Petaurus breviceps. By Meredith J. Smith

Petaurus Shaw, 1791

Petaurus Shaw, 1791. Type species *P. australis* Shaw, 1791, by monotypy. Type locality not specified in original description, restricted to Sydney, New South Wales, by Iredale and Troughton (1934).

Ptilotus Fischer, 1814. Type *P. australis*. A new name for *Petaurus*.

Belideus Waterhouse, 1839. Type species *P. sciureus* (= *P. norfolcensis*). Introduced as a subgeneric name; elevated to rank of genus by Gould (1842).

Xenochirus Gloger, 1841. Type *Didelphis sciurea* (= *P. norfolcensis*).

CONTEXT AND CONTENT. Order Marsupialia, Superfamily Phalangeroidea, Family Petauridae (Gill, 1872). The family Phalangeridae of older authors has recently been divided into three, of which the Petauridae, with eight genera, is the largest. The genus *Petaurus* contains *Petaurus australis* Shaw, 1791, *Petaurus norfolcensis* (Kerr, 1792), and *Petaurus breviceps* Waterhouse, 1839.

Petaurus breviceps Waterhouse, 1839

Sugar Glider

Petaurus (*Belideus*) *breviceps* Waterhouse, 1839. Type locality "New South Wales."

Belidea ariel Gould, 1842. Type locality "Pt. Essington, Northern Territory."

Petaurus (*Belideus*) *notatus* Peters, 1859. Type locality "Pt. Phillip district of Victoria" (Gould, 1849:text to plate 26).

Petaurus breviceps var. *papuanus* Thomas, 1888. Type locality "Huon Gulf." Elevated to species rank by Matschie (1916).

Petaurus kohlsi Troughton, 1945. Type locality "Owi Island, Schouten Group."

CONTEXT AND CONTENT. Context under genus above. Seven subspecies of *Petaurus breviceps* are recognized, as follows:

P. b. breviceps Waterhouse, 1839, see above (*notatus* Peters, 1859, a synonym).

P. b. longicaudatus Longman, 1924. Type locality "Mapoon Mission, Gulf of Carpentaria."

P. b. ariel (Gould, 1842), see above.

P. b. flavidus Tate and Archbold, 1935. Type locality "Oriomo River, New Guinea."

P. b. papuanus Thomas, 1888, see above.

P. b. tafa, Tate and Archbold, 1935. Type locality "Mt. Tafa, New Guinea."

P. b. biacensis Ulmer, 1940. Type locality "Biak Island, New Guinea" (*kohlsi* Troughton, 1945, a synonym).

The flying phalanger of New Guinea was described by Thomas (1888) as a variety (*papuanus*) of *P. breviceps* of Australia. Because of differences in the auditory bullae and fur-pattern of the heel, Matschie (1916) not only made *papuanus* a full species, but erected the subgenera *Petaurella* for *papuanus* and *Petaurula* for *breviceps*. Tate and Archbold (1935) thought that *papuanus* was specifically distinct from *breviceps* but later Tate (1945) treated *breviceps* and *papuanus* as conspecific. The Australian and New Guinean subspecies have interbred (male of *papuanus* and female of *ariel*, Fleay, 1947:88).

DIAGNOSIS. Belly color varies from pale gray to medium gray and may be tinged yellowish, but is never pure white or creamy white. The tail is furred evenly, and hairs near base of the tail are not longer than 40 mm. The three upper molars together are not longer than 6.5 mm (Thomas, 1888).

Within the genus, *P. australis* is distinguished by large size (head and body > 270 mm, tail > 400 mm) and broad palate. Digit 5 of manus is longest, whereas in *P. breviceps* and *P. norfolcensis* digit 4 is longest. *P. norfolcensis* slightly exceeds *P. breviceps* in size and has a longer and more pointed face and far bushier base of tail (hairs longer than 40 mm). Teeth larger in *norfolcensis* (M1 through M3 > 6.5 mm). The fourth lower premolar (p4) is much reduced in *breviceps* (Tate, 1945) but also may be small in *norfolcensis*.

GENERAL CHARACTERS. The genus contains animals with head and body length 130 to 320 mm and tail 120 to 480 mm. Fur is soft and silky; ears fairly large, oval, nearly naked, not tufted; tail evenly bushy all around and to its tip. A broad membrane is inserted on the outside of the manal digit 5 and the outer side of the forearm and extends along the side of the body to the hindleg, where it terminates at the base of pedal digit 1 (figure 1). The skull is short and broad; posterior squamosal part of zygomata much inflated by air cells; palate nearly or quite complete; bullae inflated, variable in size (figures 2 and 3). Dentition i 3/2, c 1/0, p 3/3, m 4/4, total 40 (Thomas, 1888).

Dorsal color of *P. b. breviceps* is a soft, pale gray. An indistinct dark brown or black band commences on muzzle, broadens into a dark patch on the crown and extends along middle of back nearly to base of tail; black line from nose through eye to ear; eye narrowly black-ringed; base of ear black with white or yellow patch anteriorly and posteriorly. A dark mark extends down the outside of the hindleg. The membrane is blackish above, fringed with white. Underside is pale gray and may be tinged with yellow. Ears are membranous, almost naked. Tail is uniformly hairy, color dusky gray, darkening to black distally (Thomas, 1888). The northern subspecies are smaller than *P. b. breviceps* and generally shorter-furred, although *P. b. tafa* has longer hair (12 mm dorsally). The dorsum may be deep mouse-gray, buff, or yellow-brown, and the underside creamy-buff, as in *P. b. flavidus*, or deep gray, as in *P. b. tafa* (Tate and Archbold, 1935). *P. b. biacensis* is uniformly fuscous-brown, relieved only by a small creamy-white ventral patch (Ulmer, 1940). The tip of the tail is pure white in some specimens of all populations. Mature males are distinguished by an almost bare patch over the frontal gland in the middle of the forehead. The sugar glider was beautifully reproduced in color by Gould (1843–1860) and Troughton (1962:pl. 7) included this species. For black-and-white photographs of live animals see Fleay (1947) and Wakefield (1961), and for line drawings, Ride (1970:pl. 18). The skull and teeth were figured in Thomas (1888).

FIGURE 1. External view of *Petaurus b. breviceps*. Photograph by E. Slater, C.S.I.R.O. Division of Wildlife Research.

FIGURE 3. Lateral view of skull and mandible of adult female *P. b. breviceps*. Drawn by the author from specimen in personal collection.
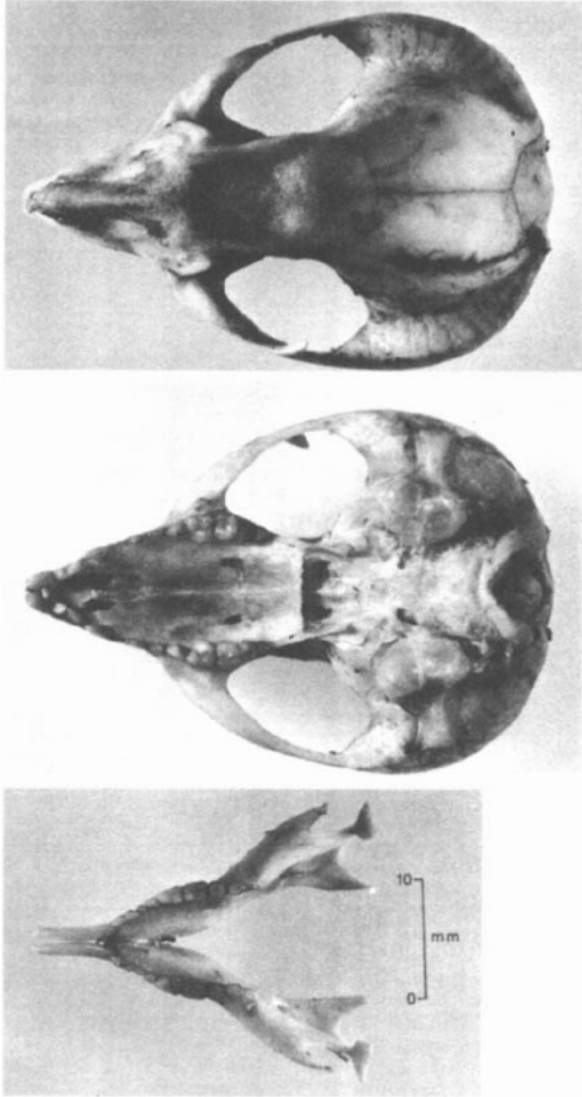
FIGURE 2. Photographs of skull and mandible of adult female *P. b. breviceps*. Photograph by R. Ruehle, South Australian Museum; specimen in personal collection of author.

to 5, and calcaneal 1 to 3 vibrissae. The submental set is present, but the inter-ramal set is absent, as are the medial antebrachial and anconeal sets (Lyne, 1959). Mystacial vibrissae are dark at the base and pale toward the tip; ulnar-carpal and calcaneal vibrissae are white bristles. Fine black

DISTRIBUTION. The sugar glider has an extensive range (figure 4) in New Guinea and the surrounding islands, and in coastal south-eastern, eastern and northern Australia (Finlayson, 1930; Laurie and Hill, 1954; Marlow, 1965; Matschie, 1916; Tate, 1952; Tate and Archbold, 1937). It is common in Arnhem Land, including several offshore islands (Johnson, 1964:452), and extends into the Kimberley region of Western Australia (Ride, 1970:237). It is absent from the southwest of Australia and is not indigenous to Tasmania (Gill, 1968; Gould, 1849:pl. 25; Wintle, 1886). Since the introduction of sugar gliders into Tasmania at Launceston in 1835, the species has spread over the island (Gunn, 1851). Altitudinal range is from sea level to at least 2,400 m in the Eastern Highlands District of New Guinea (H. M. Van Deusen, personal communication).

FOSSIL RECORD. *Petaurus breviceps* was found in Pleistocene layers (about 15,000 years BP) in a cave at Buchan, Victoria (Wakefield, 1967). At Wombeyan, New South Wales, and Naracoorte, South Australia, it occurs in deposits less reliably ascribed to the Pleistocene (Broom, 1896; Smith, 1971b). In southern Victoria it is common in cave bone deposits, many of which are accumulated owl pellets (Wakefield, 1964).

FORM. Vibrissae are well developed, the mystacials being 30 mm long, and the ulnar-carpals 10 mm. The mystacial group comprises four rows (10 to 15 vibrissae in all), the genal set 2 or 3 vibrissae, supraorbital 2, ulnar-carpal 2
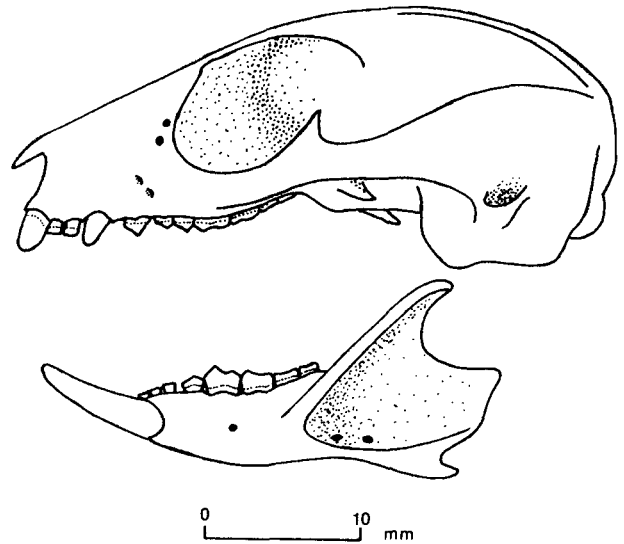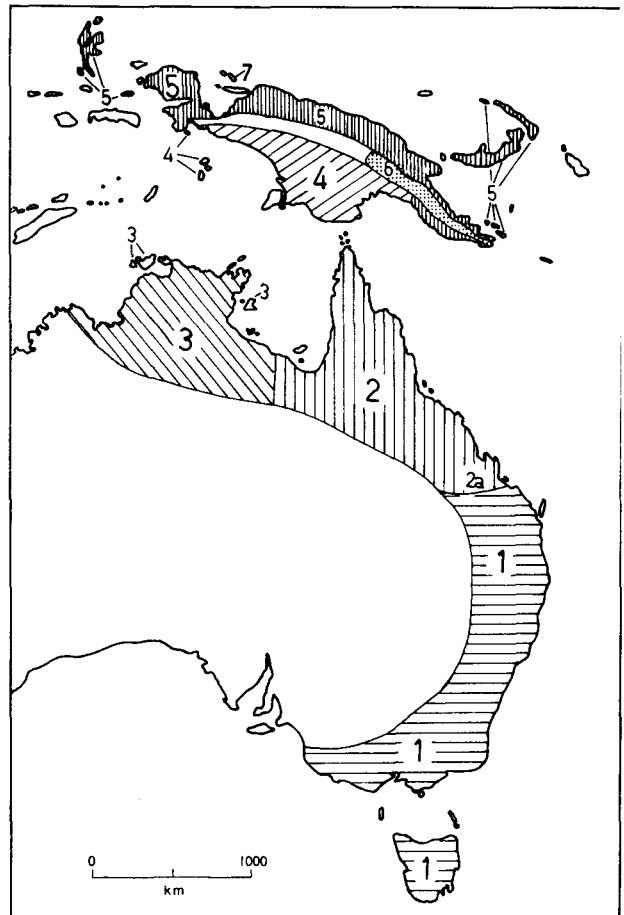

FIGURE 4. The geographic range of *Petaurus breviceps* and its subspecies in eastern Australia and adjacent areas: 1, *P. b. breviceps*; 2, *P. b. longicaudatus* (2a, Specimens from the lower Fitzroy Valley recorded as *P. b. ariel* by Finlayson, 1934, conform in tail-length with *P. b. longicaudatus*); 3, *P. b. ariel*; 4, *P. b. flavidus*; 5, *P. b. papuanus*; 6, *P. b. tafa*; 7, *P. b. biacensis*.

lashes fringe both eyelids (Jones, 1924:194). Soles of feet are naked and granular, each with five finely-striated pads. Apical pads are well developed and striated (Jones, 1924:194). In *P. b. breviceps*, the underside of heel is hairy except for a round spot on the tip, but the main naked part of sole connects to tip of heel by a narrow naked line in *P. b. papuanus* (Thomas, 1888). Pigmentation varies between subspecies (see above). Skin glands are larger and more numerous in males than in females. The frontal gland, in males only, is visible externally as an almost bare patch (as large as 16 by 18 mm) on the crown of the head. Peripherally in the frontal gland, sebaceous glands predominate, and each duct to the surface may be associated with a hair; more centrally placed are apocrine secretory tubules that have not been shown to open to the surface although their lumina contain a secretion. Two secretions (one yellow-brown and the other clear) are released from the frontal gland. A sternal gland (as large as 17 by 9 mm and present in males only) lies in the ventral midline of the body. The glandular area is darker-haired than the surrounding body surfaces, and, in actively-marking males, the center may be completely bare and the pore-openings visible with the naked eye. The peripheral sebaceous glands are united into larger groups than those of the frontal gland. The sternal gland releases a yellow-brown secretion. Males and females have anal glands (9 mm diameter) from which a whitish, strong-smelling secretion may be given off in tiny or larger drops. Males also have proctodaeal glands. The pouch lining in females contains numerous sebaceous glands, visible to the naked eye. The inside of the pouch is clean when no young are being suckled but contains a moist, brown pigment during the later pouch- and nest-life of the young. Other glands are situated behind the ear and in the inner angle of the eye of both sexes (Schultze-Westrum, 1965). The pouch, when containing young, has two lateral pockets extending far onto the flanks of the animal. The pouch opens near its anterior end. There are usually four nipples (Jones, 1924:195), but H. M. Van Deusen (personal correspondence) has found seven specimens from Mt. Wilhelm, Mt. Otto, and Mt. Michael in the Eastern Highlands District of New Guinea that have only two nipples. Dentition reflects insectivorous ancestry (Bensley, 1903). The median upper incisors are much larger than I2 and I3 (upper case letters used for upper teeth, lower case for lower teeth), which act as a stop to the sharply-pointed, upturned tips of the procumbent lower median incisors. Premolars are compressed laterally; P4 is slightly larger than P1, both have a sharp median cusp, and an anterior and a posterior cuspule; P3 is small as are the mandibular premolars. Maxillary molars are squarish and decrease in size posteriorly; each has four rounded cusps except M4, which is triangular in occlusal view. Protoconid of m1 is high and sharp-pointed, metaconid absent; m2, m3, and m4 are quadricuspid and slightly elongated anteroposteriorly (Thomas, 1888; Waterhouse, 1839). The auditory bullae are large (8 mm long) and have a marked downward projection in Australian specimens, but are much smaller (5.5 mm long) and without downward projection in New Guinean specimens (Thomas, 1888). A masseteric foramen is always present and may be duplicated or even triplicated (Abbie, 1939). Digital formula of manus is 4 > 5 > 3 > 2 > 1. The elongated fourth finger, with its sharp claw, is used to extract insects from crevices and from under loose bark of trees. The pedal formula is 4 > 5 > 2 and 3 > 1 (toes 2 and 3 are bound in a common skin, with only tips and claws free, as is characteristic of the superfamily). Digit 1 of pes is clawless and opposed to the other digits, all of which have long, curved, sharp claws (Fleay, 1947:71; Jones, 1924:194). The deltoid musculature differs slightly from that of nonvolant phalangerids. The deltoidean trapezius is juxtaposed between clavicular and acromial deltoids and acts as an abductor of the humerus, partly assisted by the deltoacromial. The spinal and clavicular deltoids adduct the raised humerus (Shrivastava, 1962). The dorsal lateral geniculate nucleus of the brain exhibits five distinct regions, four laminae, and a central core, and the high degree of lamination in this nucleus has been considered as evidence of a highly specialized visual apparatus (Johnson and Marsh, 1969). There are two ovaries and two uteri, which open on separate papillae into the anterior vaginal sinus. Median vaginal cul-de-sac is a short, undivided canal that ends blindly in the connective tissue at a considerable distance from the anterior end of the urogenital sinus. The lateral vaginae bend outward from the anterior vaginal sinus and then converge, join and open by a single aperture into the urogenital sinus. The urogenital sinus is relatively long (Hill, 1900; Pearson, 1945). A line drawing of the spermatozoan

appears in Hughes (1965); the proximal region of the head is semicircular, the dorsal surface bears a shallow depression, and, on the ventral surface, the groove for the insertion of the flagellum is broad and deep distally but becomes narrow and shallow towards its proximal extremity at about the middle of the head. Almost the entire head gives a positive Feulgen reaction for nuclear material (DNA) and the dorsal head surface gives a diffuse acrosomal reaction. Mean size of head is 5.9 by 2.5 μm, middle-piece 8.3 by 1.4 μm and flagellum 101.3 μm (Hughes, 1965). A copulation plug may be formed at mating (Smith, 1971a).

FUNCTION. Minimum heart rate was respectively 182 and 312 beats per minute in two animals (Kinnear and Brown, 1967). Heat tolerance is comparatively high, as judged by ability to achieve thermal equilibrium at an air temperature of 40°C. In three tests the average body temperature before exposure to heat was 36.9°C and the equilibrium body temperature at 40°C was 38.5°C (2°C > change in temperature from pretest value > 1°C). The animals cooled themselves by coat-licking and by assuming a sitting posture to maximally expose the wetted areas. They repeatedly drank small quantities of water. The pre-exposure breathing rate was high (187 per minute) and did not rise during heat exposure (Robinson and Morrison, 1957).

ONTOGENY AND REPRODUCTION. Breeding is not seasonally restricted in Arnhem Land (Johnson, 1964:452). In southeastern Australia, mature males produce sperm throughout the year, but young are born only between June and November (Fleay, 1947:80; Smith, 1971a). From January to May, the pouch of the adult female is a shallow, thin-walled depression. In June, the pouch walls become thick and turgid, the pouch deepens, near-surface blood vessels enlarge and the numerous small glands appear as distinct white spots. If no young are produced, the pouch regresses for the remainder of the estrous cycle, and redevelops cyclically during the breeding season. Gestation lasts about 16 days and litters of one or two young occur with about equal frequency. Twin young may be of the same or of different sex. Sugar gliders are polyestrous and bear a second litter if the first is lost or weaned during the breeding season (Schultze-Westrum, 1965; Smith, 1971a; Zuckerman, 1953).

The neonates resemble other marsupials in precocious development of forelimbs and olfactory organs. The birth weight is about 190 mg and the head length is 5.7 mm. Ear pinnae are directed forward and held to the head by epitrichium, the skin is not pigmented, and sex cannot be determined externally. Pouch or scrotum can be distinguished at day 12 to 14; at day 16 tips of ears are free and at day 25 ears are completely free and directed backwards. Fine fur appears on the muzzle at day 30 and the ears are lightly pigmented. Young first release the teat 40 days after birth, when they weigh 5.0 g. They are contained completely within the pouch until day 60; for the next few days the hindquarters protrude from the pouch while head and shoulders remain inside; by day 70 only the head is pushed into the pouch and the blind young cling to the fur of the mother or lie free in the nest. They are then fully-furred. They first release secretions of the anal gland at day 62. The eyes open at about day 80 and the young first leave the nest at day 111. Secretion from the frontal gland of males is seen as early as day 150.

Two females of *P. b. papuanus* first mated on days 227 and 246, respectively, and a *P. b. breviceps* female bore a litter when 15 months old. One male *P. b. breviceps* fathered a litter early in his second year (Schultze-Westrum, 1965; Smith, 1971a). The life span is at least 7 years in captivity (Fleay, 1947:81).

ECOLOGY. Sugar gliders are nocturnal and arboreal. Parasites are few. *P. breviceps* is the type host of a mite *Haemolaelaps calypso* Domrow, 1965, and a possible host of the mite *Mesolaelaps antipodiana* of bandicoots (Domrow, 1963, 1965). Sugar gliders are occasionally attacked by the nonspecific tick *Ixodes tasmani* (Roberts, 1960). Mackerras (1958) reported only one internal parasite, a sporozoan, *Haemogregarina petauri*, but a trematode occurs in the duodenum and small intestine (Mawson, personal communication). Owls (*Ninox* sp.) and feral cats (*Felis catus*) are the most serious predators (Calaby, 1966; Fleay, 1947:59, 81).

Social nesting communities consist of up to six adult males and females and their young. Rank order is established without fighting by the distribution of odors. Intraspecific antagonistic behavior is displayed only between communities. One or two dominant males, usually older, perform most of the

social activities, that is, odor distribution, territory maintenance, territory patrolling, aggression against foreign community members, and mating (Schultze-Westrum, 1965, 1969).

In New Guinea and surrounding islands, sugar gliders inhabit forest and coconut plantations; in Australia they require wet or dry sclerophyll forest or woodland, although on Groote Eylandt the habitat extends to wattle scrub (Fleay, 1947:68; Johnson, 1964:452). They nest in hollow branches or may rarely shelter on the ground (Calaby, 1966). A strong, distinctive odor permeates the nest, which is lined with leafy twigs carried there in bundles in the tightly-rolled tail (Fleay, 1947:75). These animals are omnivorous, seeking the nectar of flowers and the sap of young branches as well as hunting moths, beetles, insect larvae, and spiders. The long, curved lower incisors are used to pry bark from trees in the search for insects. Small birds and mammals also may be killed and eaten. Individuals feed in a head-down position, or, on a horizontal surface, sit back on the haunches while manipulating food with the hands (Fleay, 1947:77; Harrison, 1961; Wakefield, 1961). *P. breviceps* may glide 40 to 45 m from tree-trunk to tree-trunk when foraging. They take off from a head-down position, the four limbs spread out wide so that the animal appears to be square; about 3 m from landing the hindlegs are drawn in to the body, and the animal lands gently with a slight upward swoop. They are able to swerve while in flight (Fleay, 1947:76; Wakefield, 1961). Successful introduction into Tasmania has been discussed above.

Sugar gliders thrive in captivity on a simple diet (Smith, 1971a) and breed readily in zoos throughout the world (Zuckerman, 1953; records in various of the International Zoo Yearbooks of the Zoological Society of London). A pouch-young was hand-reared from about 40 days on a diet of diluted milk (Irby, 1931). Aboriginal man appreciated the flesh of the sugar glider and used the soft fur for ornamenting armlets and for making fur-string (Tindale, 1925:80). Sugar glider bones are found in Aboriginal middens (Finlayson, 1966). Specimens may be shot by eyeshine at night, though the eye-shine is faint, or may be taken from hollow tree-limbs during the day (Calaby, 1966; Fleay, 1947:71; Johnson, 1964:452). They are readily attracted to honey smeared on tree trunks and many of the regular visitors to such feeding stations become tame, allowing themselves to be examined and measured (Harrison, 1961; Wakefield, 1961).

BEHAVIOR. Like many nocturnal animals, the sugar glider has a complex chemical-communication system. Vocalizations, visual signals, and odors are used to communicate anonymously the physiological state of an animal, whereas individual-specific and community-specific communication is achieved only through odors. Males produce at least three individually-differentiated odors (frontal, sternal and urogenital) and females produce two (pouch and urogenital). The territory and members of the group are marked both passively, by incidental transfer of odors, and actively, by specialized behavior. To transfer frontal gland secretion, the male clasps the neck of the female with his paws, twists his head to face upwards and rubs his forehead on her chest with a circular motion. An adult female rubs her head in this way on the chest of the male, so that her head becomes marked with sternal gland secretion. This head-rubbing behavior is not related to courtship and mating. Although the whole community bears the odors of the dominant male, whose marking activity is greatest, adult males and females recognize each other individually. A mutual mother-young bond results in females rearing only their own offspring. Young animals first learn to recognize others (except the mother) as members of the group, later as individuals. The different odors of an individual, although perceived as different, all affect the receiver similarly depending on social attitude. The social relationship is community-specific and depends upon former chemical communication and learning. The chemical signals not only elicit immediate motor reactions, but also cause slow physiological and anatomical changes. For two groups to become integrated, they must use a common nest for several days; action within a common territory, or knowledge of the other group's odors, does not prevent aggression when the groups are united (Schultze-Westrum, 1965, 1969). Vocal communication is varied. The alarm call of the nest-young is an interrupted hissing, that of adults is a repeated "wok . . . wok . . . wok" somewhat like the yapping of a young terrier, and the anger call has been likened to the turning over of a high-pitched starter motor. Both alarm call and anger call commence full and loud, rapidly running down to faint grunts. Quiet hissing cries are sometimes given in the nest (Fleay, 1947:79; Wakefield, 1961).

GENETICS. The diploid chromosome number is 22 and all the chromosomes are metacentric or have obvious short arms. Sex determination involves XX females and XY males (Sharman, 1961).

REMARKS. Morphological differences between the Australian species *P. breviceps* and *P. norfolcensis* are slight, whereas subspecies of *P. breviceps* from Australia may differ markedly in color, size, and morphology from those of New Guinea. Although similarities in the proportions of skulls and teeth of *breviceps* and *norfolcensis* may suggest subspecific difference only (Tate, 1945) their widespread sympatry in eastern Australia (Calaby, 1966; Marlow, 1965) indicates that they are valid species. Serologically, differences between subspecies of *breviceps* are as great as between *norfolcensis* and *breviceps* (Kirsch, 1967), but some other nonmorphological characters (for example, odors or behavior) perhaps may be more widely divergent. Fertile hybrids between *P. breviceps* and *P. norfolcensis* have been born in captivity (Fleay, 1947:62; Zuckerman, 1953). Hybridization in the wild has not been reported and will unlikely be detected.

Specimens from the Huon Peninsula in New Guinea assigned by Tate and Archbold (1937) to *P. b. tafa* have been reassigned to *P. b. papuanus* by Hobart M. Van Deusen (personal communication) on the basis of restudy of the original material and study of specimens he has more recently collected there.

The sugar glider is the subject of a poem, "Flying Squirrels," by A. B. Paterson (Paterson, 1933:24).

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