A CONCHOLOGICAL METHOD OF DIAGNOSING MOLLUSC TAXA IN REFERENCE TO RECENT CYPRAEIDAE. PART 1

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Abstract: A conchological method used in the Project "Intraspecific variation in living cowries" for determining the taxonomic identity of populations belonging to the Family Cypraeidae is described. This description includes the basic definitions and criteria used in the Project and the practical details regarding measuring and calculations of shell characters, using shell characteristics and other recommendations.
Key words: Mollusca, Gastropoda, Cypraeidae, conchology, diagnostic characters, conchological method.

Cypraeidae, as many other animals, exist as interbreeding populations named biological species. The process of speciation consists of building reproductive isolating barriers that takes many generations. This process in cowries seems to be not enough studied hence science needs other methods for separating cowry populations.
The simplest way to separate species is to be sure that the interbreeding is really taking place in such groups of animals and that crossbreeding with other groups, if happened, does not produce hardy progeny. It is practically impossible to do such a test with marine molluscs including Cypraeidae hence Schilder (1960) suggested the following practical approach:

"A species contains all genetically allied individuals the physiological separation of which has reached such a degree that mutual crossing by other species does not produce any descendants…As this biological test cannot be practiced in cowries, groups of similar shells should be treated as different species if they can be separated by at least one well-recognizable character showing no intermediates even in extreme specimens."

This approach is apparently based on the fact that each organism of a cowry population can be characterized by its phenotype and by its genotype. The phenotype is what the organism actually is: its shell and its soft parts with all physiological processes. The genotype is the sum total of the genes that the organism received from its parents. The genotype does not change during an organism's life and determines which phenotypes can arise in any given sequence of environments in which the organism which carries that genotype lives and develops.

In Schilder' s approach shell characters (elements of the phenotype) are used as diagnostic characters of species hence such a method of separating cowry species is a conchological method.

Cowry shells can be characterized by dozens characters. A diagnostic character of the specific level should conform to the following requirements: a) all shells of the species should share such a character; b) this shell character should be absent in shells of all other cowry species.

A method described below is developed on the base of the Schilder's approach of studying cowry populations in a project "Intraspecific variation in living cowries" (the Project) during last twelve years.

In the beginning of the Project diagnosing of cowry taxa was completely based on the conchological recommendations given in Schilder & Schilder (1938) where 165 cowry species and numerous subspecies are described. See for a discussion of this approach in Heiman (2000).
The Schilders intended to study again the taxonomic identity of many cowry taxa mentioned in the Prodrome, especially subspecies (named then "races"); they marked these taxa "the characters of which need further research" by special signs. They made a very critical revision of their views several times during their prolonged work and changed the taxonomic status of many cowry populations but their conchological recommendations given in the past were not developed into a detailed conchological method and even those given in the Prodrome were not checked in their malacological practice.
Even later the definition of species given in Schilder (1960) was not furnished with practical recommendations and it turned out in the Project that the taxonomic level of many cowry populations should be corrected and a conchological method should be supplemented by clear definitions and criteria, which can be checked and corrected in practice.

THE FIVE CRITERIA APPROACH
Species are interbreeding populations. Populations of different cowry species may be isolated from populations of other cowry species (an allopatric distribution) or several cowry species may share the same area (a sympatric distribution). In the first case interbreeding of a certain cowry species with the other cowry species is impossible simply due to the absence of other cowry taxa. In the second case just the presence of several cowry taxa can be used as the scientific confirmation of their specific level due to the absence of hybrids (which can be diagnosed conchologically).

Criterion of species

The following definition of species is adopted from Schilder (1960) and accepted in the Project:

Groups of similar shells should be treated as different species if they can be separated by at least one substantial, well-recognizable character—the main diagnostic shell character (MDSC)—showing no intermediates even in extreme specimens; subadult and aberrant specimens excluded.

Notes:

a) As many shells as possible should be examined for establishing the MDSC.

b) It should be proven in a description of a new species that the MDSC is not an occasional deviation in the shell shape, color, dorsal pattern and so forth.

c) After a population is described as species, it is possible to check the validity of its specific level using a selective test, in other words to check small representative batches of shells because ALL shells of a species should share its MDSC (abnormalities excluded).

The specific level of about 200 species of Recent Cypraeidae can be confirmed by the conchological method using the criterion mentioned as can be seen in Heiman (2004).

Three criteria of subspecies

Subspecies are groups of geographically separated populations of a species in which the majority (70% or more) of shells differ from other populations of the same species by at least one constant diagnostic character, which is the main diagnostic shell characteristic of a subspecies. The three criteria of subspecies are:

1. All molluscs of a subspecies share the main diagnostic shell characters of the same species (the MDSC). This is "a species first rule" discussed in Heiman (2009d).
2. Populations of a subspecies should be geographically separated from other populations of the same species.
3. A subspecies should differ from other populations of the same species by at least one statistically determined (or constant) shell character; this is its main diagnostic shell characteristic.

Notes:

a) Geographical separation between subspecies does not mean the existence of a clear narrow border between subspecies. Often there may be an intermediate zone between subspecies in which their shell characters are mixed. Separation of subspecies should be apparent as, for example, between populations of the same species from East Africa, the West Pacific Ocean, and Polynesia or from the Gulf of Aqaba and the Gulf of Suez, the southern Red Sea, and the Gulf of Aden.

b) Morphometric shell characteristics can be used for separating subspecies: the average shell length, width, profile, numbers of teeth and so forth.

c) The presence or absence of a shell character can be counted and interpreted as a shell characteristic: the number of teeth; the number of shells in which the dorsal color or pattern differ; blotches, bands, marginal spots, which are present or absent, etc.

d) Diagnostic shell characteristics should be obtained using substantially large batches of shells: several hundreds, the more the better. The correct choice of the main diagnostic shell characteristic ensures repetition of the diagnosis.

e) The subspecific level of a taxon should also be checked using batches of shells although in this case such batches may be smaller comparing with those used for the original description (dozens at least). The more shells are used for such a selective test the better.

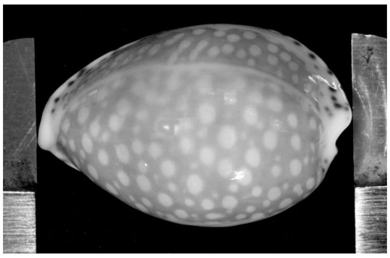
The 5th criterion is a need to present the scientific evidence for any taxonomic conclusion. This means that a description of a species or a subspecies or a decision regarding the taxonomic level of a taxon should be based on and confirmed by the scientific evidence. All that because the taxonomic level of any taxon of marine molluscs is only a hypothesis until it is confirmed by the scientific evidence.

SHELL CHARACTERS

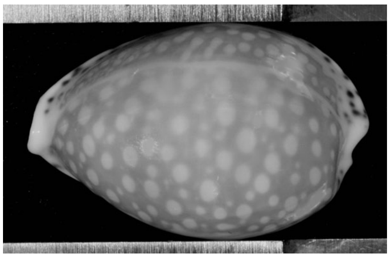
Morphometric characters

These include the shell length L, width W, height H, and their ratios: the width to length ratio W/L, and the height H to length ratio H/L. Distribution of these characters may approximately follow the so-called law of normal statistical distribution with smooth grading between two extremities and the majority of individuals being in the center, or they may deviate from this law to a different degree especially if populations of a species in certain area consist of sub-populations with different environmental conditions. These morphometric characters and their derived quantities can be used as diagnostic characteristics.

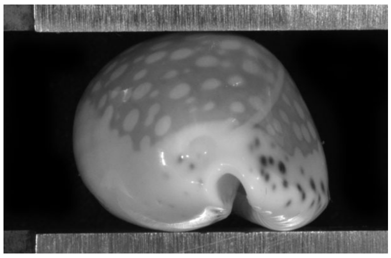
Measuring of these characters is simple as shown in Figs. 1-3:
L is the distance between two most prominent points of the shell extremities.
W is the distance between two most prominent points of the shell margins.
H is the distance between the two most prominent points of the base and the dorsum.
In any case a caliper with the accuracy of at least 0.05 mm should be used.



1. Measuring L, mm



2. Measuring W, mm



3. Measuring H, mm

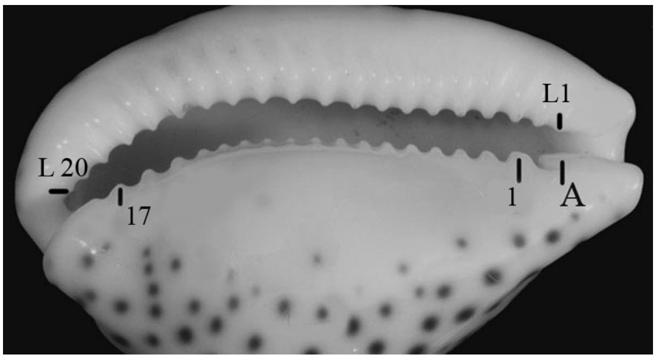
The average meaning of Lav, (W/L)av and (H/L)av and/or ranges of distribution of these parameters can be used as diagnostic characteristics of cowry populations.

Counting teeth

Numbers of the labial and the columellar teeth vary in cowries from shell to shell and from species to species and depend also on the shell length. When counting teeth the anterior terminal ridge and crenulations of the posterior top of the inner lip—Fig. 4—both excluded as mentioned in the Prodrome.

The Schilders recommended using of the so called normalized teeth count, i.e. numbers of teeth recounted to the universal shell width of 25 mm. The formulas for counting normalized teeth are given below, where L is the length of a real shell in mm; LT and CT are the real numbers of the labial and the columellar teeth of this shell, LTR and CTR are normalized numbers, so

$$LTR=7+(LT-7)x(25/L)^{1/2} \qquad CTR=7+(CT-7)x(25/L)^{1/2}$$



4. Counting teeth. Designations: A-a terminal ridge;
L1-the first labial tooth; L20-the last labial tooth;
1-the first columellar tooth; 17-the last columellar tooth.

After normalized teeth meanings for all shells are calculated their average meaning LTRav and CTRav and their standard deviations can be calculated for the studied population; they are expressed as whole numbers (two digits each). Normalized teeth can easily be re-counted to “normal or absolute” (not normalized) numbers, if necessary.

Using normalized teeth count may perhaps be useful for comparing cowry populations of a species in populations of which shells differ substantially by size. The Schilders suggested and used this approach but they did not present the evidence of its advantage or effectiveness comparing with the not normalized count.

In Schilder M. (1967) absolute numbers of teeth and a new characteristics—“closeness of teeth”—are used and it is recommended to cancel the data regarding the normalized teeth given in their previous works including the Prodrome. Schilder F. (1971) also used the relative closeness of teeth describing *C. fischeri astaryi*; this shell characteristic is still not checked in the conchological practice of long standing.

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In any case it should be always mentioned whether the teeth count is normalized.

The Vayssière-Schilders (V-S) formula
A French scientist Vayssière and later the Schilders suggested to characterize cowry populations using several characteristics in a combination named the ‘formula’.
The V-S formula consists of several shell characteristics, which includes the average (for a population) meanings of the characters mentioned above i.e. Lav, (W/L)av, LTav, and CTav, two digits for each characteristics, a total of eight digits. If one is sure that using the normalizing teeth is more effective, the last four digits may be LTRav and CTRav. It is sometimes useful to add also (H/L)av and the formula then contains ten digits.
The V-S formula characterizes a cowry population as a whole. As the conchological practice shows, it is more suitable for separating subspecies rather than species.

A conchological gap and the Main Diagnostic Shell Character (MDSC)
The definition of species given above means that species differ one from the other(s) by a conchological gap—by the presence of a diagnostic character, which is absent in other species—the main diagnostic shell character MDSC. The conchological practice shows that the morphometric characteristics can rarely be used as the MDSC because ranges of distribution of closely related taxa may overlap. The morphometric characteristics are mainly used for separating subspecies of a species, populations of which are widely distributed and may substantially (but not completely) differ one from the other by shell size, shape and so forth.

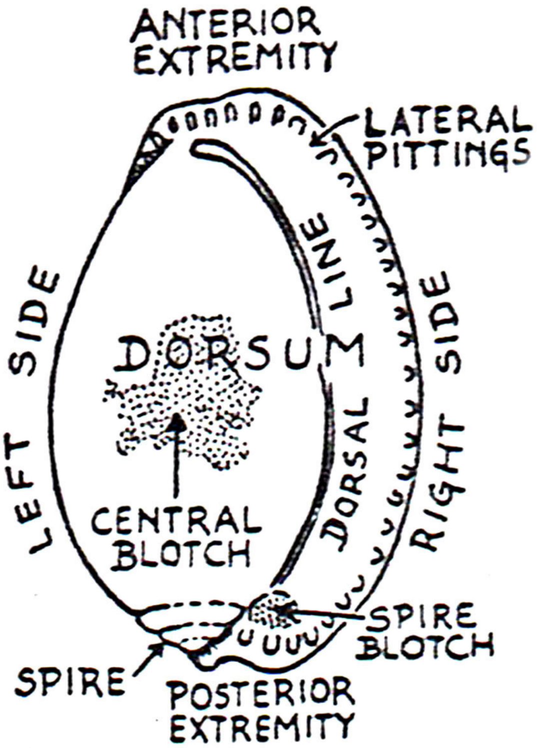
There are many other shell characters useful for diagnosing species. For these one have to be sure, that they are present in all specimens of a given species and absent in other species. For example, the dorsal color of *Lyncina aurantium* (Gmelin, 1791) is the MDSC of that species; the same can be said regarding the white shell color of *Erosaria eburnea* (Barnes, 1824); each of them differs by the unique dorsal color.

The unique shape of the dorsal line is the MDSC of *Mauritia mappa* (Linnaeus, 1758); it is not found in any other cowry species. If the MDSC is mentioned in the original description of a species, separation of such a species is easy; a lot of study is needed to clarify the taxonomic identify of a taxon if the MDSC is not given in its original description.

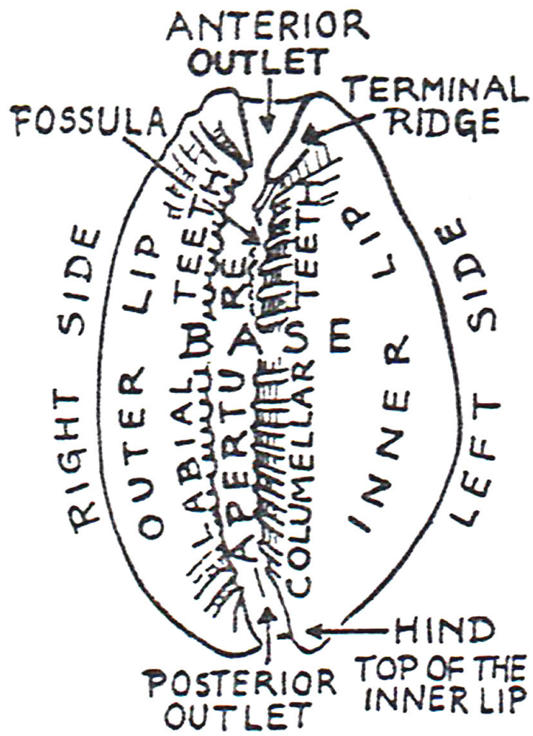
Counting shell characters
The percentage of shells with a given shell character is one of several shell characteristics used in conchology. For example, the shell shape, profile, dorsal pattern and so forth can be used as a diagnostic characteristic. For species, an idea is to check whether ALL shells of a population share the same character, which cannot be found in all other cowry populations, in other words to check whether this shell character form the conchological gap between several taxa in question.

This approach was developed for cowries in Heiman (2005, 2006, 2007) and made possible to clarify the taxonomic level of hundreds of cowry populations.
In this case the idea is to check how many shells of a large batch representing a population share a certain character. When all shells share the same shell character, it is of the specific level as, for example, the dorsal pattern of *Barycypraea fultoni* (Sowerby, 1903) or the dorsal pattern of *Lyncina argus* (Linnaeus, 1758).
If the majority (about 70% and more) of the studied shells shape a character, it may be of the subspecific level.
For example, the humped dorsum of *Mauritia arabica grayana* Schilder (1930), the flat profile of *M. arabica immanis* Schilder & Schilder 1938, or large dark spots on the shell extremities of *Luria isabella controversa* (Gray, 1824) are present in the majority of shells in the relevant populations hence those populations were treated as subspecies.
It turned out in the Project that counting shell characters id really effective for establishing the taxonomic identity of cowry populations.

Diversity of shell characters
Natural qualities of a shell, such as its shape, base and dorsal color and pattern, fossula etc. are named “shell characters.” The term “a shell characteristic” is used to indicate the results of measurements or calculations of a group of shells (the average shell length, width, height, the average number of teeth etc.).
Below the shells characters often used in conchological practice are given in Figs. 5-11 (adopted from the Prodrome; made by F.A. Schilder personally) and Figs. 12-23.
More shell characters are pictured in Figs. 12-23 but this is (together with Figs. 5-11) not exhaustive information. There are many other peculiarities related to the shell shape, dorsal pattern, teeth bordering the aperture and so forth.
Any of these shell characters may be typical for a cowry species and be in fact its main diagnostic shell character if it is present in all shells of a species. It may form the diagnostic shell characteristic of the subspecific level if it is present in the majority of shells and not in all shells.

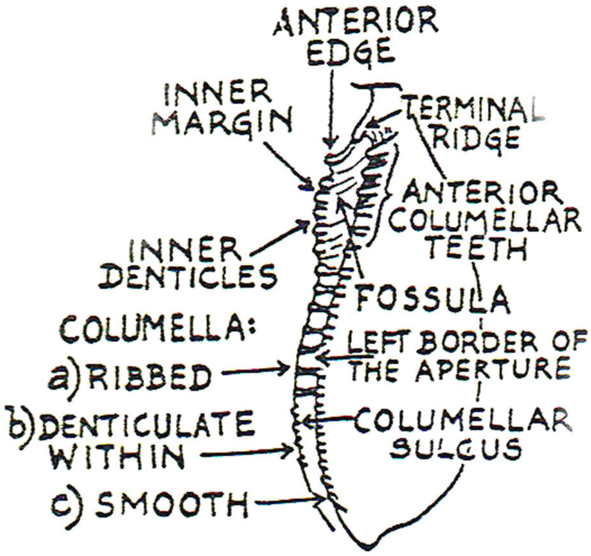


5. Dorsal view of a cowry shell

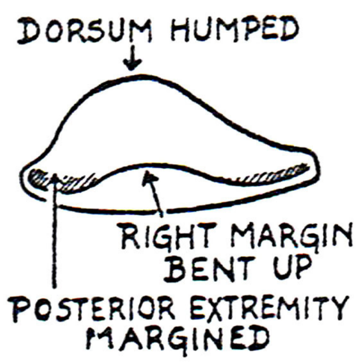


6. Basal view of a cowry shell

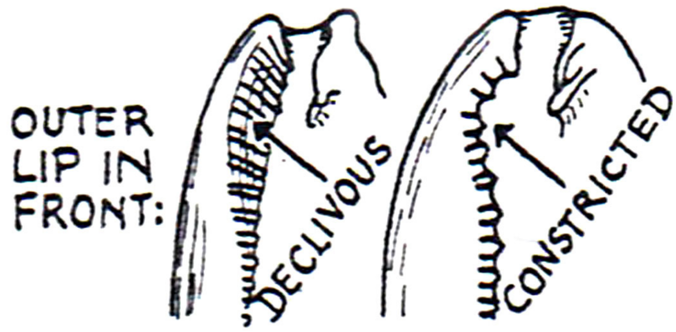
7. Peculiarities of the dorsum



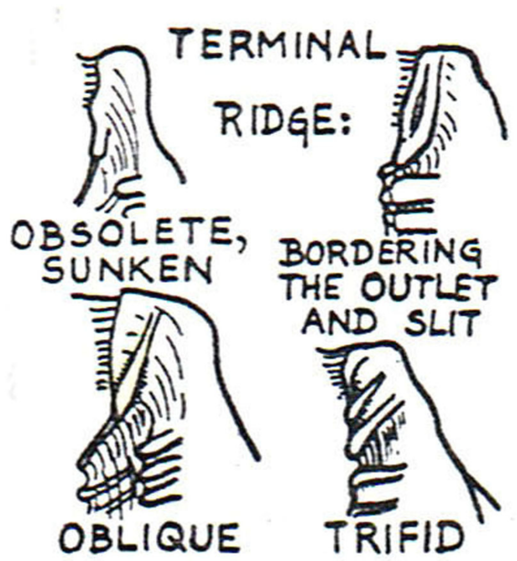
8. Peculiarities of a columella



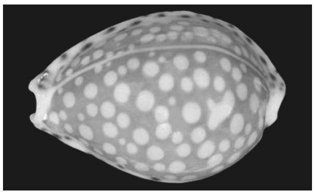
9. Peculiarities of a shell form



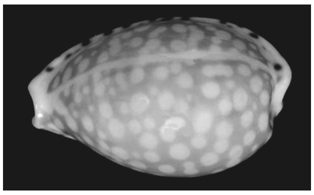
10. Details of the outer lip



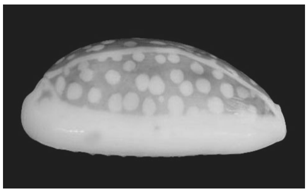
11. Details of the terminal ridge



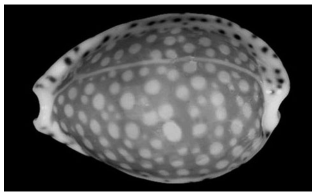
12. Shape oval, the posterior part is the widest



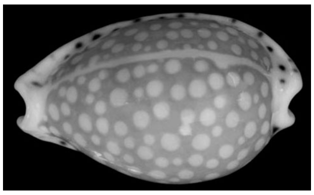
13. Shape elongate-oval (a shell is more elongate)



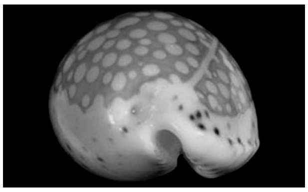
14. Profile convex to flat



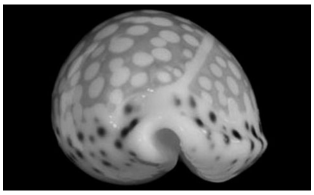
15. Blunt extremities



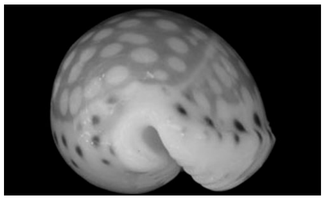
16. Acuminate extremities



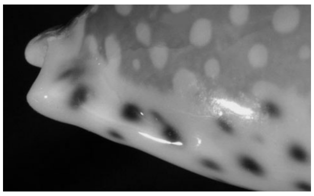
17. Depressed spire



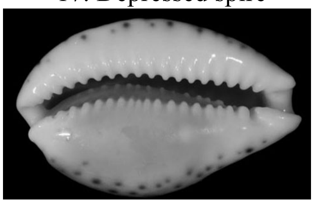
18. Right margin angled



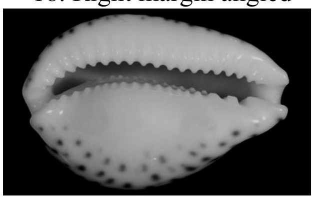
19. Left margin round



20. Left margin angled only anteriorly



21. Basal spots



22. Aperture curved left

23. Fossula ribbed

Intraspecific variation—forms (varieties)

A cowry population (as a species) is said to have a constant gene pool, which is the sum total of the genes carried by the individual genes of the population. Gene pools of cowry species may be divided into the smaller gene pools of sub-populations living in different separated or overlapping areas. A genetic change arising anywhere in a cowry population may spread throughout the whole population or throughout its parts depending on environmental conditions. So, different sub-populations of the same species may differ in the frequencies of some genes and, as a result, in different phenotypes of individual organisms (in this case in the differences in shells). If the gene frequencies differ substantially (the majority of individuals differ from the typical individuals) one can treat such sub-populations as subspecies.

In conchological terms, the majority of shells in every cowry population share not only the MDSC of the species but also other shell characters typical to the species. Such shells are known as a typical form. For example, in *Erosaria nebrites* (Melvill, 1888) the majority of shells have elongate-elliptical to elongate-oval shape but sometimes the shape is oval due

to a dilated outer lip; this recurring form is known as the form dilated; it never comprise the majority. Deviations from the typical—forms—are known in many cowry species as shown in Heiman (2005, 2006, and 2007).
Intraspecific variation and forms will be treated in the second part of this work.

LIterature

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Correction:
The text above is the same as published in TRITON 23 (2011) with one exception:
in the words printed with Fig. 20 a mistake 'posteriorly' is changed to 'anteriorly.'