INCREMENTAL GROWTH ZONES IN MAMMALS AND THEIR ARCHAEOLOGICAL VALUE

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Abstract.

A brief discussion regarding the occurrence of incremental growth structures in the teeth and bones of mammals, both terrestrial and marine, is presented, and the use of such structures to indicate age and season of death of the individual is suggested. A table is presented listing a number of mammals by species along with the structures known to yield incremental growth patterns to serve as a quick reference for the archaeologist. A bibliography of current literature is included.

Incremental growth zones.

The occurrence of incremental growth zones in the various skeletal elements of animals has been well documented among poikilotherms (Senning, 1940; Bryuzgin, 1939; Peabody, 1958; Barker, 1970; Rhoads and Pannella, 1970; Pannella and MacClintock, 1968; Nikolskii, 1963; Chugunova, 1959; Warren, 1963). There is also evidence indicating the appearance of annual and sub-annual growth increments in the teeth and bones of mammals, both terrestrial and marine. Evidence regarding the presence of these incremental growth structures in mammals has been steadily accumulating since the latter part of the 19th century.

The development of incremental growth lines in mammals is apparently caused by variations in calcification due to variations in the rate of tissue growth (Klevezal' and Kleinenberg, 1969, p. 28). The value of these incremental growth zones in the skeletal parts of mammals is that

they allow the archaeologist to make two very important observations: 1) the age of the individual mammal; and 2) the approximate season of its death. All other methods of assessing the age of the individual mammal from bone remains, such as degree of tooth wear, root development, width of dental canal, external structure and measurements of the skull, surface characters of the limb bones, ossification of epiphyses, and others, share a set of shortcomings. First, the criteria are subject to individual and geographic variations. Second, though they allow the breaking down of a series into age groups, they do not allow precise determination of the ages of adult and old individuals. Third, most of these methods are applicable only to a quite limited group of species (Klevezal' and Kleinenberg, 1969, p. 3).

Chaplin has stated that incremental structures "offer the only means of determining an absolute age for the animals" (1971, p. 84).

The method developed by Novakowski for the study of bison seems to have some considerable value to the archaeologist involved in studying the domestication of the Bovidae, especially where age structure of the faunal assemblage is concerned (see Ducos, 1969), since as Novakowski has noted, prior to this time, "no precise technique of age determination in the Bovidae has yet been developed in spite of the fact that cattle (Bos sp.) have been domesticated by man for some time" (1965, p. 173).

The use of annular or incremental growth structures to indicate not only age, but season of death is an idea with considerable utility for the archaeologist. Klevezal' and Kleinenberg noted

> . . . in all of the species studied the transparent bands of

> an annual layer or line of adhesion is formed between December and February and the non-transparent band of dentine and cementum and the layer of bone tissue--during the remaining part of the year (1969, pp. 30-31).

Figure 1 shows the time of band formation in the mammals studied by Klevezal' and Kleinenberg.

With increasing attention being paid to detailed analyses of faunal materials by archaeologists, questions of a more exacting nature are being required of faunal studies. Since a number of studies have stressed the need to know the age structure of the animal species constituting man's prey populations, both domestic (Ewbank, Phillipson, Whitehouse, and Higgs, 1964; Higgs and White, 1963; Bökönyi, 1972) and wild (Nimmo, 1971), and since some major difficulties can be encountered in the application of standard aging techniques, the use of incremental growth structures seems to offer the archaeologist and economic prehistorian a valuable tool (Chaplin, 1971; Gustafson, 1968; Gilbert, 1966; Saxon and Higham, 1969).

The following table and appended bibliography provide a quick reference to current literature on incremental growth structures in mammals. Table 1 presents a list of many of the mammals known to show incremental growth zones. The table is based upon a table in Klevezal' and Kleinenberg (1969, Table II) with some additions. All additions have been made in accordance with the system of Anderson and Jones (1967). In addition to the studies presented in Table 1, incremental growth rings have been observed in the dentine of fur seals (Yagi, Nishiwaki, and Nakajima, 1963) and the pilot whale (Sergeant, 1962), and ridged annuli have been observed on the baleen plates of the blue whale (Nishiwaki,

1950) and the humpback whale (Chittleborough, 1960). The references lited in Table 1 provide good descriptions of laboratory techniques for studying incremental growth structures. These generally focus on sectioning, grinding, etching, and/or staining in combination with microscopic examination. For an excellent review of mammal aging techniques, as well as for additional references dealing with age determination by means of incremental growth structures, see Morris (1972).

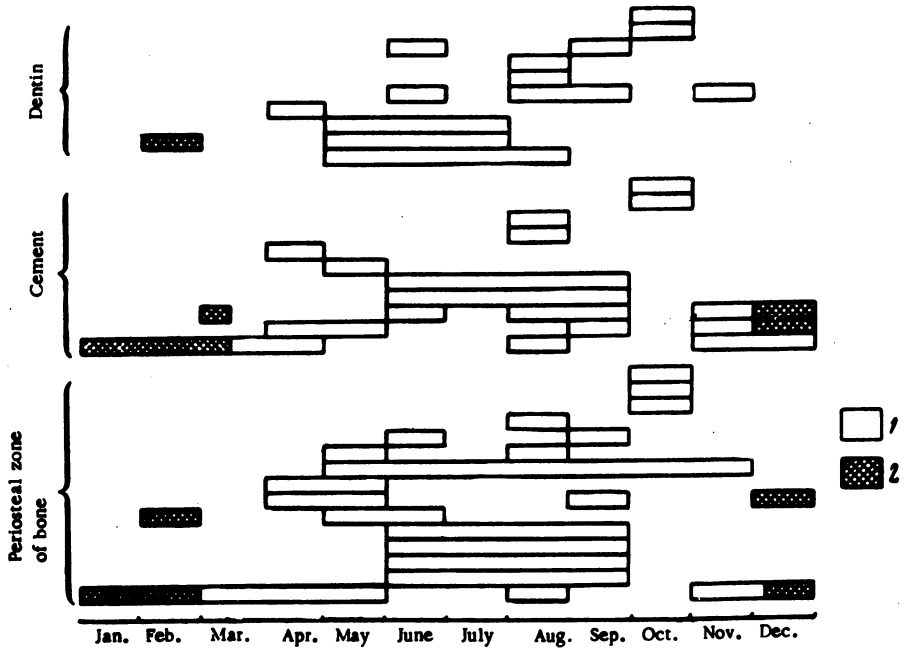

Fig. 1. Times of formation of individual bands of annual layers of dentine, cementum, and periosteal zone of bone in various species of mammals (after Klevezal' and Kleinenberg, 1969, fig. 6). 1 = the wide band of an annual layer. 2 = the narrow transparent band of dentine and cementum, the line of coherence of the bone. Reading from the bottom up, the periosteal zone of bone is shown for the beaver, field mouse, grey rat, common hamster, common colphin, common brown-tooth shrew, sable, and Arctic fox; the cementum is shown for the beaver, muskrat, wild ass, field mouse, grey rat, common hamster, large mouse-eared bat, spotted deer, common brown-tooth shrew, sable, and Arctic fox; and the dentine is shown for the red noctule, ribbon seal, ringed seal, large mouse-eared bat, wild ass, common brown-tooth shrew, spotted deer, common dolphin, sable, and Arctic fox.

Table 1

Incremental and annual layers in dental tissues and periosteal zone of bone in mammals (modified from Klevezal' and Kleinenberg 1969: Table II).

Family	Species	ridges	dentine	cementum	periosteal zone	enamel	Author
	Order-Marsupicarnivora						
Didelphidae	"opossum"		+			+	Schour and Hoffman 1935a.
	Order-Insectivora						
Soricidae	Common shrew *Sorex araneus*		+	+	+		Klevezal' 1966; Kleinenberg and Klevezal' 1966.
	Order-Chiroptera						
Vespertilionidae	Great brown bat *Eptesicus fuscus*		+				Christian 1956.
	Large mouse-eared bat *Myotis myotis*		+	+			Klevezal' 1966.
	Red noctule *Nyctalus noctula*		+	+			Klevezal' 1966.
	Order Primates						
Hominidae	Man *Homo sapiens*			+	+		Chaplin 1971; Anderson and Jørgensen 1960.

Table I (continued)

		Order-Lagomorpha						
Ochotonidae	Long-eared pika *Ochotona roylei*				+			Bernstein and Klevezal' 1965.
	Red pika *Ochotona rutila*				+			Bernstein and Klevezal' 1965.
Leporidae	"rabbit"		+			+		Schour and Hoffman 1935 a, b.
		Order-Rodentia						
Castoridae	Beaver *Castor fiber*			+	+			Klevezal' and Kleinenberg 1964; van Nostrand and Stephenson 1964; Kleinenberg and Klevezal' 1966.
Sciurudae	Small suslik *Citellus pygmaeus*				+			Meier 1957.
	Thin toed suslik *Spermophilopsis leptodactylus*			+	+			Klevezal' 1966.
	Gray marmot *Marmota baibacina*		+	+	+			Klevezal' and Kleinenberg 1969.
	"ground squirrel"		+			+		Schour and Hoffman 1935a, b.
Muridae	Field mouse *Apodemus agrarius*			+	+			Klevezal' and Lavrova 1966.
	Gray rat *Rattus norvegicus*			+	+			Klevezal' and Lavrova 1966.
	Tamarisk gerbil *Meriones tamariscinus*			+	+			Klevezal' 1966.
	Common hamster *Cricetus cricetus*			+	+			Klevezal' 1966.
	Muskrat *Ondatra zibethica*			+	+			Klevezal' 1966.

Table I (continued)

	Water rat *Arvicola terrestris*				+		Klevezal' 1966.
	Common vole *Microtus arvalis*				+		Klevezal' and Lavrova 1966.
	Pine vole *Microtus majori*				+		Klevezal' and Lavrova 1966.
	"rat"		+			+	Schour and Steadman 1935; Schour and Hoffman 1935a, b.
Caviidae	"guinea pig"		+			+	Schour and Hoffman 1935a, b.
	Order-Cetacea						
Physeteridae	Sperm whale *Physeter catodon*	+	+	+	+		Nishiwaki, Ohsumi, and Kasuya 1961; Nishiwaki, Hibiya, and Ohsumi 1958; Berzin 1961, 1964; Ohsumi, Kasuya, and Nishiwaki 1963; Bow and Purday 1966; Laws 1952, 1960b.
Phocoenidae	Common porpoise *Phocena phocoena*		+	+			Sergeant 1959.
Delphinidae	Beluga *Delphinapterus leucas*		+	+	+		Sergeant 1959; Khuzin 1961, 1963; Brodie 1969.
	Pilot whale *Globicephala maelaena*		+	+			Sergeant 1959.
	Killer whale *Orcinus orca*		+	+			Sergeant 1959.
	Dolphin *Lagenorhynchus acutus*		+	+			Sergeant 1959.
	Bottle-nosed dolphin *Tursiops truncatus*		+	+			Sergeant 1959.

Table 1 (continued)

	Common dolphin Delphinus delphis			+	+	+		Sergeant 1959; Kleinenberg and Klevezal' 1962; Klevezal' 1966.
	Blue-white dolphin Stenella caeruleoalbus			+				Nishiwaki and Yagi 1953.
Balaenidae	Balaena glacialis					+		Yablokov and Andreyeva 1965.
Balaenopteridae	Fin whale Balaenoptera physalus		+					Klevezal' 1966; Yablokov and Andreyeva 1965; Nishiwaki 1951; Ohsumi 1964.
	Sei whale Balaenoptera borealis					+		Yablokov and Andreyeva 1965.
	Blue whale Balaenoptera musculus					+		Yablokov and Andreyeva 1965.
	Little piked whale Balaenoptera acutorostrata					+		Yablokov and Andreyeva 1965.
	Megaptera nodosa					+		Yablokov and Andreyeva 1965.
	Order-Odontoceti							
Ziphiidae	Giant bottle-nosed whale Berardius bairdi			+				Omura, Fujino, and Kimura 1955.
	Order-Carnivora							
Ursidae	Brown bear Ursus arctos				+			Smirnov 1960; Mundy and Fuller 1964.
	Black bear Ursus americanus			+	+			Rausch 1961.
	Thalarctos maritimus		+					Laws 1953a.
Canidae	Arctic fox Alopex lagopus			+	+	+		Klevezal' 1965, 1966.
	"dog" Canis sp.			+			+	Schour and Hoffman 1935a, b.

Table I (continued)

Mustelidae	Sable *Martes zibelina*		+	+	+		Klevezal' 1965, 1966.
	American mink *Mustela vison*			+	+		Klevezal' 1965, 1966.
	Sea otter *Enhydra lutris*			+			Klevezal' and Makarov 1966.
Hyaenidae	*Hyaena* sp.	+					Laws 1953a.
Felidae	"cat"		+			+	Schour and Hoffman 1935a, b.
	Felis leo	+					Laws 1953a.
	Order-Pinnipedia						
Odobenidae	Walrus *Odobenus rosmarus*		+	+	+		Chapskii 1952; Mansfield 1958a; Krylov 1965.
Otaridae	Southern sea lion *Otaria byronia*		+	+			Fiscus 1961; Spalding 1964; Laws 1962
	Steller sea lion *Eumetopias jubata*		+	+			Fiscus 1961; Spalding 1964.
	South African fur seal *Arctocephalus pusillus*		+				Rand 1956 (cited in Laws 1962).
	Arctocephalus tropicalis		+				Laws 1962.
	South American fur seal *Arctocephalus australis*		+				Laws 1962.
	Northern fur seal *Callorhinus ursinus*	+	+				Chiasson 1957; Scheffer and Kraus 1964; Kenyon and Scheffer 1954; Scheffer 1950.

Table 1 (continued)

Phocidae	Common seal *Phoca vitulina*		+	+		Mansfield and Fisher 1960; Tikhomirov and Klevezal' 1964; Laws 1952.
	Ringed seal *Pusa hispida*		+	+	+	McLaren 1958; Tikhomirov and Klevezal' 1964.
	Caspian seal *Pusa caspica*		+	+	+	Chapskii 1965.
	Baikal seal *Pusa sibirica*		+	+	+	Klevezal 1961.
	Harp seal *Pagophilus groenlandicus*		+	+	+	Chapskii 1952; Laws 1952; Rasmussen 1957; McLaren 1958; Yakovenko 1960, 1961.
	Ribbon seal *Histriophoca fasciata*		+	+		Tikhomirov and Klevezal' 1964.
	Bearded seal *Erignathus barbatus*		+		+	Tikhomirov and Klevezal' 1964.
	Grey seal *Halichoerus grypus*		+	+		Hewer 1960, 1964.
	Crabeater seal *Lobodon carcinophagus*		+	+		Laws,1952, 1953a, 1957.
	Leopard seal *Hydruga leptonyx*		+	+		Laws 1952, 1953a, 1957.
	Weddell seal *Leptonychotes weddelli*		+	+		Laws 1952; Mansfield 1958b.
	Ross seal *Ommatophoca rossi*		+			Laws 1953a.
	Hooded seal *Cystophora cristata*		+	+		Laws 1952, 1953a; Rasmussen 1957; Yakovenko 1959; Popov 1960.

Table 1 (continued)

	Northern elephant seal *Mirounga leonina*	+	+	+	+		Laws 1952, 1953a, b, 1960a, b, 1962.
	Hawaiian monk seal *Monachus schauinslandii*		+	+			Kenyon and Fiscus 1963.
	Order-Proboscidea						
Elephantidae	*Elephas indicus*	+					Laws 1953a.
	Order Sirenia						
	Dugong *Dugong dugong*		+				Scheffer 1970.
	Order-Perissodactyla						
Equidae	Wild ass *Equus hemionus*		+	+			Klevezal' 1966.
	Order-Artiodactyla						
Suidae	*Sus* sp.	+					Laws 1953a.
Hippopotamidae	*Hippopotamus amphibus*	+					Laws 1953a.
Cervidae	Roe deer *Capreolus capreolus*		+	+			Klevezal' 1966.
	Spotted deer *Cervus nippon*		+	+			Klevezal' 1966.
	Red deer *Cervus elephus*			+			Mitchell 1963, 1967.
	Caribou *Rangifer tarandus*			+			McEwan 1963.
	Elk *Alces alces*		+	+			Sergeant and Pimlott 1959.
	Mule deer *Odocoileus hemionuss*			+			Low and Cowan 1963.

Table 1 (continued)

	White-tailed deer *Odocoileus virginianus*		+	+			Gilbert 1966; Ransom 1966.
Bovidae	Bison *Bison bison*			+			Novakowski 1965.
	Bison spp.	+					Laws 1953a.
	Bighorn sheep *Ovis canadensis*	+					Cowan 1940.
	Sheep (domestic) *Ovis* spp.		+	+			Saxon and Higman 1969.

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