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EXCEPTIONAL SIZE AND UNUSUAL MORPHOLOGY OF SPERMATOZOA IN *NOCTILIO ALBIVENTRIS* (NOCTILIONIDAE)

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Sufficient morphometric data for mammalian spermatozoa are available to show that sperm-head length ordinarily falls within the range of approximately 4-12 μm ; lengths > 12 μm are extremely rare. Published sperm-head lengths for bats range from < 4 μm in *Macrotus waterhousii* and *Glossophaga soricina* (Forman and Genoways, 1979) to nearly 7 μm in *Pipistrellus subflavus* (Forman, 1968). The exceptionally large head dimensions and unusual morphology of spermatozoa from the southern bulldog bat, *Noctilio albiventris*, are

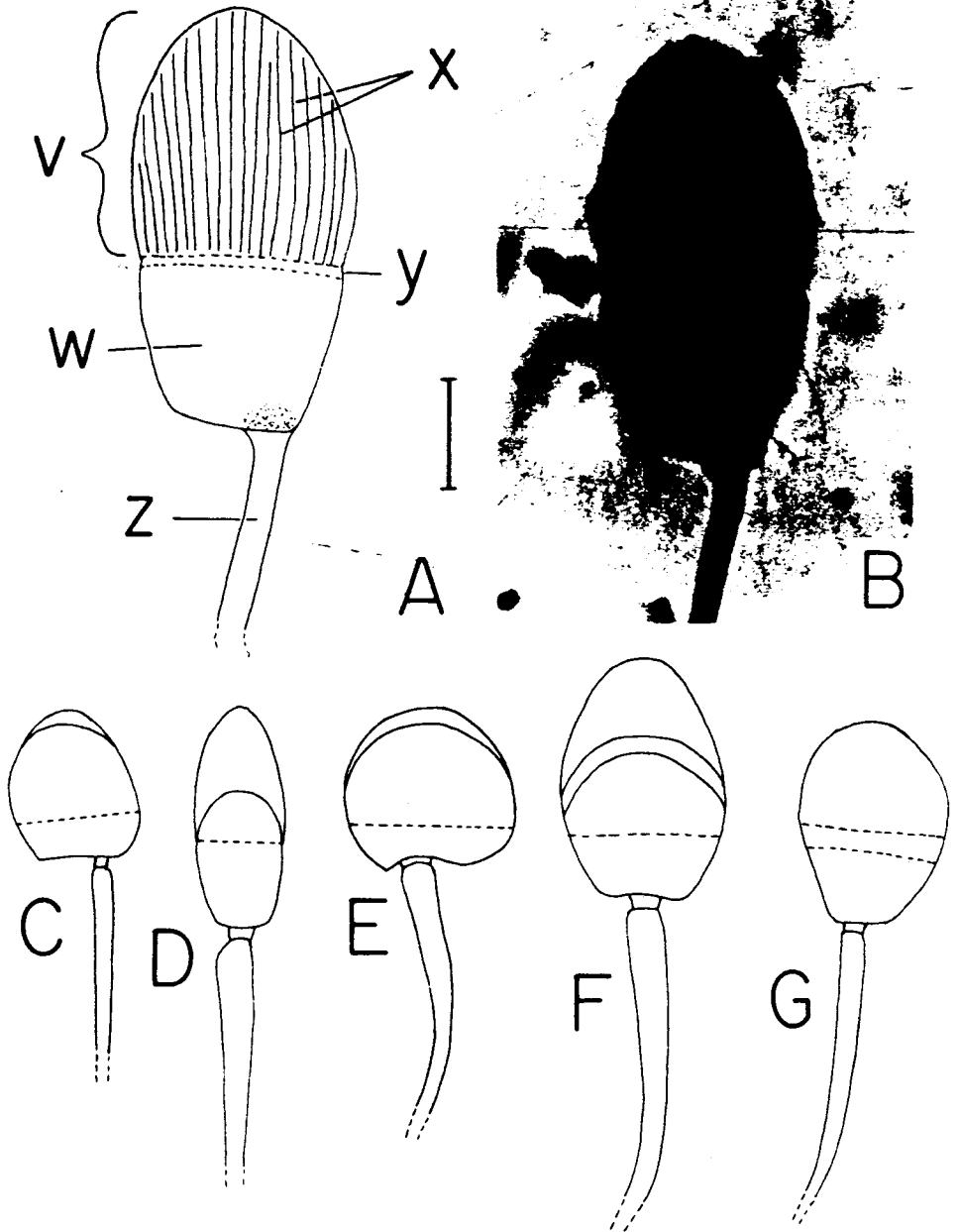


FIG. 1.—a, line drawing of the spermatozoan head of *Noctilio albiventris* (LACM 16292); v = acrosomal (head) cap, w = position of nucleus, x = "striations" on acrosome, y = posterior limit of acrosome, z = midpiece, b, photograph of sperm head of *N. albiventris* (LACM 16292); c-g, line drawings (all to scale) of the spermatozoan heads of selected bats: c, Natalidae (*Natalus stramineus*, LACM 24759); d, Hipposideridae (*Hipposideros calcaratus*, LACM 66390); e, Megadermatidae (*Cardioderma cor*, LACM 19621); f, Pteropodidae (*Pteropus capistratus*, LACM 65409); g, Nycteridae (*Nycteris hispidus*, LACM 19601). Scale = 4 μ m.

reported here for the first time. In addition, this unusual cytomorph is considered in light of the unresolved systematic relationship of the Noctilionidae to other families of New World bats.

Sperm morphology of bats has been useful in taxonomic studies where interspecific, intergeneric, or subfamilial relationships required clarification (Breed and Inns, 1985; Forman et al., 1968). The potential

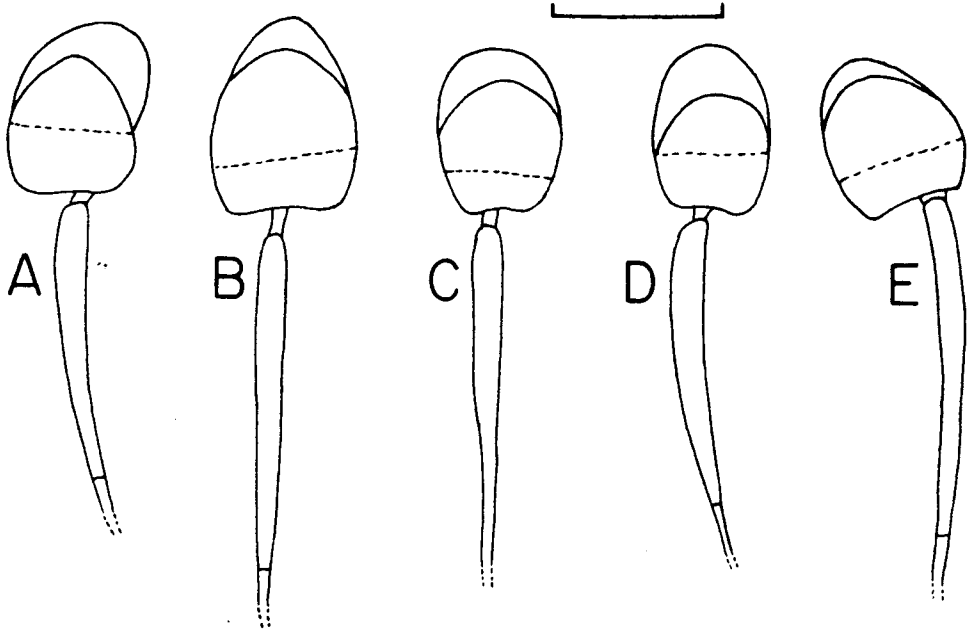


FIG. 2.—Line drawings of spermatozoa from selected phyllostomid bats (after Forman and Genoways, 1979), and one mormoopid: Phyllostomidae—a, *Mimon crenulatum*; b, *Choeronycteris mexicana*; c, *Carollia brevicauda*; d, *C. perspicillata*; Mormoopidae—e, *Pteronotus parnelli* (KU 84962). Scale = 5 μ m.

applicability of these data to understanding relationships between families has not been tested. One family of New World bats whose relationship to others remains an enigma is the Noctilionidae. The spermatozoa of *Noctilio* are compared to those of species from two other New World families (Phyllostomidae and Mormoopidae) with which the Noctilionidae are thought to be related.

Two specimens (male) of *Noctilio albiventris* on deposit at the Natural History Museum of Los Angeles Co. (LACM 16292) and California State University, Fullerton (personal collection of J. D. Smith, 2689) from Brazil and Venezuela, respectively, were examined. Four male specimens of *Noctilio leporinus* (fisherman bat) were examined for spermatozoa, but no intact cells were observed. However, sufficient fragments of cells confirmed the presence in this species of spermatozoa of similar size and form to those of *N. albiventris*. Previously unreported data for sperm-head length for three species of bats are included in Table 1. Museum identifications for these specimens are: *Pteropus neohibernicus* (LACM 65358), *Dobsonia praedatrix* (LACM 65588), and *Cardioderma cor* (LACM 19621). Previously unreported sperm morphology for several species of bats are provided for comparison with *N. albiventris*. Material from *Pteronotus parnelli* was obtained from the collection of the Museum of Natural History, The University of Kansas (KU). All other material was obtained from the LACM. Museum identifications for these specimens are included in the legends for Figs. 1 and 2.

Smears of spermatozoa were prepared by teasing or macerating epididymal tubules in a small quantity of 70% ethanol on a clean glass slide, then allowed to air dry. Dried smears were stained with one drop of 0.1% toluidine blue O. A coverslip was added and sealed at the edges with mounting media. This methodology, or a variant of it, has been employed successfully in studies of comparative sperm morphology in bats and rodents (Forman and Genoways, 1979; Genoways, 1973). Measurements (in μ m) were obtained using a dial micrometer (Unitron) calibrated with a stage micrometer (American Optical).

All previously unpublished drawings of sperm cells were produced by tracing individually photographed cells projected from film using a photographic enlarger.

The head of the spermatozoon from *Noctilio albiventris* is extremely large, ovoid, and tapers to a greater or lesser degree at its base (Fig. 1a, b). The acrosome (head cap, Fig. 1a) is broadly rounded at its apex and represents approximately two-thirds to three-fourths of the surface area of the head. The posterior limit of the acrosome is slightly concave in the direction of the base of the head, and appears to constrict the nucleus slightly at its lateral limits (y, Fig. 1a). Overall head shape is variable. Some heads are relatively narrow (Fig. 1a); others are more robust. Narrowly separated, nearly parallel longitudinal striations are present on

TABLE 1.—Head lengths of spermatozoa from selected species of mammals.

Species	Head length \bar{x} (μm)	Reference
<i>Mustela vison</i> (Mink)	5.83	Kim et al., 1979
<i>Gorilla gorilla</i>	9.78	Martin et al., 1975
<i>Physeter macrocephalus</i> (Sperm whale)	6.00	calculation based on published photograph (Matano et al., 1976)
<i>Macropus kangaroo</i> (Kangaroo)	7.30	Hughes, 1965
<i>Dasyuroides byrnei</i> (Kowari)	12.70	Hughes, 1965
<i>Suncus murinus</i> (Asiatic musk shrew)	21.50	Koehler, 1977
Domestic bull	9.40	Mukherjee and Singh, 1966
<i>Liomys pictus</i> (Spiny mouse)	5.22	Genoways, 1973
<i>Peromyscus polionotus</i> (Oldfield mouse)	5.40	Linzey and Layne, 1974
<i>Ototylomys phyllotis</i> (Climbing rat)	4.57	Helm and Bowers, 1973
<i>Eptesicus fuscus</i> (Big brown bat)	6.59	Forman, 1968
<i>Noctilio albiventris</i> (Bulldog bat)	15.70	This report
<i>Artibeus jamaicensis</i> (Jamaican fruit bat)	4.48	Forman and Genoways, 1979
<i>Cardioderma cor</i> (Heart-nosed bat)	5.34	This report
<i>Pteropus conspicillatus</i> (Spectacled flying fox)	7.70	Rouse and Robson, 1986
<i>Pteropus neohibernicus</i> (Bismarck flying fox)	7.58	This report
<i>Dobsonia praedatrix</i> (Naked-backed bat)	7.83	This report

the surface of, or beneath, the acrosome throughout its length (Fig. 1a, b). The precise position of these striations could not be determined using light-level methods. They are not, however, visible in sperm heads turned "on edge" (side view or sagittal view); therefore, we suggest that they probably are deep to the outer surface of the acrosome.

The head narrows at its asymmetrical base and the base (and nucleus) often is more rounded on one side than the other. Occasionally, the base forms a broad point near the junction with the midpiece. There is a dark-staining area (stippled region in Fig. 1a) at this junction. The anterior apex of the nucleus is not visible beneath the acrosome and the head stains intensely with toluidine blue throughout its length and breadth suggesting that nuclear material may be present throughout.

The short neck region connecting head with midpiece, often observed in spermatozoa of other bat families (Forman, 1968; Forman and Genoways, 1979; Rouse and Robson, 1986), is not distinguishable in *Noctilio*. The midpiece tapers gradually to its junction with the tail, and appears to have a smooth surface without spiraling or other distinguishing topographic detail.

The heads of the spermatozoa of *Noctilio albiventris* are the largest known for any bat. In the two specimens examined, sperm heads ranged in length from 14.9 μm to 16.6 μm ($\bar{X} = 15.7$, $n = 27$). The range in width was 8.5 to 9.0 μm ($\bar{X} = 8.8$, $n = 22$). Acrosome length averaged 11.9 μm (range, 10.9–12.5 μm ; $n = 19$). The midpiece is only slightly longer than the head, averaging 21.7 μm in two cells from one specimen.

The extremely large head, a nucleus constricted where the acrosome terminates posteriorly, parallel acrosomal striations, and dark-staining junction of head and midpiece have not been reported in the spermatozoa of other families of bats, or were they observed in any of the bats illustrated here for comparison. They are an apparently unique set of derived features. If the cell nucleus extends throughout the dimensions of the head, as observations suggest, then the sperm nucleus of *Noctilio* is the largest known for mammals.

Values of mean length of the sperm head (Table 1) for *Gorilla* (9.78 μm) and *Dasyuroides* (12.7 μm) represent the largest sperm heads of 10 species of primates and 18 species of marsupials, respectively, reported in each of two studies. Green and Dryden (1976) reported that the remarkably large sperm head of the Asiatic musk shrew, *Suncus murinus* (Table 1), was the result of an exceptionally long and broad acrosome. In contrast to the small, circular spermatozoan nucleus of *Suncus* (length = 4.5–5 μm ; Cooper and Bedford, 1976), that of *Noctilio* is of considerably greater dimension, being as broad as the head itself. The great size of *Noctilio* sperm heads is illustrated by the fact that some values for its breadth exceed all known lengths of sperm heads for other species of bats.

Large-sized bats of the family Pteropodidae (e.g. *Pteropus*, *Dobsonia*—Fig. 1f; Table 1) have sperm heads substantially smaller than those of the much smaller-bodied *Noctilio*. This fact suggests little relationship between overall body size and sperm size in bats, and that sperm head and nuclear size in *Noctilio* are indeed exceptional.

Sperm-morphology data from light-level studies are available in the literature for the bat families Rhinolophidae, Phyllostomidae, Molossidae, and Vespertilionidae (Bishop and Austin, 1957; Forman, 1968; Forman and Genoways, 1979; Forman et al., 1968; Hirth, 1960). When compared with published and unpublished (Figs. 1, 2) data for other families, the spermatozoa of *Noctilio albiventris* are clearly unique.

Several investigators of various features of noctilionids have attempted to clarify the relationship of this family to other New World families. Hood and Smith (1982) studied female reproductive tracts of *Noctilio* and concluded that recognition of the superfamily Phyllostomoidea, to include the Mormoopidae, Noctilionidae, and Phyllostomidae was justified. Patton and Baker (1978) earlier provided karyotypic data that supported allying the Noctilionidae with the Mormoopidae in a group distinct from the Phyllostomidae at a systematic level above family. However, information from multiple data sets (electrophoretic analyses, immunological analyses, karyotypes, morphology) has not led to congruence regarding the relationship of noctilionids to other bats (Arnold et al., 1982).

A comparison of the morphology of the nuclei and acrosomes from species of phyllostomids and a mormoopid (*Pteronotus parnelli*; Fig. 2) shows considerable congruence. However, the spermatozoa of neither family resemble those of *Noctilio* with regard to any feature of the head. Data from sperm morphology neither support nor refute proposed groupings of these three phyllostomoid families.

Nevertheless, the unusual size of the sperm nucleus of *Noctilio* raises questions that may be of interest to developmental and cell biologists, and to mammalogists. Spermiogenesis may be unique in *Noctilio*, and these "giant" cells may be metamorphosed or stored in an unusual manner. Ova of *Noctilio* females may be differentiated to participate in fertilization in ways that specifically accommodate penetration by exceptionally large nuclei.

The unique acrosomal striations might facilitate or in some way effect denudation of the ovum, penetration of the zona pellucida or egg membrane, or participate in removal of the acrosome during fertilization events.

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