A Re-examination of the Cloacal Sacs and Gland of the Blind Snake, *Leptotyphlops dulcis* (Reptilia: Leptotyphlopidae)

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ABSTRACT The cloacal sacs of *Leptotyphlops dulcis* are nonglandular, posterior evaginations of the cloaca. The median cloacal gland is tubuloalveolar. Similar unpaired cloacal glands as well as paired sacs are noted in certain colubrid snakes. Terminology applied to these cloacal derivatives is discussed, and a standardization of names is provided.

In many snakes the sacs and glands associated with the cloaca act as sex attractors, deterrants or repellents to possible adversaries, or serve as inter- and intraspecific chemical communicators. Unfortunately terms applied to these accessory cloacal structures vary from author to author and species to species. As a result, their use in ophidian morphology is sometimes misleading or actually erroneous.

Baumann ('29) noted that in *Vipera aspis* Linnaeus cloacal glands function in sex attraction during the breeding season, while Noble and Clausen ('36) demonstrated that in *Thamnophis sirtalis* Linnaeus and *Storeria dekayi* (Holbrook) cloacal glands lack hedonic function. Volsøe ('44) indicated that in vipers [esp. *Vipera berus* (Linnaeus)] anal glands or sacs (he used both terms interchangeably) probably function in sex attraction, although their use in defensive behavior was not discounted. He further suggested, however, that anal glands or sacs probably have different functions in different species of snakes. Klauber ('56) indicated that in rattlesnakes postanal glands may serve a defensive function, while Gehlbach ('70) used the term "cloacal sacs" in describing defensive behavior in certain leptotyphlopids, colubrids, and elapids. Brisbin ('68) reported that postanal glands function as possible chemical communicators in *Lampropeltis getulus* Linnaeus.

Guibé ('48) noted the presence of enlarged dorsal glands and paired anal sacs in *Typhlops unguirostris* Peters, *T. curvirostris* Peters, and *T. polygrammicus* Schlegel, but he did not speculate on the function of the glands or sacs. Gehlbach, Watkins, and Reno ('68) suggested that in *Leptotyphlops dulcis* Baird and Girard anal glands discharge defensive substances; however, Watkins, Gehlbach, and Kroll ('70) indicated that a cloacal sac substance (= "anal gland" secretion of Gehlbach et al., '68) was defensive in *L. dulcis*. Robb ('60) and Fox ('65), working on Typhlopidae and Leptotyphlopidae, respectively, observed a pair of musk glands and a median, compound, tubuloaveolar cloacal sac.

This study was undertaken to elucidate the structure of the cloacal sacs and gland of *L. dulcis* in an effort to (1) understand their functions; (2) stabilize their terminology; and (3) clarify both morphology and terminology of similar structures in colubrid snakes.

MATERIALS AND METHODS

Twenty-eight *L. dulcis* from Marshall Co., Oklahoma were examined. Specimens prepared for histological examination were fixed in 10% formalin, tails excised at the vent, decalcified, sectioned, stained, and mounted as given in Reno ('66, '69) for some species of cyprinids. The cloacal sacs and glands of some specimens were illustrated *in situ*, removed from the tail, embedded in celloidin, sectioned, stained, and mounted as given in Reno ('66, '69) for

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some species of cyprinids. Drawings of histological materials were made from photomicrographs taken with a 35-mm camera mounted on a trinocular microscope, traced, and reproduced as line drawings. Comments about the cloacal sacs and glands of certain colubrid snakes are based on similar gross and histological examination of specimens collected from McLennan Co., Texas.

OBSERVATIONS

In *L. dulcis* the sacs and glands associated with the cloaca are situated in a cavity at the base of the tail. Dorsal in the tail cavity, there are two large, elongated cloacal sacs and, ventral to the cloacal sacs, a small, median cloacal gland (fig. 1). In female *L. dulcis* these three structures almost fill the tail cavity, while in male *L. dulcis* they share the cavity with ventrally placed hemipenes.

Cloacal sacs are cylindrical structures which extend posteriad from the cloacal wall to end blindly near the tip of the tail. Distally, both sacs are flexed mesad and are of uniform diameter throughout. Anteriorly, the sacs are narrowed into ducts which bend downward at right angles, pierce the cloacal wall, and open ventrolaterally into the cloaca (fig. 1). Each duct and duct opening is regulated by a sphincter of voluntary muscle (figs. 1–2). The sacs are held *in situ* by loose areolar connective tissue, and at regular intervals, each is enclosed by bands of voluntary muscle. The muscle bands originate from the centra of caudal vertebrae and insert on the basement membrane underlying the ventral scales (fig. 2). According to Robb ('60), similar muscles are packed between, but not around, the cloacal sacs (= "scent glands" of Robb) of certain species of *Typhlops*. Histologically, the cloacal sacs and ducts are lined with cornified, stratified squamous epithelium. The epithelium is divisible into three easily recognized cellular parts: a stratified layer, a cornified layer, and a desquamating layer (fig. 3). Volsøe ('44), Gabe and Saint-Girons ('65), and others have indicated that in vipers, typhlopids, and leptotyphlopids the cloacal sacs are holocrine in function; however, in the *L. dulcis* we examined, no holocrine activity was observed (see fig. 3).

The cloacal gland of *L. dulcis* is cylindrical and smaller in all dimensions than the cloacal sacs (table 1). Anteriorly, this gland tapers sharply into a duct (fig. 1). The duct proceeds anteroventrad, passes through the cloacal wall, and opens middorsally into the cloaca (fig. 2). Like the cloacal sacs, the cloacal gland is held in place by loose areolar connective tissue; but, unlike the ducts of the cloacal sacs, the cloacal gland duct is not regulated by a sphincter muscle.

The cloacal gland is compound and tubular, with the distal end of each tubule expanded into an alveolus (fig. 4). The

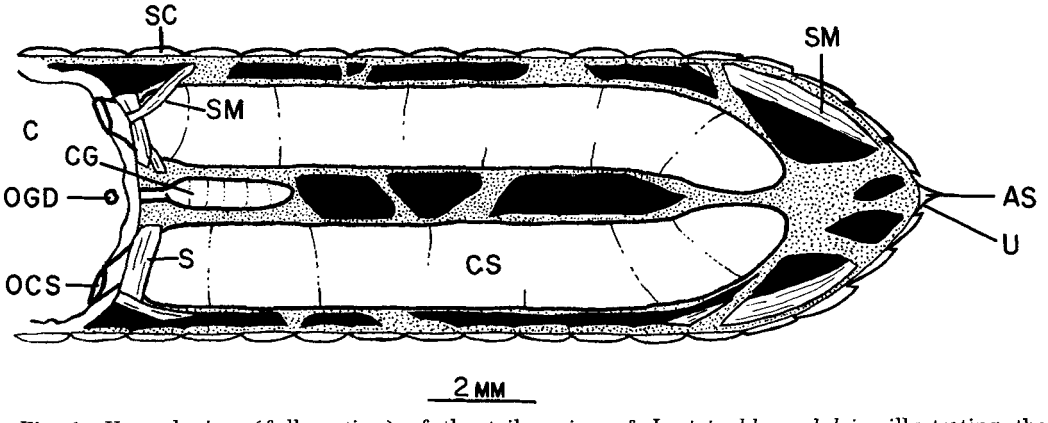

Fig. 1 Ventral view (full section) of the tail region of *Leptotyphlops dulcis*, illustrating the large cloacal sacs and median, unpaired cloacal gland. AS, apical spine; C, cloaca; CG, cloacal gland; CS, cloacal sac; OCS, opening of cloacal sac duct; OGD, opening of cloacal gland duct; S, voluntary muscle sphincter; SC, scale; SM, skeletal muscle; U, position of unidentified structure illustrated in figure 5.

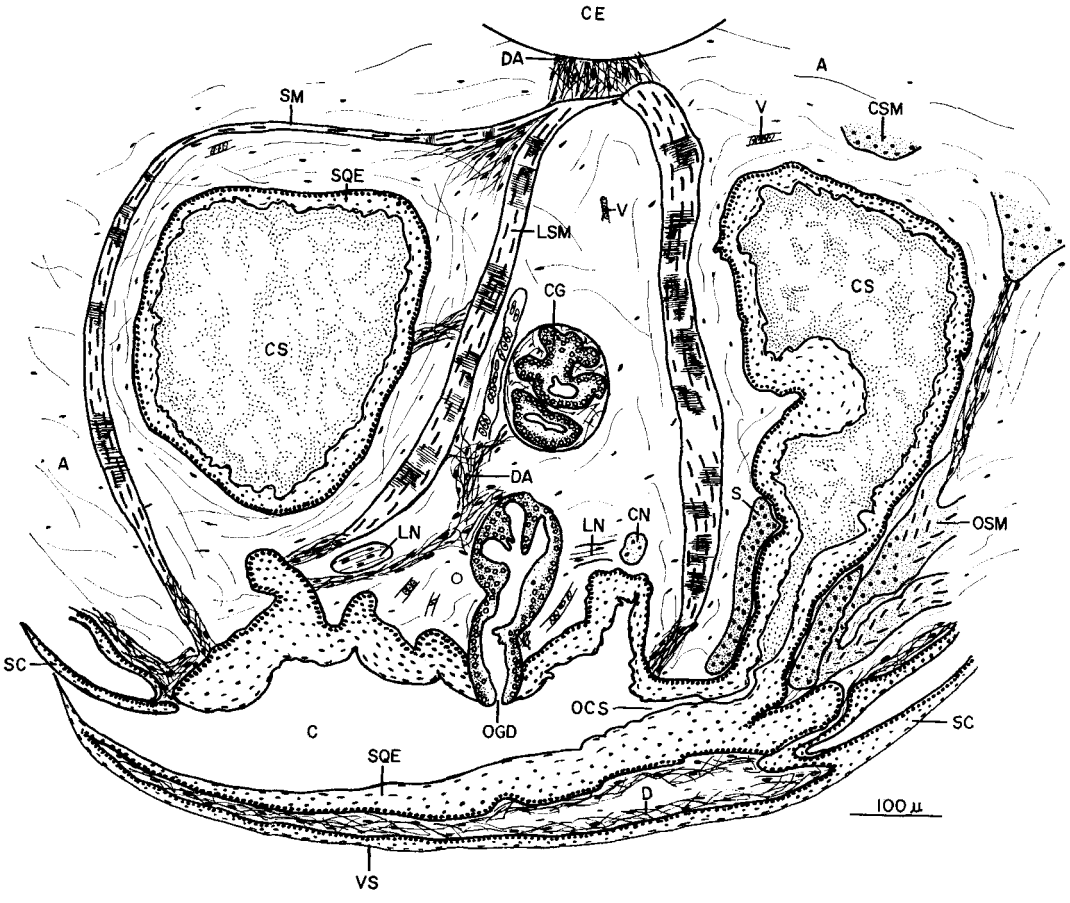

Fig. 2 Transverse section through cloaca of *Leptotyphlops dulcis*, illustrating the cloacal sacs, cloacal sac duct, cloacal gland, and cloacal gland duct. A, loose areolar connective tissue; CE, centrum of caudal vertebra; CN, cross section of nerve; CSM, cross section skeletal muscle; D, dermis; DA, dense areolar connective tissue; LN, longitudinal section of nerve; LSM, longitudinal section skeletal muscle; OSM, oblique section skeletal muscle; SQE, keratinized stratified squamous epithelium; V, blood vessel; VS, ventral scute. Other abbreviations as in figure 1.

gland, encapsulated by dense irregular connective tissue, has an inner lining of secretory, columnar epithelium. Typically, nuclear basophilia of the columnar epithelium is diffuse and granular. The paranuclear and subnuclear cytoplasms are ergastoplasm-like, that is, dark staining and filled with basophilic granules. The supranuclear cytoplasm is light staining and abundantly supplied with secretion vacuoles. The epithelial lining of the gland duct is typically low columnar and/or cuboidal. The nuclei of the epithelium are spheroid, are centrally placed within cells, and have diffuse and granular basophilia. The cell cytoplasm is clear (without inclusions) and light staining throughout. These descriptions corroborate, in part, Fox's ('65) findings in several other species of *Leptotyphlops*.

Gabe and Saint-Girons ('65) found margino-cloacal glands near the urogenital papillae in male *L. dulcis*; however, they did not examine female *L. dulcis* for similar structures. We observed margino-cloacal glands in male *L. dulcis*, but found no such structures in the females examined.

In three *L. dulcis* we observed novel, alveolar-like secretory structures in the epithelium at the base of the apical tail spine (fig. 1). These "glands" were round, hollow,

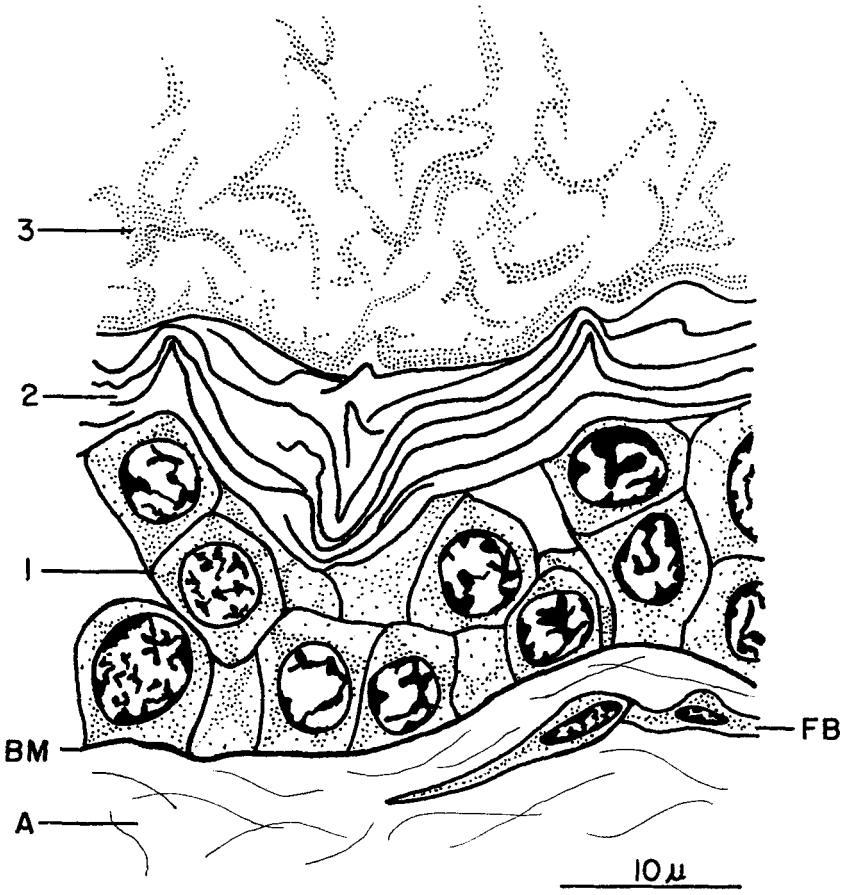

Fig. 3 Transverse section through a cloacal sac of *Leptotyphlops dulcis*, illustrating the three layers of the epithelium. 1, stratified cell layer; 2, cornified layer; 3, desquamating layer; BM, basement membrane; FB, fibroblast. Other abbreviations as in figure 2.

TABLE 1

Comparisons of mean lengths and diameters of tails, cloacal sac (CS), and cloacal glands (CG) of male and female Leptotyphlops dulcis. Measurements in millimeters

Sex	No. specimens	Tail length	Tail diam.	CS length	CS diam.	CG length	CG diam.
Male	17	10.2	3.8	7.7	0.8	2.2	0.3
Female	11	9.1	3.7	6.8	0.8	2.2	0.2

and independently couched in the surrounding keratinized scale epithelium (fig. 5). The "gland" cells were filled with numerous basophilic granules and large granulated, centrally placed nuclei. Aota ('40) described similar gland-like structures in the skin epithelium of *Typhlops braminus* (Daudin) and speculated that their mode of secretion was holocrine. Whether the structures described by Aota and those observed in *L. dulcis* are homologous in structure and function is problematical.

DISCUSSION

This morphological study suggests that *L. dulcis* can alter the size and shape of its cloacal sacs. As a result, it quanti-

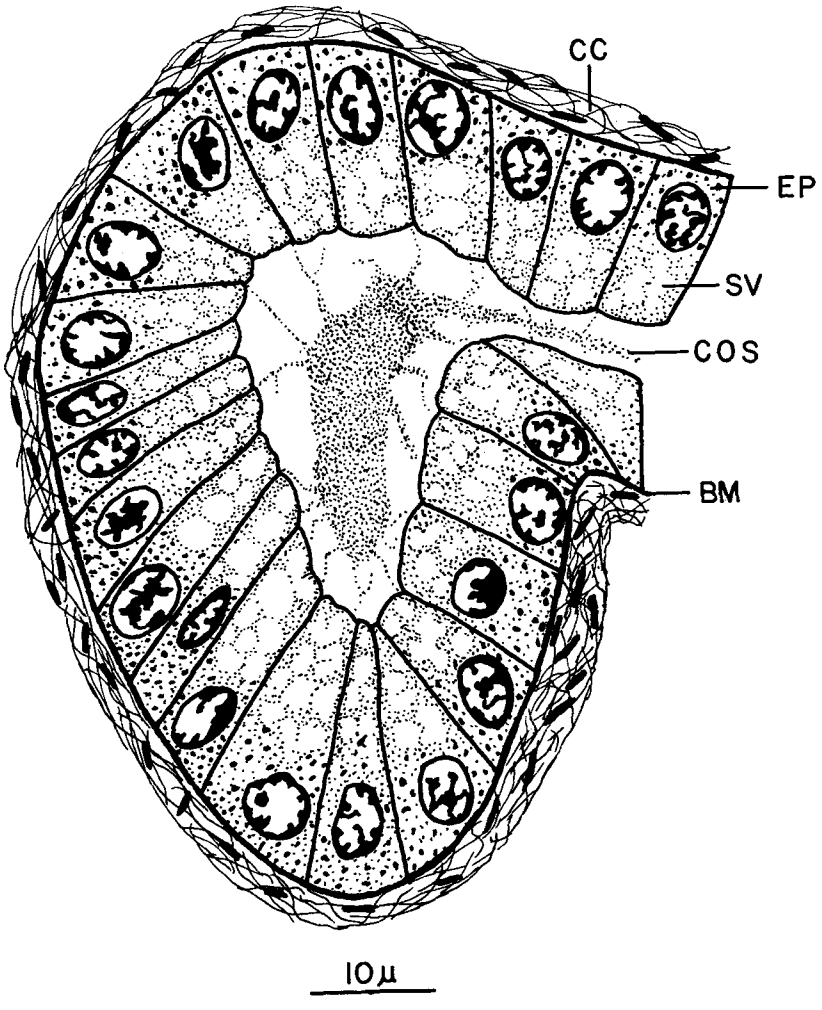

Fig. 4 Transverse section through a cloacal gland alveolus of *Leptotyphlops dulcis*, illustrating the secretory epithelium. CC, connective tissue capsule; COS, colloidal secretion; EP, columnar epithelium; SV, secretion vacuoles. Other abbreviations as in figure 3.

tatively regulates substances contained therein. In general, the cloacal sac's contents are opaque and semifluid, being a mixture of desquamated epithelial cells with some fecal debris (mainly fragments of insect exoskeletons). Since (1) the epithelial lining of the cloacal sacs is keratinized, stratified squamous epithelium, and (2) this type of epithelium is generally nonsecretory and characteristic of surfaces subjected to mechanical and chemical abrasion (Leeson and Leeson, '67; Ham, '69), it is probable that liquid and fecal components of the cloacal sac substance originate from the cloaca. Although the desquamated epithelium forms the principal solid component of the cloacal sac contents, it is possible that the desquamated cells secondarily function as a transport vehicle by adsorbing the liquid and fecal components and holding them in place until the cloacal sac contents are discharged into the cloaca and ultimately to the outside.

Smith ('54) postulated that in *Natrix natrix* Linnaeus the cloacal sacs (= "anal glands" of Smith) are emptied by involuntary action during certain periods of ani-

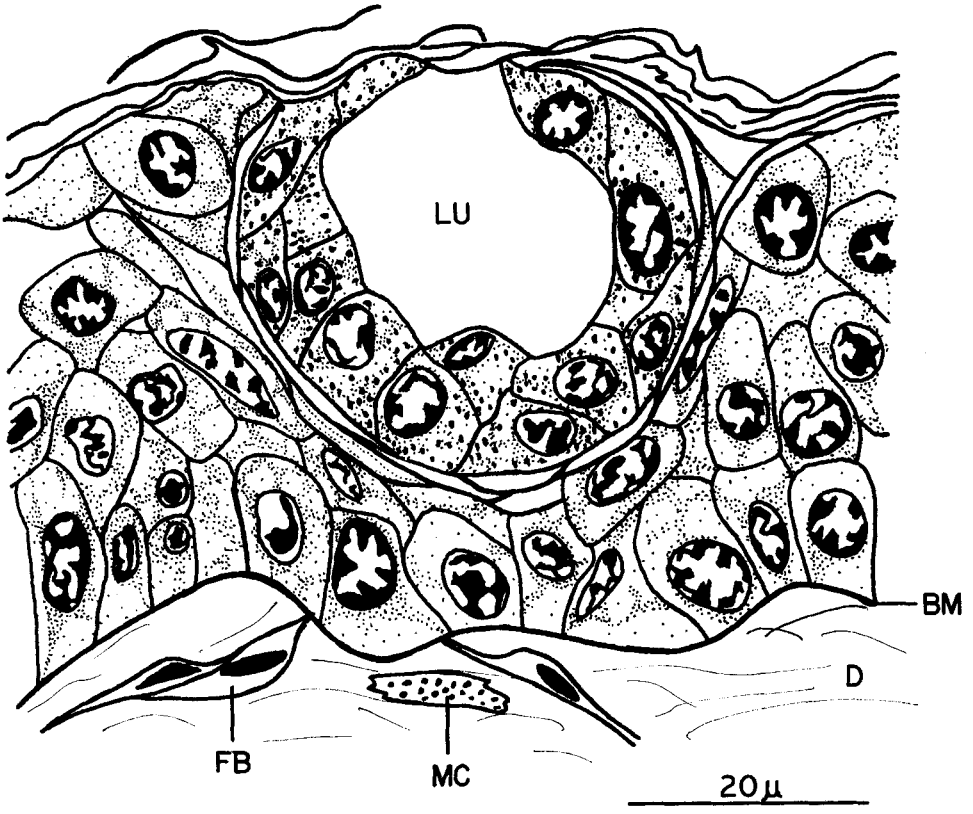

Fig. 5 Transverse section through epithelium of apical spine of *Leptotyphlops dulcis*, illustrating alveolar-like secretory structure. LU, lumen of alveolar-like structure; MC, mast cell. Other abbreviations as in figures 2, 3 and 4.

mal excitation. In *L. dulcis*, however, we contend that, because the cloacal sacs are enclosed by bands of skeletal muscle and that the cloacal sac ducts are regulated by sphincters, extrusion of cloacal sac contents is a voluntary response. Furthermore, we observed in some colubrids [*viz.*, *Natrix rhombifera* (Hallowell), *Sonora episcopa* (Kennicott), *Virginia striatula* (Baird and Girard), and *Tantilla gracilis* (Baird and Girard)] that cloacal sacs and sac ducts are also enclosed by bands of skeletal muscle and regulated by sphincters. We assume that in these species the cloacal sacs are also emptied by voluntary activity.

In the previously mentioned colubrids, median, unpaired cloacal glands are present also. These glands morphologically and histologically resemble the cloacal gland of *L. dulcis*. Although Fox ('65) suggested that the cloacal gland is unique to blind snakes, we agree with Gabe and Saint-Girons ('65) that cloacal glands are more generally distributed among snakes than was previously assumed.

Fox ('65) reported that secretory activity of the cloacal gland of *Typhlops vermicularis* Merrem was correlated with the reproductive season (February–May). In *L. dulcis* the cloacal gland exhibits the same cyclic phenomenon, although merocrine secretion continues through mid-summer. Since the test period reported by Watkins et al. ('70) overlapped periods of presumed secretory activity and inactivity, it seems doubtful that the cloacal gland of *L. dulcis* produces a secretion which either directly or indirectly attracts or repels animals. The cloacal gland of *L. dulcis* may function in sperm transfer and reception during coitus, as Robb ('60) suggested for certain species of *Typhlops*.

TERMINOLOGY

Many terms applied to sacs and glands associated with the snake cloaca apparently were coined without much regard to morphological relationships, anatomical structure, physiological activity, and homology and analogy within and between snake taxa. Terms such as "anal glands," "scent glands," "postanal glands," "musk glands," are commonly used; yet, these are misused when one considers that they are applied to cloacal derivatives. In addition, since the epithelial lining of the cloacal sacs is keratinized and generally nonglandular, the term "gland" also seems inappropriate.

In blind snakes "scent glands," "anal glands," and "cloacal glands" are terms commonly applied to the cloacal sacs. However, these terms have been so misused by authors that their comparative value is minimal. Robb ('60) applied the term "scent glands" to paired cloacal sacs in *Typhlops australis* Gray and, later in the same paper, she used the term "cloacal glands" for apparently identical structures in *T. ligatus* Peters (cf., her figs. 19 and 22, pp. 207, 212). Gabe and Saint-Girons ('65) referred to the paired cloacal sacs of *Typhlops* as "anal glands" and those of *Leptotyphlops* as "anal sacs" (cf., pp. 228, 229). Gehlbach et al. ('68) used the term "anal glands" in reference to the origin of repellent substances in writhing *L. dulcis*, while Watkins et al. ('70) applied the term "cloacal sacs" to the same structures. No anatomical justification was given for changing terminology by the latter authors.

It is suggested that in snakes the term *cloacal sacs* be applied to those paired, saclike derivatives of the cloaca whose epithelium is stratified squamous and whose function is storage rather than secretion. The term *cloacal gland* should be reserved for the single, median gland whose products are seasonally discharged directly into the cloaca.

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