31 Skull

14. Explanation of Symbols and Abbreviations Used in Illustrations

1	interpremaxillary suture
2	internasal suture
3	nasopremaxillary suture
4	frontal suture (metopic suture; usually obliterated in adults of higher primates)
5	interparietal suture (sagittal suture)
6	coronal suture
7	lambdoidal suture (parieto-occipital suture)
8	maxillopremaxillary suture, vertical
9	maxillonasal suture
10	frontonasal suture
11	frontomaxillary suture
12	frontolacrimal suture
13	frontoethmoid suture
14	ethmolacrimal suture (lacrimoethmoid suture)
15	maxillolacrimal suture (lacrimomaxillary suture)
16	maxilloethmoid suture
17	frontozygomatic suture (frontomalar suture; zygomaticofrontal suture)
18	sphenofrontal suture
19	sphenoethmoid suture
20	sphenomaxillary suture
21	sphenozygomatic suture
22	sphenoparietal suture
23	sphenosquamosal suture (sphenotemporal suture)
24	parietozygomatic suture (zygomaticoparietal suture)
25	parietotemporal suture (squamosal suture)
26	parietomastoid suture
27	zygomaticomaxillary suture
28	zygomaticotemporal suture
29	maxillopremaxillary suture, transverse
30	intermaxillary suture
31	maxillopalatine suture
32	interpalatine suture
33	sphenopalatine suture
34	spheno-occipital suture
35	occipitomastoid suture
36	ethmopalatine suture
37	orbitosphenoid suture
38	intermaxillovomer suture
39	palatovomer suture
40	sphenovomer suture
41	ethmovomer suture

A	medial pterygoid plate
a	anterior
ac	anterior crus
acfos	anterior cranial fossa
acpr	anterior clinoid process
aEf	anterior ethmoidal foramen
agl	angle
alf	anterior foramen lacerum
alpr	alveolar process
appy	apex pyramidis
ar	artery
aS	alisphenoid bone
asng	ascending
asngrm	ascending ramus
aV	ala vomeris
B	lateral pterygoid plate
base	base of mandible
basO	basion
bE	bulla ethmoidalis
bin	body of incus
bO	basioccipital (pars basilaris)
body	body of mandible
bS	basisphenoid bone
c	canal
ca	canine tooth
cav	cavity
cc	carotid canal
cdl	condyle
cf	carotid foramen
cfos	cerebellar fossa
cgE	crista galli
cgS	chiasmatic groove (optic groove)
co	coronion
coch	cochlea
copr	coronoid process
cr	crest
crfos	cerebral fossa (occipital fossa)
csS	carotid sulcus or groove
dggr	digastric groove
dgrg	digastric ridge or shelf
div	diverticulum
dpl	diploe (diploë)
dsng	descending
dsS	dorsum sella turcica
E	ethmoid bone
eam	external auditory meatus
Ec	cartilaginous plate of ethmoid bone
Ecp	cribriform plate (lamina cribrosa)
Ect	ectoturbinal bone

ect	ectotympanic (tympanic ring or tympanic annulus)
Ef	ethmoidal foramen
Efos	ethmoidal fossa (houses olfactory lobes)
Enty	entotympanic bone
Eoff	olfactory foramina
eOp	external occipital protuberance (inion)
ept	epitympanic cavity
epT	epitympanum
Es	ethmoidal sinus
Et	ethmoturbinal bones (I-IV)
Et-I	turbinate bone, middle (ethmoturbinal-I; concha nasalis media; middle nasal concha)
Et-II	ethmoturbinal-II (concha nasalis superior; superior nasal concha)
Et-III	ethmoturbinal-III (concha nasalis suprema; supreme nasal concha)
Et-IV	ethmoturbinal IV
Et-n	nasoturbinal (superior turbinate)
exO	exoccipital bone
F	frontal bone
f	foramen
faq	fallopian aqueduct
fC	foramen Civinini
fcr	foramen crotaphiticum
feno	fenestra ovale (fenestra ovalis, fenestra vestibuli)
fenr	fenestra rotundum (fenestra rotunda; fossa fenestra cochleae; round window)
fis	fissure
fmO	foramen magnum
fo	foramen ovale
fos	fossa
Fs	frontal sinus
Fso	frontal sinus, ostium
gfos	glenoid fossa (mandibular fossa)
gn	gnathion
gnlfos	genial fossa
gon	gonion
gPalf	greater palatine foramen (major palatine foramen)
gr	groove
grC	groove Civinini
hcO	condylar foramen (hypoglossal canal or foramen)
hmal	head of malleus
hpS	hamular process of pterygoid (hamulus pterygoideus; hamular process)
hsc	horizontal semicircular canal
hypt	hypotympanum (bulla)
hyptc	hypotympanic cells
hyptd	hypotympanic cavity, dorsomedial
hyptl	hypotympanic cavity, lateral
i	incisor tooth
iam	internal auditory meatus (temporal meatus)
icar	internal carotid artery
if	infraorbital foramen
ifos	foramen lacerum posterius (posterior lacerated foramen)
im	inferior meatus
imof	inferior margin of optic foramen
in	incus
inf	inferior
infmasrg	inferior masseteric ridge
infMn	inferior mandibular notch
inion	inion (external occipital protuberance)
iOcr	internal occipital crest
iof	interorbital foramen
iofis	inferior orbital fissure (sphenomaxillary fissure)
iOprt	internal occipital protuberance
iP	Inca bone
ipsgr	groove for inferior petrosal sinus
jf	jugular foramen and fossa
jfos	jugular fossa (jugular foramen; posterior lacerated foramen)
L	lacrimal bone
l	line
lcin	long crus of incus
lcr	lambdoid crest (superior nuchal line)
Lfos	lacrimal fossa
lig	ligament
lmal	lamina of malleus
Lml	marginal lingula of lacrimal bone
loE	lamina orbitalis (orbital plate of ethmoid; os planum)
lofis	lateral orbital fissure (also situated behind alisphenoid and malar, or between malar and parietal)
lPalf	lesser posterior palatine foramen (minor posterior palatine foramen)
lpE	lamina perpendicularis (perpendicular plate of ethmoid)
lpS	lateral plate of pterygoid process (lamina lateralis processus pterygoidea)
lpsfis	lateral petrosphenoidal fissure
ls	limbus sphenoidalis
lsc	lateral semicircular canal (horizontal semicircular canal)
ltS	transverse lamina
ltscp	longitudinal tympanic septum
lun	lunar notch
M	maxillary bone (superior maxilla, maxilla)
m	molar tooth
ma	malleus
magr	groove or grooves for branches of middle meningeal artery
mal	malleus
masfos	masseteric fossa
mest	mesotympanic cavity (mesotympanum; atrium)
mfos	mesopterygoid fossa
mlf	mental foramen
mlprt	mental protuberance
mlsp	mental spine
mm	middle meatus
mmal	manubrium, of malleus
Mn	mandible
Mnf	mandibular foramen
mngr	groove for maxillary branch of trigeminal nerve
MPmso	maxillopremaxillary sinus, ostium
Mpr	maxillary process of zygomatic arch
mpS	medial pterygoid plate
mpsfis	median petrosphenoidal fissure
mprT	mastoid process
mpT	mastoid process
Mrg	maxillary ridge
Ms	maxillary sinus
msf	mastoid foramen

Mso	maxillary sinus, ostium
Mt	maxilloturbinal bone (inferior turbinate bone)
mT	mastoid bone
mTc	mastoid cells
mTf	mastoid foramen
mygr	mylohyoid groove
myl	mylohyoid line
N	nasal bone
ncdl	neck of condyle
ncr	inferior nuchal line (nuchal crest)
O	occipital bone
obl	oblique line
Oc	occipital condyle
Ocl	clivus of basioccipital
Ocr	external or medial occipital crest (occipital crest)
oEs	ostium, ethmoidal sinus
of	optic foramen
ofos	orbital fossa
oOrg	oblique occipital ridge
op	occipital point
opO	opisthion
org	orbital ridge or crest
oS	orbitosphenoid bone
P	parietal bone
p	post; posterior; postero-
Pal	palatine bone
Palc	palatine canal
Palf	palatine foramen
Pals	palatine sinus
Palsp	posteromedian palatine spine
pbof	posterior border of optic foramen
pcpr	posterior clinoid process
pEf	posterior ethmoidal foramen
pfos	pterygoid fossa
pgf	postglenoid foramen
pgpr	postglenoid process
plc	posterolateral canal
plf	foramen lacerum posterius (posterior lacerated foramen)
pls	planum sphenoideum
Pm	premaxillary bone
pm	premolar tooth
Pmf	incisive foramen
pofis	petro-occipital fissure
pog	pogonion
postn	posterior nares
ppr	pterygoid process
pr	process
prgr	processus gracilis
prom	promontorium (promontorium cochleae)
proma	promontory artery
prt	protuberance
prS	sphenoidal spine, spinous process
pS	presphenoid bone
psc	posterior semicircular canal
psT	petrous spine
pT	petrous part of temporal bone
ptcr	petrous crest
ptfis	glaserian fissure (Glaserian fissure; petrotympanic fissure)
pt lam	pterygospinous lamina
pye	pyramidal eminence
qsT	quadrilateral surface
rf	foramen rotundum
rg	ridge
rgMnn	ridge of mandibular neck
rm	ramus
rtrmf	retromolar foramen
rtrmfos	retromolar fossa
rtrmtr	retromolar triangle
S	sphenoid bone
s	sinus
sagcr	sagittal crest
scin	short crus of incus
scr	sulcus crotaphiticum
sep	septum
seT	subarcuate eminence
sf	foramen spinosum
sfos	subarcuate fossa
sgn	sigmoid notch
sgr	sigmoid groove (lateral groove)
sm	superior meatus
smf	stylomastoid foramen
SMs	sphenomaxillary sinus
sncr	supreme nuchal line
sof	supraorbital foramen or notch
sofis	superior orbital fissure
sp	spine
spC	spina Civinini
spn	spina nasalis
spp	spinous process (sphenoidal spine)
spr	styloid process
spsgr	groove for superior petrosal sinus
Spt	sphenoidal point
srg	sagittal ridge
Ss (1–4)	sphenoidal sinus (1–4)
ssc	superior semicircular canal
sT	squamosal portion of temporal bone
sta	stapes
star	stapedial artery, superior branch
statn	stapedial tendon
stS	sella turcica (hypophyseal fossa)
su	suture
sub	sub-
sublfos	sublingual fossa
submfos	submaxillary fossa
sup	superior
supmasrg	superior masseteric ridge
SupMnn	superior mandibular notch
sym	symphysis
symf	symphyseal foramen
T	temporal bone (squamosal bone)
t	concha (turbinate bone)
tant	tympanic antrum
tbT	tympanic bulla (auditory bulla)
tcav	tympanic cavity
tcr	temporal crest
tdr	tympanic drum
Tfos	temporal fossa
tent	tentorium osseum (tentoralis petrosi)
tentpr	tentoralis petrosi, processus
Tfos	temporal fossa
tip	trigeminal impression
tm	tympanic membrane
tpr	tympanic process of petrous bone
tpraS	tympanic process of alisphenoid bone
tr	transverse
trg	superior temporal line or ridge

trmsep	transverse mastoidal septum
trs	transverse ridge or sulcus
trtsep	transverse tympanic septum
ts	tuberculum sellae
tt	auditory tube (Eustachian tube; tympanic tube; pharyngotympanic tube)
ttm	auditory tube, meatus
upr	uncinate process
V	vomer
vfos	vermiform fossa
Vs	vomerine sinus
vsh	vaginal sheath of styloid process
Z	malar, zygomatic, jugal bone
Zf	malar foramen (zygomaticofacial foramen)
Zof	zygomatico-orbital foramen
Zp	malar process (zygomatic process)
ZpT	squamous portion of zygomatic arch (temporal process of zygomatic arch)

Cranial Terminology with Symbols and Abbreviations

ala vomeris	aV
alisphenoid bone	aS
alveolar process	alpr
angle	agl
anterior	a
anterior clinoid process	acpr
anterior cranial fossa	acfos
anterior crus	ac
anterior ethmoidal foramen	aEf
anterior foramen lacerum	alf
apex pyramidis	appy
artery	ar
ascending	asng
ascending ramus	asngrm
atrium (mesotympanic cavity; mesotympanum)	mest
auditory bulla	tbT
auditory tube (Eustachian tube; tympanic tube; pharyngotympanic tube)	tt
auditory tube, meatus	ttm
base of mandible	base
basioccipital (pars basilaris)	bO
basion	basO
basisphenoid bone	bS
body of incus	bin
body of mandible	body
bulla ethmoidalis	bE
canal	c
canine tooth	ca
carotid canal	cc
carotid foramen	cf
carotid sulcus or groove	csS
cartilaginous plate of ethmoid bone	Ec
cavity	cav
cerebellar fossa	cfos
cerebral fossa (occipital fossa)	crfos
chiasmatic groove (optic groove)	cgS
clivus of basioccipital	Ocl
cochlea	coch
concha (turbinate bone)	t
concha nasalis media	Et-I
concha nasalis superior	Et-II
concha nasalis suprema	Et-III
condylar foramen (hypoglossal canal or foramen)	hcO
condyle	cdl
coronal suture	6
coronion	co
coronoid process	copr
crest	cr
cribriform plate (lamina cribrosa)	Ecp
crista galli	cgE
descending	dsng
digastric groove	dggr
digastric ridge or shelf	dgrg
diploe (diploë)	dpl
diverticulum	div
dorsum sella turcica	dsS
ectoturbinal bone	Ect
ectotympanic (tympanic ring or tympanic annulus)	ect
entotympanic bone	Enty
epitympanic cavity	ept
epitympanum	epT
ethmoid bone	E
ethmoid; cartilaginous portion of septum	Ec
ethmoidal foramen	Ef
ethmoidal fossa (houses olfactory lobes)	Efos
ethmoidal sinus	Es
ethmolacrimal suture (lacrimoethmoid suture	14
ethmopalatine suture	36
ethmoturbinal bones (I-IV)	Et (I-IV)
ethmoturbinal I (turbinate bone; concha nasalis media; middle nasal concha)	Et-I
ethmoturbinal II (concha nasalis superior; superior nasal concha)	Et-II
ethmoturbinal III (concha nasalis suprema; supreme nasal concha)	Et-III
ethmoturbinal IV	Et-IV
ethmovomer suture	41
Eustachian tube	tt
exoccipital bone	exO
external auditory meatus	eam
external occipital protuberance (inion)	eOp
external or medial occipital crest (occipital crest)	Ocr
fallopian aqueduct	faq
fenestra cochleae	fenr
fenestra ovale (fenestra ovalis; fenestra vestibuli)	feno
fenestra rotundum (fenestra rotunda; fossa fenestra cochleae; round window)	fenr
fenestra vestibuli (fenestra ovale, fenestra ovalis)	feno
fissure	fis
foramen	f
foramen Civinini	fC
foramen, condylar	hcO
foramen crotaphiticum	fcr
foramen, hypoglossal (hypoglossal canal or foramen)	hcO
foramen lacerum posterius (posterior lacerated foramen)	ifos, plf
foramen magnum	fmO
foramen ovale	fo
foramen rotundum	rf

foramen spinosum	sf
foramen, stylomastoid	smf
fossa	fos
frontal bone	F
frontal suture (metopic suture)	4
frontal sinus	Fs
frontal sinus, ostium	Fso
frontoethmoid suture	13
frontolacrimal suture	12
frontomalar suture (frontozygomatic suture)	17
frontomaxillary suture	11
frontonasal suture	10
frontozygomatic suture (frontomalar suture)	17
genial fossa	gnlfos
glaserian fissure (Glaserian fissure; petrotympanic fissure)	ptfis
glenoid fossa (mandibular fossa)	gfos
gnathion	gn
gonion	gon
greater palatine foramen (major palatine foramen)	gPalf
groove	gr
groove Civinini	grC
groove for inferior petrosal sinus	ipsgr
groove for maxillary branch of trigeminal nerve	mngr
groove or grooves for branches of middle meningeal artery	magr
groove for superior petrosal sinus	spsgr
hamular process of pterygoid (hamulus pterygoideus; hamular process)	hpS
head of malleus	hmal
horizontal semicircular canal	hsc
hypoglossal canal (condylar foramen)	hcO
hypophyseal fossa (sella turcica)	stS
hypotympanic cavity, dorsomedial	hyptd
hypotympanic cavity, lateral	hyptl
hypotympanic cells	hyptc
hypotympanum (bulla)	hypt
Inca bone	iP
incisive foramen	Pmf
incisor tooth	i
incisura Civinini	iC
incus	in
inferior	inf
inferior mandibular notch	infMn
inferior margin of optic foramen	imof
inferior masseteric ridge	infmasrg
inferior meatus	im
inferior nuchal line (nuchal crest)	ncr
inferior orbital fissure (sphenomaxillary fissure)	iofis
inferior turbinate (maxilloturbinal bone)	Mt
infraorbital foramen	if
inion (external occipital protuberance)	inion
intermaxillary suture	30
intermaxillovomer suture	38
internal auditory meatus (temporal meatus)	iam
internal carotid artery	icar
internal occipital crest	iOcr
internal occipital protuberance	iOprt
internasal suture	2
interorbital foramen	iof
interpalatine suture	32

interparietal bone	iP
interparietal suture (sagittal suture)	5
interpremaxillary suture	1
jugal bone (malar, zygoma)	Z
jugular foramen and fossa	jf
jugular fossa (jugular foramen; posterior lacerated foramen)	jfos
lacerum, anterior foramen	alf
lacrimal bone	L
lacrimal bone, marginal lingula of	Lml
lacrimal fossa	Lfos
lacrimoethmoid suture (ethmolacrimal suture)	14
lacrimomaxillary suture (maxillolacrimal suture)	15
lambdoidal suture (parieto-occipital suture)	7
lambdoid crest (superior nuchal line)	lcr
lamina cribrosa (cribriform plate)	Ecp
lamina lateralis processus pterygoidea	lpS, B
lamina of malleus	lmal
lamina orbitalis of ethmoid (orbital plate of ethmoid; os planum)	loE
lamina perpendicularis (perpendicular plate of ethmoid)	lpE
lateral groove (sigmoid groove)	sgr
lateral orbital fissure (also situated behind alisphenoid and malar, or between malar and parietal)	lofis
lateral petrosphenoidal fissure	lpsfis
lateral plate of pterygoid process (lamina lateralis processus pterygoidea)	lpS
lateral pterygoid plate	B, lpS
lateral semicircular canal (horizontal semicircular canal)	lsc
lesser palatine foramen	lPalf
ligament	lig
limbus sphenoidalis	ls
line	l
long crus of incus	lcin
longitudinal tympanic septum	ltscp
lunar notch	lun
malar, zygoma, jugal bone	Z
malar foramen (zygomaticofacial foramen)	Zf
malar process or zygomatic process	Zp
malleus	ma, mal
mandible	Mn
mandibular base	base
mandibular foramen	Mnf
mandibular fossa (glenoid fossa)	gfos
manubrium, of malleus	mmal
masseteric fossa	masfos
mastoid bone	mT
mastoid cells	mTc
mastoid foramen	msf, mTf
mastoid process	MprT
maxillary bone (superior maxilla, maxilla)	M
maxillary process of zygomatic arch	Mpr
maxillary ridge	Mrg
maxillary sinus	Ms
maxillary sinus, ostium	Mso
maxilloethmoidal suture	16
maxillolacrimal suture (lacrimomaxillary suture)	15
maxillonasal suture	9
maxillopalatine suture	31

maxillopremaxillary sinus, ostium	Mpmso
maxillopremaxillary suture, transverse	29
maxillopremaxillary suture, vertical	8
maxilloturbinal bone (inferior turbinate)	Mt
medial plate of pterygoid process	A, mpS
median petrosphenoidal fissure	mpsfis
mental foramen	mlf
mental protuberance	mlprt
mental spine	mlsp
mesopterygoid fossa	mfos
mesotympanic cavity (mesotympanum; atrium)	mest
mesotympanum (mesotympanic cavity; atrium)	mest
metopic suture (frontal suture)	4
middle concha	Et-I
middle meatus	mm
middle nasal concha	Et-I
molar tooth	m
mylohyoid groove	mygr
mylohyoid line	myl
nasal bone	N
nasopremaxillary suture	3
nasoturbinal (superior turbinate)	Et-n
neck of condyle	ncdl
nuchal crest (inferior nuchal line)	ncr
oblique line	obl
oblique occipital ridge	oOrg
occipital bone	O
occipital condyle	Oc
occipital crest (external or medial occipital crest)	Ocr
occipital fossa (cerebral fossa)	crfos
occipital point	op
occipitomastoid suture	35
olfactory foramina	Eoff
opisthion	opO
optic foramen	of
optic groove (chiasmatic groove)	cgS
orbital fossa	ofos
orbital plate of ethmoid (lamina orbitalis; os planum)	loE
orbital ridge or crest	org
orbitosphenoid bone	oS
orbitosphenoid suture	37
os planum (orbital plate of ethmoid; lamina orbitalis)	loE
ostium, ethmoidal sinus	oEs
ovale, foramen	fo
palatine bone	Pal
palatine canal	Palc
palatine foramen	Palf
palatine foramen, greater (major)	gPalf
palatine foramen, lesser (minor)	lPalf
palatine sinus	Pals
palatovomer suture	39
parietal bone	P
parietomastoid suture	26
parieto-occipital suture (lamboidal suture)	7
parietotemporal suture (squamosal suture)	25
parietozygomatic suture (zygomaticoparietal suture)	24
perpendicular plate of ethmoid (lamina perpendicularis)	lpE
petro-occipital fissure	pofis

petrotympanic fissure (glaserian fissure)	ptfis
petrous crest	ptcr
petrous spine	psT
petrous part of temporal bone	pT
pharyngotympanic tube (Eustachian tube; tympanic tube)	tt
planum sphenoideum	pls
pogonion	pog
post; posterior; postero-	p
posterior border of optic foramen	pbof
posterior clinoid process	pcpr
posterior ethmoidal foramen	pEf
posterior lacerated foramen (foramen lacerum posterius)	plf, ifos
posterior nares	postn
posterior palatine foramen, greater (major)	gPalf
posterior palatine foramen, lesser (minor)	lPalf
posterior semicircular canal	psc
posterolateral canal	plc
posteromedian palatine spine	Palsp
postglenoid foramen	pgf
postglenoid process, postglenoid tubercle	pgpr
premaxillary bone	Pm
premolar tooth	pm
presphenoid bone	pS
process	pr
processus gracilis	prgr
promontorium (promontorium cochleae)	prom
promontory artery	proma
protuberance	prt
pterygoid fossa	pfos
pterygoid process	ppr
pterygospinous lamina	pt lam
pyramidal eminence	pye
quadrilateral surface	qsT
ramus	rm
retromolar foramen	rtrmf
retromolar fossa	rtrmfos
retromolar triangle	rtrmtr
ridge	rg
ridge of mandibular neck	rgMnn
round window (fenestra rotundum; fenestra rotunda; fossa fenestra cochleae)	fenr
sagittal crest	sagcr
sagittal ridge	srg
sagittal suture (interparietal suture)	5
sella turcica (hypophyseal fossa)	stS
septum	sep
short crus of incus	scin
sigmoid groove (lateral groove)	sgr
sigmoid notch	sgn
sinus	s
sphenobasilar suture (spheno-occipital suture)	34
sphenoethmoid suture	19
sphenofrontal suture	18
sphenoidal point	Spt
sphenoidal process	prS
sphenoidal sinus (1–4)	Ss (1–4)
sphenoidal spine, spinous process	prS, spp
sphenoid bone	S
sphenomaxillary fissure (inferior orbital fissure)	iofis
sphenomaxillary sinus	SMs
sphenomaxillary suture	20

spheno-occipital suture (sphenobasilar suture)	34
sphenopalatine suture	33
sphenoparietal suture	22
sphenosquamosal suture (sphenotemporal suture)	23
sphenotemporal suture (sphenosquamosal suture)	23
sphenovomer suture	40
sphenozygomatic suture	21
spina Civinini	spC
spina nasalis	spn
spine	sp
spine, petrous	psT
spinous process (sphenoidal spine)	spp
squamosal bone (temporal bone)	T
squamosal portion of temporal bone	sT
squamosal suture (parietotemporal suture)	25
squamous portion of zygomatic arch (temporal process of zygomatic arch)	ZpT
stapedial artery, superior branch	star
stapedial tendon	statn
stapes	sta
styloid process	spr
stylomastoid foramen	smf
sub-	sub
subarcuate eminence	seT
subarcuate fossa	sfos
sublingual fossa	sublfos
submaxillary fossa	submfos
superior	sup
superior mandibular notch	supMnn
superior masseteric ridge	supmasrg
superior maxilla (maxillary bone; maxilla)	M
superior meatus	sm
superior nasal concha (ethmoturbinal-II; concha nasalis superior)	Et-II
superior nuchal line (lamboid crest)	lcr
superior orbital fissure	sofis
superior semicircular canal	ssc
superior temporal line or ridge	trg
supraorbital foramen or notch	sof
supreme nasal concha (ethmoturbinal-III; concha nasalis suprema)	Et-III
supreme nuchal line	sncr
suture	su
symphyseal foramen	symf
symphysis	sym
temporal bone (squamosal bone)	T
temporal crest	tcr
temporal fossa	Tfos
temporal meatus (internal auditory meatus)	iam
temporal process of zygomatic arch (squamous portion of zygomatic arch)	ZpT
temporal ridge (superior temporal line)	trg
tentoralis petrosi	tent
tentoralis petrosi, processus	tentpr
tentorium osseum	tent
transverse	tr
transverse lamina	ltS
transverse mastoidal septum	trmsep
transverse ridge or sulcus	trs
transverse tympanic septum	trtsep
trigeminal impression	tip
tuberculum sellae	ts
turbinate (turbinal bone; ethnoturbinal bone)	Et
turbinate bone (concha)	t
turbinate bone, inferior (maxilloturbinate bone)	Mt
turbinate bone, middle (ethmoturbinal-I; concha nasalis media; middle nasal concha)	Et-I
turbinate bone, superior (ethmoturbinal-II; concha nasalis superior; superior nasal concha)	Et-II
tympanic annulus (ectotympanic; tympanic ring)	ect
tympanic antrum	tant
tympanic bulla	tbT
tympanic cavity	tcav
tympanic drum	tdr
tympanic membrane	tm
tympanic process of alisphenoid bone	tpraS
tympanic process of petrous bone	tpr
tympanic ring (tympanic annulus; ectotympanic)	ect
tympanic tube (Eustachian tube; auditory tube; pharyngotympanic tube)	tt
uncinate process	upr
vaginal sheath of styloid process	vsh
vermiform fossa	vfos
vomer	V
vomerine sinus	Vs
zygomatic bone (malar bone; jugal bone)	Z
zygomatic process (malar process)	Zp
zygomaticofacial foramen (malar foramen)	Zf
zygomaticofrontal suture (frontozygomatic suture; frontomalar suture)	17
zygomaticomaxillary suture	27
zygomatico-orbital foramen	Zof
zygomaticoparietal suture (parietozygomatic suture)	24
zygomaticotemporal suture	28

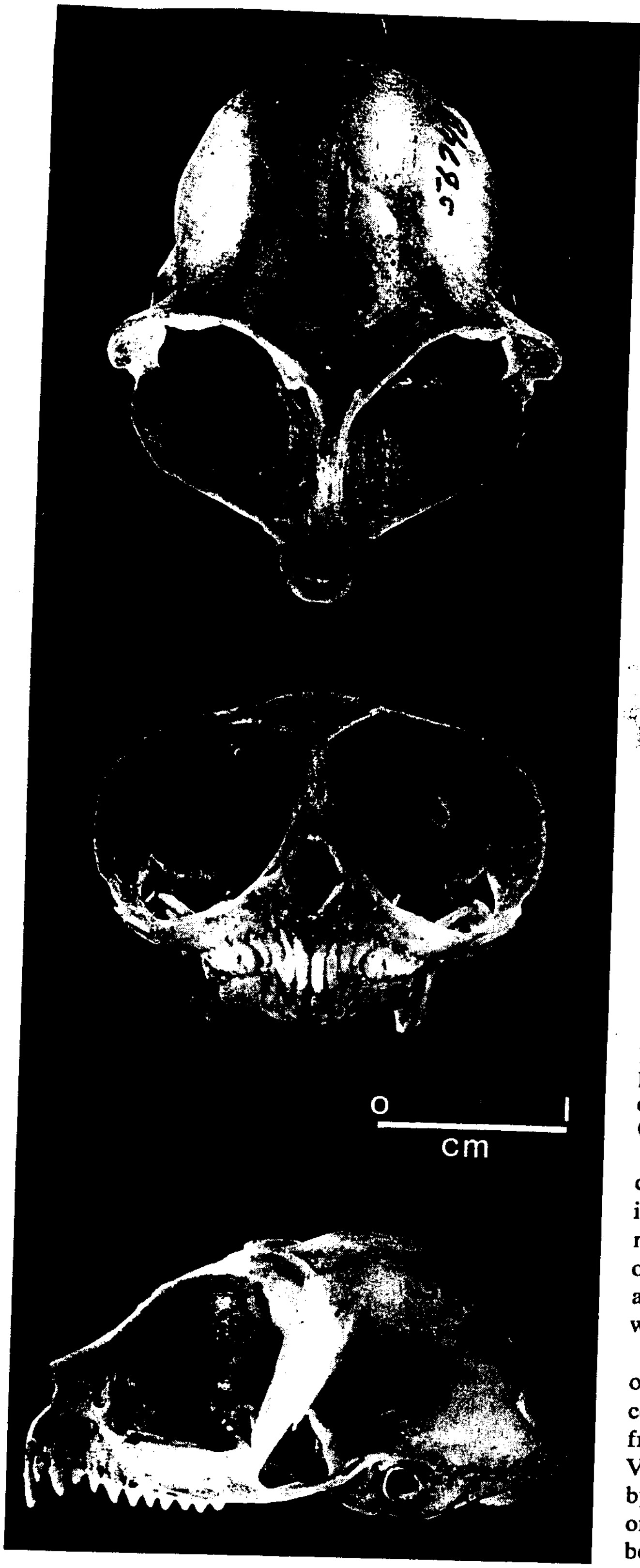


Fig. IV.7. *Tarsius*: Dorsofrontal, frontal, and left lateral aspects of skull.

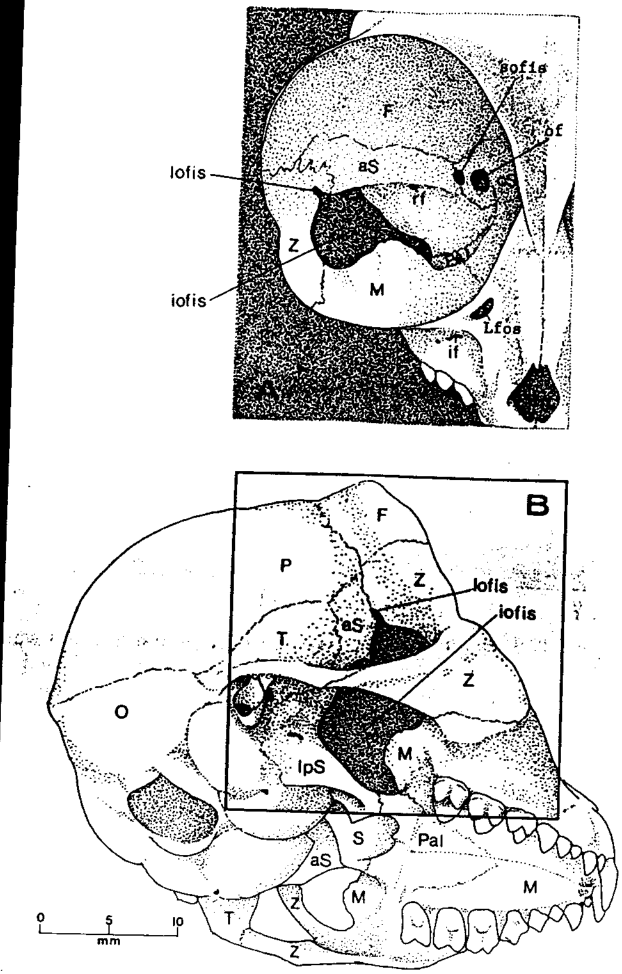


Fig. IV.8. *Tarsius*: Orbital fissures from in front and ventrolaterally, showing bones involved in early haplorhine stage of postorbital closure; see chapter 31 for key to abbreviations (From Hershkovitz 1974.)

outward and downward growth of a flange of the frontal (with relatively little malar expansion) while in higher Primates [platyrrhines and catarrhines] the greater part of the dorsolateral area of enclosure is contributed by the development of an orbital plate of the malar." In our large series of Philippine and Bornean tarsiers (*Tarsius syrichta* and *T. bancanus*), the incomplete dorsolateral closure is produced mainly by a projection of the malar bone anteriorly and an extension of the alisphenoid bone posteriorly; the maxillary bone contributes to ventrolateral closure. Involvement of the frontal bone in lateral closure is minor in most primates. Simons and Russell make no mention of the alisphenoid bone. The sutures of this part of the sphenoid bone in *Tarsius* are faint or indistinguishable and the element itself becomes fused or confused with the frontal bone.

Postorbital closure in higher primates is a continuation of the process that began in early tarsioids. The principal contributors to closure are malar, alisphenoid, maxillary, frontal, and sometimes the parietal, bones (fig. IV.9). Variation in the amount of postorbital surface occupied by each bone is considerable even within the same species or population. In all haplorhines, however, the malar bone contributes most, the parietal least, if anything, to formation of the bony wall between orbital and temporal fossae.

Present evidence shows that a single but highly variable type of ossified postorbital closure occurs among the Haplorhini (tarsioids, platyrrhines, catarrhines). In Strepsirhini, elaboration of bony support for the eyeball did not evolve beyond the postorbital bar stage.

Orbital Fissures and Internal Foramina

Closure of the lateral, inferior, and posterior orbital walls is complete in platyrrhines except for the residual

In Old World monkeys the outer lateral orbital wall may consist mainly of the malar, or of approximately equal parts of malar and frontal bones in some species, or of variable amounts of frontal and alisphenoid in others. Sutural contact between malar and parietal bones, which occurs in nearly all platyrrhines, is excluded in catarrhines by interposition of the alisphenoid alone or by both alisphenoid and squamosal bones.

Sutural combinations of the temporal region are classified by Olivier, Libersa, and Fenart (1955, p. 218, fig. 135) as jugo (malar)-sphenoparietal, corresponding to pattern I (fig. IV.9), sphenoparietal for pattern VI, frontotemporal (squamosal) for pattern IV, and intermediate type for pattern VII. The arrangement in catarrhines, according to these authorities is either sphenoparietal (VI) or frontotemporal (IV), with one *Colobus* exhibiting the intermediate type (VIII). The proportional distribution of the various sutural patterns in several thousand catarrhine skulls was also calculated by Olivier, Libersa, and Fenart (1955, p. 220).

Orbital Cavity and Inner Medial Wall

The platyrrhine orbital cavity is more or less rounded in outline, with the lower anterior surfaces and floor evenly curved. In the vast majority of catarrhines, the cavity is modified by an inflation of the lower half of the inner anterior surface that forms a notable bulge on the orbital floor and often constricts the inferior orbital fissure.

The primitive arrangement of the primate inner medial orbital surface is based on broad sutural contact between frontal and maxillary bones and unexposed ethmoid, as in *Daubentonia* (fig. IV.10[II]). Partial intervention of the orbital plate of the palatine between frontal and maxillary bones, as in the Malagasy lemur, *Cheirogaleus* (fig. IV.10[III]), is an advanced condition. It leads to complete separation of frontal and maxillary by the palatine bone in most lemuriforms. Other advanced arrangements are exhibited by *Propithecus* (fig. IV.10[IV]), and tupaiids (fig. IV.10[V]).

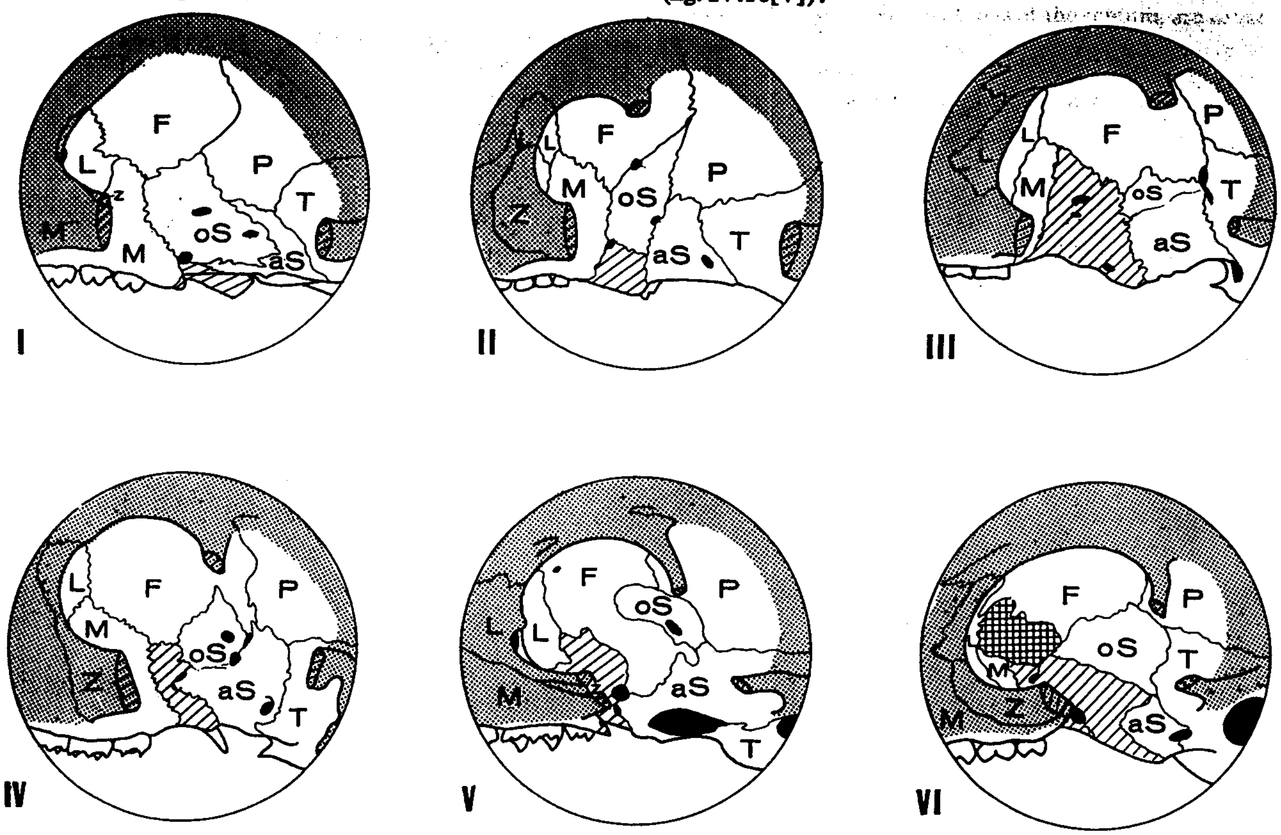
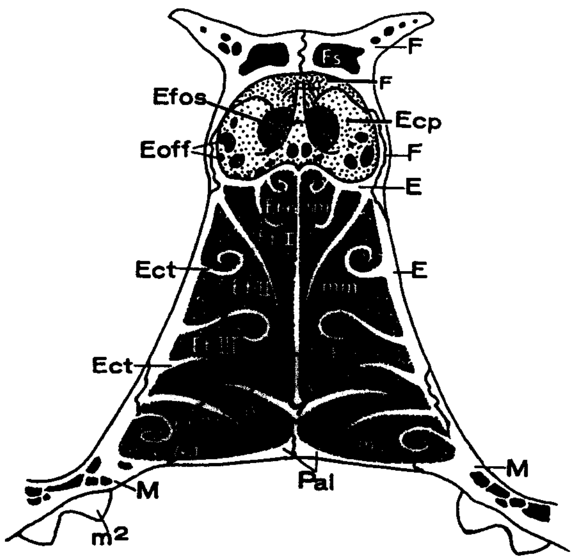


Fig. IV.10. Bone relationships on median and posterior orbital walls; lateral wall including part of zygomatic arch removed, *palatine bone lined diagonally, ethmoid bone cross-hatched. I,* Primitive mammalian pattern, with frontal (*F*) and maxillary (*M*) bones in wide contact, palatine excluded from contact with lacrimal (*L*), ethmoid bone unexposed; arrangement present in some insectivores (e.g., *Echinosorex, Tenrec, Hemiechinus*) and some lemuriforms. *II,* Primitive pattern in *Daubentonia. III,* Advanced pattern with contact between maxillary (*M*) and orbitosphenoid (*oS*) bones excluded by palatine bone, as in *Cheirogaleus* and other lemuriforms, some tupaiids and other insectivores. *IV,* Advanced arrangement as in *Propithecus. V,* Mixed pattern with contact between maxillary and frontal bones excluded by contact between palatine and lacrimal bones as found in *Didelphis, Tupaia, Urogale,* and some lemuriforms. The pattern may be primitive in some mammalian lines but appears to be secondary in primitive primates. *VI,* Complex pattern, ethmoid exposed and excluding palatine and maxillary bones from contact with frontal bone, as in *Microcebus,* lorisiforms, tarsier, platyrrhines, catarrhines. Other bones shown are *aS* = alisphenoid, *P* = parietal, *T* = temporal.

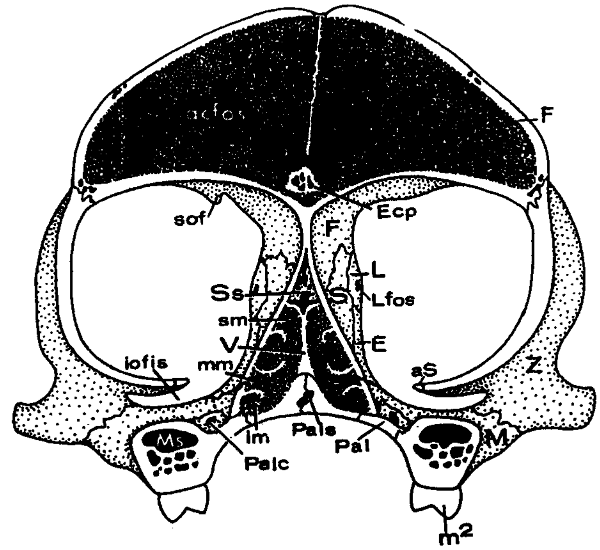
Intervention of both palatine bone and orbital plate of the ethmoid bone between frontal and maxillary bones, as in adult *Microcebus* (fig. IV.10[VI]) and possibly other lemuriforms (cf. Major 1901, p. 131), lorisiforms, tarsiers, and higher primates is the most complex arrangement.

All primate patterns of medial orbital bone articulations, from primitive to complex, are present in lemuri-



GALAGO

Fig. IV.12. Transverse cranial section, *Galago crassicaudatus;* plane behind m²; greatest skull length, 65 mm, orbital breadth, 42 mm; symbols explained in chapter 31; see also fig. IV.10.



SAGUINUS

Fig. IV.13. Transverse cranial section, *Saguinus;* anterior plane behind m²; greatest skull length, 52 mm, orbital breadth, 27 mm; symbols explained in chapter 31.

cerocranial increase, and the orbits were forced apart, air cells accounting for the additional space between them (fig. IV.11). The same is true, but to a lesser degree, in a number of other primate phyletic lines. In contrast, facial bone enlargement in baboons and macaques greatly exceeded braincase expansion, while interorbital breadth decreased proportionately. In callitrichids and marmosetlike cebids, neurocranial increase, mainly toward dolichocephaly, was considerably greater than viscerocranial enlargement, but the orbits moved closer, and in *Saimiri* they are virtually tangential. Notwithstanding, small air cells and sinuses form between the septal angles in all lower platyrrhines.

The cebid morphological series arranged by Du Brul (1965, fig. 8) to demonstrate the asserted correlation between increasing interorbital breadth and pneumaticity with increasing skull size makes use of dubious examples. *Saimiri,* the first in Du Brul's sequence is a dead end, with secondarily thin and deficient interorbital septum. *Callicebus* (fig. IV.16), mentioned by Du Brul as a member of the same size group, possesses a comparatively broad and well-pneumatized interorbital region. *Pithecia* (fig. IV.31), with larger skull and perfect interorbital septum, follows *Saimiri* in Du Brul's scheme, but absence of interorbital pneumatization (persistent in *Saimiri*) argues against its placement in the series. *Lagothrix* (fig. IV.34), next in line, is followed by *Cebus* (figs. IV.19, 20). In size, *Lagothrix* considerably exceeds *Cebus* and should follow it, but its skull is less cavitated. *Alouatta* (fig. IV.32) tops Du Brul's platyrrhine sequence for size and

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lines indicate major primate groupings. Curved white lines on interorbital region of some skulls (*Cebuella, Tarsius, Macaca,* others) show boundaries of orbits in sphenoethmoidal region, where they depart widely from the orbital boundaries on facial surface of nasal bones. Arrows point to main directions of expansion or encroachment of one facial region on another, as follows: *Lemur* (primitive primate)—orbits expanding and converging from side of skull to front; braincase expanding; primitively broad interorbital region in process of reduction. *Cebuella-Saguinus* (callitrichid line)–orbits more nearly frontal, expanding medially by invasion of interorbital region and laterally by distension of free or outer border, braincase expansion nearly commensurate. *Aotus* (marmosetlike cebid)—orbital expansion extreme among platyrrhines, lateral orbital wall distended well beyond borders of more slowly expanding braincase, medial orbital expansion moderate. *Tarsius* (highly specialized prosimian)—orbital expansion extreme among primates, interorbital region compressed to thin septum, outer or free lateral orbital borders distended far beyond borders of slowly expanding braincase. *Saimiri* (marmosetlike cebid)—medial orbital expansion extreme with bony sphenoethmoidal portion of interorbital septum largely fenestrated; braincase expansion mainly anteroposterior, resulting in extreme dolicocephaly. *Alouatta* (primitive cebid)—expanded interorbital and maxillary regions and relatively small orbits, correlated with enlargement of cranial surface for origin of masticatory muscles without commensurate increase in diameter of orbits and braincase; compare with orbits, braincase, and sinuses of *Homo*. *Cebus* (advanced cebid)—interorbital and maxillary regions (sinuses included) expanded; lateral expansion of orbits associated with lateral expansion of braincase. *Colobus–Cercopithecus–Macaca* (cercopithecid line)—main orbital expansion mediad with compression of sphenoethmoidal portion of interorbital wall into a thin, sometimes perforated septum as in *Macaca* and some species of *Cercopithecus;* lateral expansion of braincase involved complementary thickening of lateral orbital wall. Contrast with lateral orbital wall of *Tarsius*. *Homo* (specialized hominid)—extreme secondary expansion of braincase and a nearly proportionate increase in width of interorbital region without commensurate orbital expansion, entailed enlargement of frontal, ethmoidal, sphenoidal and maxillary air spaces or sinuses to accommodate the small orbits. Sinuses shown in skull sectioned transversely between plane of first and second molars.

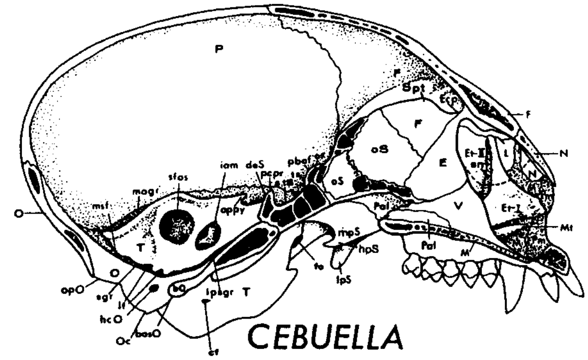


Fig. IV.22. Sagittal section of *Cebuella pygmaea* skull; lateral plate of ethmoid bone removed, its position indicated by dotted line; greatest skull length, 36 mm, orbital breadth, 21 mm; symbols explained in chapter 31.

primitive haplorhine primates. The interorbital region of *Tarsius* retains its primitive orientation relative to the brain, but its constriction is extreme among lower primates and consistently exceeded only by that of *Saimiri* among higher primates. It is even more difficult to understand why Cave (1967, p. 279) dismisses as non-primate the truly primitive type of primate nasal fossa found in *Lemur* and *Galago*. These peculiar views, combined with a rigid concept of the nature of paranasal sinuses, obliged Cave (1967, p. 287) to regard as secondary reacquisitions the very primitive characteristics these lemuroids had never lost in the first place.

Turbinal Bones

The primitive nasoturbinate system, exemplified by that of the marsupial *Didelphis* or the insectivore *Erinaceus,* consists of a highly developed nasoturbinal at the anterior or superior end of the nasal cavity, a larger, more complicated maxilloturbinal at the inferior end, and four endoturbinals, or ethmoturbinal bones, between, in a recess formed by the sphenoid body behind, by the transverse lamina of the same bone below, and largely by the cribriform plate above. The upper or anterior ethmoturbinal (I) is largest, the others (II–IV) follow in order of decreasing size. A second series of turbinals, the ectoturbinals consist of small processes with one or more between each pair of ethmoturbinals, including the nasoturbinal. Presence of more than four ethmoturbinals in highly macrosmatic mammals derives from a bifurcation of one or more basal plates of the primitive ethmoturbinals. Fewer ethmoturbinals, as in microsmatic mammals, including higher primates, result from fusion of

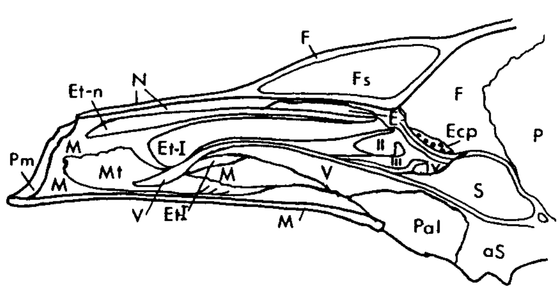


Fig. IV.23. *Lemur*: Sagittal section of skull exposing turbinal system; greatest skull length, 89 mm, orbital breadth, 50 mm; symbols explained in chapter 31.

some turbinals and reduction and loss of others. Ectoturbinals may proliferate in great numbers, especially between nasoturbinal and ethmoturbinal I, in specialized "smell" animals, whereas they tend to disappear in dominantly "sight" animals, as in primates.

The primitive turbinate system, although somewhat reduced, prevails in *Lemur* (fig. IV.23) and *Galago* (fig. IV.12), among strepsirhines. Evolution of the system in

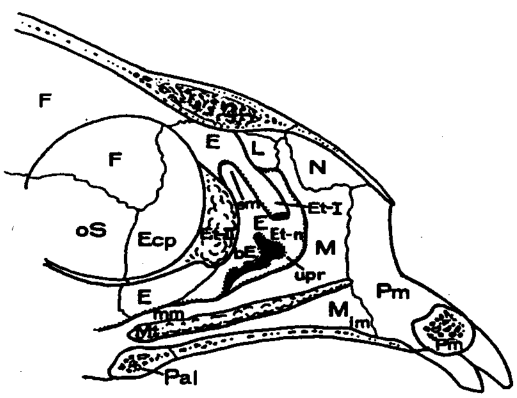


Fig. IV.24. Sagittal section of anterior half of *Cebuella pygmaea* skull with most of ethmoturbinal-I (*Et-I*) removed to expose bones behind; symbols explained in chapter 31.

higher primates is degenerative and involves reduction in size and importance of all turbinals, with obsolescence or loss of ethmoturbinal IV and all but one, or possibly two, ectoturbinals in adults of all species (fig. IV.83). In lemuriforms the dominant turbinals are the naso- and maxilloturbinals (fig. IV.23). In lorisiforms, an expanded ethmoturbinal I overlaps a large maxilloturbinal (fig. IV.12). In higher primates, ethmoturbinal I is usually dominant, the maxilloturbinal reduced but still important, the nasoturbinal usually smaller than ethmoturbinal I and often reduced to a mere ridge or tubercle (figs. IV.22, 25–36).

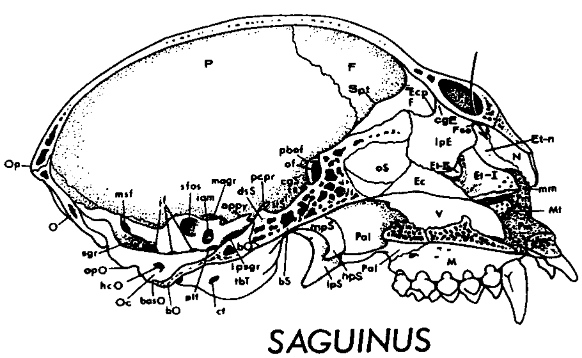
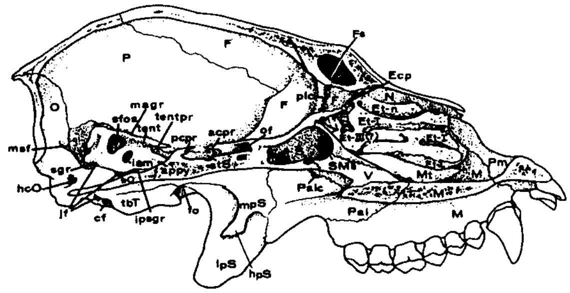


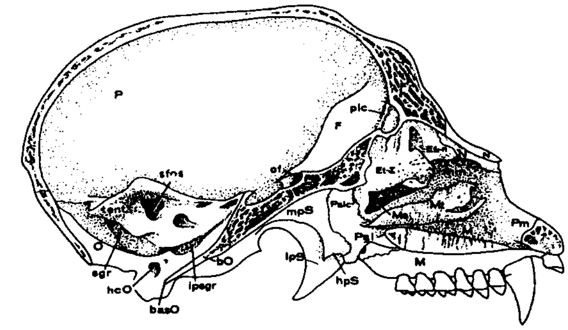
Fig. IV.25. Sagittal section of *Saguinus oedipus* skull; greatest-length of skull, 52 mm, orbital breadth, 27 mm; arrow shows communication between frontal sinus and nasal cavity; symbols explained in chapter 31.

Abbreviation and downward flexure of the muzzle in higher primates entailed a corresponding reduction in size and complexity of all turbinals and a shift in orientation of the long axis of the ethmoturbinals from anteroposterior to nearly vertical. Actual rate of reduction and loss of turbinals relative to change in muzzle length and curvature differs in each phyletic line. The platyrrhine turbinate system, for example, is more primitive than



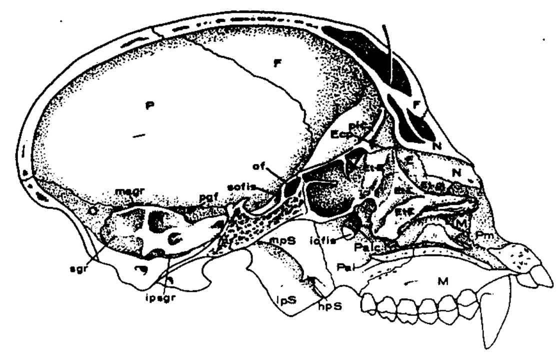
ALOUATTA

Fig. IV.32. Sagittal section of *Alouatta seniculus* skull; greatest length of skull, 123; orbital breadth, 64 mm; arrow shows communication between frontal sinus and nasal cavity; symbols explained in chapter 31.



ATELES

Fig. IV.35. Sagittal section of *Ateles paniscus* skull; greatest length of skull, 121 mm, orbital breadth, 67 mm; symbols explained in chapter 31.



CEBUS APELLA

Fig. IV.33. Sagittal section of *Cebus apella* skull; greatest length of skull, 98 mm, orbital breadth, 53 mm; symbols explained in chapter 31.

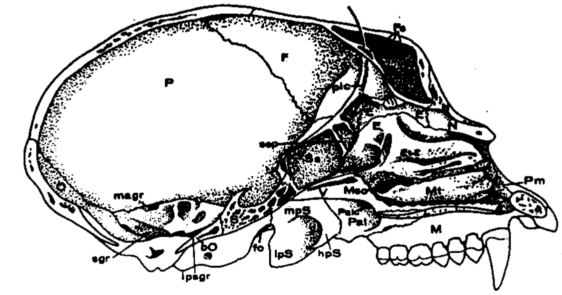
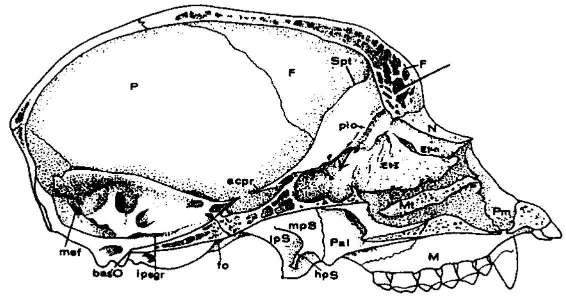
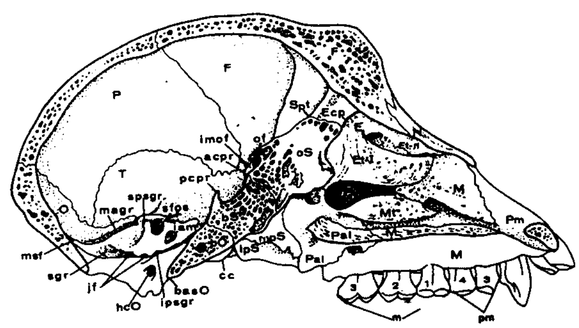


Fig. IV. 36. Sagittal section of *Cebus nigrivittatus* skull; greatest length of skull, 102 mm, orbital breadth, 55 mm; symbols explained in chapter 31.



LAGOTHRIX

Fig. IV.34. Sagittal section of *Lagothrix lagothricha* skull; greatest length of skull, 111 mm, orbital breadth, 60 mm; symbols explained in chapter 31.



MACACA

Fig. IV.37. *Macaca mulatta*, sagittal section of skull; greatest length of skull, 133 mm, orbital breadth, 76 mm; symbols explained in chapter 31.

The *maxilloturbinal* is present and comparatively well developed in all primates.

Ethmoturbinal I is largest and most complex in platyrrhines and in some species, most notably among atelines (fig. IV.35), is as large as or larger than all other turbinals combined. It is comparatively poorly developed and less rolled in catarrhines (fig. IV.83) and more reduced in monkeys, generally, than in man and apes, where it is known as the *middle concha*.

The platyrrhine *ethmoturbinal II* is a small but constant feature in all callitrichids (fig. IV.24) and in *Callimico* (fig. IV.27). It is well developed to vestigial in the sectioned specimens of pithecines, well developed in *Aotus* (fig. IV.29), but absent or vestigial in *Callicebus* (fig. IV.30) and *Saimiri* (fig. IV.28). Its presence and shape are variable in *Cebus* (figs. IV.33, 36), and it appears to be obsolete or absent in samplings of the larger prehensile-tailed species. In *Alouatta* (fig. IV.32), however, it seems to be either well-developed or confused with a lamina of ethmoturbinal I.

The condition of ethmoturbinal II in catarrhines is obscure. In our samples, the bone is moderately well developed in *Cercocebus* (fig. IV.38), absent in other monkeys, and poorly developed in *Hylobates*. Paulli (1900, p. 544) notes the presence of ethmoturbinal II in the hamadryas baboon and the drill, and of ethmotur-

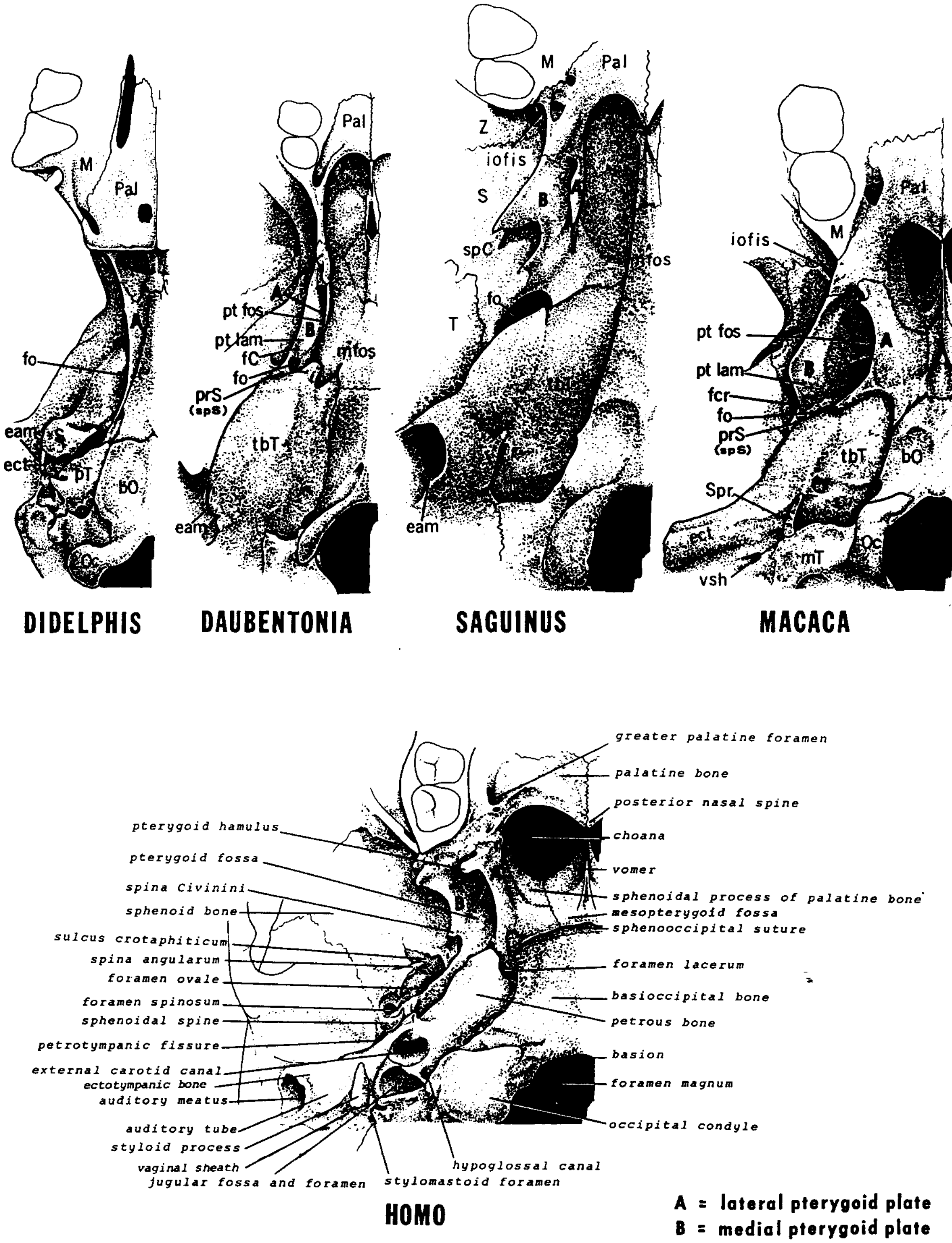


Fig. IV.51. Pterygoid and auditory regions in *Didelphis, Daubentonia, Saguinus, Macaca, Homo,* all drawn to same length. Most symbols used in upper figures are explained in lower; cranial elements labeled are: **A,** medial plate of pterygoid process; **B,** lateral plate of pterygoid process; *M,* maxillary bone; *Pal,* palatine bone; *bO,* basioccipital bone; *Oc,* occipital bone; *S,* sphenoid bone; *T,* temporal bone; *Z,* zygomatic or malar bone; *eam,* external auditory meatus; *ect,* ectotympanic bone or auditory tube; *fC,* foramen Civinini; *fcr,* foramen crotaphiticum; *fo,* foramen ovale; *iofis,* inferior orbital fissure; *prS,* sphenoidal process or spine; *pT,* petrous bone (of temporal); *pt fos,* pterygoid fossa; *pt lam,* pterygospinous lamina; *tbT,* tympanic bulla (of petrous portion of temporal bone). Note: The distal spinous component of the medial pterygoid plane (**A**) is loosely connected in didelphids and missing in the *Didelphis* skull figured.

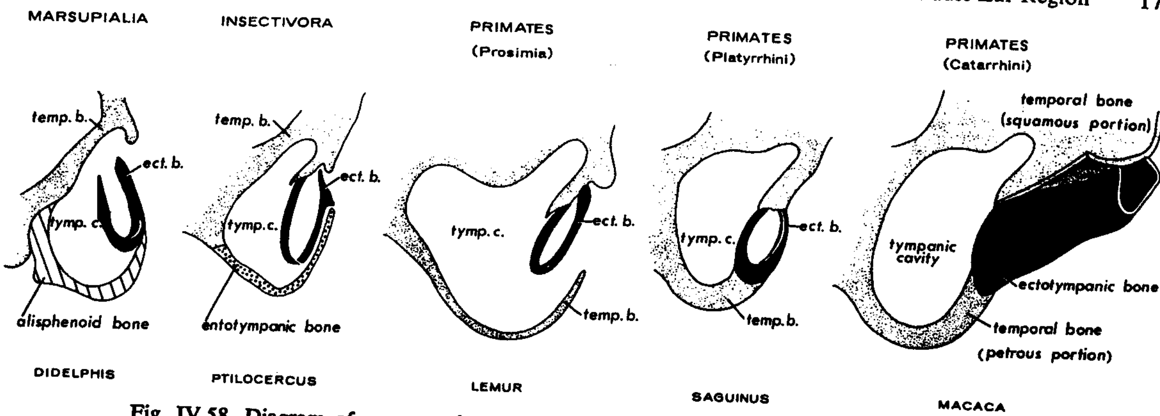


Fig. IV.58. Diagram of cross section of mammalian tympanic bulla and bordering temporal region seen from behind. Tympanic cavity (*tymp. c.*) exposed to show position of tympanic ring or ectotympanic bone (*ect. b.*) in a representative marsupial (*Didelphis*, Didelphidae), tupaiid insectivore (*Ptilocercus*, Tupaiidae), lemurid (*Lemur*, Lemuridae), platyrrhine callitrichid (*Saguinus*, Callitrichidae), catarrhine monkey (*Macaca*, Cercopithecidae). Main bone of auditory bulla (*shaded*) is the alisphenoid in didelphids, entotympanic in tupaiids, and temporal (*temp b*) in all primates.

platyrrhines from catarrhines (fig. IV.58). The bony meatus in lemuriforms is derived from the petrous, or petrous and squamous, portions of the temporal bone. In lorisiforms, the main part of the meatus consists of ectotympanic and squamosal bones. The entrance may be wide and annular as in platyrrhines, or constricted and canopied rather than tubular.

Differences between platyrrhine and catarrhine meati are correlated with responses to changes in braincase form. Increasing brachycephaly in catarrhines was associated with lateral elongation of the meatus in the form of a tube. In platyrrhines with braincases tending toward greater dolichocephaly, the vertical plane of the tympanic ring remains near the lateral surface of the skull and requires no extension tube for union with the cartilaginous auricular meatus. In those platyrrhine neurocrania tending toward brachycephaly, the dorsal border or lip of the meatus slopes outward, scooplike, without contraction or modification into a tube. The subtubular meatus of *Tarsius* may also be correlated with the brachycephalic skull.

Auditory Bulla

The main part of the mammalian osseus bulla, or tympanum, is formed by the ectotympanic bone, the petrous part of the temporal bone, the alisphenoid bone, or from the independently developed and strictly mammalian entotympanic bone (fig. IV.58). Other basicranial bones which may contribute to formation of small parts of the bullar wall or floor are basisphenoid, alisphenoid, basioccipital, exoccipital, and squamous and mastoidal portions of the temporal bone.

The auditory bulla of tupaiids (figs. IV.58, 60) and macroscelidids develops from the entotympanic bone (Major 1899, p. 987; Van Kampen 1905, p. 704; Spatz 1966, p. 26). The same bone (cf. Van Kampen 1905, pp. 363 ff.; Starck 1967, p. 495) forms the main body of the bulla among the Chiroptera, Dermoptera, Pholidota, Xenarthra, some Carnivora, Hyracoidea, some Artiodactyla (*Sus*), some Perissodactyla (*Rhinoceros*), and some Marsupialia; but in didelphids (figs. IV.58, 59), the alisphenoid forms an incomplete drum. The outer bullar wall of the rodentlike *Plesiadapis* (fig. I.4) is formed by the entotympanic.

The primate auditory bulla arises from the petrous portion of the temporal bone. Other basicranial bones may contribute small portions to formation of the bullar wall, but an os entotympanicum is absent (figs. IV.58, 61, 62).

The entotympanic bone was regarded by W. E. Le Gros Clark (1959, p. 134) as an extension of the petrous bone. This view, based on conclusions reached by Saban (1957, p. 93) and others, weighed heavily in Clark's treatment of tupaiids as primates. Saban erred, however, in his identification of an entotympanic bone in primates. He also failed to note that basisphenoid and alisphenoid bones contribute to the bullar wall in many primates. In relating tupaiids to primates, Saban regarded the tupaiid malleolar processus gracilis as reduced, the petrotympanic (Glaserian) fissure closed. In mature skulls of tupaiids I have examined, in all except the single available adult skull of *Anathana* the petrotympanic fissure is open and a well-developed vanelike processus gracilis projects through it to beyond the plane of the auditory meatus. In *Tupaia*, the process is fused to the anterior crus of the tympanic annulus, not to the malleus, as in primates. The structure moves freely in its slot, causing the tympanic ring to move. In life, movement of the processus gracilis is presumably controlled by the sphenomandibular ligament. In the related tupaiid *Urogale*, the process is immovable. In *Ptilocercus* (1 specimen), the process is free of the ring, the posterior half forms part of the roof of the bony meatus, and the anterior half projects outside the bulla. The processus gracilis in adult tupaiids seems to represent a combination of the lamina and anterior process of the malleus of didelphids and primates. For a discussion of the development of the anterior process in mammals see Wassif (1957).

The intrabullar position of the tympanic ring in tupaiids, somewhat as in lemuriforms, was also regarded by Le Gros Clark (1959, p. 139) as evidence of primate affinities. The same character, however, evolved independently in the unrelated American marsupial *Dromiciops* (Microbiotheridae) and in the Australian dasyurid *Dasycercus cristicauda* (Wood Jones and Lambert 1939, p. 72). In the dasyurid

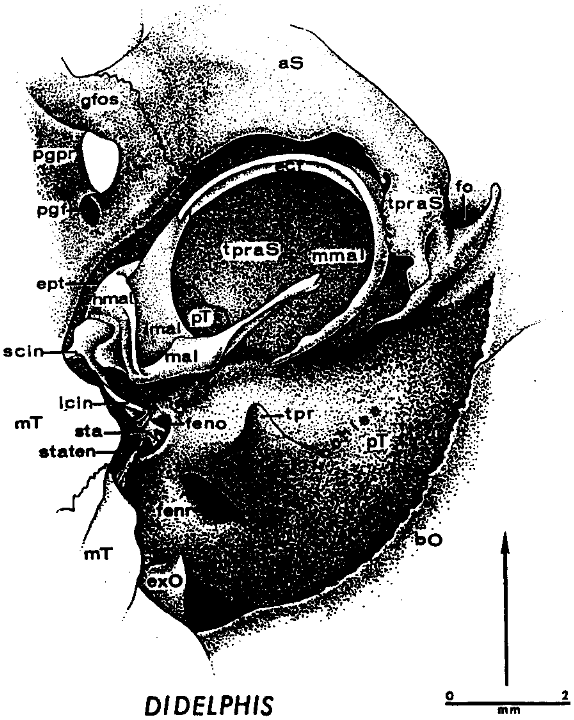
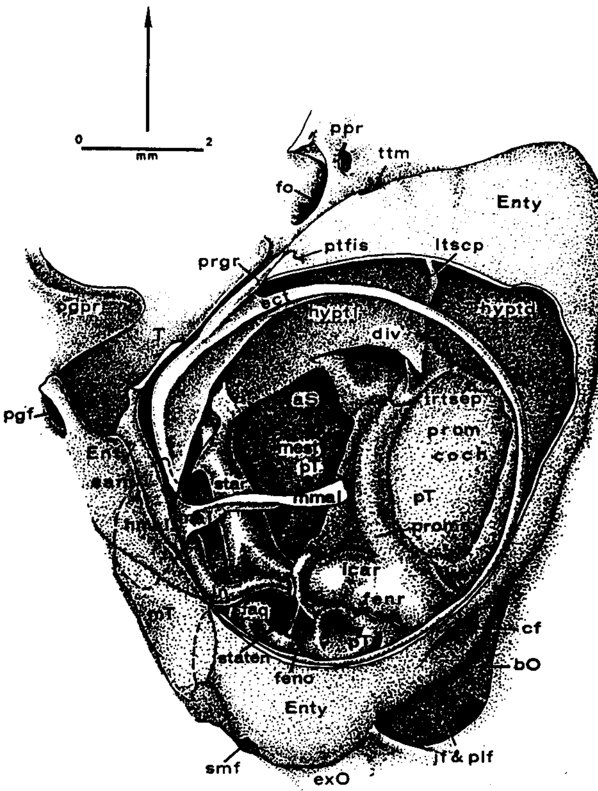


Fig. IV.59. Middle ear region of *Didelphis* (Didelphidae, Marsupialia), incomplete tympanic bulla formed by alisphenoid bone (*aS*), tympanic ring and cochlea completely exposed; arrow point anterior; symbols explained in chapter 31.



TUPAIA

Fig. IV.60. Middle ear region of *Tupaia* (Tupaiidae, Insectivora, *sensu lato*); tympanic bulla, formed by independently evolved entotympanic bone (*Enty*), partially removed to expose tympanic ring, arterial system; petrous bone including cochlear promontorium, and tympanic process of alisphenoid (*aS*); arrow point anterior; symbols explained in chapter 31.

the ectotympanic bone is broad and free, with half the width of the band protruding as an external meatus while the remaining half lies concealed within the bulla. Other evidence from middle ear morphology opposing tupaiid affinities with primates has been presented by Van Valen (1965). The same and more anatomical data have been critically reviewed by Campbell (1974).

Szalay (1972*a*) suggested that the extrabullar ectotympanic seen in all nonlemuriforms was probably the primitive condition in primates. It seems unlikely, however, that a rigidly sutured extrabullar bone would evolve into the suspended intrabullar ectotympanic of lemuriforms (figs. IV.58, 61). It is more likely that the middle-ear cavity was not completely enclosed in the ancestral primate. As the bullar wall expanded among early prosimians the ectotympanic became enclosed in at least one phyletic line and became extrabullar in the others.

Tympanic Cavities and Bullar Size

The primitive primate tympanic bulla consists of three more or less defined communicating cavities (fig. IV.63). The *epitympanic cavity, recess,* or *attic* is smallest and houses the head of the malleus and body of the incus. The recess is little differentiated in primates and mammals generally. In didelphids (fig. IV.59) it is rudimentary, and it is larger and deeper in tupaiids (fig. IV.60) than in primates.

The *mesotympanic cavity,* or tympanic proper, communicates with the mastoid cells behind through the atrium, and opens in front into the auditory or eustachian tube. The cavity ordinarily contains the malleolar manubrium, the long crus of the incus, the stapes, the cochlea with its visible oval and round windows, and the tympanic ring, membrane, and chord. The tympanic ring in lemuriforms is almost entirely free and contained within the cavity. Most of the ring in all other primates is fused with the petrosal bone. The stapedial artery which traverses the stapes between the cruces (fig. I.13) is present in lemuriforms, reduced or absent in lorisiforms, and absent in higher primates. The carotid enters from behind the cochlea in lemuriforms, but along the medial border near the anterior end of the cochlea in lorisiforms and higher primates.

The cochlear promontory and lateral aspect of the bony canal of the carotid artery occupy most of the mesotympanic cavity and are prominently exposed when seen through the auditory meatus, especially in noncatarrhines. In some platyrrhines, the bony canal encasing the facial nerve and stylomastoid artery are likewise visible along the anterior border of the meatus. A peculiar stirrup-shaped process of this canal, the *stapedial process* (fig. IV.64), just laterad to the fenestra rotunda, is often present in some uncrested species of capuchins, genus *Cebus,* but has not been found in other platyrrhines (Hershkovitz 1971*b*).

The tensor tympani muscle behind the malleus lies in the groove which extends from the tympanic or Eustachian tube to just mediad of the malleolar manubrium. The tendon of the muscle, often preserved in the dry,

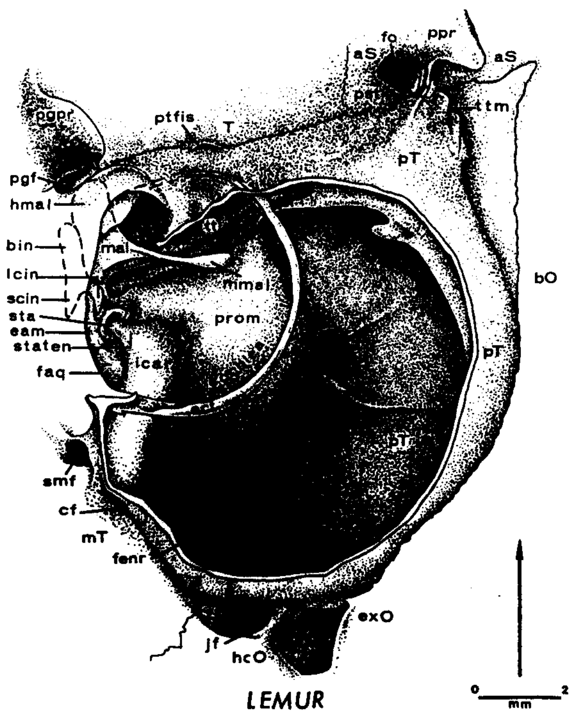


Fig. IV.61. Middle ear region of *Lemur* (Lemuridae), tympanic bulla formed by petrous bone (*pT*) partially removed to expose tympanic ring, internal carotid artery (*icar*) and petrous bone including cochlear promontorium (*prom*); arrow point anterior; symbols explained in chapter 31.

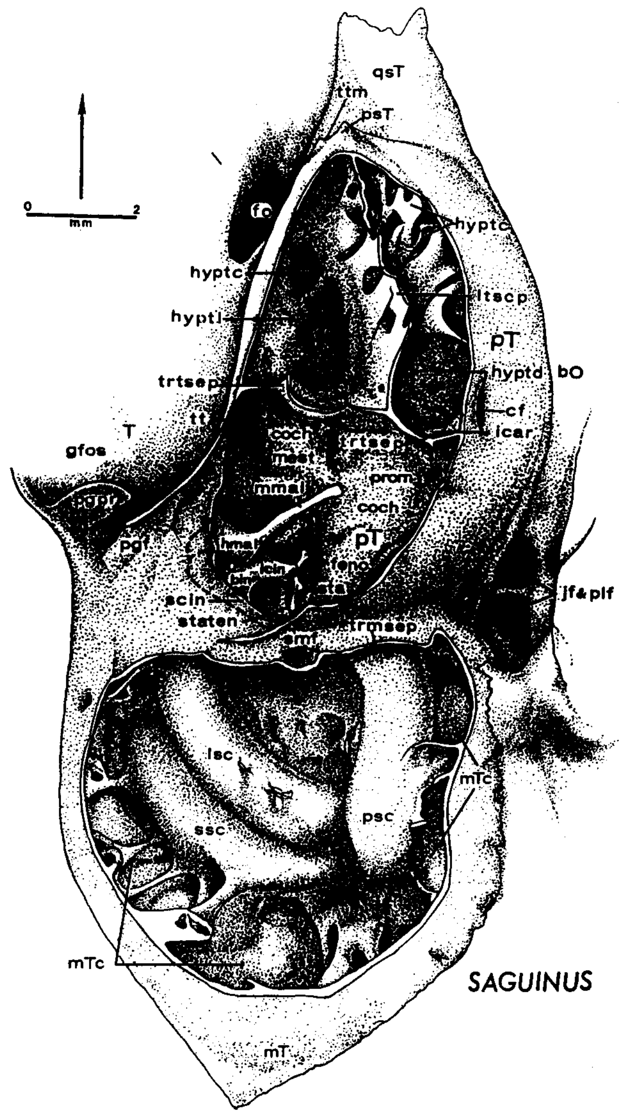


Fig. IV.62. Middle ear region of *Saguinus* (Callitrichidae), tympanic bulla, formed by petrous bone (*pT*) partially removed to expose septa and cells of tympanic cavities; semilunar canals in mastoid region exposed by partial removal of mastoid bone (*mT*); arrow point anterior; symbols explained in chapter 31.

cleaned skull, attaches to the medial surface of the manubrium.

The *hypotympanic cavity* occupies the anterior half of the primate bulla (fig. IV.63). It is more or less subdivided into two large chambers. The lateral, or main, chamber is traversed by the auditory tube and carotid canal which open into the pharynx. The dorsomedial, or quadrilateral, chamber is simple in *Lemur* (fig. IV.61), subdivided or cellular in higher primates and separated from the lateral chamber by an irregular and perforated longitudinal septum. The posterior boundary of the hypotympanic cavity is defined by the cochlea alone in primitive forms and by the cochlea and a more or less pneumatized transverse septum (fig. IV.62) in advanced forms. A more detailed description of primate temporal bone pneumatization is given by Saban (1964).

In lorisiforms and higher primates, an increase in volume of the hypotympanic cavity concomitant with increasing trabeculation and honeycombing results in a relative decrease in size of the other two cavities, but mostly the mesotympanic.

Pneumatization of the mastoid bone is usually correlated with inflation of the hypotympanic cavity, particularly in nocturnal species and the small diurnal ones with well-developed olfactory sense (cf. IV.82; chap. 29). This type of secondary inflation is extreme in lorisoids and, to a lesser extent, in callitrichids and marmosetlike cebids, particularly the night monkey, *Aotus*. The bulla remains prominent in the next-larger-sized pithecines, but the mastoidal swelling is absent.

With progressive increase in body size and importance of the visual sense among diurnal primates, the tympanic bulla and mastoid bone decreased in relative size. In prehensile-tailed cebids, the bulla is large but proportionately less pneumatized than in smaller platyrrhines, and the mastoid region is flattened. The catarrhine auditory bulla is noticeably less inflated, although pneumatization among many smaller species may be approximately as great as in some similar-sized platyrrhines. The bulla of larger cercopithecines, colobines, and gibbons is little inflated and that of baboons hardly or not at all, while the normally pneumatized mastoid is flattened or only slightly convex. In remaining apes and in man, little or virtually no external distention of the auditory bulla or mastoid bone is apparent.

Auditory Ossicles

The three ear bones, malleus, incus, and stapes (figs. IV.64–73), develop precociously and entirely within the