-Conanine*



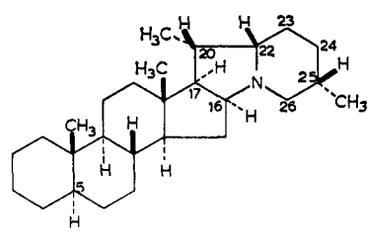
(101)
5-Conenine*

Appendix. Guide Lines for Steroids Containing Additional Rings

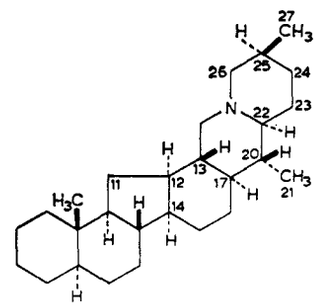
1. General. When additional rings are formed within, or on, a steroid nucleus, situations often arise where either the resemblance to a normal steroid is obscured or the steroid-type name becomes so complex that recourse to general systematic nomenclature is preferable. On the other hand, the general rules, with one exception, are based on that form of each component that contains the maximum number of conjugated double bonds, the whole fused system is then renumbered, and the stereochemistry must be defined separately for each chiral position; the final name resulting is then cumbrous and in a form that is often barely recognizable by a steroid specialist chemist and even less so by a biochemist or biologist. The paragraphs below give suggestions as to how general nomenclature may be modified to incorporate steroid names, but without an attempt to legislate rigidly or to cover every case. The decision whether any one compound shall receive such a modified steroid name or a general systematic name is left to authors and editors in the particular circumstances of each case. Nor are the requirements of journals and compendia or abstracts necessarily identical.



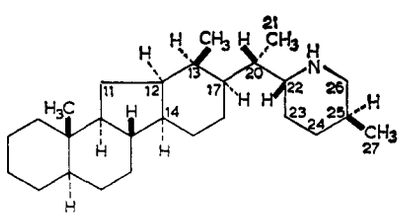
(102)
(22*S*,25*S*)-5α-Tomatanine



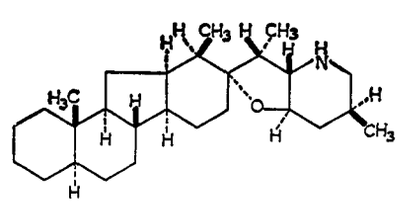
(103)
(22*S*,25*S*)-5α-Solanidanine



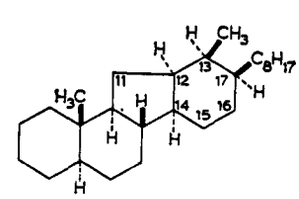
(104)
(22*S*,25*S*)-5α-Cevanine



(105)
(22*R*,25*S*)-5α-Veratranine



(106)
(22*S*,23*R*,25*S*)-5α-Jervanine



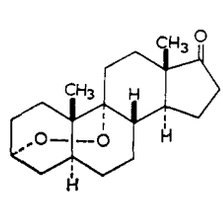
(107)
5α-Jervane**

TABLE III: Parent Names for Groups of Steroid Alkaloids[a]

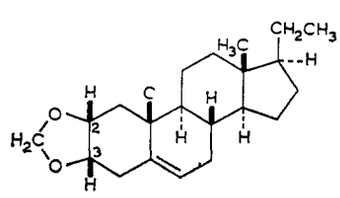
Formula	Name of Parent	Stereochemistry[b] Implied in Name, as Shown in Formula	Stereochemistry to be Indicated by Sequence-Rule Prefixes (or ξ)
100	Conanine	17α*H*,20*S*	
102	Tomatanine[c]	16α*H*,17α*H*,20*S*	22, 25
103	Solanidanine[d]	16α*H*,17α*H*,20*S*	22, 25
104	Cevanine[e]	13β*H*,17α*H*,20*R*	22, 25
105	Veratranine[e,f]	17α*H*,20*S*	22, 25
106	Jervanine[e,f]	17α*O*, 20*R*	22, 23, 25

[a] Some of the names in this table were suggested in the Introduction to "Optical Rotatory Power, 1a, Steroids," Tables des Constantes, Pergamon Press, Oxford, 1965, pp 2a and 2f. [b] Additional to that at positions 8, 9, 10, 13, and 14. [c] The compounds are oxa–aza analogs of the spirostans (which are dioxa spiro compounds). Formulae are conveniently drawn analogously to those of the spirostans. [d] This group includes rubijervine and isorubijervine. [e] These structures contain a *D*-homo-*C*-nor skeleton, with the stereochemistry shown. However, they are commonly considered as 14(13→12)*abeo* structures and are numbered as such. [f] Jervanine, as defined here, is the same as veratranine except for addition of an epoxy bridge, but it is convenient to have two separate names: the veratranine skeleton [see (105)] is present in the alkaloid veratramine. It should be noted that the name 5α-jervane has been used for the rearranged hydrocarbon skeleton (107) [Fried, J., and Klingsberg, A. (1953), *J. Am. Chem. Soc. 75*, 4934], for which the *abeo*-type numbering given in (107) is here recommended.

2. Rings Derived from Functional Groups. Bivalent functional groups such as –O– and –O–O– linked to two different positions, thus forming additional rings, are named by the ordinary methods of organic chemistry; for example, (108) is 3α,9-epidioxy-5α-androstan-17-one. Similarly, methylenedioxy derivatives are best named as such, *e.g.*, (109) 2α,3α-methylenedioxy-5-pregnene. In the same way, lactones and acetals formed by linkage between two different positions of a steroid skeleton are best named as such instead of by framing the name on the newly modified ring system.



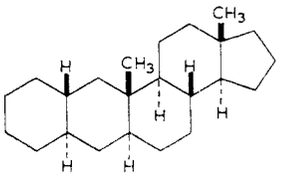
(108)



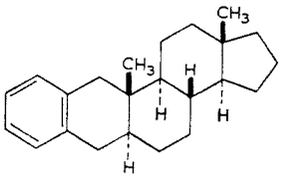
(109)

* *Cf.* Haworth, R. D., and Michael, M. (1957), *J. Chem. Soc.*, 4973.
** See Table III, footnote *f*.

3. Additional Carbocyclic or Heterocyclic Fused Rings. It is tempting to adapt the simple substitutive procedure for fusion of steroid nuclei with simple carbocyclic rings, particularly if the latter are saturated. Thus (110) might be named 2α,3β-tetramethylene-5α-androstane.* However, formation of additional rings by



(110)



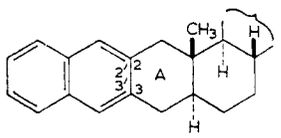
(111)

alkylene (-[CH_2]$_x$-) prefixes is not in accord with IUPAC nomenclature and is often difficult to apply when unsaturation is present. Alternatives are thus preferable.

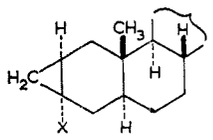
The exceptional case (Rule A-23.5) referred to above enables 2,3-benz-5α-androst-2-ene to be a name for (111), and a slight extension of the rule would allow (110) to be called 2α,3β-cyclohexano-5α-androstane. Such methods might be used in simple cases but these too become difficult when complex ring systems are fused and often when unsaturation is present in the additional component.

For a general procedure it is better to modify systematic IUPAC general practice to permit the steroid component to be cited in a reduced state, the reason why modification is necessary at all being of course the wish to keep the description of the stereochemistry as simple as possible. The suggestions below are closely similar to present practices of *Chemical Abstracts*.

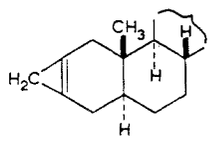
An additional carbocyclic component is cited in its most unsaturated form by its fusion name (usually ending in -o), placed in front of the name of the steroid component, and the position of fusion is indicated by numerals in brackets; for instance, benz[2,3]-5α-androst-2-ene for (111). Here note that the unsaturation of the benzo ring causes unsaturation also in the steroid component and this must be cited (-2-ene). Similarly, (112) is naphth[2′,3′:2,3]-5α-androst-2-ene; the steroid *A* ring is still considered unsaturated



(112)



(113)



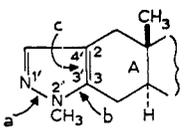
(114)

even though it may be preferred to write the naphthalene double bonds as in the formula shown; note also that the locants for the nonsteroid component receive primes, and that, when choice is possible, its locants for ring fusion are as low as possible and in the same direction as in the steroid component (*i.e.*, not 6′,7′:2,3 or 3′,2′:2,3).

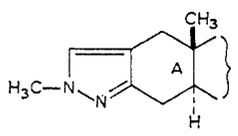
The reduced compound (110) is then 2β,3α,3′,4′,5′,6′-hexahydrobenz[2,3]-5α-androstane. Note the citation of the configuration at the new ring-junction positions and that the steroid component is now cited in its saturated state.

Two further points can be illustrated with (113). Consider first the hydrocarbon where X = H. The additional ring is cited as cyclopropa, denoting an unsaturated three-membered ring as in (114). In (114) the position of the "extra" (indicated) hydrogen must be cited as 3′*H*. Reduction of (114) to (113; X = H) adds 2α,3α-dihydro to the name, which thus becomes 2α,3α-dihydro-2′*H*-cycloprop[2,3]-5α-androstane. If X were not hydrogen but, say, OH, the hydro prefixes would still be needed to show the state of hydrogenation and the OH group would be named additionally; in such cases it is preferable to state the configuration for the OH group that is present rather than that of the H atom that has been replaced; the name then becomes 2α,3′-dihydro-2′*H*-cycloprop-[2,3]-5α-androstan-3α-ol.

The same fundamental principle can be used for heterocyclic components, but conveniently modified to accord with general nomenclature as follows: (a) the heterocyclic component is cited after the steroid component (to permit modification of the ending for salt formation, etc.), and (b) the position of fusion of the heterocyclic component is cited by letters as in the standard IUPAC and Ring Index method. Thus, (115) is 2′-methyl-2′*H*-5α-androst-2-eno[3,2-*c*]pyrazole; note the numbering of the pyrazole ring so that numbers for ring fusion are as low as possible; if the methyl group in (115) were replaced by hydrogen, the double bonds would



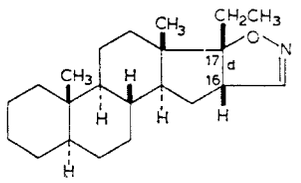
(115)



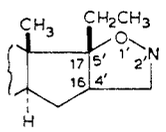
(116)

be placed in the mesomeric pyrazole ring just as in (115) so as to retain this low numbering for ring fusion. In the isomer (116) the steroid component is no longer unsaturated and is therefore cited as androstano-; the full name for (116) is 1′-methyl-1′*H*-5α-androstano[3,2-*c*]pyrazole.

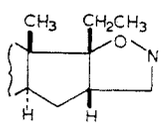
Further problems arise when ring fusion involves a quaternary carbon atom. The name for (117), for instance, could be built up as follows: to 5α-pregnane is fused an isoxazole skeleton, giving



(117)



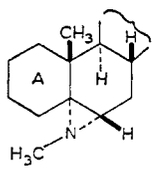
(118)



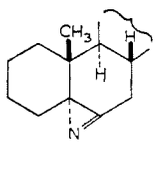
(119)

(118); into this, only one double bond can be introduced, so that one hydrogen atom must be added as indicated hydrogen, which gives a 4′β*H*- prefix and a skeleton (119). The last step, inserting the double bond, gives the full name 4′β*H*-5α-pregnano[16,17-*d*]-isoxazole, even though it appears in (117) as if the heterocyclic ring should be named as the partly hydrogenated system isoxazoline.

Not all such fusions cause all these complications. For instance,



(120)



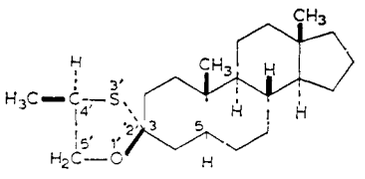
(121)

for (120) one fuses androstane to azirine, obtaining a skeleton into which one inserts a double bond as in the hypothetical compound 121; then, clearly, (120) is 1′,3′-dihydro-1′-methyl-5α-androstano[5,6-*b*]azirine.

4. Stereochemistry. Stereochemistry in additional rings that lie in the approximate plane of rings A–D is cited as α or β, but in other cases by means of sequence-rule symbols.

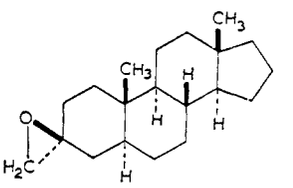
* For simplicity, nomenclature in this Appendix is mostly described in terms of androstane, and partial formulae are to be understood accordingly. The principles, however, are general.

5. Spiro Derivatives. Spiro derivatives of steroids are named n accordance with the principles laid down in IUPAC Rules A-41, A-42, B-10, and B-11. Additional stereochemistry due to the spiro junction and substituents in the nonsteroid ring is designated by the sequence-rule procedure. Alternative names permitted by IUPAC rules are illustrated for (122) and (123).



(122)

4′*R*-Methyl-(*R*)-spiro[5α-androstane-3,2′-(1′,3′-oxathiolane)] or 5α-androstane-3(*R*)-spiro-2′-(4′*R*-methyl-1′,3′-oxathiolane)



(123)

(3*S*)-Spiro[5α-androstane-3,2′-oxiran] or (3*S*)-5α-androstane-3-spiro-2′-oxiran

Acknowledgment

We are indebted to the editors and publishers (Elsevier Publishing Company) of *Biochimica et Biophysica Acta* for permission to reproduce photographically the chemical structures that appeared in their publication of these tentative rules.

Phosphonic Acids and Esters. XX.[1] Preparation and Ring-Opening Reactions of α,β- and β,γ-Epoxyalkylphosphonates. The Proton Magnetic Resonance Spectra of Vicinally Substituted Ethyl- and Propylphosphonates

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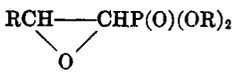
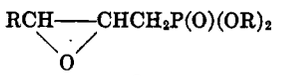
Diethyl (**3a**) and dimethyl (**3b**) α,β-epoxyethylphosphonates have been prepared by the epoxidation of the corresponding vinylphosphonates with *t*-butyl hydroperoxide in the presence of a basic catalyst. These epoxides fail to undergo thermal or acid-catalyzed rearrangements in contrast to the behavior of their β-substituted analogs. Both **3** and diethyl β,γ-epoxypropylphosphonate (**4**) undergo conventional hydrations, alcoholyses, and aminolyses to give α,β-disubstituted ethyl- and β,γ-disubstituted propylphosphonates, respectively. In every case, the products are formed by attack of nucleophile at the terminal carbon of the epoxide and isomerically pure products are formed. Attempted sodium borohydride reductions and Grignard reactions with **3** and **4** failed. The structures of **3** and **4** and their transformation products were established by proton magnetic resonance spectroscopy. Certain aspects of these spectra, namely, geminal β-proton nonequivalence in XCH_2–CHY–P systems and three- (P–C–O–H) and four- (P–O–C–C–H, P–C–C–C–H) bond spin–spin couplings, are discussed.

Despite their obvious potential as synthetic intermediates, relatively little attention has been directed to the preparation and reactions of dialkyl alkylphosphonates possessing an epoxide function in either the α,β (**1**) or β,γ (**2**) positions. Although the synthesis of

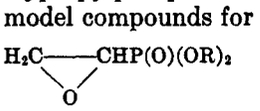


1

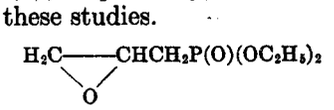


2

2 can be achieved by standard methods, *e.g.*, the Arbuzov reaction of epiiodohydrin with trialkyl phosphites,[2] the synthesis of **1** is more difficult. The formation of α-substituted **1** as by-products in the reactions of sodium dialkyl phosphonates with halomethyl ketones has been reported,[3,4] but the yields are low and a complex mixture of products (enol phosphate, β-ketoalkylphosphonate, and **1**) is formed. Similarly, α-substituted **1** may be prepared by alkaline treatment of the halohydrins formed by the addition of dialkyl phosphonates to halomethyl ketones,[4] but the slow rate of reaction and low yields limit the utilization of the reaction. To date, the most effective method for the preparation of **1** and its β,β-disubstituted analogs is the Darzens condensation of aromatic aldehydes and aryl and alkyl ketones with dialkyl chloromethylphosphonates.[5–7] The reaction is, however, ineffective for the preparation of β-alkyl and α-alkyl or aryl substituted **1**.[7] Because of our interest in the skeletal rearrangements of **1**[6,7] and the possible utilization of **1** and **2** as starting materials for the preparation of α,β- and β,γ-difunctionalized alkylphosphonates as substrates for neighboring-group participation studies,[8] we have examined alternative routes for the synthesis of **1** and certain ring-opening reactions of both **1** and **2**. The simplest examples of **1** and **2**, diethyl and dimethyl α,β-epoxyethylphosphonates (**3**), and diethyl β,γ-epoxypropylphosphonate (**4**),[2] respectively, were chosen as model compounds for these studies.



3a, R = C_2H_5
b, R = CH_3



4

(1) Part XIX: R. Obrycki and C. E. Griffin, *J. Org. Chem.*, **33**, 632 (1968).

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(8) R. B. Davison, Ph.D. Thesis, University of Pittsburgh, 1965; M. Gordon, V. A. Notaro, and C. E. Griffin, *J. Amer. Chem. Soc.*, **86**, 1898 (1964).