

Data Collection Manual

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Craniometrics

LANDMARKS

- [al] **ALARE** – (*paired*) - the most lateral points on the nasal aperture in a transverse plane; determined by instrument
- [alv] **ALVEOLON** – the point on the hard palate where a line drawn through the most posterior points of the alveolar ridges crosses the midline; balance toothpick behind 3rd maxillary molars to sight down
- [ast] **ASTERION** – (*paired*) – the point where the lambdoidal, parietomastoid, and occipitomastoid sutures meet
- [au] **AURICULARE** – (*paired*) - a point on the lateral aspect of the root (posterior portion) of the zygomatic process at the deepest incurvature, wherever it may be
- [ba] **BASION** – the midline point on the anterior margin of the foramen magnum; for *cranial height measurements*, define the point as on the anteroinferior portion of the foramen's rim; for *cranial length measurements*, define the point as the most posterior point on the foramen's anterior rim (aka – endobasion)
- [b] **BREGMA** – ectocranial midline point where the coronal and sagittal sutures meet.
- [cdl] **CONDYLION LATERALE** – (*paired*) – the most lateral point on the mandibular condyle
- [d] **DACRYON** (*paired*) – along the medial border of the orbit, the point of intersection of the frontal, lacrimal, and maxilla; also the intersection of the lacrimo-maxillary suture and the frontal bone
- [ec] **ECTOCONCHION** – (*paired*) – along the lateral border of the orbit, this is the intersection point of the most anterior surface of the border with a line that bisects the orbit along its long axis. Use a toothpick to divide the orbit into two equal halves in the transverse plane, and mark the point on the anterior margin with a pencil; the instrumentally determined most lateral point on the orbit's lateral margin
- HOWELLS defines ectoconchion as the most anterior point on the lateral border of the orbit, i.e. – the inner surface of this border
 - MARTIN defines ectoconchion as this point on the RIM (very edge) of the lateral border
- [ecm] **ECTOMOLARE** – (*paired*) the most lateral point on the outer surface of the alveolar borders of the maxilla, often opposite the middle of the second maxillary molar
- [edb] **ENDOBASION** – see basion, for *cranial length measurements*, define the point as the most posterior point on the foramen's anterior rim
- [eu] **EURYON** – (*paired*) – instrumentally determined ectocranial points on opposite sides of the skull that form the endpoints of the line of maximum cranial breadth.
- [fma] **FRONTOMALARE ANTERIOR** – (*paired*) – the most anteriorly projecting point on the frontomalar/frontozygomatic suture; anterior to frontomolare temporale
- [fmt] **FRONTOMALARE TEMPORALE** – (*paired*) – the most laterally positioned point on the frontomalar/frontozygomatic suture; point where the frontozygomatic suture crosses the temporal line or outer orbital rim
- [ft] **FRONTOTEMPORALE** – (*paired*) - the point where the temporal line reaches its most anteromedial position on the frontal; medial most point of curve of temporal ridge
- [g] **GLABELLA** – the most anterior midline point on the frontal bone, usually above the frontonasal suture
- [gn] **GNATHION** – the most inferior midline point on the mandible; taken on the inferior border
- [go] **GONION** – (*paired*) – a point along the rounded posteroinferior border of the mandible between the ramus and body. To determine, imagine extending the posterior ramus border down and the inferior corpus border back to get an obtuse angle. A line bisecting this angle would meet the gonial edge at gonion.
- [id] **INFRADENTALE** – the midline point at the superior tip of the septum between the mandibular central incisors
- *[jug] **JUGALE** – (*paired*) - the deepest point of curvature on the posterior border of the zygomatic between the frontal and temporal processes
- [la] **LACRIMALE** – (*paired*) – the point where the posterior lacrimal crest meets the frontolacrimal suture; posterior to maxillofrontale
- [l] **LAMBDA** – the ectocranial midline point where the sagittal and lambdoidal sutures intersect; if obscured

by wormian bones, project the sutural lines to determine where they would meet in the absence of wormian bones

[mf] MAXILLOFRONTALE – (*paired*) – the point where the anterior lacrimal crest of the maxilla meets the frontomaxillary suture; anterior to lacrimale

[n] NASION – the point of intersection between the frontonasal suture and the midsagittal plane

[ns] NASOSPINALE – the point where a line drawn between the inferiormost points of the nasal aperture crosses the midsagittal plane. Not necessarily located on the tip of nasal spine!

[o] OBELION – the ectocranial midline point where a line connecting the parietal foramina (when present) intersects the midline

[o] OPISTHION – the midline point at the posterior margin of the foramen magnum

[op] OPISTHOCRANION – most posterior point of the skull not on the external occipital protuberance; instrumentally determined

[orb] ORBITALE – (*paired*) – the vertically lowest point on the lower orbital margin (?)

[po] PORION – (*paired*) – the uppermost (superior) point on the margin of the external auditory meatus

[pr] PROSTHION – the most anterior point in the midline of the alveolar processes of the maxillae

[st] STEPHANION – (*paired*) – the point where the coronal suture crosses the temporal line

[ss] SUBSPINALE – the deepest point below the anterior nasal spine; seen in profile

[zy] ZYGION – the most lateral point (broadest) on the zygomatic arch; instrumentally determined

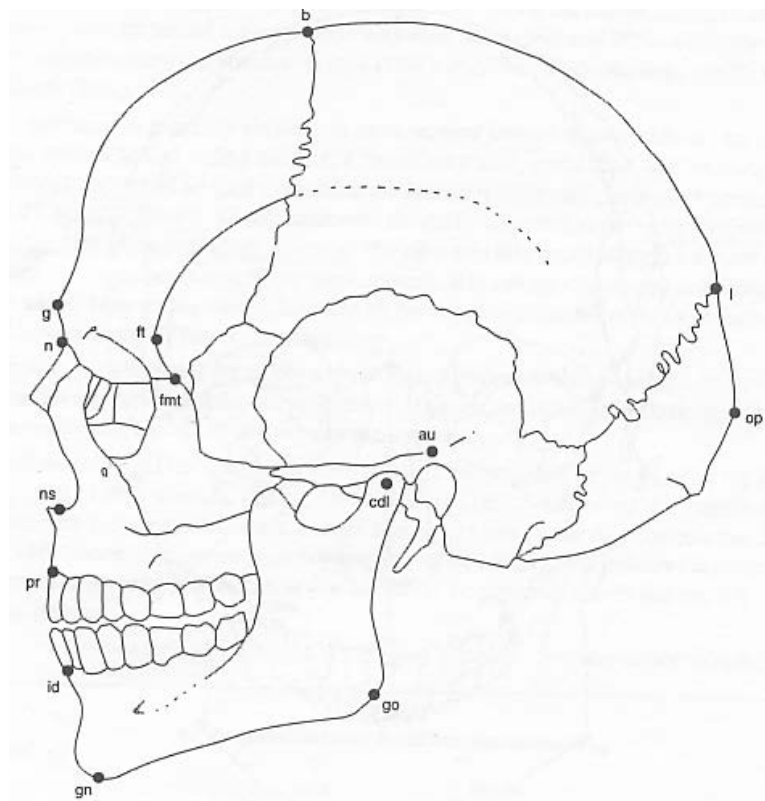
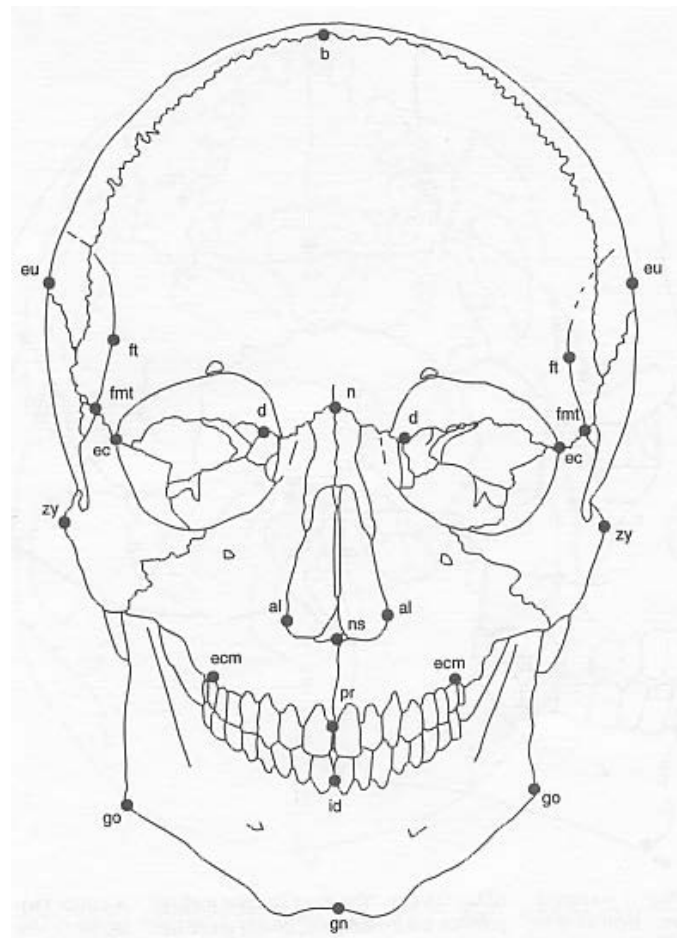
***[zma] ZYGOMAXILLARY ANTERIOR** – (*paired*) - the intersection of the zygomaxillary suture and the limit of the attachment of the masseter muscle, on the facial surface

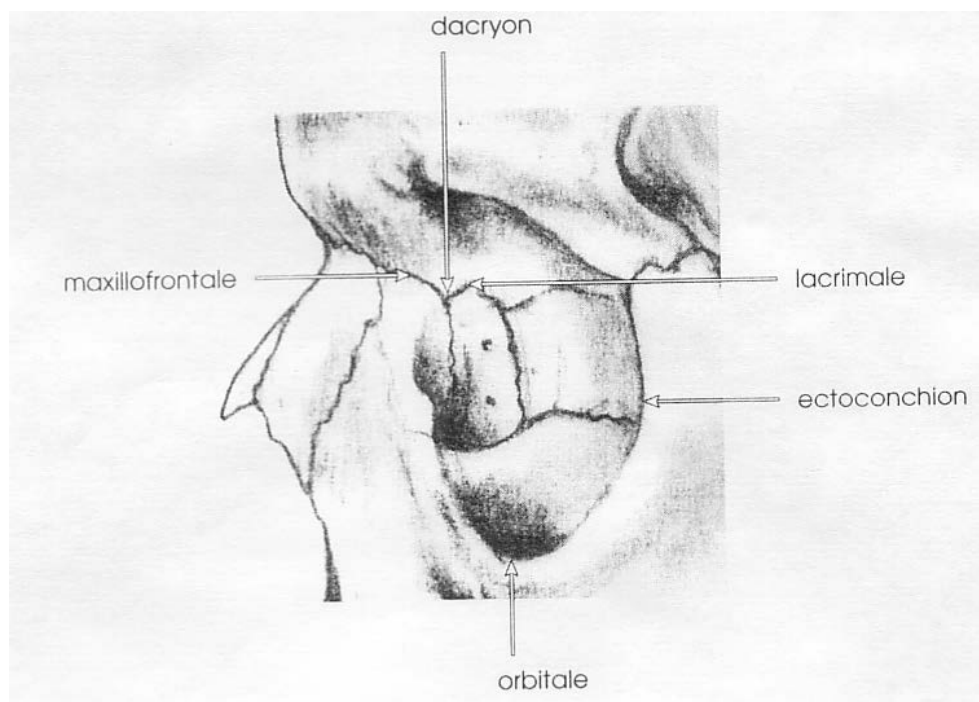
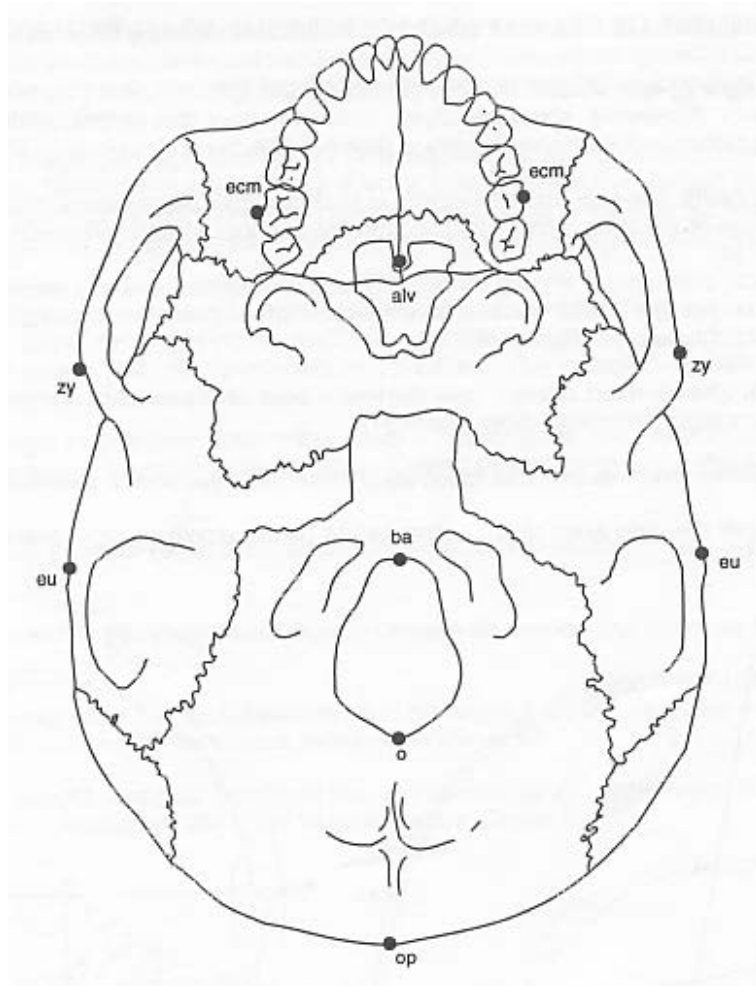
[zo] ZYGOORBITALE – (*paired*) – the junction of the zygomaxillary suture with the lower border of the left orbit

[zt] ZYGOTEMPORAL SUTURE – (*paired*) - the most inferior point on the external surface of the zygotemporal suture

Landmark Checklist

	Prosthion		Right Euryon
	Right Ectomolare		Left Euryon
	Left Ectomolare		Obelion
	Subspinale		Right Auriculare
	Right Nasospinale		Left Auriculare
	Left Nasospinale		Right Porion
	Right Alare		Left Porion
	Left Alare		Right Asterion
	Right Zygion		Left Asterion
	Left Zygion		Lambda
	Right Jugale		Opisthocranion
	Left Jugale		UP ANCHOR 1 (Prosthion)
	Right Maxillofrontale		UP ANCHOR 2R (Right Ectomolare)
	Left Maxillofrontale		UP ANCHOR 2L (Left Ectomolare)
	Right Dacryon		UP ANCHOR 3R (Right Porion)
	Left Dacryon		UP ANCHOR 3L (Left Porion)
	Right Lacrimale		UP ANCHOR 4R (Right Asterion)
	Left Lacrimale		UP ANCHOR 4L (Left Asterion)
	Right Ectoconchion (Howells)		UP ANCHOR 5 (Opisthocranion)
	Left Ectoconchion (Howells)		DOWN ANCHOR 1 (Prosthion)
	Right Ectoconchion (Martin)		DOWN ANCHOR 2R (Right Ectomolare)
	Left Ectoconchion (Martin)		DOWN ANCHOR 2L (Left Ectomolare)
	Right Orbitale		DOWN ANCHOR 3R (Right Porion)
	Left Orbitale		DOWN ANCHOR 3L (Left Porion)
	Right Zygoorbitale		DOWN ANCHOR 4R (Right Asterion)
	Left Zygoorbitale		DOWN ANCHOR 4L (Left Asterion)
	Right Zygomaxillary Anterior		DOWN ANCHOR 5 (Opisthocranion)
	Left Zygomaxillary Anterior		Opisthion
	Right Zygotemporal Suture		Basion
	Left Zygotemporal Suture		Endobasion
	Nasion		Alveolon
	Glabella		Right Lowest TMJ
	Right Frontomolare Anterior		Left Lowest TMJ
	Left Frontomolare Anterior		MANDIBLE - Gnathion
	Right Frontomolare Temporale		MANDIBLE - Infradentale
	Left Frontomolare Temporale		MANDIBLE – Right Gonion
	Right Frontotemporale		MANDIBLE – Left Gonion
	Left Frontotemporale		MANDIBLE – Right Condylion Laterale
	Right Stephanion		MANDIBLE – Left Condylion Laterale
	Left Stephanion		MANDIBLE – Right highest condyle point
	Bregma		MANDIBLE – Left highest condyle point





CRANIOMETRICS

MAXIMUM CRANIAL LENGTH (GOL)

- Spreading Calipers
- Glabella – Opisthocranium
- Rest skull with base facing up. Put left caliper point in midline glabellar region and brush right point down the occiput at midline to find maximum reading.
- Howells/Hanihara worldwide means (F: 174.81mm), (M: 183.02mm)
- Howells/Hanihara worldwide range (151.00mm – 211.00mm)

NASION-OCCIPITAL LENGTH (NOL)

- Spreading Calipers
- Nasion – Opisthocranium
- Rest skull with base facing up. Place left caliper point at nasion and brush right point down the occiput at midline to find maximum reading.
- Howells/Hanihara worldwide means (F: 172.73mm), (M: 180.40mm)
- Howells/Hanihara worldwide range (151.00mm – 200.00mm)

BASION-NASION LENGTH (BNL)

- Spreading Calipers
- Basion – Nasion
- Rest skull with base facing up. Place left caliper point at nasion and right caliper point at basion.
- Howells/Hanihara worldwide means (F: 96.07mm), (M: 100.99mm)
- Howells/Hanihara worldwide range (83.00mm – 121.00 mm)

BASION-BREGMA HEIGHT (BBH)

- Spreading Calipers
- Basion – Bregma
- Rest skull on occiput, with its right side facing observer. Put left caliper point at bregma and right caliper point at basion.
- Howells/Hanihara worldwide means (F: 128.18mm), (M: 134.57mm)
- Howells/Hanihara worldwide range (107.00mm – 155.00mm)

MAXIMUM CRANIAL BREADTH (XCB)

- Spreading Calipers
- Euryon – Euryon
- Rest skull on base, with occiput facing observer. Try to find maximum breadth on parietals by brushing caliper points up and down. If maximum breadth must be found on temporals, be certain to avoid the supramastoid crests completely.
- Howells/Hanihara worldwide means (F: 133.12mm), (M: 138.19mm)
- Howells/Hanihara worldwide range (110.00mm – 167.00mm)

MAXIMUM FRONTAL BREADTH (XFB)

- Spreading Calipers
- Rest skull on base, with face towards observer. Put caliper points on coronal suture on either side, making sure they are at symmetrical levels. Find maximum at any level. This is the maximum external breadth of the isolated frontal bone.
- Howells/Hanihara worldwide means (F: 110.68mm), (M: 115.95mm)
- Howells/Hanihara worldwide range (93.00mm – 145.00mm)

BASION – PROSTHION LENGTH (BPL)

- Spreading or Sliding Calipers
- Basion – Prosthion
- Rest the skull with the base up and the face to the left. Put left caliper point at prosthion, and the right caliper point at basion.
- Howells/Hanihara worldwide means (F: 95.53mm), (M: 98.89mm)
- Howells/Hanihara worldwide range (78.00mm – 123.00mm)

BASION – PORION LENGTH (BAP)

- Spreading or Sliding Calipers
- Basion – Porion
- Rest skull with right half of face down. Put left caliper point at porion, right caliper point at basion.
- Howells did not take

BISTEPHANIC BREATH (STB)

- Sliding Calipers
- Stephanion – Stephanion
- Mark the intersection of the inferior temporal line (or superior if two separate lines cannot be distinguished) and the coronal suture on both sides of the cranium. Rest the skull on its base with face towards observer. Measure between the marked stephania.
- Howells/Hanihara worldwide means (F: 107.72mm), (M: 110.72mm)
- Howells/Hanihara worldwide range (81.00mm – 140.00mm)

BIZYGOMATIC BREADTH (ZYB)

- Sliding Calipers
- Zygion – Zygion
- Rest skull on occiput with base toward observer, place caliper arms on the zygomatic arches at their broadest point, making sure the caliper is vertical to median plane.
- Howells/Hanihara worldwide means (F: 124.74mm), (M: 132.94mm)
- Howells/Hanihara worldwide range (105.00mm – 158.00mm)

MINIMUM CRANIAL BREADTH (WCB)

- Sliding Calipers
- Rest skull with base up and occiput towards observer. Find the petrotympanic fissure posterior to the external auditory meatus and anterior to the mandibular fossa. Find the place on the sphenoid at approximately this level that will yield the minimum breadth. Measure the breadth across the sphenoid at this level (or at the infratemporal crests at the base of the temporal fossae, if you can find them).
- Howells/Hanihara worldwide means (F: 69.00mm), (M: 72.66mm)
- Howells/Hanihara worldwide range (57.00mm – 89.00mm)

BIAURICULAR BREADTH (AUB)

- Sliding Calipers
- Auriculare – Auriculare
- Rest skull on occiput with base towards observer. Place caliper points on the outside of the roots of the zygomatic processes at the level of their greatest incurvature, usually slightly anterior to the meatus.
- Howells/Hanihara worldwide means (F: 115.88.23mm), (M: 121.84mm)
- Howells/Hanihara worldwide range (98.00mm – 149.00mm)

BIASTERIONIC BREADTH (ASB)

- Sliding Calipers
- Asterion – Asterion
- Rest skull on frontal region with the occiput facing observer. Measure distance from one asterion to the other with sharp points of calipers.
- Howells/Hanihara worldwide means (F: 104.10mm), (M: 108.39mm)
- Howells/Hanihara worldwide range (88.00mm – 138.00mm)

MINIMUM FRONTAL BREADTH (WFB)

- Sliding Calipers
- Frontotemporale – Frontotemporale
- Rest skull on occiput with face facing observer. Find the frontotemporale, or medial most points of curvature for the right and left temporal lines. Place sharp tips on frontotemporales and measure.
- Howells did not take

BIJUGAL BREADTH (JUB)

- Sliding Calipers
- Jugale – Jugale
- Rest skull on occiput with face facing observer. Find the jugalia, the deepest points of curvature between the frontal and temporal processes of the zygomatics. Place the sharp tips of the calipers on these points and measure.
- Howells/Hanihara worldwide means (F: 111.16mm), (M: 118.56mm)
- Howells/Hanihara worldwide range (97.00mm – 138.00mm)

NASION-PROSTHION HEIGHT (NPH)

- Sliding Calipers
- Nasion – Prosthion
- Rest the skull with the face up and the base to the right. Place one sharp tip of the caliper on nasion, the other on prosthion.
- Howells/Hanihara worldwide means (F: 63.54mm), (M: 68.03mm)
- Howells/Hanihara worldwide range (48.00mm – 82.00mm)

NASAL HEIGHT (NLH)

- Sliding Calipers
- Nasion – Nasospinale
- Rest the skull face up, with base to the right. Anchor stationary end of caliper at nasion, measure down to nasospinale on both the right and left sides and use an average of the two measurements as final value.
- Howells/Hanihara worldwide means (F: 48.26mm), (M: 51.39mm)
- Howells/Hanihara worldwide range (23.00mm – 66.00mm)

NASAL BREADTH (NLB)

- Sliding Calipers
- Alare – Alare
- THIS IS **NOT** AN INSIDE MEASUREMENT!!!!!! Place the sharp points of the calipers on the anterior edges of the nasal aperture at its widest extent (alare).
- Howells/Hanihara worldwide means (F: 25.40mm), (M: 26.00mm)
- Howells/Hanihara worldwide range (17.00mm – 55.00mm)

ORBITAL BREADTH (OBB)

- INSIDE Sliding Calipers
- Ectoconchion (Howells) – Dacryon
- THIS IS AN INSIDE MEASUREMENT!!!! Rest the skull upside down with the face facing the observer. Place the inside tips of the calipers on ectoconchion and dacryon and measure. Remember that for OBB, ectoconchion is located on INSIDE of lateral border of left orbit
- LEFT ORBIT
- Howells/Hanihara worldwide means (F: 38.68mm), (M: 40.18mm)
- Howells/Hanihara worldwide range (33.00mm – 46.00mm)

ORBITAL HEIGHT (OBH)

- INSIDE Sliding Calipers
- THIS IS AN INSIDE MEASUREMENT!!!! Rest the skull upside down with the face facing the observer. Visually bisect the left orbit into right and left (or medial and lateral halves). Measure the height between the upper and lower borders of the left orbit PERPENDICULAR to the long axis defined for OBB. Remember to use the inside surface of the calipers.
- LEFT ORBIT
- Howells/Hanihara worldwide means (F: 33.42mm), (M: 33.89mm)
- Howells/Hanihara worldwide range (26.00mm – 42.00mm)

ORBITAL BREADTH II (OBB2)

- Sliding Calipers
- Maxillofrontale – Ectoconchion (Martin)
- THIS IS NOT AN INSIDE MEASUREMENT!!!! Rest the skull upside down with the face facing the observer. Place the stationary tip of the calipers on maxillofrontale, which will be lateral and inferior to dacryon of OBB. Measure across to ectoconchion, making sure that the moveable tip of the calipers rests on the rim of the orbit, not the inner surface.
- LEFT ORBIT
- Should be somewhat larger than Howells'

BIORBITAL BREADTH (EKB)

- Sliding Calipers
- Ectoconchion (Howells) - Ectoconchion (Howells)
- Remember that Howells' ectoconchion is not on the rim of the orbit. Rest the skull on the occiput, with face upwards. Place the two caliper points on right and left ectoconchia and measure.
- Howells/Hanihara worldwide means (F: 95.17mm), (M: 99.18mm)
- Howells/Hanihara worldwide range (83.00mm – 113.00mm)

PORION – BREGMA LENGTH (POB)

- Sliding Calipers
- Left Porion – Bregma
- Rest skull on occiput with left side upwards. Place tips of calipers on bregma and left porion and measure.
- Howells did not take

PORION – NASION LENGTH (PON)

- Sliding Calipers
- Left Porion – Nasion
- Rest skull on occiput with left side upwards. Place tips of calipers on nasion and left porion and measure.
- Howells did not take

PORION – SUBSPINALE LENGTH (POS)

- Sliding Calipers
- Left Porion – Subspinale
- Rest skull on occiput with left side upwards. Place tips of calipers on subspinale and left porion and measure.
- Howells did not take

FORAMEN MAGNUM LENGTH (FOL)

- Sliding Calipers
- Basion – Opisthion
- Rest skull with base up. Use the inside edges of the calipers for ease in taking this, but remember that this is **NOT** an inside measurement.
- Howells/Hanihara worldwide means (F: 34.81mm), (M: 36.60mm)
- Howells/Hanihara worldwide range (27.00mm – 50.00mm)

EXTERNAL ALVEOLAR BREADTH (MAB)

- Sliding Calipers
- Ectomolare – Ectomolare
- Rest skull with base up. Apply arms of calipers to the maxillary bone at the widest margin, usually at the level of the second maxillary molars.
- Howells/Hanihara worldwide means (F: 61.14mm), (M: 64.33mm)
- Howells/Hanihara worldwide range (30.00mm – 79.00mm)

MALAR LENGTH, INFERIOR (IML)

- Sliding Calipers
- Left Zygomaxillary anterior – Left Zygotemporal suture
- Rest skull on right parietal. Measure the left side of the skull between zygomaxillary anterior and zygotemporal suture, which should be marked.
- Howells/Hanihara worldwide means (F: 34.59mm), (M: 37.39mm)
- Howells/Hanihara worldwide range (20.00mm – 49.00mm)

MALAR LENGTH, MAXIMUM (XML)

- Sliding Calipers
- Left Zygotemporal suture – Left Zygoorbitale
- Rest the skull on the occiput with the left frontal region facing the observer. Place the stationary point of the calipers on the left zygotemporal suture point and measure to zygoorbitale.
- Howells/Hanihara worldwide means (F: 50.40mm), (M: 54.60mm)
- Howells/Hanihara worldwide range (38.00mm – 69.00mm)

CHEEK HEIGHT (WMH)

- Sliding Calipers
- Rest the skull on the occiput with the face facing upwards towards the observer. Measure the MINIMUM distance, in any direction, from the lower border of the **left** orbit to the lower margin of the **left** maxilla, mesial to the masseter attachment.
- Howells/Hanihara worldwide means (F: 21.69mm), (M: 23.63mm)
- Howells/Hanihara worldwide range (14.00mm – 35.00mm)

BIMAXILLARY BREADTH (ZMB)

- Coordinate Calipers
- Zygomaxillary anterior – Zygomaxillary anterior
- Rest the skull on the occiput with the face facing upwards. Set each arm of the coordinate calipers on the zygomaxillary anterior marks and screw down caliper.
- Howells/Hanihara worldwide means (F: 91.90mm), (M: 97.57mm)
- Howells/Hanihara worldwide range (79.00mm – 120.00mm)

BIMAXILLARY SUBTENSE (SSS)

- Coordinate Calipers
- Subspinale
- With the coordinate calipers in position for ZMB, drop the coordinate arm to reach subspinale.
- Howells/Hanihara worldwide means (F: 22.17mm), (M: 23.53mm)
- Howells/Hanihara worldwide range (11.00mm – 35.00mm)

INTERORBITAL BREADTH (DKB)

- Coordinate Calipers
- Dacryon – Dacryon
- Rest skull on occiput with face upwards. Place the coordinate caliper arms on the marked dacryon points and screw down the caliper.
- Howells/Hanihara worldwide means (F: 20.88mm), (M: 22.27mm)
- Howells/Hanihara worldwide range (13.00mm – 72.00mm?)

NASODACRYL SUBTENSE (NDS)

- Coordinate Calipers
- With the coordinate calipers in position for DKB, drop the coordinate arm to reach the deepest point in the profile of the nasal bones.
- Howells/Hanihara worldwide means (F: 9.15mm), (M: 9.96mm)
- Howells/Hanihara worldwide range (4.00mm – 17.00mm)

BIFRONTAL BREADTH (FMB)

- Coordinate Calipers
- Frontomale anterior - Frontomale anterior
- Place the skull on the occiput with the face upwards. Find frontomale anterior on either side and measure distance between these points, screwing down the arms of the calipers.
- Howells/Hanihara worldwide means (F: 94.52mm), (M: 99.05mm)
- Howells/Hanihara worldwide range (81.00mm – 112.00mm)

NASIO-FRONTAL SUBTENSE (NAS)

- Coordinate Calipers
- Nasion
- With the coordinate calipers in position for FMB, drop the coordinate arm to reach nasion.
- Howells/Hanihara worldwide means (F: 15.75mm), (M: 16.69.05mm)
- Howells/Hanihara worldwide range (8.00mm – 25.00mm)

SUPRAORBITAL PROJECTION (SOS)

- Coordinate Calipers
- Supraorbital region
- Rest skull on right occiput with left frontal region facing observer. Place fixed arm of calipers on the frontal surface next to the incurvature of the LEFT temporal line, and the other arm somewhere near glabella. Drop the coordinate arm to the LEFT supraorbital region, and move it back and forth to find the maximum reading
- NOTE: even females with little or no supraorbital margins will show some measure – usually about 4 or 5 mm according to Howells
- NOTE: only take to the nearest whole millimeter
- Howells/Hanihara worldwide means (F: 5.11mm), (M: 6.38mm)
- Howells/Hanihara worldwide range (2.00mm – 11.00mm)

GLABELLA PROJECTION (GLS)

- Coordinate Calipers
- Glabellar region
- Rest skull on right occiput with left side toward observer so that the lower left frontal region is in FULL profile. Place the fixed arm of the coordinate calipers on nasion, and the other arm at a region on the frontal above any glabellar eminence. Drop the coordinate arm and move back and forth to find maximum expression of glabellar eminence.
- NOTE: only take this to the nearest whole millimeter
- Howells/Hanihara worldwide means (F: 2.31mm), (M: 3.63mm)
- Howells/Hanihara worldwide range (0.00mm – 9.00mm)

FRONTAL CHORD (FRC)

- Coordinate Calipers
- Nasion – Bregma
- Place the skull on right occiput, so that left frontal region is in good profile. Take this measurement along the midline. Place the caliper arms at bregma and nasion and screw down the caliper.
- Howells/Hanihara worldwide means (F: 107.15mm), (M: 111.86mm)
- Howells/Hanihara worldwide range (92.00mm – 144.00mm)

FRONTAL SUBTENSE (FRS)

- Coordinate Calipers
- With the coordinate calipers in position for FRC, drop the coordinate arm and brush back and forth along frontal to find the highest tangential value to the curve of the frontal. Screw down the coordinate arm
- Howells/Hanihara worldwide means (F: 25.45mm), (M: 25.42mm)
- Howells/Hanihara worldwide range (16.00mm – 35.00mm)

FRONTAL FRACTION (FRF)

- Coordinate Calipers
- With the coordinate arm set for FRS, read the position of the coordinate arm along the main measuring bar.
- Howells/Hanihara worldwide means (F: 46.95mm), (M: 50.30mm)
- Howells/Hanihara worldwide range (36.00mm – 66.00mm)

PARIETAL CHORD (PAC)

- Coordinate Calipers
- Bregma - Lambda
- Place the skull on right occiput, so that left parietal region is in good profile. Take this measurement along the midline. Place the caliper arms at bregma and lambda and screw down the caliper.
- Howells/Hanihara worldwide means (F: 108.61mm), (M: 113.37mm)
- Howells/Hanihara worldwide range (89.00mm – 99.00mm)

PARIETAL SUBTENSE (PAS)

- Coordinate Calipers
- With the coordinate calipers in position for PAC, drop the coordinate arm and brush back and forth along parietal to find the highest tangential value to the curve of the parietal. Screw down the coordinate arm
- Howells/Hanihara worldwide means (F: 22.96mm), (M: 24.08mm)
- Howells/Hanihara worldwide range (mm – mm)

PARIETAL FRACTION (PAF)

- Coordinate Calipers
- With the coordinate arm set for PAS, read the position of the coordinate arm along the main measuring bar.
- Howells/Hanihara worldwide means (F: 56.03mm), (M: 58.56mm)
- Howells/Hanihara worldwide range (34.00mm – 77.00mm)

OCCIPITAL CHORD (OCC)

- Coordinate Calipers
- Lambda - Opisthion
- Place the skull on the face, so that the left occipital region is in good profile. Take this measurement along the midline. Place the caliper arms at lambda and opisthion, making sure to anchor the arm at opisthion with right thumb, and screw down the caliper.
- Howells/Hanihara worldwide means (F: 94.08mm), (M: 96.43mm)
- Howells/Hanihara worldwide range (76.00mm – 139.00mm)

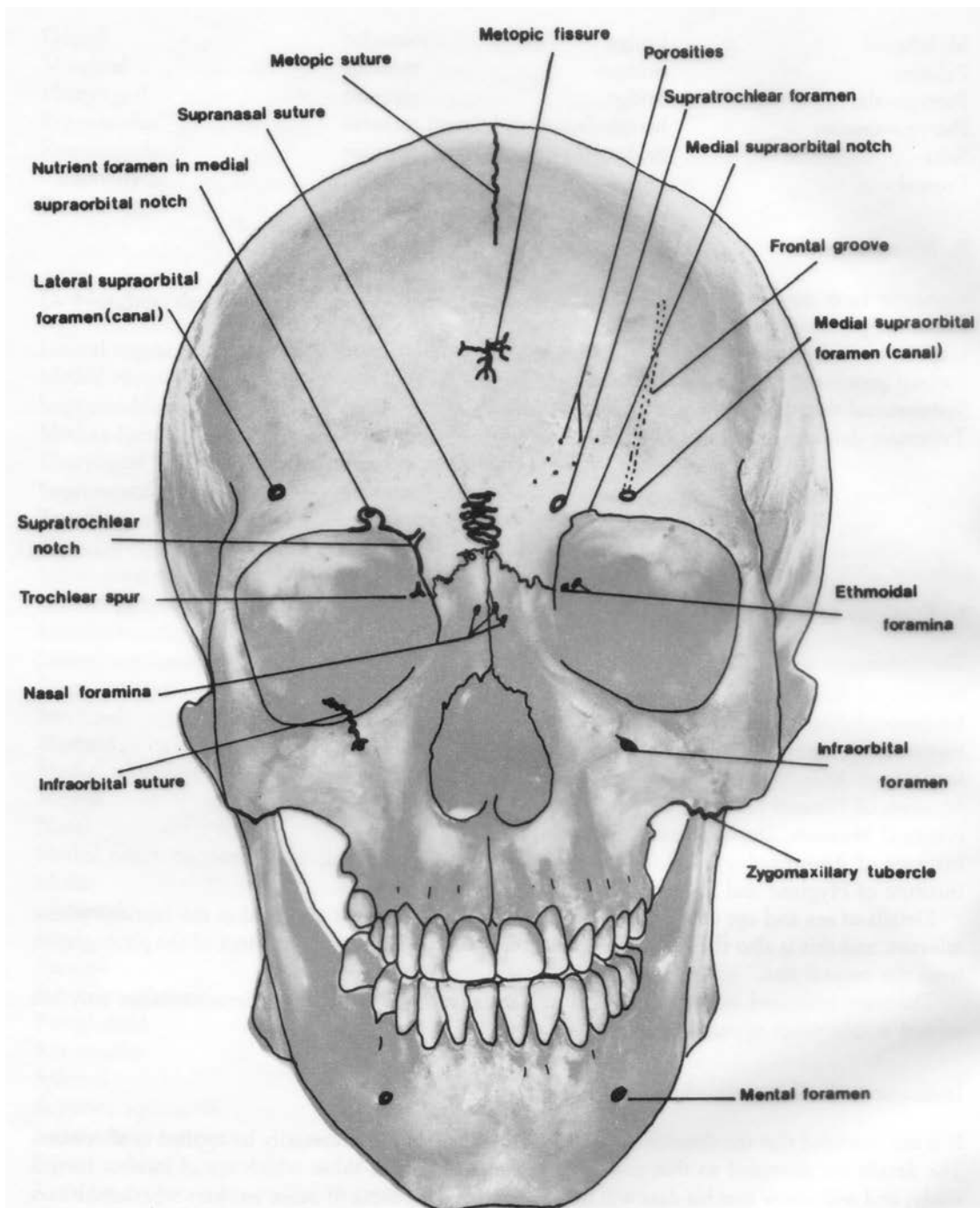
OCCIPITAL SUBTENSE (OCS)

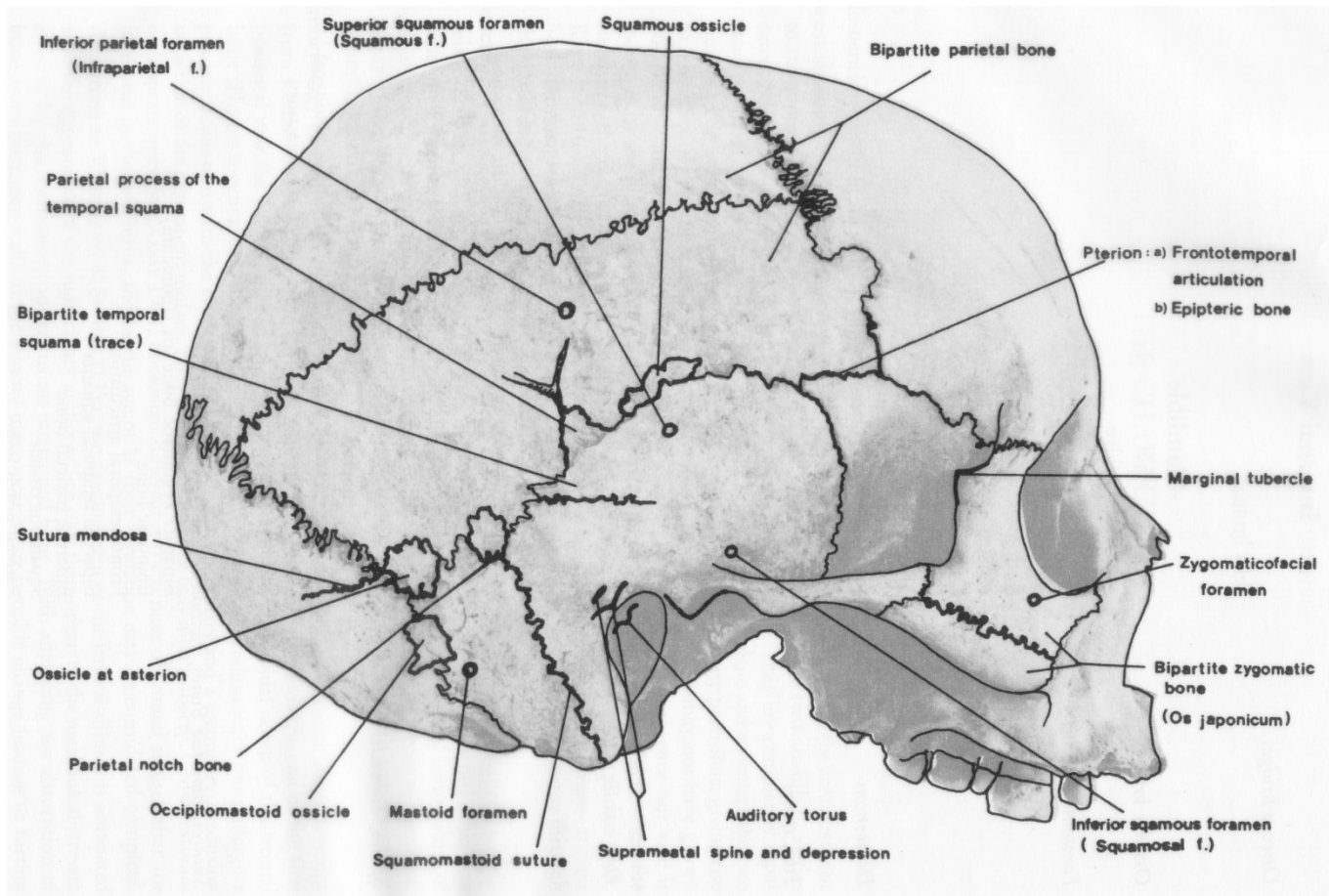
- Coordinate Calipers
- With the coordinate calipers in position for OCC, drop the coordinate arm and brush back and forth along occipital to find the highest tangential value to the curve of the occipital. Screw down the coordinate arm
- Howells/Hanihara worldwide means (F: 27.34mm), (M: 28.31mm)
- Howells/Hanihara worldwide range (15.00mm – 41.00mm)

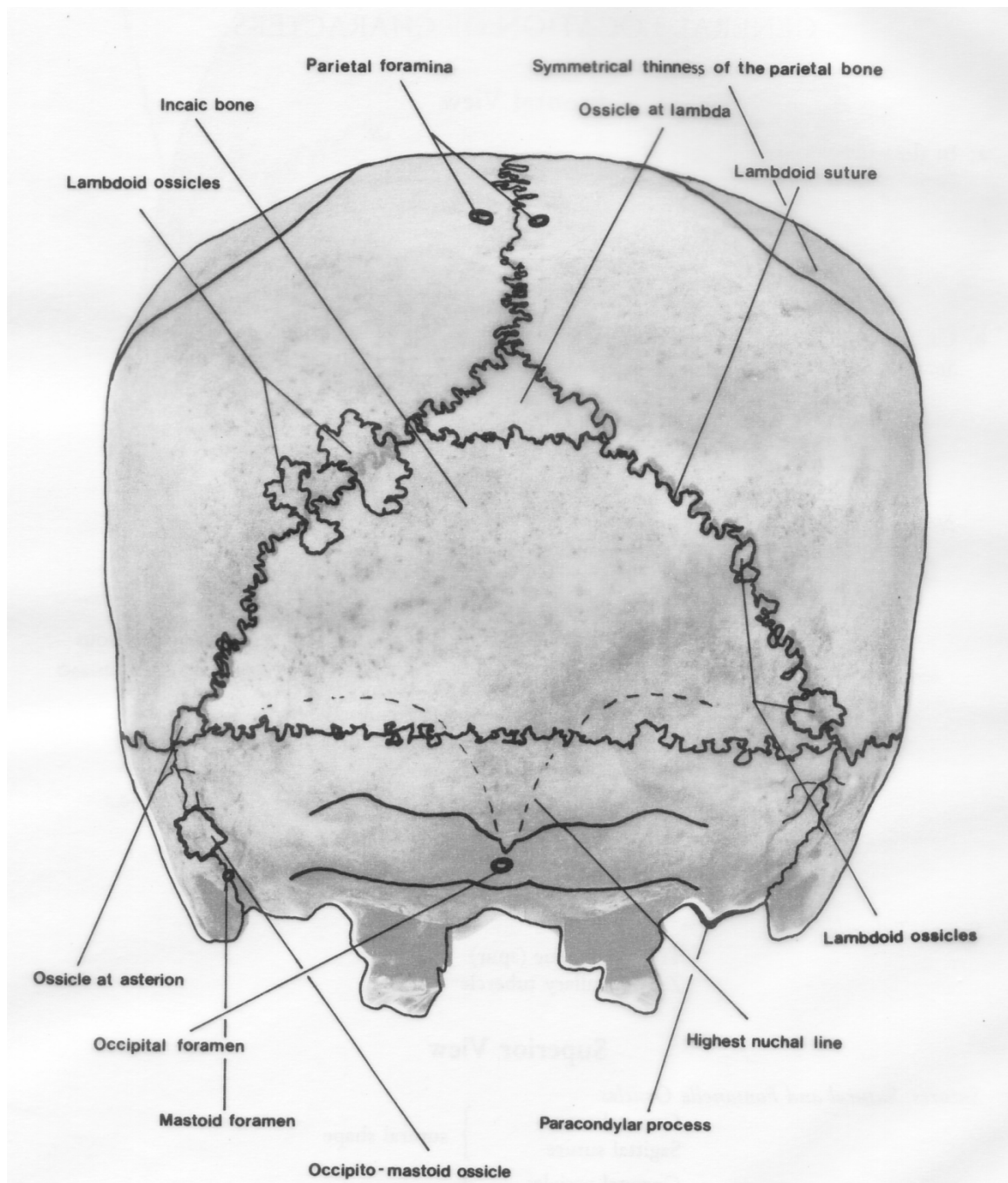
OCCIPITAL FRACTION (OCF)

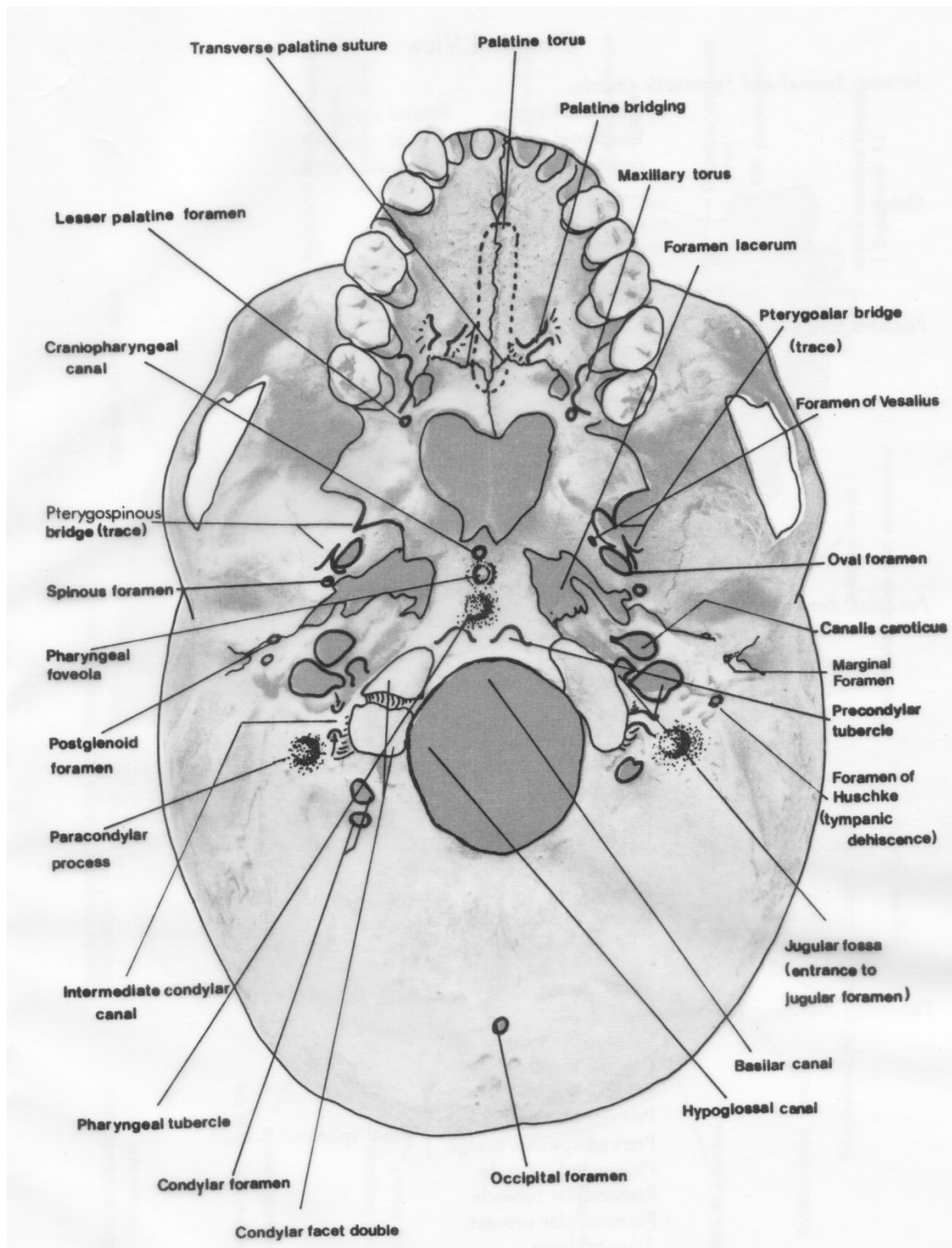
- Coordinate Calipers
- With the coordinate arm set for OCS, read the position of the coordinate arm along the main measuring bar.
- Howells/Hanihara worldwide means (F: 45.41mm), (M: 47.43mm)
- Howells/Hanihara worldwide range (29.00mm – 70.00mm)

Cranial Discrete Traits









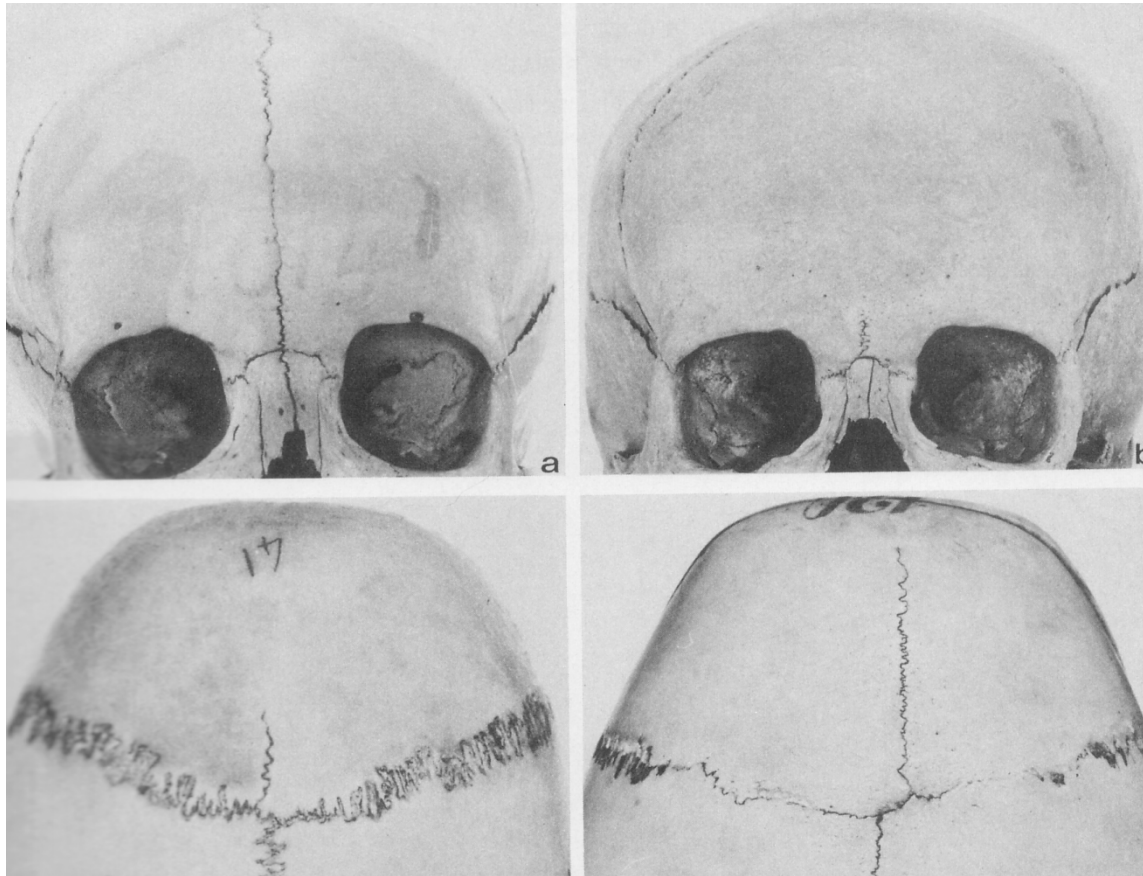
METOPIC SUTURE- Full or partial presence of this trait past the age of three (or latest, past 8 years of age) suggests that complete fusion of the frontals has not occurred. Since this suture contributes to the transverse dimension of the skull, failure to fuse supposedly allows for changes in cranial shape. It is known that multiple additive genes control this trait, and previous studies have shown a low hereditary value.

NOTE: While the metopic suture may be incomplete, with part of it originating above nasion, it should not

be confused with the supranasal suture, which is present in most individuals just above nasion. The metopic suture would be relatively strait and austere, while the supranasal suture shows a complex, zig-zag shape that deviates out from either side of the midline.

SCORING:

0 – Absent.	Suture is completely obliterated
1 – Partial.	Suture is present either above nasion, below bregma, or at both locations with obliteration in between.
2 – Complete.	Suture is visible extending from nasion to bregma, although it may deviate from the midline of the frontal.
99 – Unobserv.	The frontal is damaged to a degree that does not permit observation.



FRONTAL GROOVE – Obliquely oriented grooves on the frontal bone between the frontal tuber and the temporal line are called frontal grooves. These can be single, paired, or multiple, and are thought to conduct a branch of the supraorbital nerve into the scalp. They can be observed running all the way to the coronal suture, and may have medial or lateral spiculae or complete bridges covering them. Frontal grooves are known to develop early, suggesting they have a genetic component. This would support the idea that frontal grooves for the supraorbital nerve are necessary when the ophthalmic nerve fails to develop properly over the growing cranium.

****The NUMBER and LENGTH should be scored bilaterally.**

SCORING:

(Number)	0 – Absent.	No frontal grooves are present.
	1 – One.	A single frontal groove exists on the frontal.
	2 – Two.	A pair of frontal grooves are present.
	3 – 3 or more.	Multiple frontal grooves are present.
	99 – Unobserv.	The frontal is damaged to a degree that does not permit observation.

(Length)	0 – Absent.	No frontal grooves are present.
	1 – Trace.	The frontal groove extends for less than 10 mm along the frontal.
	2 – Well Expr.	The frontal groove extends greater than 10 mm in length
	99 – Unobserv.	The frontal orbit is damaged to a degree that does not permit observation.



SUPRAORBITAL NOTCH – Supraorbital notches occur above the eye socket, intersecting the orbital margin distally. Notches with internal foramina are passageways for nutrient vessels and nerves to the frontal sinus. Notches lacking internal foramina shunt veins or nutrient vessels to the forehead. They are thought to be genetically controlled to some degree, since they follow the patterning of vessels on the forehead. Bifurcation of vessels can be expressed within families by observation of these notches.

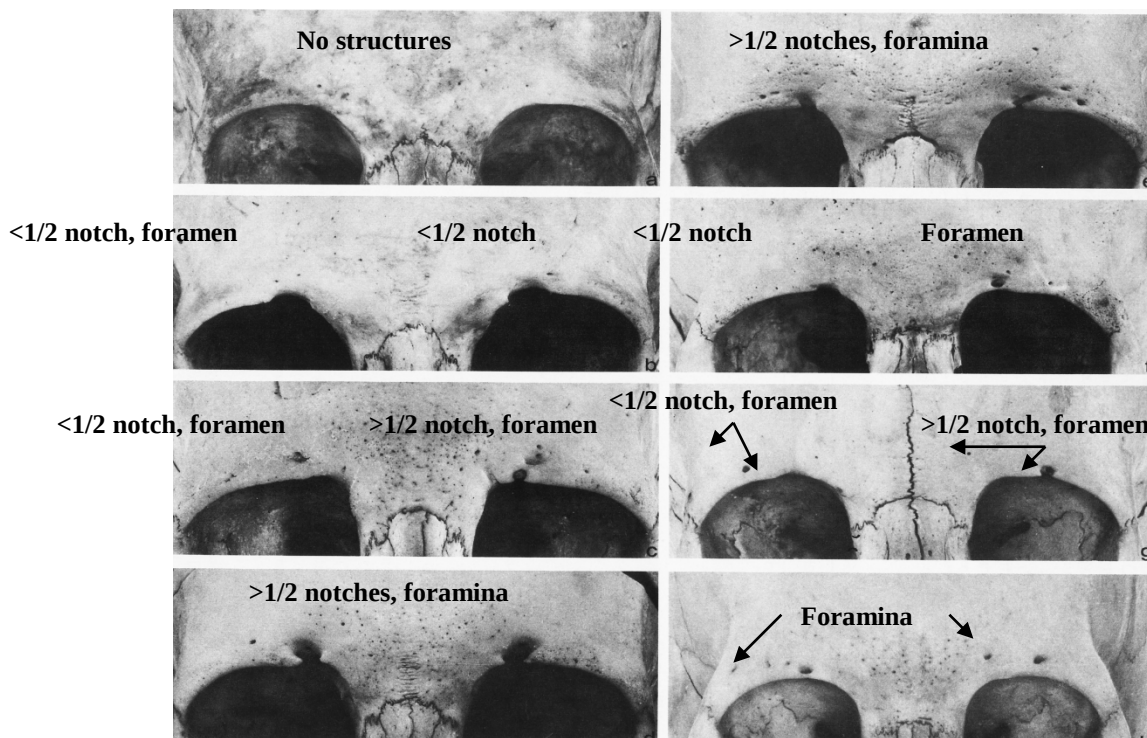
****The OCCLUSION or NUMBER of notches should be scored *bilaterally*.**

SCORING:	0 – Absent.	No notches observed above the orbit.
	1 – <1/2 occl.	One notch is present, but its distal margin is wide and does not show spiculae that close off the notch more than halfway.
	2 – >1/2 occl.	One notch is present and its distal margin is narrow, with spiculae that close off the notch more than halfway.
	3 – Unk. occl.	One notch is present, but its degree of occlusion cannot be assessed due to damage or alteration of the orbital margin.
	4 – Multiple	Two or more notches are present; degree of occlusion is not considered.
	99 – Unobserv.	The orbit is damaged to a degree that does not permit observation.

SUPRAORBITAL FORAMEN – Foramina are found above the superior orbital margin, most often just below or within the brow ridge. They differ from normal porosity in that foramina are larger than pinpricks and usually patent. As with notches, foramina in this region carry vessels either to the frontal sinus (those with internal foramina) or to the forehead (those without internal foramina). Some genetic component of this trait is suggested, but this may have more to do with the heritability of vessel patterning than with inheritance of bony structure.

****The NUMBER of foramina should be scored *bilaterally*.**

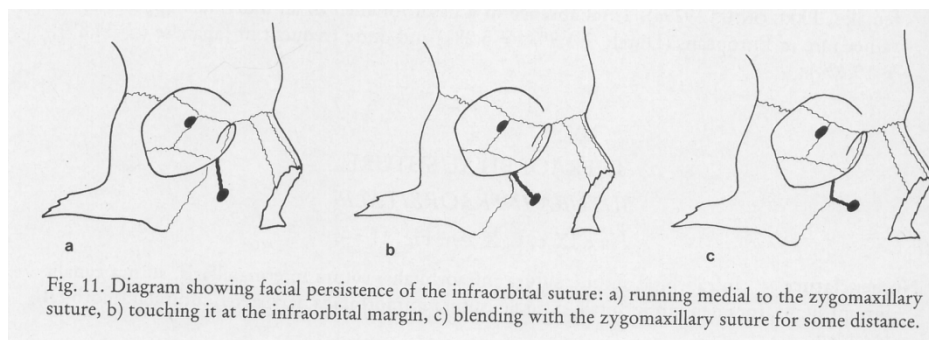
SCORING: 0 – Absent. No foramina observed above the orbital margin.
 1 – One. A single foramen is observed.
 2 – Multiple. Two or more foramina are observed above the orbit.
 99 – Unobserv. The orbit is damaged to a degree that does not permit observation.



INFRAORBITAL SUTURE – This suture originates below the infraorbital margin and continues to the infraorbital foramen. This trait is scored on a presence/absence base rather than describing the degree of formation or expression, although its location relative to the zygomaxillary suture is important. The infraorbital suture allows for bone growth in infant crania, though no hereditary studies have been performed on it.

****The LOCATION of the suture's origination should be scored bilaterally.**

SCORING: 0 – Absent. The suture cannot be seen below the infraorbital margin.
 1 – Med Zygo The superior end of the suture is located on the infraorbital margin at a position medial to the superior point of the zygomaxillary suture.
 2 – Touching The infraorbital and zygomaxillary sutures meet superiorly at the level of the infraorbital margin.
 3 – Blending The infraorbital suture meets and blends with the zygomaxillary suture below the level of the infraorbital margin.
 99 – Unobserv. This region damaged to a degree that does not permit observation.

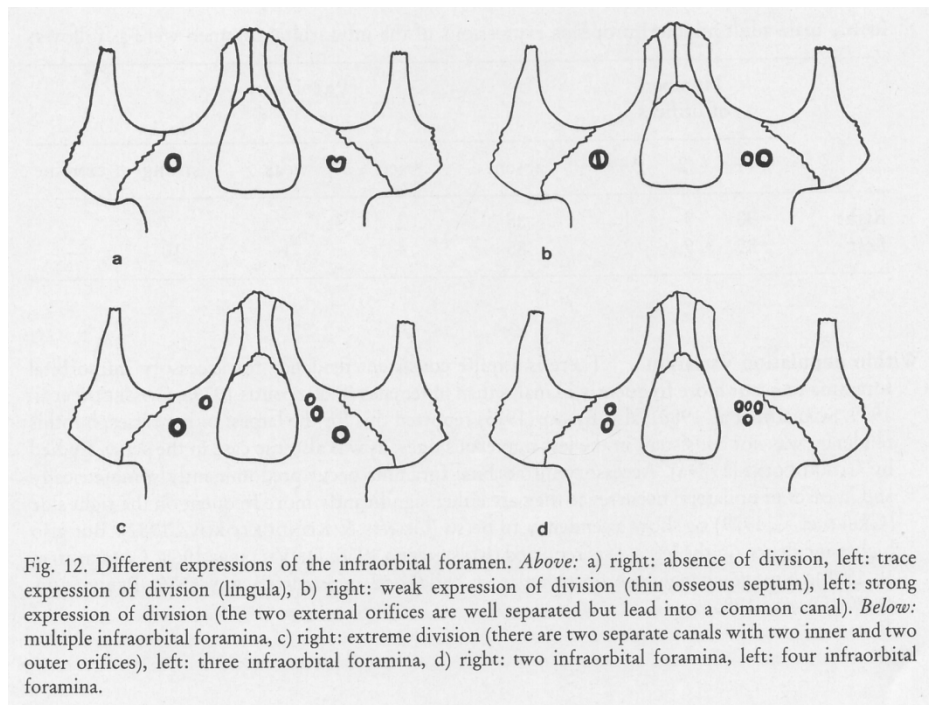


MULTIPLE INFRAORBITAL FORAMINA – The infraorbital canal conducts the infraorbital nerve and vessels to the face from the orbit. This trait is scored on the degree and location of division of the normally single foramen. Some familial and developmental studies suggest a high heritability for this trait.

****The LOCATION/DEGREE (internal/external) of division should be scored *bilaterally*.**

SCORING:

0 – Absent.	There is a single infraorbital foramen without internal division. At most, discontinuous spiculae may be present within the foramen.
1 – Internal.	A thin, continuous spicule of bone located within the canal divides the single infraorbital foramen into two separate openings.
2 – Two.	The foramen is divided into two separate canals by a sheath of bone that occurs on the surface of the maxilla.
3 – 3 or more	Three or more distinct canals are present and divided by bone on the surface of the maxilla.
99 – Unobserv.	This region damaged to a degree that does not permit observation.



ZYGOMATICOFACIAL FORAMINA – Normal porosities are not considered zygomaticofacial foramina. These foramina conduct the zygomaticofacial nerve and vessels to the face, but the reason for development of more than one foramen is unknown. Heritability for the complete absence of this foramen is thought to be low.

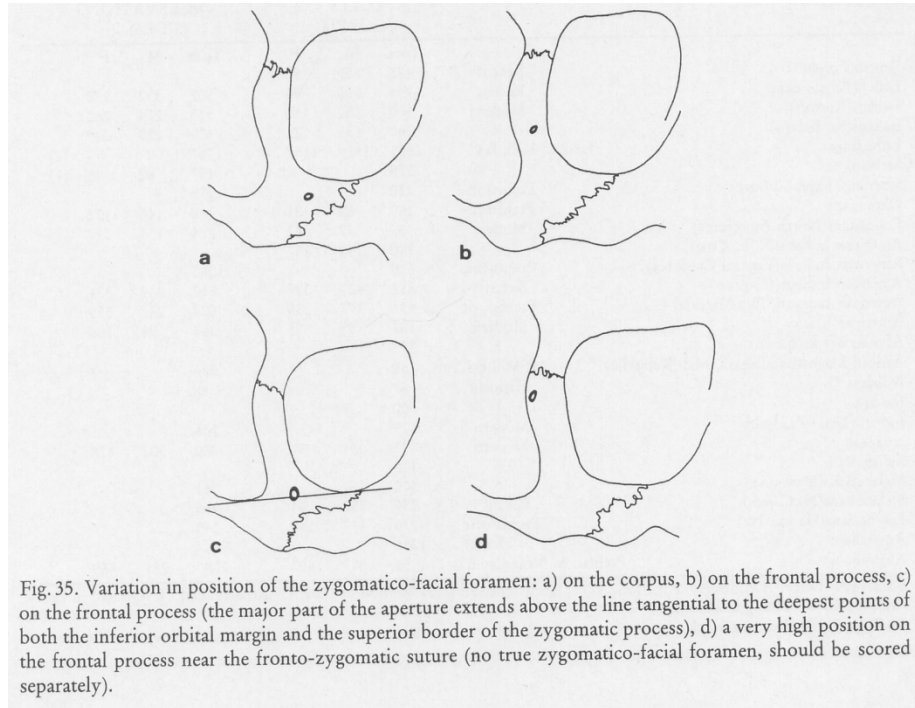
****The NUMBER and SIZE of foramina should be scored *bilaterally*.**

SCORING:

0 – Absent.	No foramen is present inferior or lateral to the eye orbit.
1 – 1 Large.	One foramen greater than 1 mm in diameter is located laterally or inferiorly to the orbit.
2 – 1 Lg.+Sm.	One foramen greater than 1 mm in diameter occurs with one or more smaller foramina (less than 1 mm in diameter).
3 – 2 Large	Two foramina, each greater than 1 mm in diameter, are present either inferior or lateral to the orbit.
4 – 2 Lg.+Sm.	Two foramina greater than 1 mm in diameter occur along with one or more smaller foramina (less than 1 mm in diameter).
5 – 1 Small	One foramen less than 1 mm in diameter is present.
6 – Mult. Sm.	More than one foramen, each less than 1 mm in diameter, occur either lateral

or inferior to the orbit.

99 – Unobserv. This region damaged to a degree that does not permit observation.

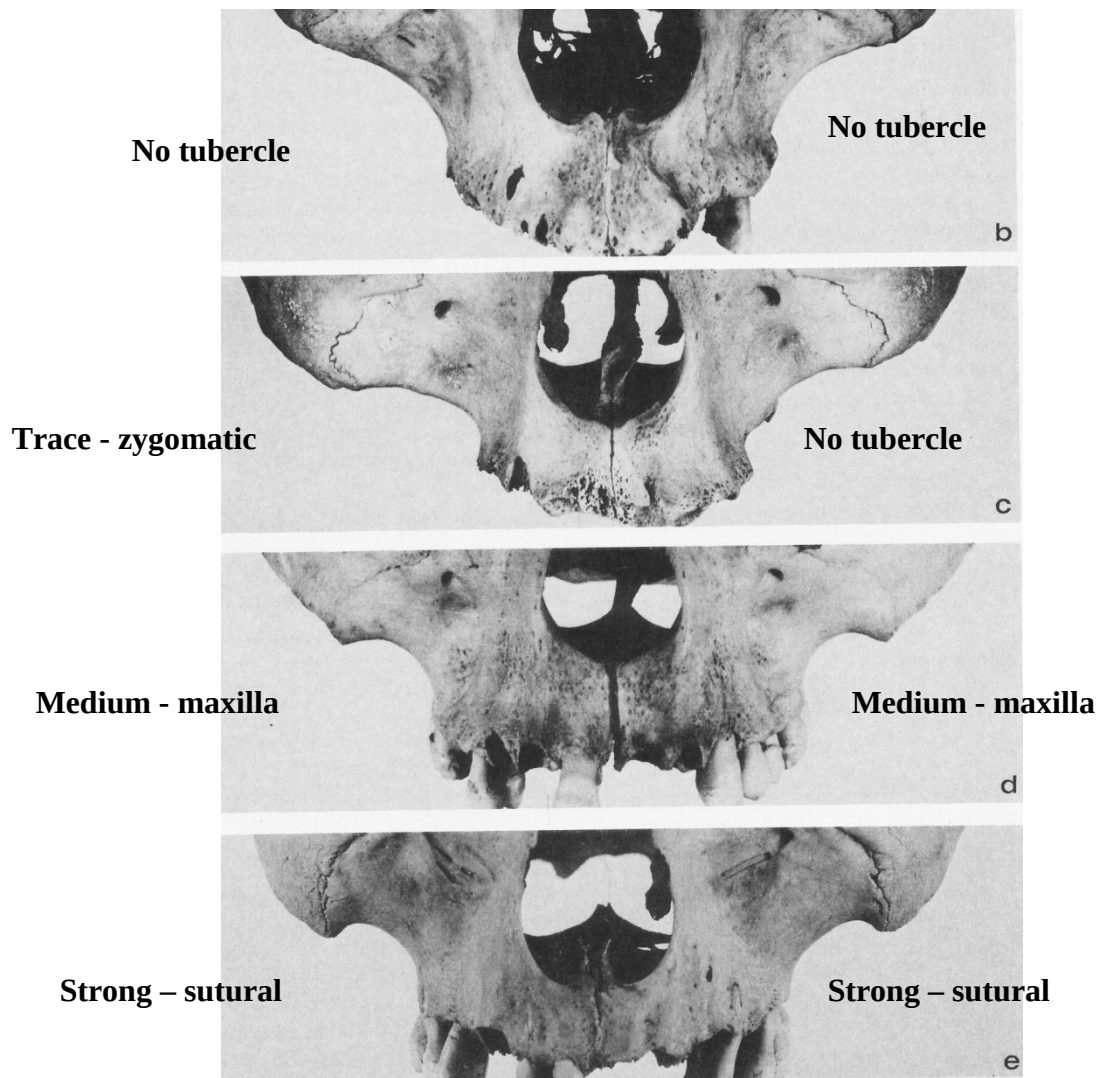


ZYGOMAXILLARY TUBERCLE – The tendinous origin for the masseter muscle is on the inferior margin of the zygomatic process, at approximately the level of the zygomaxillary suture. In some cases, dependent on the exact location and strength of the muscle, a bony tubercle may be present. This trait is thought to have a high genetic component because of its early development, but so far, no studies have been done.

**** The SIZE and LOCATION of this trait should be scored bilaterally.**

SCORING:

(Size)	0 – Absent.	No bony tubercle exists on the inferior border of the zygomatic.
	1 – Trace.	A bony protrusion of less than 2 mm extends below the natural line of the inferior border of the zygomatic bone.
	2 – Medium.	A bony protrusion of between 2 mm and 4 mm extends below the natural line of the inferior border of the zygomatic.
	3 – Strong.	A bony protrusion of 4 mm or more extends below the natural line of the inferior border of the zygomatic.
	99 – Unobserv.	This region damaged to a degree that does not permit observation.
(Location)	0 – Absent.	No bony tubercle exists on the inferior border of the zygomatic.
	1 – Zyg.	The tubercle occurs posterior to the zygomaxillary suture, on the zygomatic bone.
	2 – Sutural	The tubercle occurs at the level of the zygomaxillary suture.
	3 – Max.	The tubercle occurs anterior to the suture, on the maxilla
	99 – Unobserv.	This region damaged to a degree that does not permit observation.



BIPARTITE ZYGOMATIC BONE (OS JAPONICUM) – The zygomatic bone can be divided into two or more individual bones by multiple complex sutures. Usually the bone is bipartite, divided into two pieces of differing sizes by a single horizontal suture. More complex divisions are possible but rare. Surprisingly, the heritability of os japonicum has not been studied, despite general observation that its presence is highest among people of Japanese descent. Make sure this is a suture, rather than a fracture.

****This trait is scored on the EXPRESSION of division, *bilaterally*.**

SCORING:

0 – Absent.	The zygomatic bone shows no extra partial or complete sutures.
1 – Partial.	The zygomatic bone shows partial division by a suture.
2 – Transverse	The zygomatic bone is divided by a single suture that runs antero-posterior in the Frankfort plane.
3 – Oblique.	The zygomatic is divided by a single suture on a curved or diagonal plane.
4 – Multiple.	The zygomatic is divided into more than 2 separate bones by two or more complete sutures.
99 – Unobserv.	This region damaged to a degree that does not permit observation.

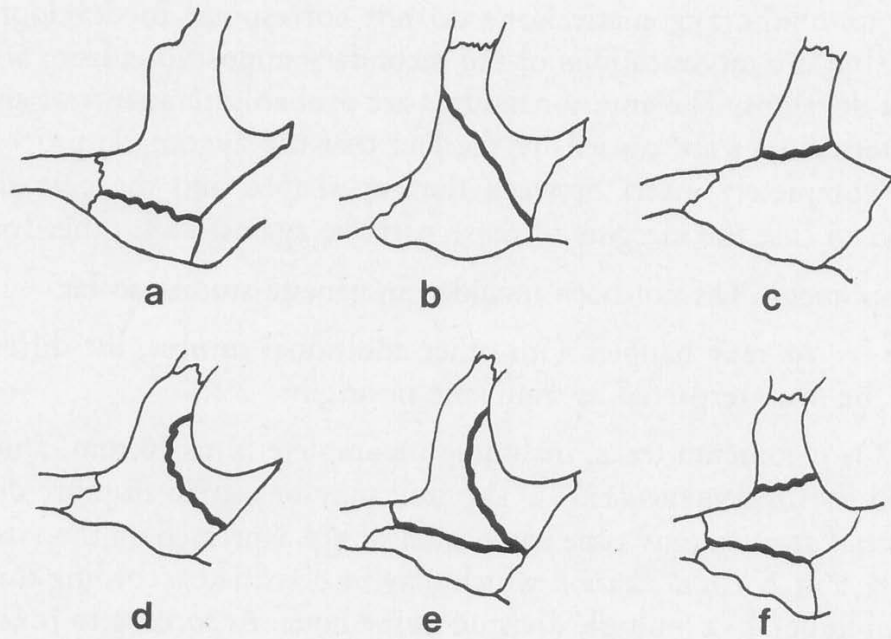


Fig. 34. Variants of complete sutural division of the zygomatic bone: a–d) bipartite; e, f) multipartite. a) single transverse (inferior) suture, b) single oblique (lateral) suture, c) single transverse (superior) suture, d) single oblique (medial) suture, e) transverse (inferior) and oblique (medial) suture. f) transverse (superior) and transverse (inferior) suture.

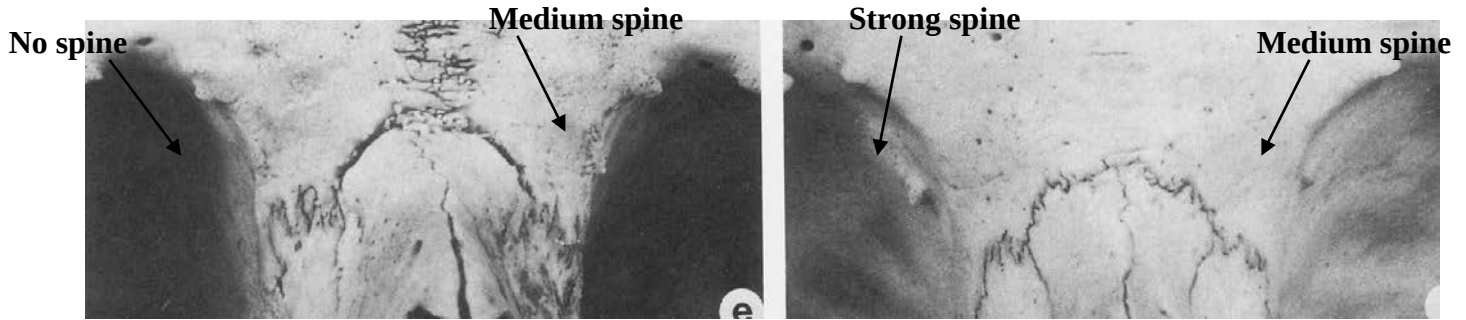
TROCHLEAR SPINE/SPUR – The trochlear pit, located approximately 10 mm above the fronto-lacrimal suture on the edge of the eye orbit, is sometimes replaced by a bony spicule or spine of varying lengths. This spine can be curved or straight, sharp or blunt, and may exist as two separate spines. The trochlear spine/pit is the location for the pulley system of the superior orbital muscle.

****** In scoring this trait, consider the POSITION, SHAPE, DEGREE, and NUMBER of spines/spurs. Score this trait **bilaterally**.

SCORING:

(Position)	0 – Absent.	No trochlear spur/spine is present.
	1 – Superior.	The spine/spur is located high up on the medial margin of the orbit, closer to the superior medial corner.
	2 – Inferior.	The spine/spur is located lower, closer to the frontolacrimal suture.
	99 – Unobserv.	This region damaged to a degree that does not permit observation.
(Shape)	0 – Absent.	No trochlear spur/spine is present.
	1 – Spine.	The bony projection is slender with a sharp tip.
	2 – Tubercle.	The bony projection is more dull, but can be wide or narrow.
	3 – Crest.	The projection is wide, but has a sharp edge.
	99 – Unobserv.	This region damaged to a degree that does not permit observation.
(Degree)	0 – Absent.	No trochlear spur/spine is present.
	1 – Trace.	The spine/spur is only palpable or barely visible.
	2 – Moderate.	Spine projects < 2 mm.
	3 – Strong.	Spine projects > 2mm.
	99 – Unobserv.	This region damaged to a degree that does not permit observation.

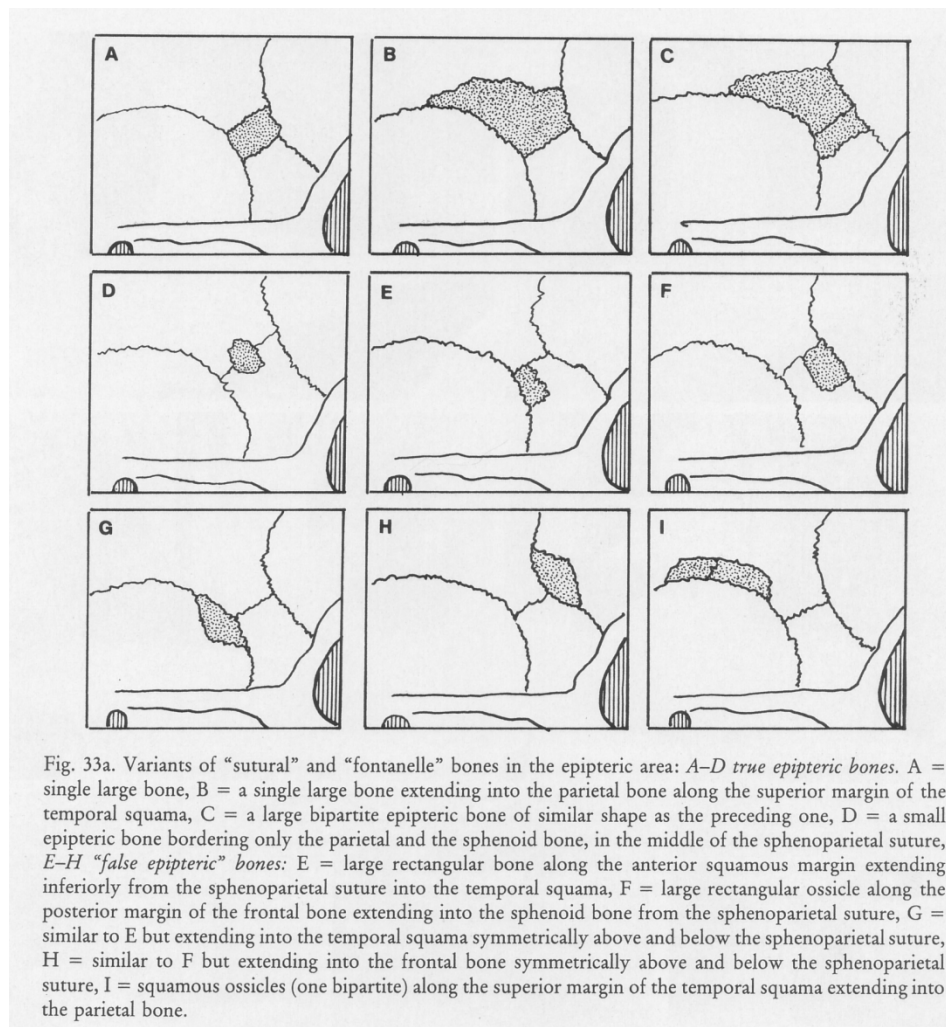
- (Bifid)
- | | |
|----------------|---|
| 0 – Absent. | No bifid spine is present. |
| 1 – Present. | A spine divided into two distinct projections is present. |
| 99 – Unobserv. | This region damaged to a degree that does not permit observation. |



EPIPTERIC BONE (SUTURAL) – This bone occurs as the paired parietal and frontal fontanelles and the greater wings of the sphenoid close after birth. The ossicle can touch 2, 3, or 4 of these connecting bones, and can vary in size and shape.

****Score this trait bilaterally.**

- SCORING:**
- | | |
|----------------|---|
| 0 – Absent. | Suture can be fully observed and contains no sutural bones. |
| 1 – Present. | At least one sutural bone can be seen within the suture. |
| 99 – Unobserv. | This region damaged to a degree that does not permit observation. |



CORONAL OSSICLE (SUTURAL) – This ossicle occurs anywhere along the coronal suture, with the exception of the junction between the sagittal and coronal sutures (bregmatic bone).

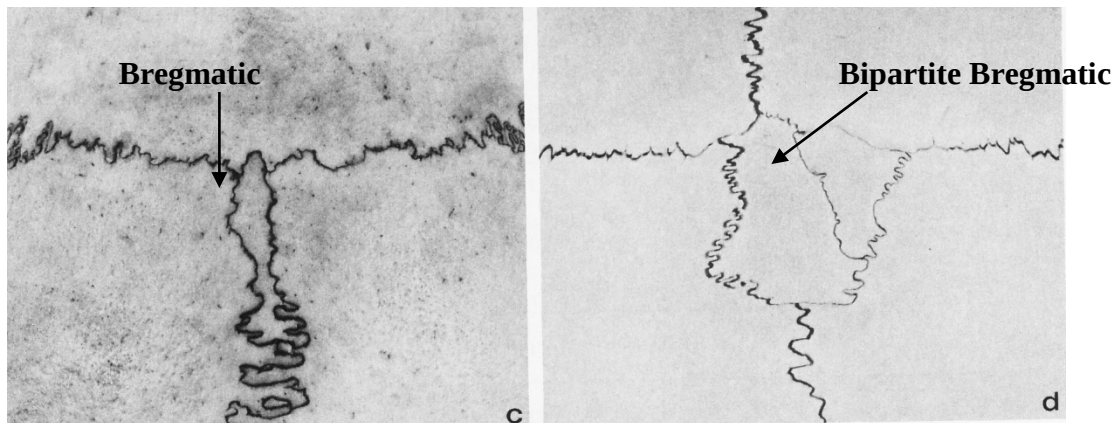
****Score this trait bilaterally.**

SCORING: 0 – Absent. Suture can be fully observed and contains no sutural bones.
 1 – Present. At least one sutural bone can be seen within the suture.
 99 – Unobserv. This region damaged to a degree that does not permit observation.

BREGMATIC BONE (SUTURAL) – This ossicle is located at bregma, or over the point of junction between the sagittal and coronal sutures. It can extend into either suture, and can be divided into several parts.

****Score this trait on the midline.**

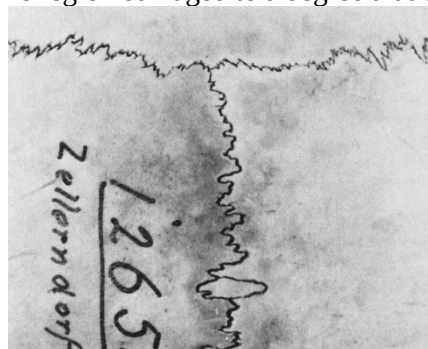
SCORING: 0 – Absent. Suture can be fully observed and contains no sutural bones.
 1 – Present. At least one sutural bone can be seen within the suture.
 99 – Unobserv. This region damaged to a degree that does not permit observation.



SAGITTAL OSSICLE (SUTURAL) – This bone occurs anywhere along the sagittal suture, with the exception of the junctions between the sagittal and coronal, and sagittal and lambdoid sutures.

****Score this trait on the midline.**

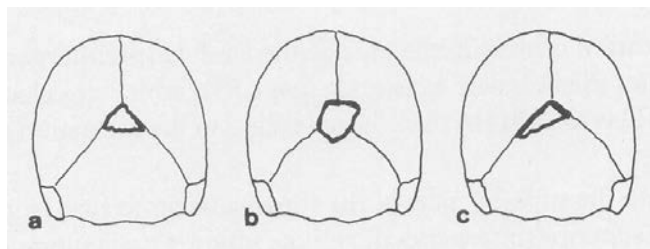
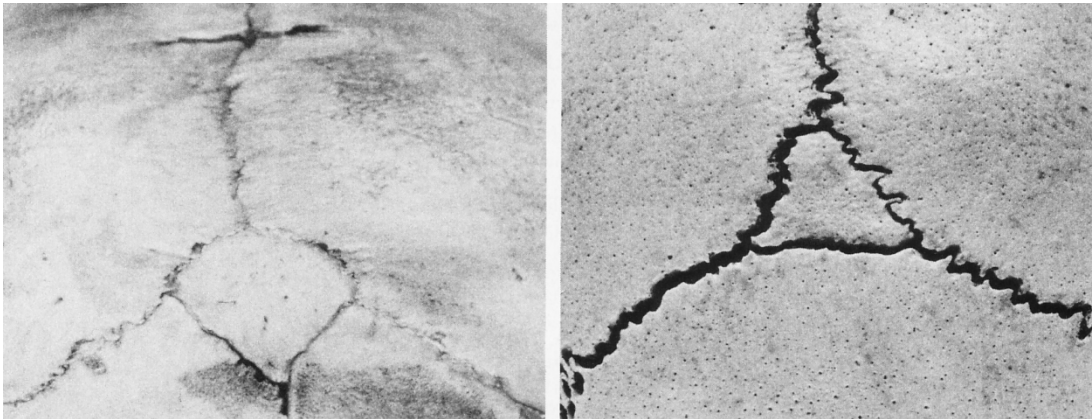
SCORING: 0 – Absent. Suture can be fully observed and contains no sutural bones.
 1 – Present. At least one sutural bone can be seen within the suture.
 99 – Unobserv. This region damaged to a degree that does not permit observation.



APICAL BONE (SUTURAL) – This bone forms between the posterior faces of the parietal fontanelles and the occipital. The apical bone covers lambda. The ossicle can protrude further into the occipital or one or both of the parietals.

****Score this trait on the midline.**

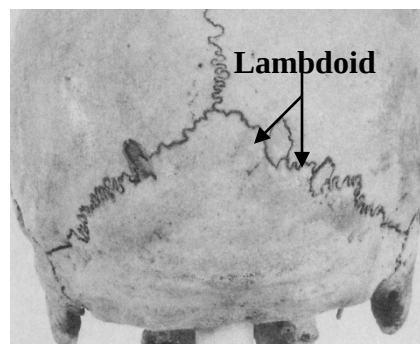
SCORING: 0 – Absent. Suture can be fully observed and contains no sutural bones.
 1 – Present. At least one sutural bone can be seen within the suture.
 99 – Unobserv. This region damaged to a degree that does not permit observation.



LAMBDOID OSSICLE (SUTURAL) – This ossicle occurs anywhere within the lambdoid suture, with the exceptions of the junction of the lambdoid and sagittal sutures, and along the occipitomastoid suture.

****Score this trait bilaterally.**

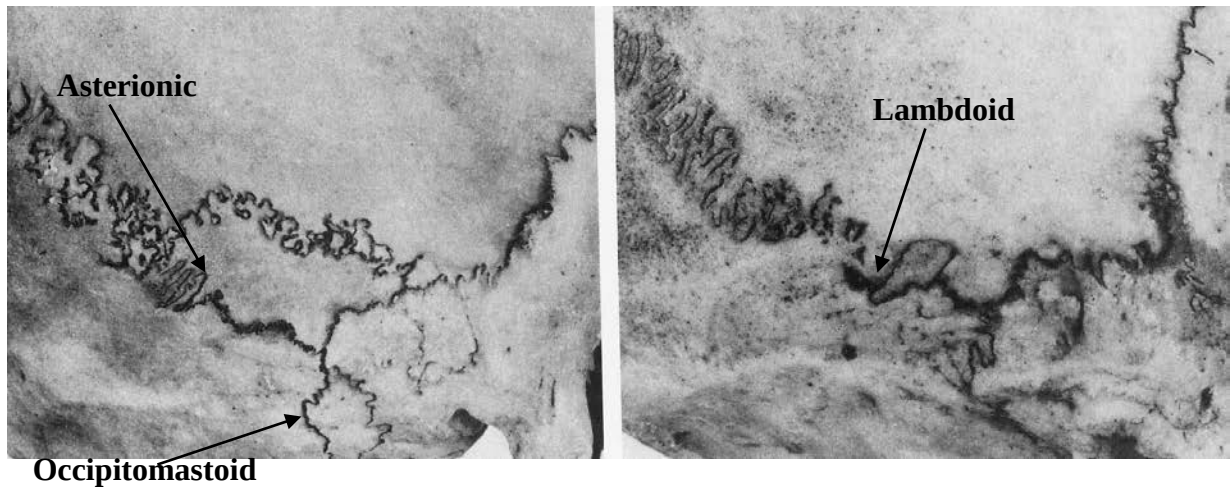
SCORING: 0 – Absent. Suture can be fully observed and contains no sutural bones.
 1 – Present. At least one sutural bone can be seen within the suture.
 99 – Unobserv. This region damaged to a degree that does not permit observation.



ASTERIONIC BONE (SUTURAL) – This bone is located at the junction of the occipital, parietal, and temporal bones, or where the lambdoid suture becomes the occipitomastoid suture.

****Score this trait bilaterally.**

SCORING: 0 – Absent. Suture can be fully observed and contains no sutural bones.
 1 – Present. At least one sutural bone can be seen within the suture.
 99 – Unobserv. This region damaged to a degree that does not permit observation.



OCCIPITOMASTOID SUTURAL BONE – This bone occurs in the suture between the temporal and occipital bones.

****Score this trait bilaterally.**

SCORING: 0 – Absent. Suture can be fully observed and contains no sutural bones.
 1 – Present. At least one sutural bone can be seen within the suture.
 99 – Unobserv. This region damaged to a degree that does not permit observation.

PARIETAL NOTCH BONE (SUTURAL) – This ossicle is located between the parietal and the squamosal section of the temporal, or where the parietal bone notches into the posterior temporal bone above the mastoid process.

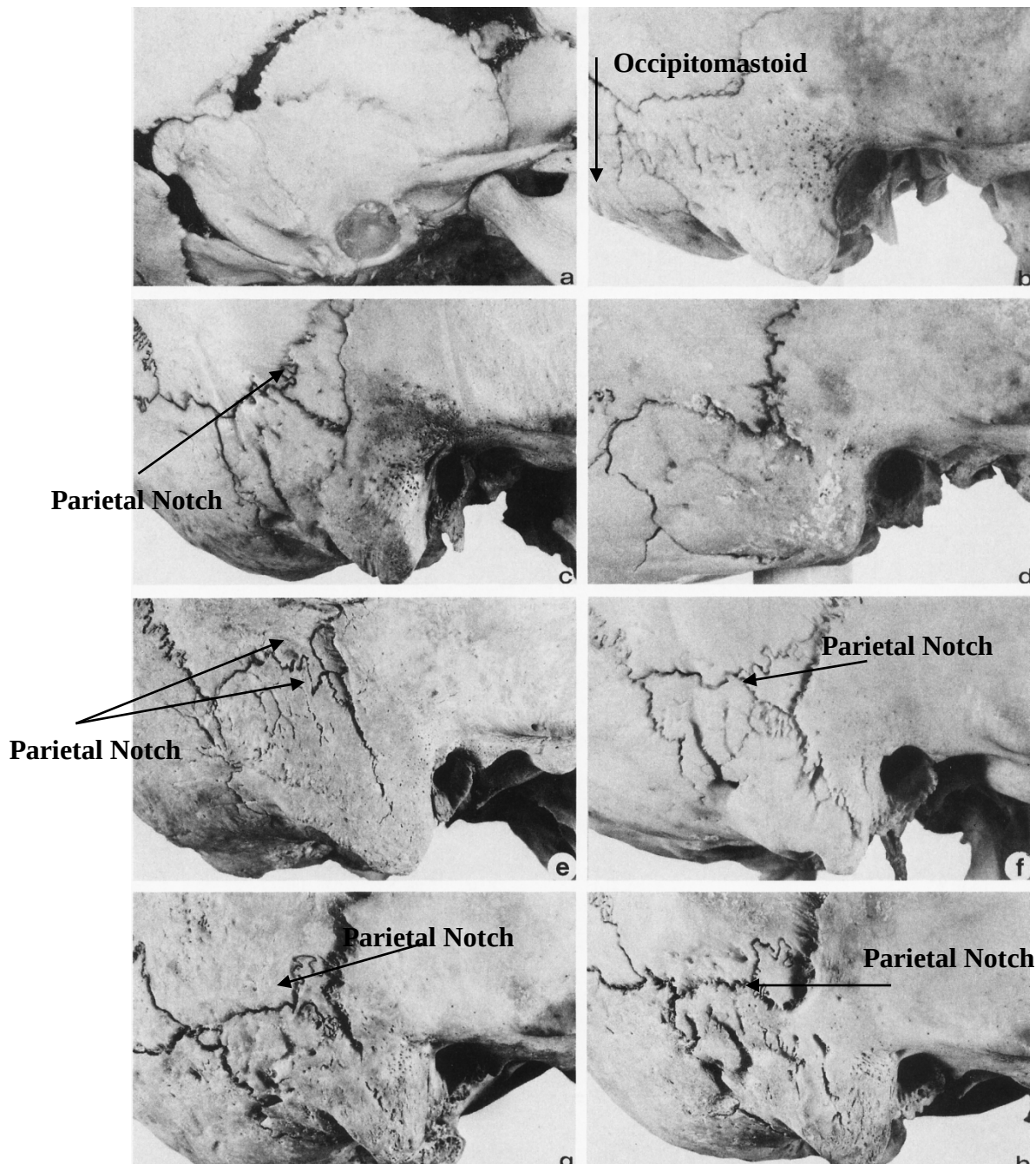
****Score this trait bilaterally.**

SCORING: 0 – Absent. Suture can be fully observed and contains no sutural bones.
 1 – Present. At least one sutural bone can be seen within the suture.
 99 – Unobserv. This region damaged to a degree that does not permit observation.

SQUAMOSAL OSSICLE (SUTURAL) – This bone occurs anywhere along the squamosal suture between the temporal and parietal bones with the exception of the parietal notch.

****Score this trait bilaterally.**

SCORING: 0 – Absent. Suture can be fully observed and contains no sutural bones.
 1 – Present. At least one sutural bone can be seen within the suture.
 99 – Unobserv. The suture is obliterated or damaged to a degree that does not permit observation.

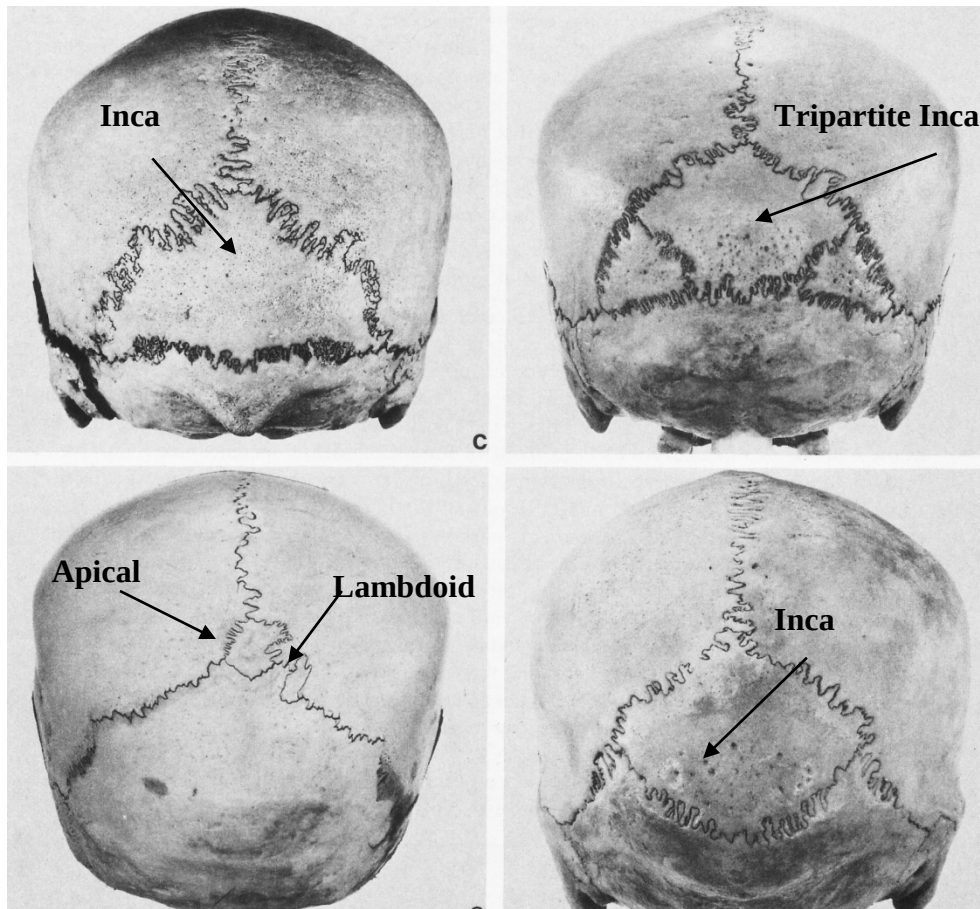


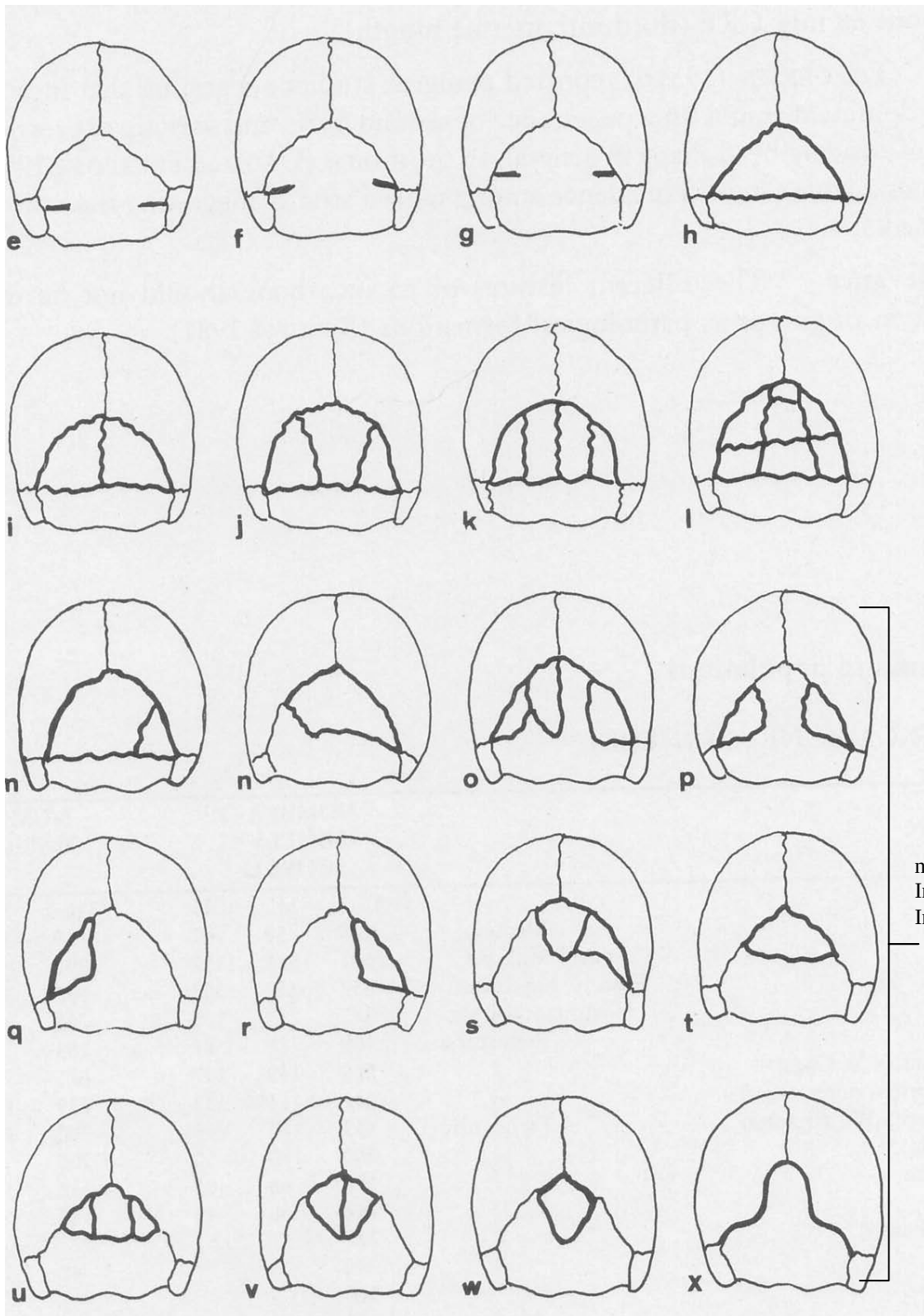
INCA BONE – This bone is formed when a suture divides the occipital at the level of the most superior nuchal crest. This bone can be divided further into two or more pieces by infero-superior or diagonal sutures. While there appears to be no relevant function for the formation of the Inca bone, it has a high hereditary value, and probably varies in pattern due to the shape of the skull.

SCORING:	0 – Absent.	The occipital consists of a single, undivided bone.
	1 – Complete.	The Inca bone is distinct from the inferior occipital, but it only exists as a single bone, not further divided by other sutures.
	2 – Bipartite.	The Inca bone contains one infero-superior suture that bisects it into either asymmetrical or symmetrical pieces.
	3 – Tripartite.	The Inca bone is divided into three symmetrical or asymmetrical pieces by the addition of two longitudinal or diagonal sutures.

4 – Partial. - The transverse suture of the Inca bone along the superior nuchal line is incomplete.

99 – Unobserv. The occipital is damaged to the extent that this trait cannot be assessed.

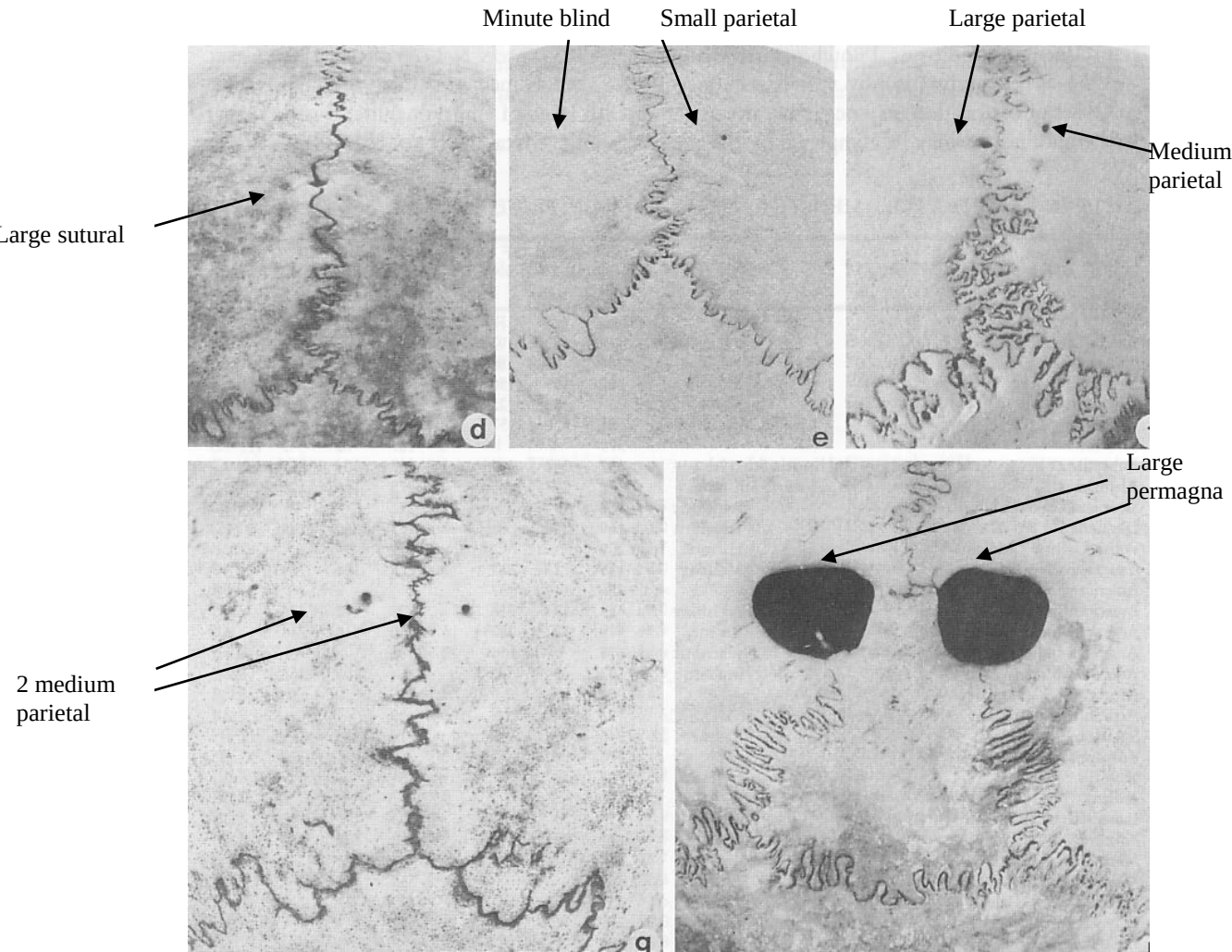




PARIETAL FORAMEN – While the foramina are usually located bilaterally on the parietal bones near the sagittal suture, they can also be unilaterally or bilaterally absent, or occur within the suture. The parietal foramen transports Santorini’s vein into an anastomosis of veins on the parietal. Heritability appears to be high.

Score this trait **bilaterally.

SCORING:	0 – Absent.	No foramen is present in the suture or on the parietal proper.
	1 – Present, parietal.	A foramen (large or small) is expressed on the parietal bone and is not associated with the sagittal suture.
	2 – Present, sutural.	A foramen is observed with the sagittal or lambdoid suture.
	99 – Unobserv.	This region is damaged to the extent that this trait cannot be assessed.

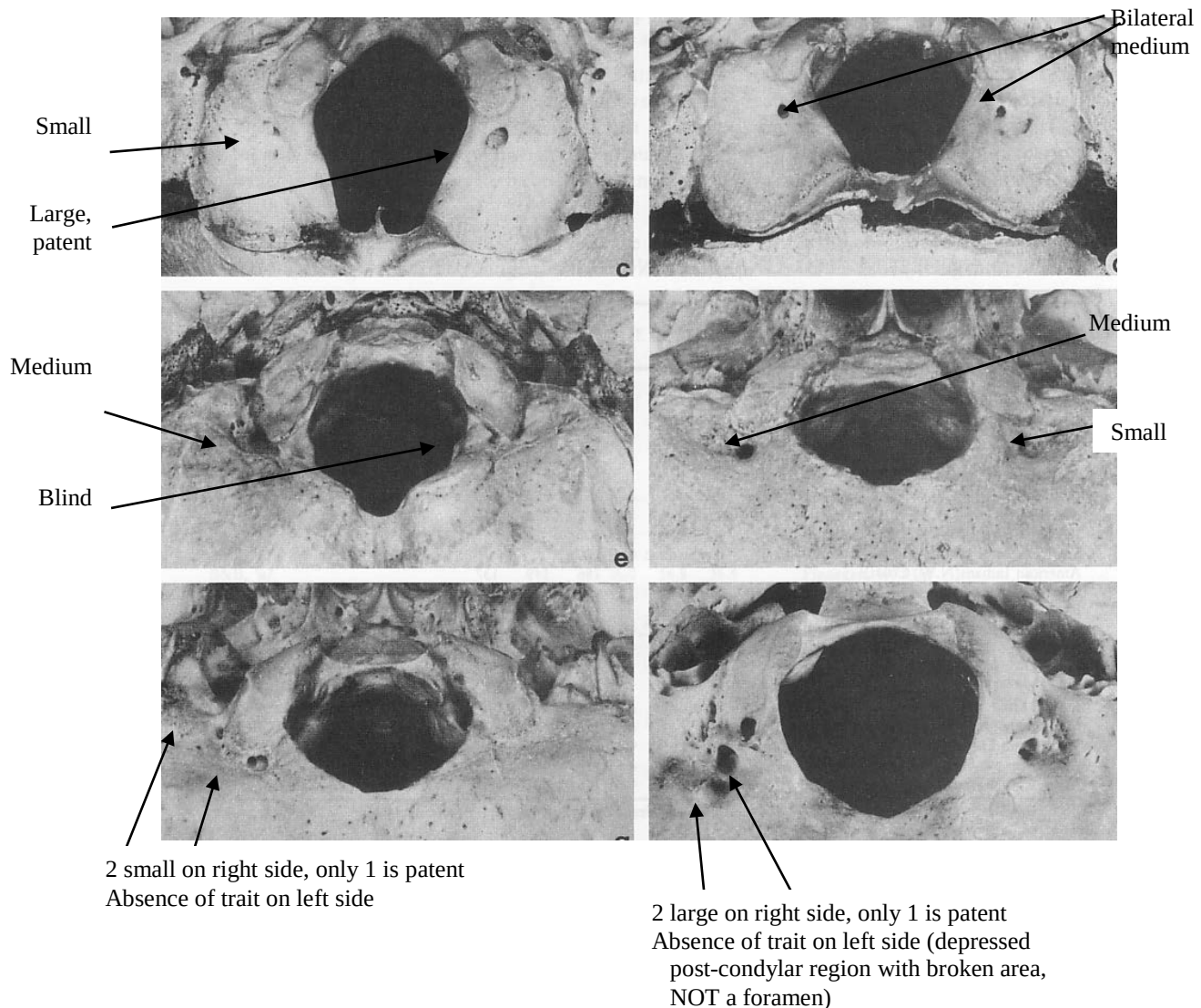


CONDYLAR CANAL – Located posterior to the occipital condyles in the condylar fossa, the condylar canal can be patent internally or not patent. In addition, it can be completely absent or divided into two canals by a bony bridge. The important observation is patency. This canal transports an emissary vein to join the sigmoid sinus. Heritability rates are very low.

****Score this trait bilaterally.**

SCORING:

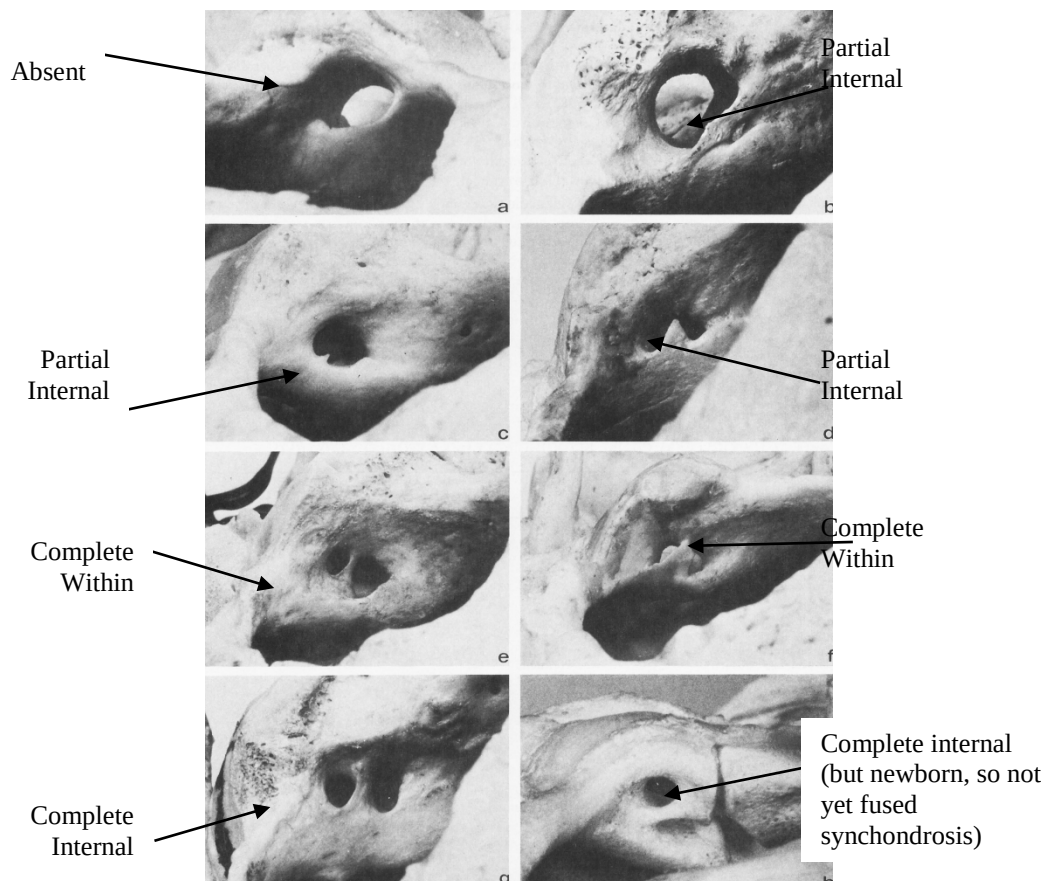
- 0 – Absent. There is no visible opening in the condylar fossa.
- 1 – Not patent. An external opening exists on the condylar fossa, but it does not extend into the cranial cavity. Determine this using a broom bristle.
- 2 – Patent. An external opening exists on the condylar fossa, and it extends fully into the cranial cavity.
- 99 – Unobserv. This region is damaged to the extent that this trait cannot be assessed.



DIVIDED HYPOGLOSSAL CANAL – The hypoglossal canal is oriented medio-laterally at the base of the occipital condyle. It is best viewed by tipping the foramen magnum to a shallow angle and, with your head over one of the occipital condyles, looking at the base of the other occipital condyle. The degree of division within the canal should be scored. The hypoglossal canal carries the XIIth cranial nerve as well as a venous plexus. Since the shape and pattern of division of this canal are developed before birth, most geneticists believe that a genetic component and heritability levels are high.

****Score this trait bilaterally.**

SCORING:	0 – Absent.	The canal is completely undivided; no spiculae or osseous bridges obstruct the canal opening.
	1 – Part, internal.	A spicule or nodule of bone originating from the internal surface of the foramen magnum (the surface you are observing) protrudes OVER the canal opening, although not completely. Can originate from top or bottom.
	2 – Part, within.	A spicule or nodule of bone originating from the roof or floor WITHIN the canal protrudes into the opening, but does not completely divide it.
	3 – Compl, internal.	An osseous bridge located on the internal surface of the foramen magnum completely divides the canal.
	4 – Compl, within.	An osseous bridge located within the canal itself completely divides the canal.
	99 – Unobserv.	This region is damaged to the extent that this trait cannot be assessed.



FLEXURE OF SUPERIOR SAGITTAL SULCUS – This is a tactile, rather than visual trait. Follow the groove for the superior sagittal sulcus on the internal surface of the occipital with your index finger. It will flex diagonally inferior to the right, left, or split and run in both directions. The flexure should form a smooth change from the longitudinal groove; if you feel your finger run over a raised area (the internal occipital protuberance), the sulcus probably flexes to the other side. This trait is assessed along the midline. This groove holds the transverse sinus.

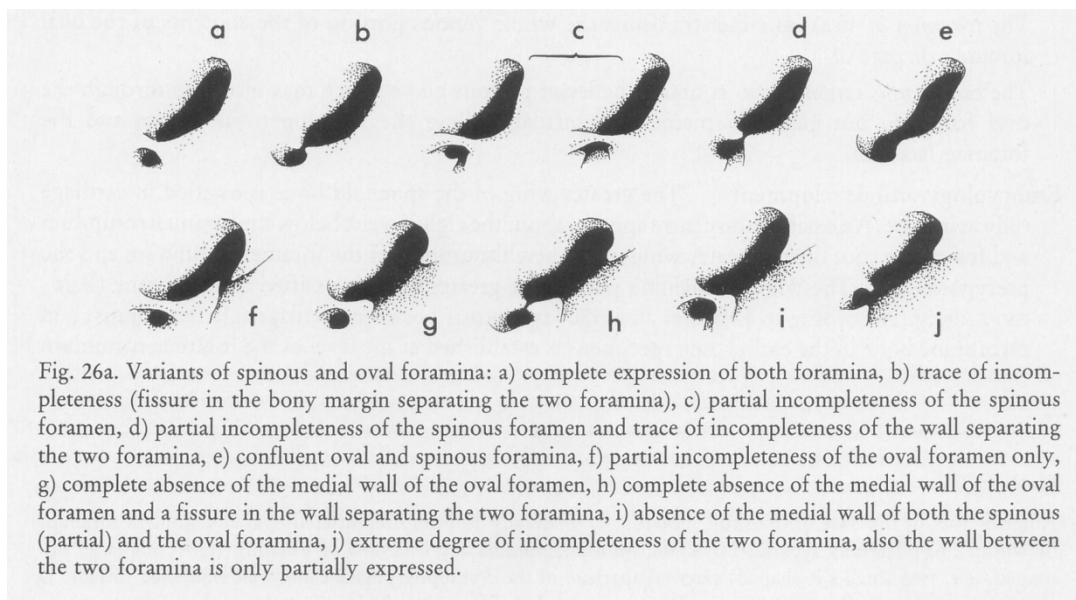
SCORING: 1 – Right. The groove flexes to the right.
 2 – Left. The groove flexes to the left.
 3 – Bifurcated. The groove splits into two separate channels that flex to either side.
 99 – Unobserv. The occipital is damaged to the extent that this trait cannot be assessed.

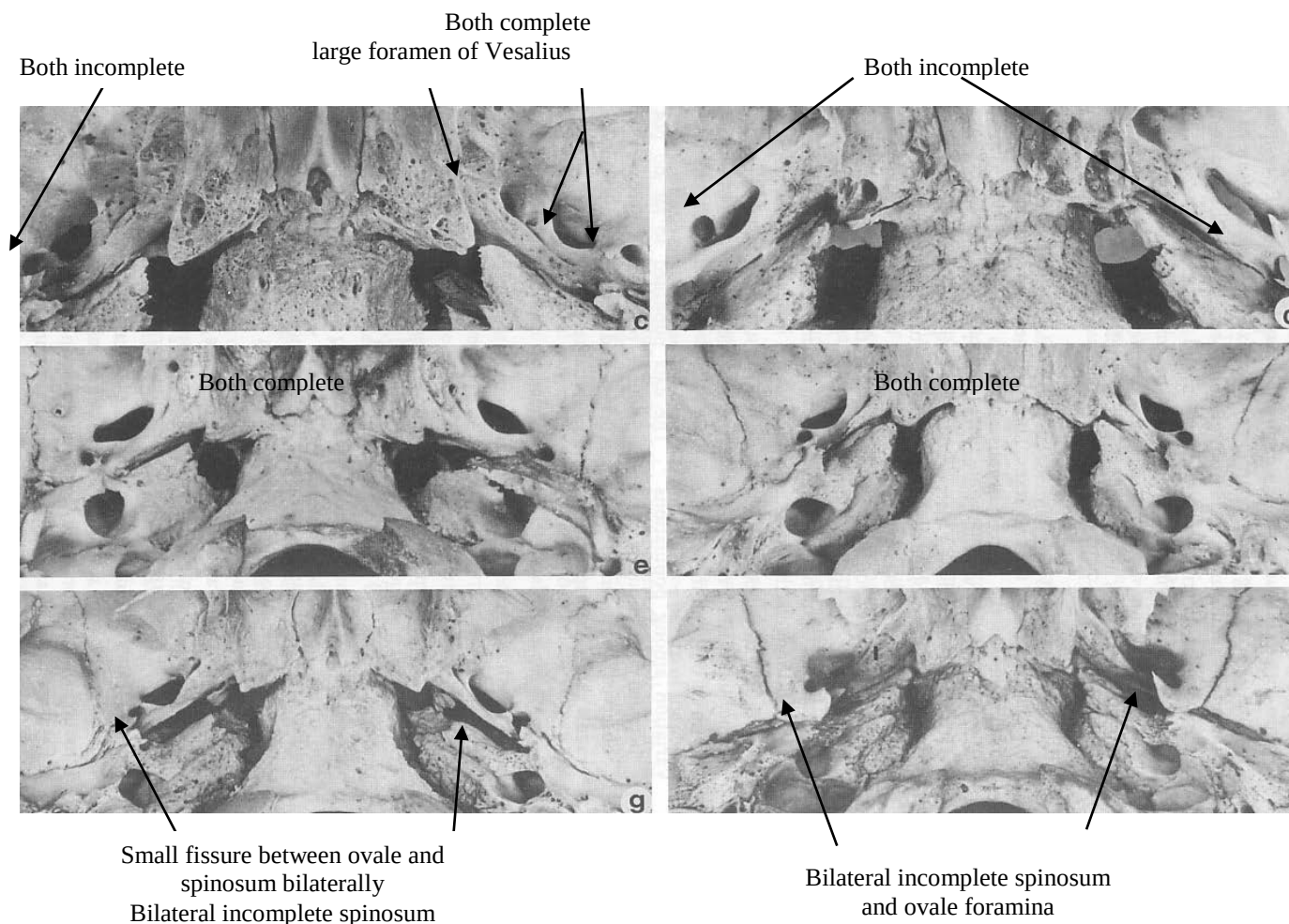
FORAMEN OVALE INCOMPLETE

FORAMEN SPINOSUM INCOMPLETE – The foramen ovale is located on the posterior portion of the greater wing of the sphenoid, lateral to the sphenoid body. The foramen spinosum is located directly POSTERIOR to foramen ovale (the foramen located anterior to foramen ovale is the foramen of Vesalius). When complete, the foramen ovale is bounded on all sides by bone. Incomplete foramina ovale will often be connected to adjacent foramina, or show spiculae that do not quite touch to complete the oval. The single heritability study done on this trait suggests that it is highly heritable. The foramen spinosum is much smaller than foramen ovale, and can exist as a distinct opening, an almost complete foramen, or as an incomplete opening that is attached to its larger neighbor.

****Score this trait bilaterally.**

SCORING: 0 – Absent. The foramen ovale or spinosum is COMPLETE, and surrounded by a ring of bone. It can be differentiated from all other surrounding foramina.
 1 – Partial. The foramen is almost complete, but is not fully ringed by bone or it joins a nearby foramen to a small extent (less than 50%)
 2 – No definition. The foramen ovale or spinosum is INCOMPLETE. It is not close to being complete, or it joins with nearby foramina to a significant extent (> 50%)
 99 – Unobserv. The sphenoid is damaged to the extent that this trait cannot be assessed.



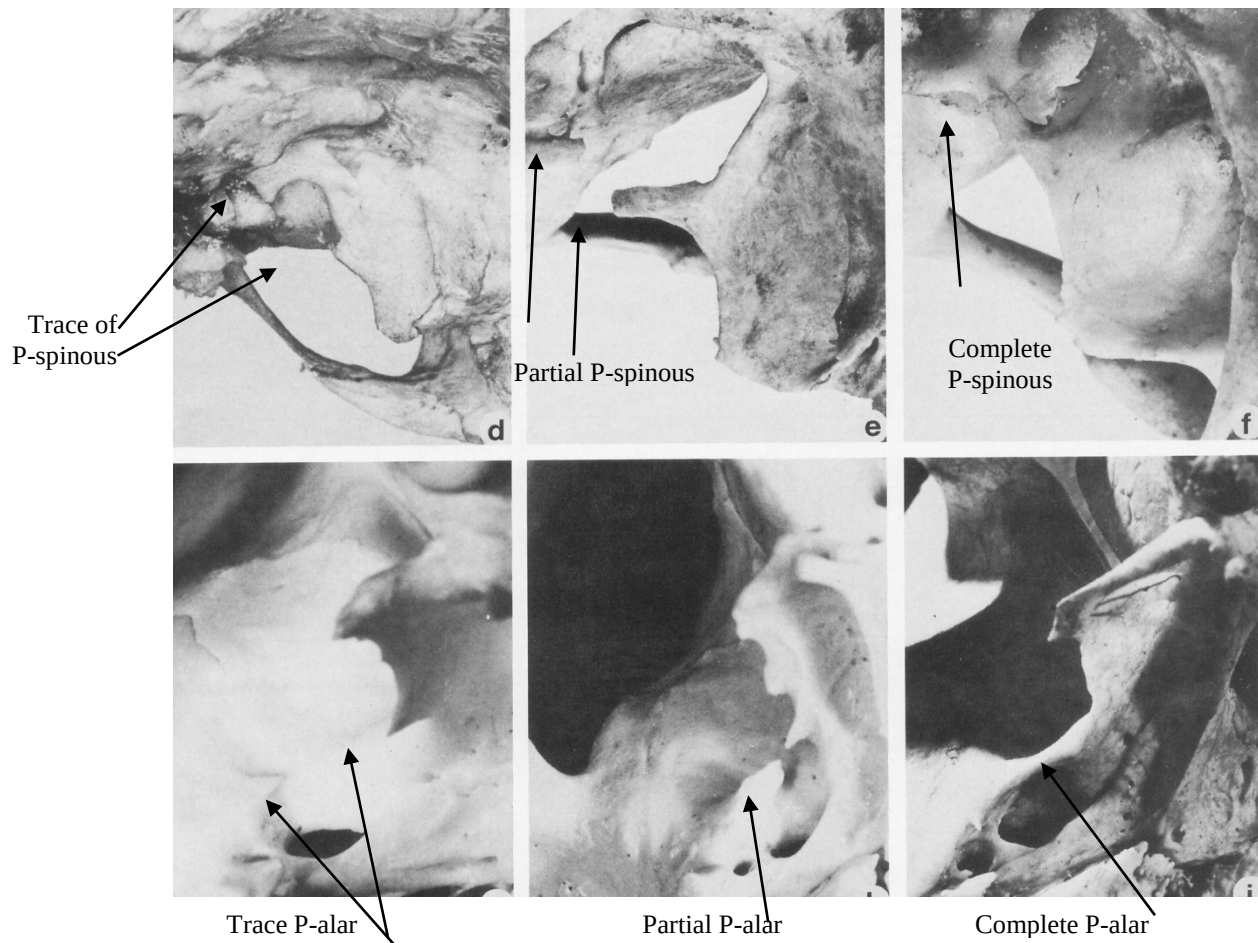
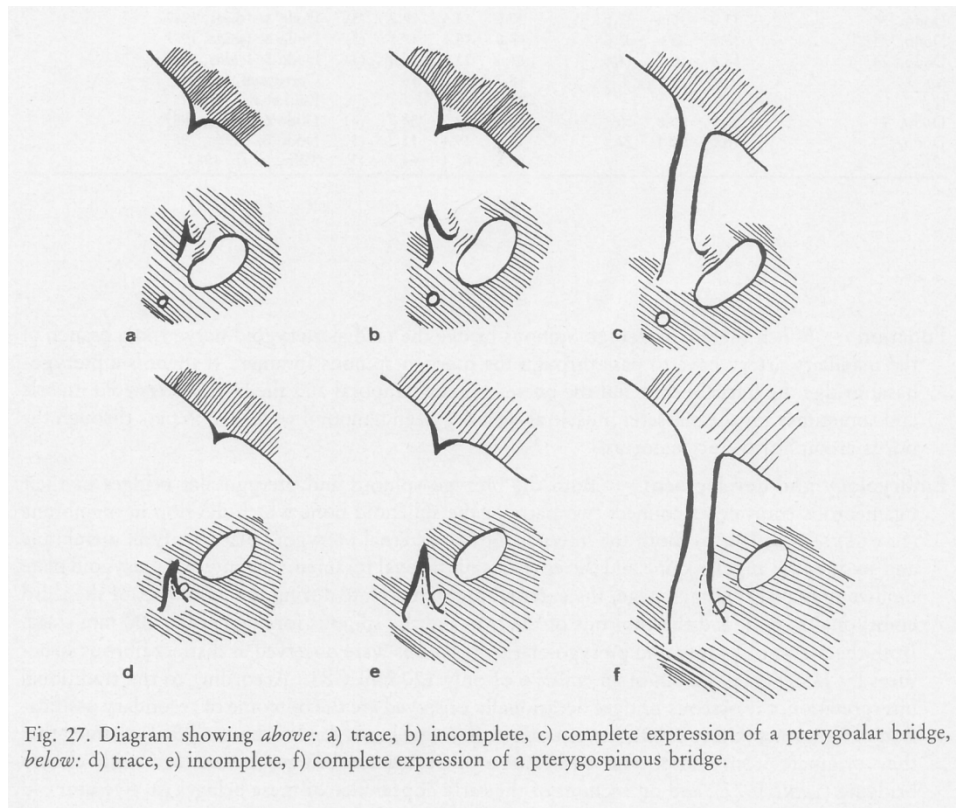


PTERYGOSPINOUS BRIDGE

PTERYGOALAR BRIDGE – The pterygospinous and pterygoalar bridges are scored according to degrees of development. On the basilar sphenoid, a spicule of bone may exist originating posterior to the foramen spinosum. When this spicule joins one descending from the margin of the lateral pterygoid lamina, the pterygospinous bridge is complete. The distinguishing factor between this trait and the pterygoalar bridge is the location of the posterior portion of the spine; for the pterygospinous bridge, it originates POSTERIOR to foramen spinosum (as well as to foramen ovale), while in the case of the pterygoalar bridge, it originates on the LATERAL side of foramen ovale and/or foramen spinosum. The pterygoalar bridge is complete when this postero-lateral portion meets a spicule of bone descending from the margin of the lateral pterygoid lamina. These bridges are involved in the routing of cranial nerves and arteries.

****Score this trait bilaterally.**

SCORING:	0 – Absent.	The regions in which a bridge would form are smooth and show no evidence of spicule formation
	1 – Trace.	SPICULE ONLY. Very small spiculae of bone are observed in the superior and inferior regions discussed above.
	2 – Partial.	Spiculae have elongated, but do not meet.
	3 – Complete.	A full bridge of bone extends between the margin of the lateral pterygoid lamina and the regions either lateral to or posterior to the aforementioned foramina.
	99 – Unobserv.	The area is damaged to the extent that this trait cannot be assessed.

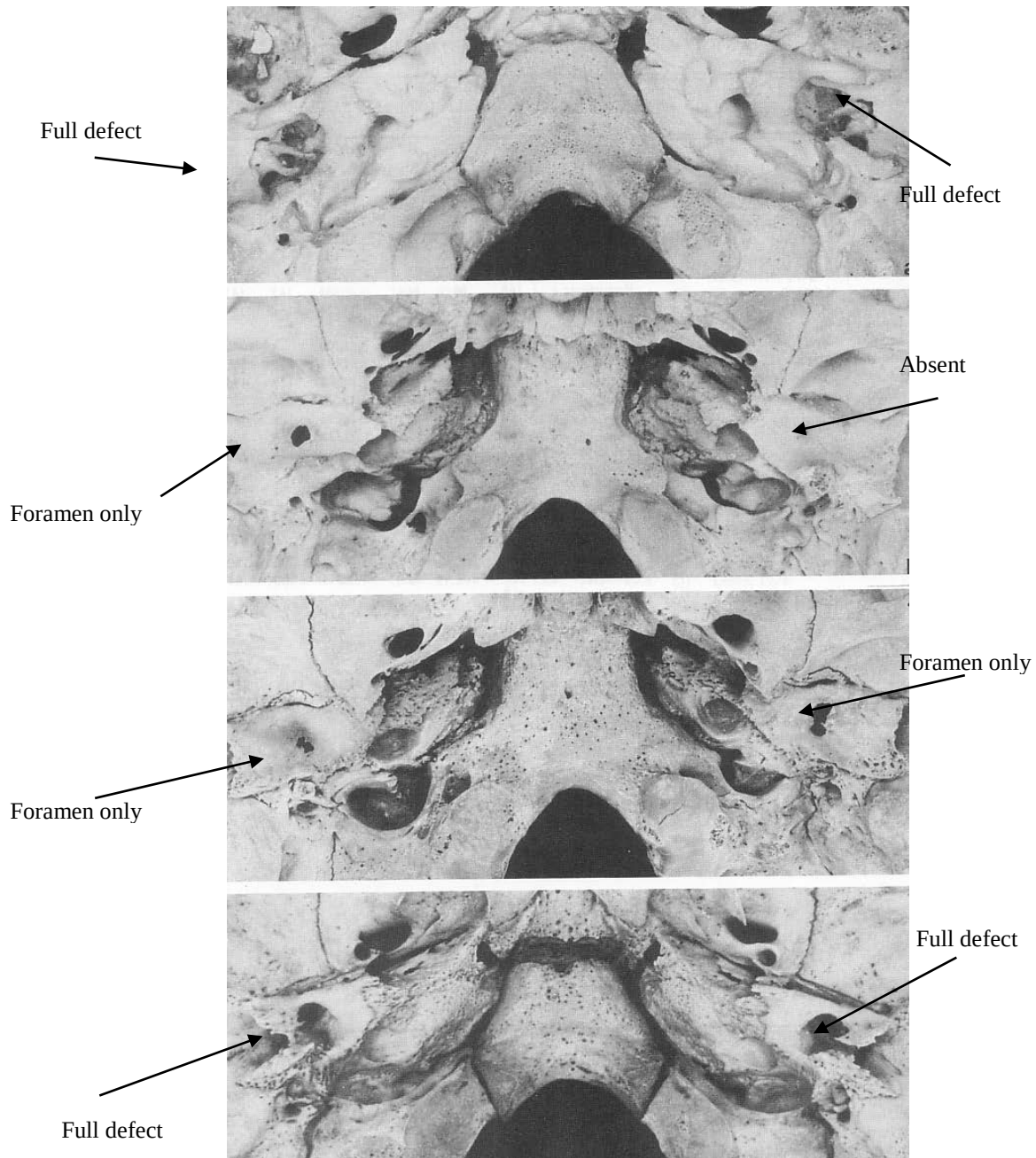


TYMPANIC DEHISCENCE/FORAMEN OF HUTSCHKE – The tympanic plate is the floor of the external acoustic meatus; tympanic dehiscence is the partial or complete lack of this plate. Occasionally, the plate will show thinning, but unless there is at least a foramen present (the Foramen of Hutschke), this trait should be scored as absent.

****Score this trait bilaterally.**

SCORING:

0 – Absent.	The tympanic plate is present and shows no patent foramina.
1 – Foramen.	At least one foramen of any size and shape is evident on the tympanic plate.
2 – Full defect.	The tympanic plate is completely absent, allowing you to see into the auditory meatus.
99 – Unobserv.	The region is damaged to the extent that this trait cannot be assessed.



AUDITORY EXOSTOSIS – The auditory exostosis is a protrusion of bone across part of all of the auditory canal. Generally, this protrusion originates from either the superficial margin of the canal, or deeper inside. Scoring relies on the degree of occlusion of the bone over the canal. The genetic contribution to the presence of this trait is undetermined, but some studies indicate that cold water swimming may play a significant role in its development.

****Score this trait bilaterally.**

SCORING:

0 – Absent.	No exostoses are visible in the ear canal.
1 - <1/3 canal.	Less than one-third of the TOTAL area of the canal is covered by bony protrusions.
2 – 1/3 to 2/3.	Between one- and two-thirds of the TOTAL area of the canal is covered by bony protrusions.
3 - > 2/3 canal.	More than two-thirds of the TOTAL area is covered by bony protrusions.
99 – Unobserv.	The region is damaged to the extent that this trait cannot be assessed.

MASTOID FORAMEN – Connected to the sigmoid sinus, the mastoid canal transports a variety of vessels. It can sometimes send branches of the occipital artery to the outer surface of the cranium; these pass through mastoid foramina that are located on the temporal, occipital, occipitomastoid surface, or on any combination of these. The location and number of foramina do not appear to have a large genetic component, and probably result from fetal blood supply variations. Both the number and location of the foramina should be assessed.

****Score this trait bilaterally.**

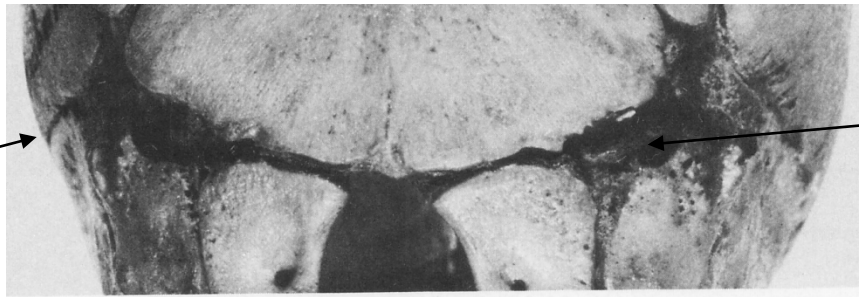
SCORING:

(Location)	0 – Absent.	None of the regions mentioned above show mastoid foramina.
	1 – Temporal.	At least one mastoid foramen is located on the temporal bone.
	2 – Sutural.	At least one mastoid foramen is located within the occipitomastoid suture.
	3 – Occipital.	At least one mastoid foramen is located on the occipital bone.
	4 – Sut & Temp	Foramina occur on the temporal bone AND occipitomastoid suture.
	5 – Occip & Temp	Foramina occur on the occipital AND temporal bone.
	99 – Unobserv.	The region is damaged to the extent that this trait cannot be assessed.

(Number)	0 – Absent.	No mastoid foramina present.
	1 – One.	One mastoid foramen is present.
	2 – Two.	Two mastoid foramina are present.
	3 – Three+	More than 2 foramina are present
	99 – Unobserv.	The region is damaged to the extent that this trait cannot be assessed.

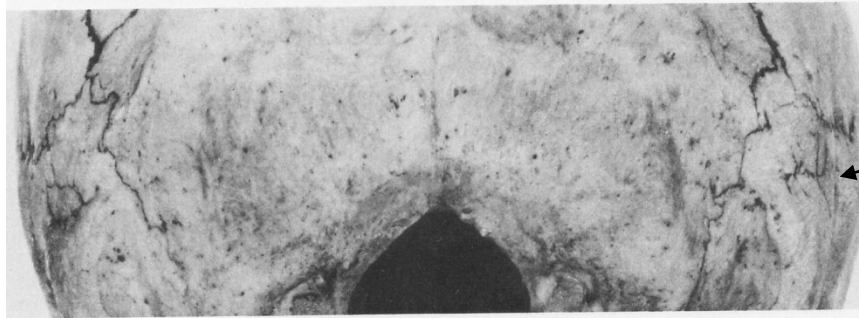
Large temporal

Large temporal



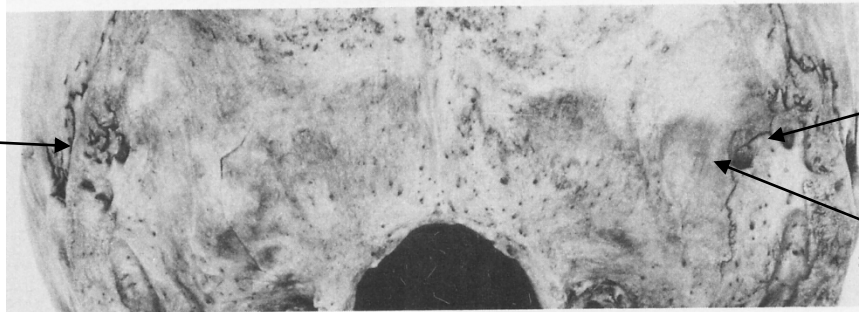
Absent

Absent



Small sutural
Small temporal

Small temporal
Medium
sutural-temporal



Medium temporal
mastoid

2 small temporal
mastoid



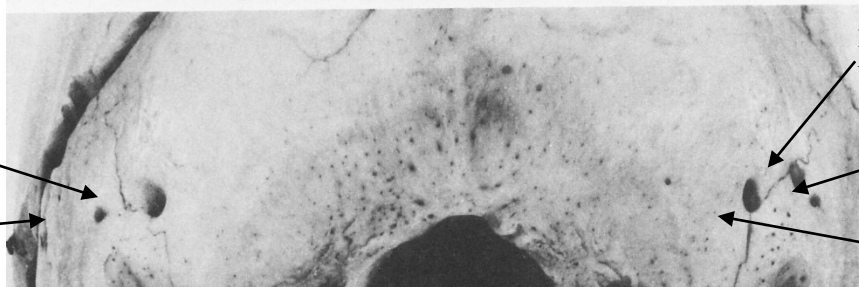
Large sutural-
occipital

Small temporal

Large sutural-
temporal

Small temporal

Large sutural-
occipital

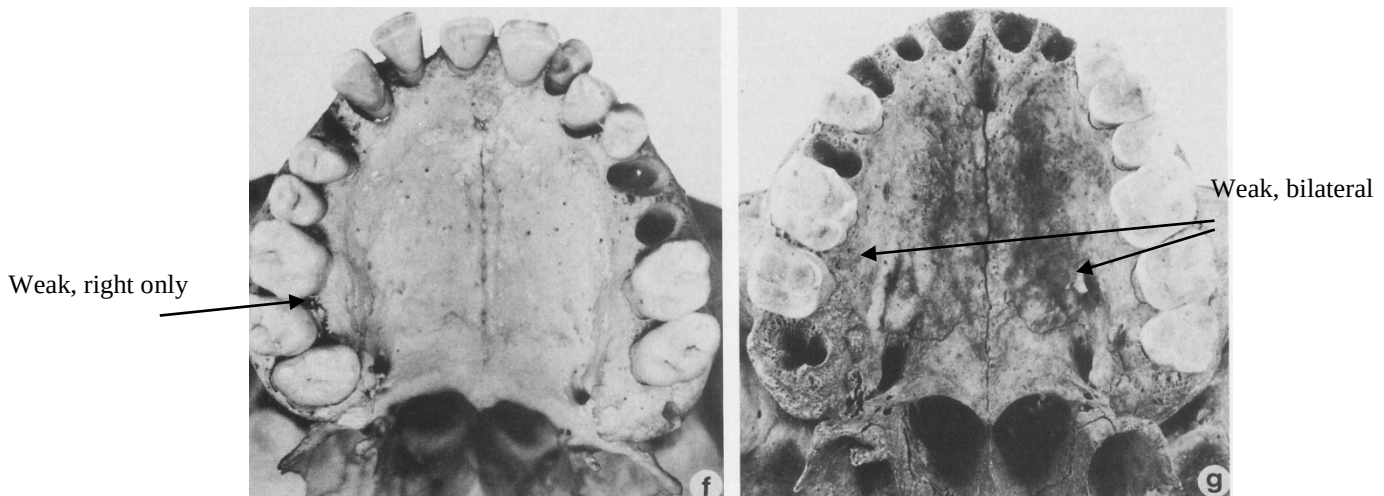


MAXILLARY TORUS – Occasionally, the alveolar bone on the lingual surface of the first and second maxillary molars will be enlarged, most likely reflecting chewing forces. The hypertrophy usually takes the form of nodules on the lingual surface, but may also appear on the labial alveolus, or extend over 5 mm in elevation. The amount of genetic contribution to the maxillary torus is not known, but the environment is also thought to play a part. This trait is scored based on its degree of development.

****Score this trait bilaterally.**

SCORING:

0 – Absent.	No maxillary torus is present.
1 – Small.	Small bony nodules. Slight elevation of lingual alveolar bone around the molars.
2 – Large.	Well-developed protrusion. Clear elevation of the lingual and possibly labial alveolar bone around the molars.
3 – Marked.	Elevation is > 5 mm.
99 – Unobserv.	The region is damaged to the extent that this trait cannot be assessed.



PALATINE BRIDGING – The medial and lateral palatine grooves originate from the greater palatine foramen and travel up the hard palate as far as the canine. These grooves conduct nerves and vessels to the hard palate, and can form spiculae along either or both sides of each groove. When these spiculae or spines join across one of the grooves, they form a bony bridge with a canal to better hold the various vessels. The degree of completeness and position of the bridge should be assessed. Although single-site observations suggest that there might be a genetic component to the formation of these bridges, no concentrated cross-cultural study has been attempted.

****Score this trait bilaterally.**

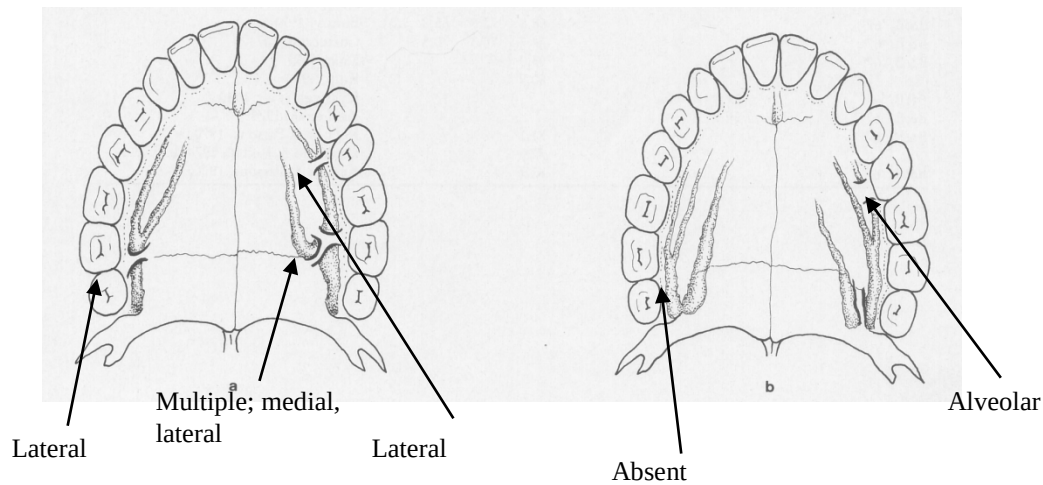
SCORING:

(Completeness)

0 – Absent.	No palatine bridging is observed.
1 – Incomplete.	Spiculae or tubercles may be present along the grooves, but none of these ossify with projections on the opposite side of the groove.
2 – Complete.	Spines on either side of the groove have completely ossified.
99 – Unobserv.	The region is damaged to the extent that this trait cannot be assessed.

(Position)

0 – Absent.	No palatine bridging is observed.
1 – Medial.	A bridge is formed over the medial palatine groove.
2 – Lateral.	A bridge is formed over the lateral palatine groove.
3 – Alveolar.	A bridge is formed over a lateral branch of the lateral palatine groove, usually up into the alveolar bone.
99 – Unobserv.	The region is damaged to the extent that this trait cannot be assessed.

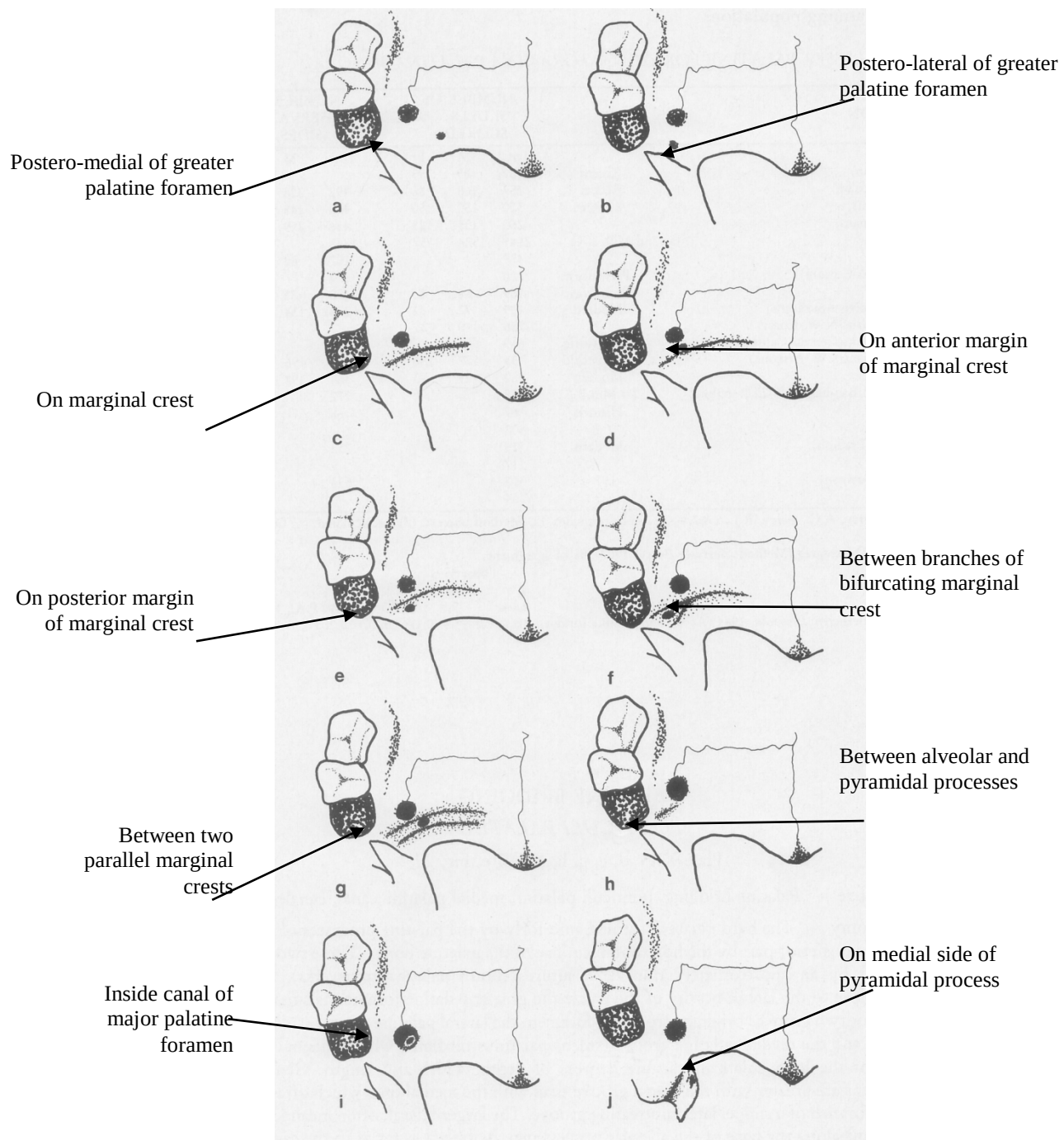


LESSER PALATINE FORAMINA – Medial to the posterior alveolar process lies the major palatine foramen. Posterior to this foramen, the horizontal palatine lamina extends postero-laterally, and in this region, one or more smaller foramina may exist. These are the lesser palatine foramina, and they vary in number, shape, size, and location on the horizontal palatine lamina. They are responsible for transporting nerves and vessels to the soft palate, but it appears from low heritability estimates that the patterning of the vessels is not under stringent genetic control. Most often, these foramina are slit-shaped.

Score each descriptor of this trait **bilaterally.

SCORING:

- | | | |
|----------------|---|---|
| (Number) | 0 – Absent. | No lesser palatine foramina are present. |
| | 1 – One. | One lesser palatine foramen is present. |
| | 2 – Two. | Two lesser palatine foramina are present. |
| | 3 – Three+ | Three or more lesser palatine foramina are present. |
| | 99 – Unobserv. | The region is damaged to the extent that this trait cannot be assessed. |
| (Shape) | 0 – Absent. | No lesser palatine foramina are present. |
| | 1 – Round. | The majority of lesser palatine foramina present are ROUND in shape. |
| | 2 – Oval. | The majority of lesser palatine foramina present are OVAL in shape. |
| | 3 – Slit. | The majority of lesser palatine foramina present are SLIT-SHAPED. |
| | 99 – Unobserv. | The region is damaged to the extent that this trait cannot be assessed. |
| (Largest size) | 0 – Absent. | No lesser palatine foramina are present. |
| | 1 – Small. | A 0.3mm wire can enter the largest of the lesser palatine foramina. |
| | 2 – Medium. | A 1.0mm wire can enter the largest of the lesser palatine foramina. |
| | 3 – Large. | A 1.2mm wire can enter the largest of the lesser palatine foramina. |
| | 4 – Excessive. | A 2.0mm wire can enter the largest of the lesser palatine foramina. |
| | 99 – Unobserv. | The region is damaged to the extent that this trait cannot be assessed. |
| (Position) | 0 – Absent. | No lesser palatine foramina are present. |
| | 1 – Postero-medial of the major palatine foramen. | |
| | 2 – Postero-medial of the major palatine foramen. | |
| | 3 – Located on a marginal crest. | |
| | 4 – Located on the anterior margin of a marginal crest. | |
| | 5 – Located on the posterior margin of a marginal crest. | |
| | 6 – Located between the branches of a laterally bifurcating marginal crest. | |
| | 7 – Located between two parallel marginal crests. | |
| | 8 – Located between the alveolar and pyramidal processes. | |
| | 9 – Located inside the canal of the major palatine foramen. | |
| | 10 – Located on the medial side of the pyramidal process. | |



TRANSVERSE PALATINE SUTURE – This suture connects the maxilla and the two palatine bones. The suture is squamosal in nature, with the palatines overlying the maxilla. Sutural shape, alignment/symmetry (aka – scalaris), size of convexity, and maximal size of sutural extension should be scored.

SCORING:

(Shape)	0 – Absent.	The transverse palatine suture has been obliterated.
	1 – Straight.	The suture travels horizontally across the palate from one lingual surface of the alveolar bone to the other.
	2 – TotalAntConvex.	Suture is totally anteriorly convex.
	3 – MedialAntConvex.	Suture is anteriorly convex ONLY MEDIALY.
	4 – LateralAntConvex.	Suture is anteriorly convex ONLY LATERALLY.
	5 – TotalPostConvex.	Suture is totally posteriorly convex.
	6 – MedialPostConvex.	Suture is anteriorly convex ONLY POSTERIORLY.
	7 – LateralPostConvex.	Suture is anteriorly convex ONLY POSTERIORLY.
	8 – Separate.	Right and left palatine bones are completely separated by a posterior process of the maxilla which forms the posterior margin of the osseous palate.
	99 – Unobserv.	The region is damaged; this trait cannot be assessed.
(Alignment)	0 – Absent.	The transverse palatine suture has been obliterated.
	1 – Symmetrical.	The right or left side of the transverse palatine suture is no more than 2mm anterior or posterior to the other side along the line of the median palatine suture.
	2 – Asymmetrical.	The right or left side of the transverse palatine suture is more than 2mm anterior or posterior to the other side along the line of the median palatine suture.
	99 – Unobserv.	The region is damaged; this trait cannot be assessed.
(Convexity size)	0 – Absent.	The transverse palatine suture has been obliterated.
	1 – Small.	When the space between a horizontal line connecting the lateral ends of the transverse palatine suture and (for anterior convexity) a horizontal line drawn at the posterior border of the incisive foramen OR (for posterior convexity) the horizontal posterior edge of the bony palate is considered, the convexity protrudes into less than 1/3 rd of this space.
	2 – Large.	When the space between a horizontal line connecting the lateral ends of the transverse palatine suture and (for anterior convexity) a horizontal line drawn at the posterior border of the incisive foramen OR (for posterior convexity) the horizontal posterior edge of the bony palate is considered, the convexity protrudes into between 1/3 rd and 1/2 of this space.
	3 – Excessive.	When the space between a horizontal line connecting the lateral ends of the transverse palatine suture and (for anterior convexity) a horizontal line drawn at the posterior border of the incisive foramen OR (for posterior convexity) the horizontal posterior edge of the bony palate is considered, the convexity protrudes into more than 1/2 of this space.
	99 – Unobserv.	The region is damaged; this trait cannot be assessed.

(Suture extension) 0 – Absent.

1 – Small.

2 – Medium.

3 – Large.

99 – Unobserv.

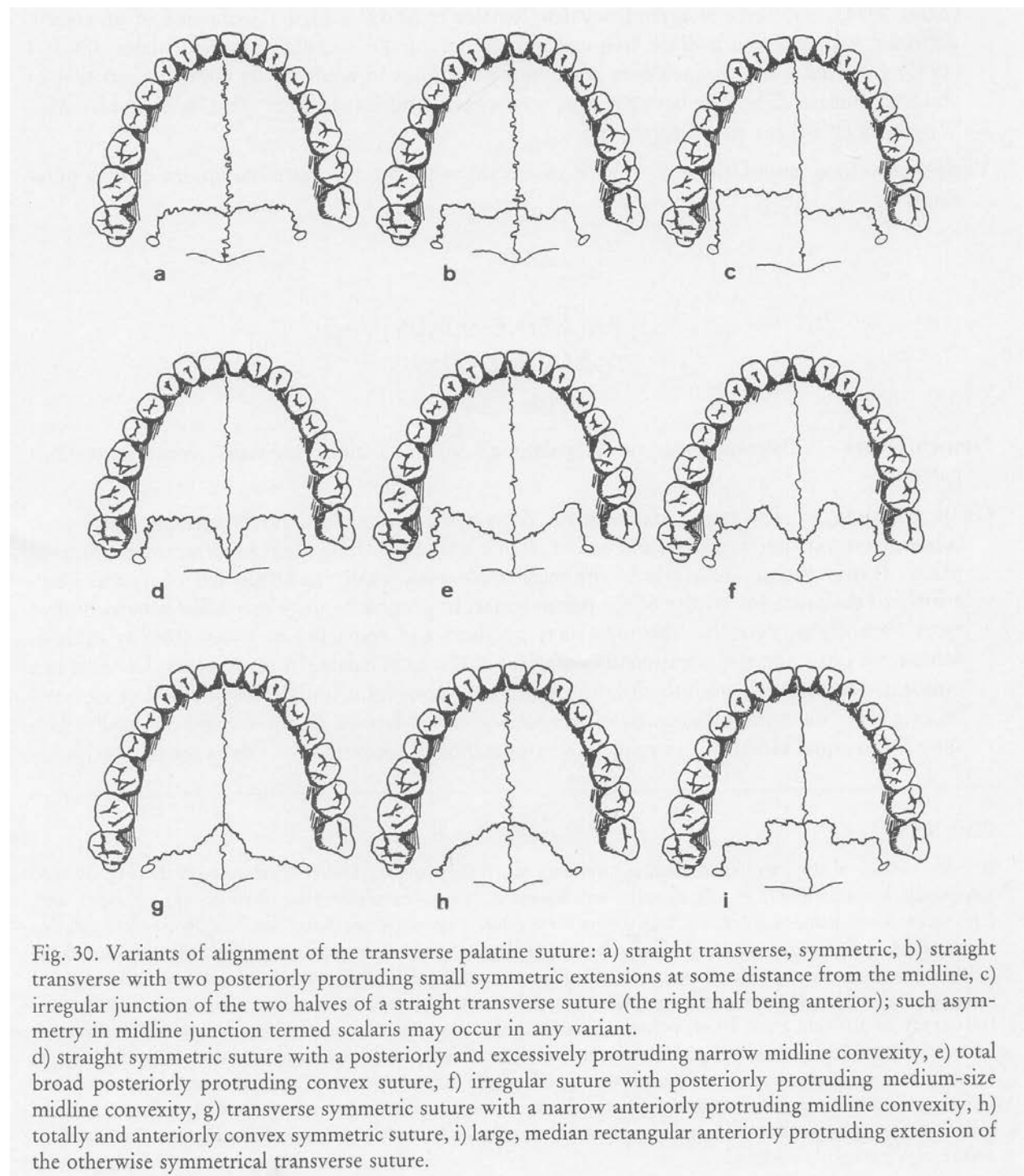
The transverse palatine suture has been obliterated.

Considering the overall breadth of the pattern, at least three of the largest extensions must extend up to 0.5mm from the straight horizontal.

Considering the overall breadth of the pattern, at least three of the largest extensions must extend between 0.5mm and 1.0mm from the straight horizontal.

Considering the overall breadth of the pattern, at least three of the largest extensions must extend more than 1.0mm from the straight horizontal.

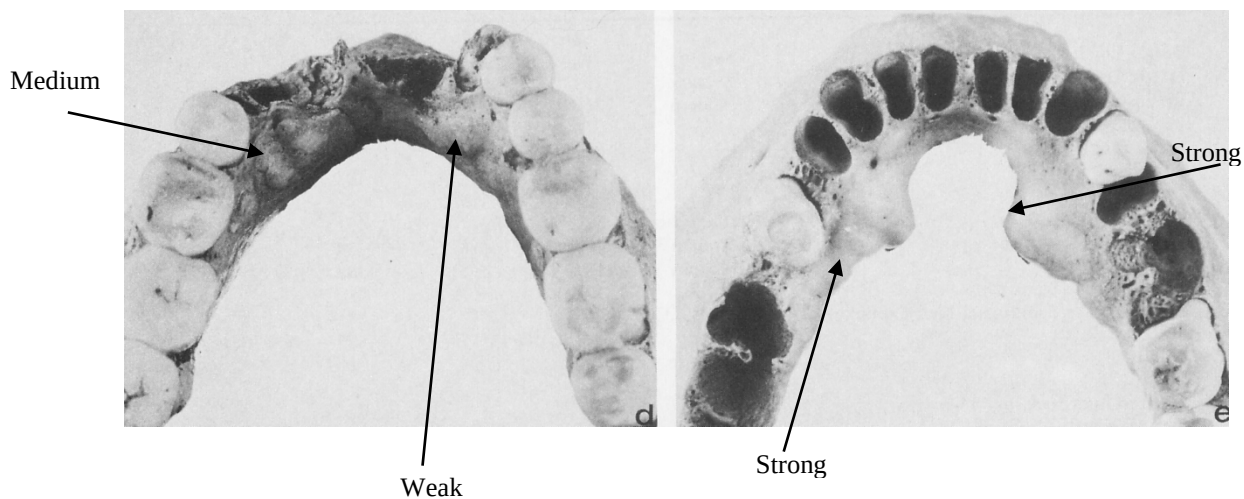
The region is damaged; this trait cannot be assessed.



MANDIBULAR TORUS – The mandibular torus also occurs on the lingual surface, but is generally located near the root of the second premolar. As with the maxillary torus, the mandibular torus is thought to form as a result of chewing stresses. The mandibular torus is usually bilateral, and can either present as a swelling (of various sizes) or a series of swellings (called tubercular type).

****Score each descriptor of this trait bilaterally.**

SCORING:	0 – Absent.	Lingual surface below the teeth is smooth without any thickening or rugosity.
	1 – Weak.	Lingual surface of the mandible below the line of the teeth shows some rugged patches separated by grooves.
	2 – Medium.	On the lingual side of the mandible below the line of the teeth, elongated oval thickenings occur together with small protrusions and nodules.
	3 – Strong.	Thickenings are very large and may reach the size of a walnut. There may be a chain of several such thickenings.
	99 – Unobserv.	The region is damaged to the extent that this trait cannot be assessed.

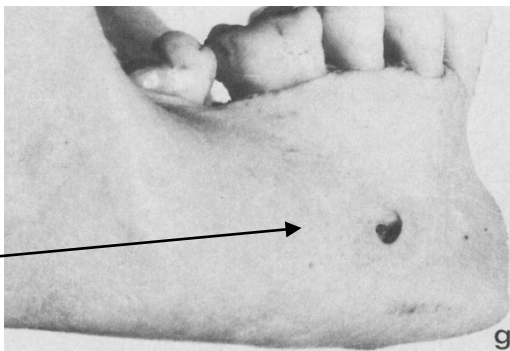


MENTAL FORAMEN – The mental foramen is the exit point for a branch of the inferior alveolar nerve and associated arteries and veins. It is usually located just lateral to the mandibular symphysis, in the external surface of the mandible. Variations can include complete absence, single, or multiple foramina, depending on the pattern of the vessels. Heritability of this trait is unknown. Score the number of foramina present.

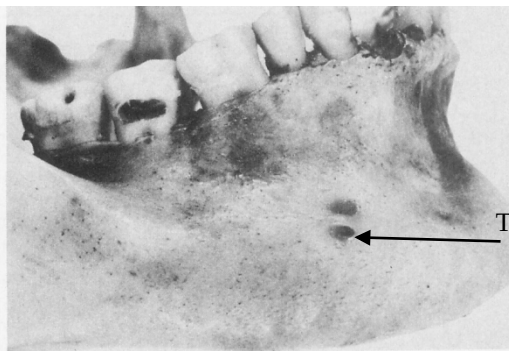
****Score each descriptor of this trait bilaterally.**

SCORING:	0 – Absent.	No patent mental foramen is present.
	1 – One.	A single mental foramen is present.
	2 – Two.	Two mental foramina are present.
	3 – Three+.	Three or more mental foramina are present.
	99 – Unobserv.	The region is damaged to the extent that this trait cannot be assessed.

One



Two



Odontometrics

ODONTOMETRICS

NOTE: Only measure RIGHT tooth if left is not present or cannot be assessed!!!

MESIODISTAL DIAMETER

- The greatest mesiodistal dimension, taken parallel to the occlusal and buccal surfaces of the crown.
- If malocclusion has caused a tooth to be rotated or displaced, find points that would form the mesial and distal contacts if the tooth were in normal occlusion.
- Place fine caliper arms on buccal surface of tooth to obtain greatest mesiodistal diameter.
- Watch for interproximal and occlusal wear, as these can obliterate maximum mesiodistal diameter.

BUCCOLINGUAL DIAMETER

- The greatest distance between the buccal and lingual surfaces of the crown, taken at right angles to the plane in which the mesiodistal diameter was taken.
- Hold calipers so that beam is parallel to occlusal surface, and apply arms to most prominent bulges on the buccal and lingual sides.

Dental Discrete Traits

DENTAL ANATOMY

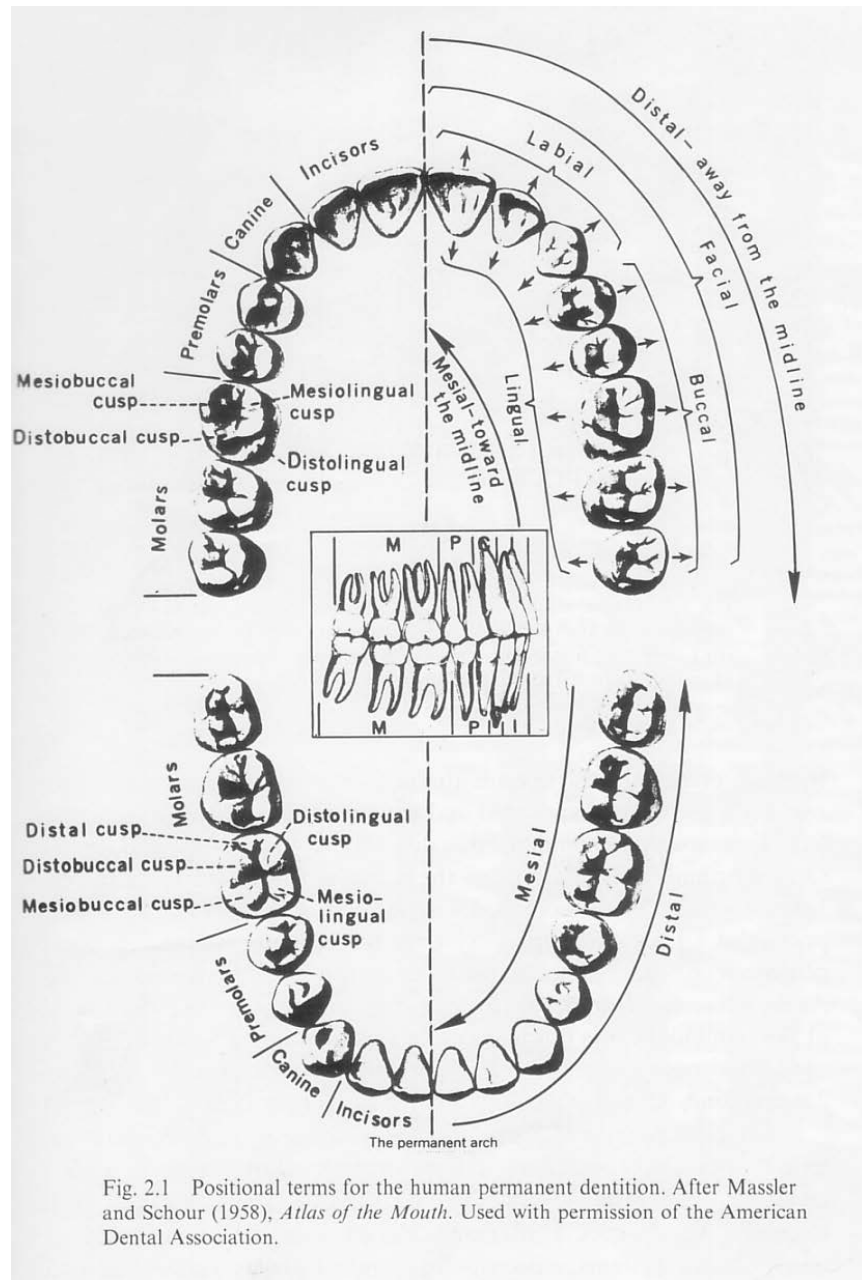
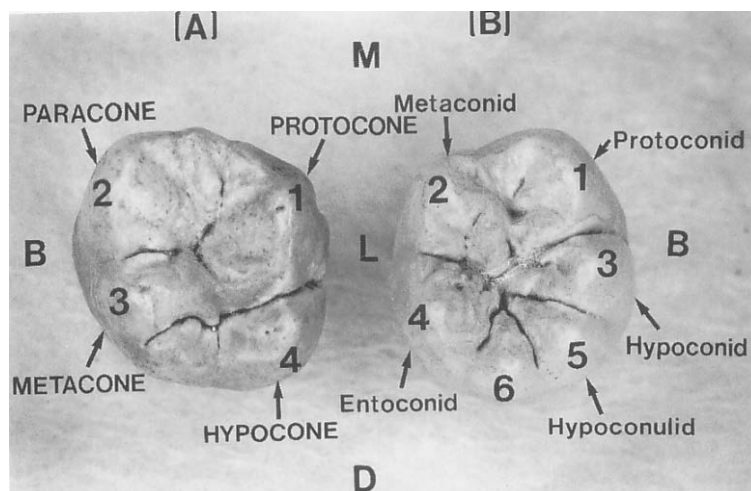
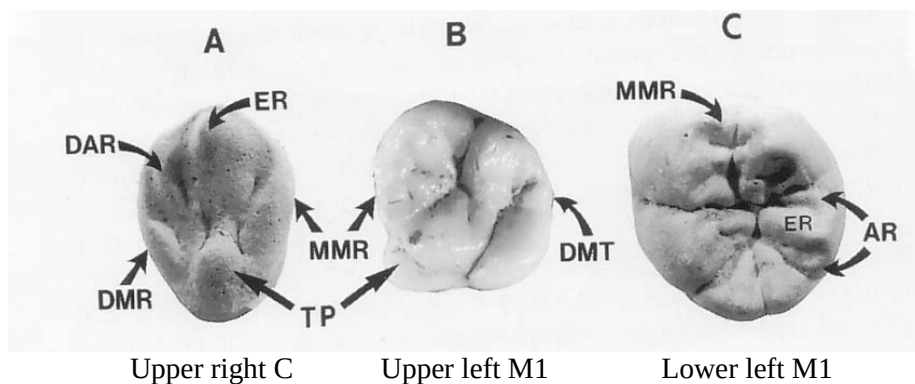
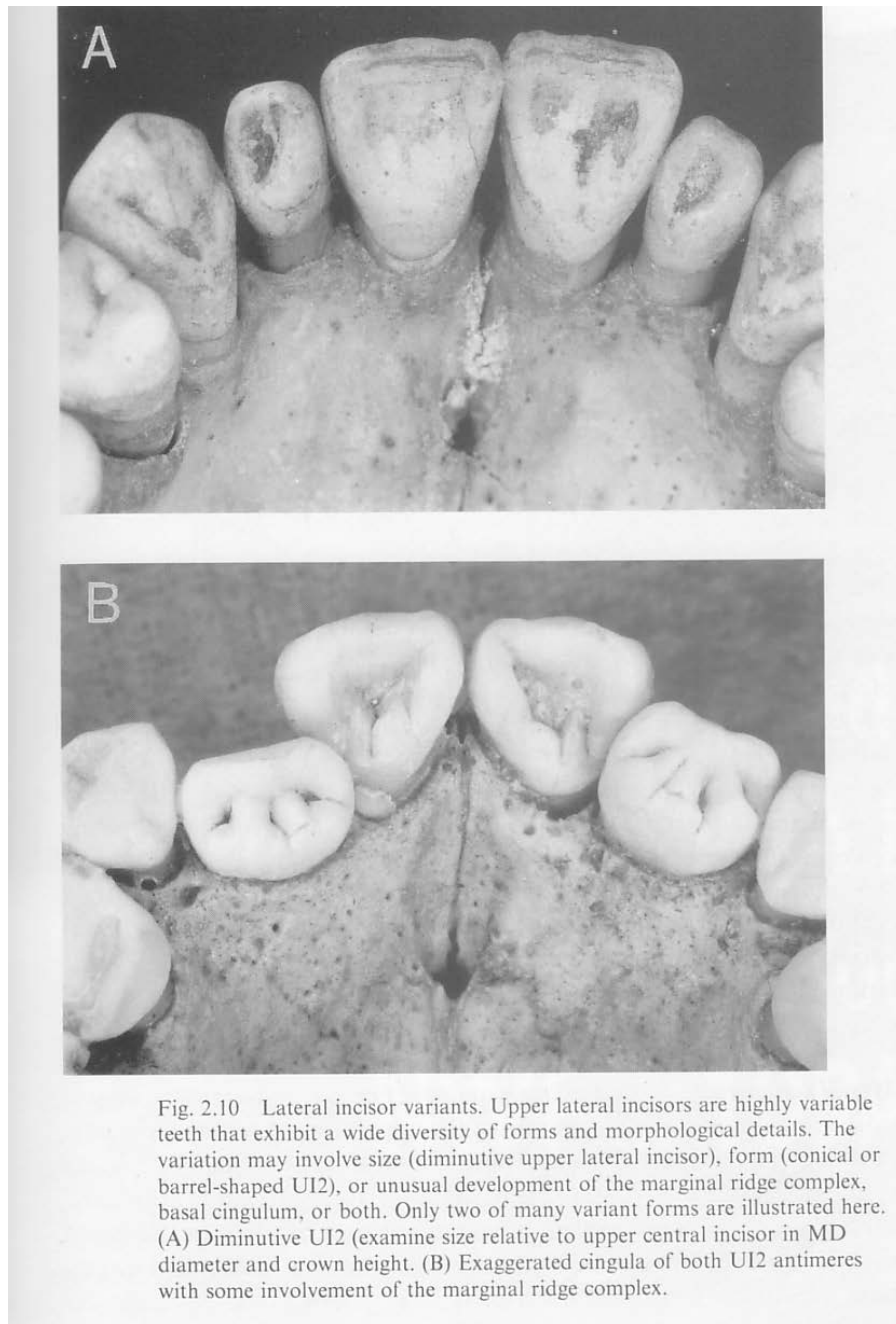


Fig. 2.1 Positional terms for the human permanent dentition. After Massler and Schour (1958), *Atlas of the Mouth*. Used with permission of the American Dental Association.



SPECIFIC CUSP TRAITS



WINGING – Rotation of the upper central incisors. Rotation of only one incisor could indicate dental crowding, so this should be differentiated from genetically-induced winging.

TOOTH: UI1

PLAQUE: none

SCORING:	0 – Absent.	The upper central incisors form a straight line; no winging.
	1 – Bilateral ML.	Both incisors are rotated MESIOLINGUALLY to form an angle GREATER THAN 20 degrees.
	2 – Bilateral ML.	Both incisors are rotated MESIOLINGUALLY to form an angle LESS THAN 20 degrees.
	3 – Unilateral.	Only one incisor is rotated, but there is no evident dental crowding.
	4 – Crowding.	One incisor is rotated, but it is obviously due to dental crowding.
	5 – Bilateral DL.	Both incisors are rotated DISTOLINGUALLY.
	99 – Unobserv.	This tooth is damaged to the extent the trait cannot be assessed.

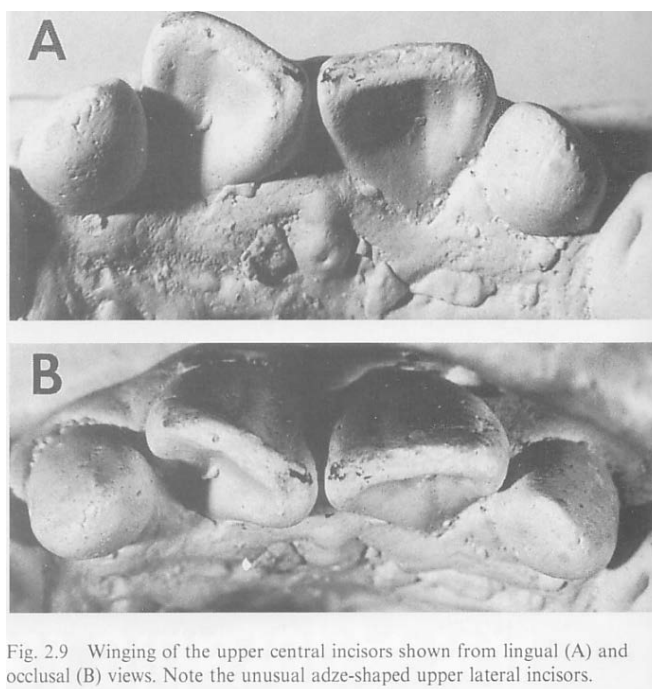


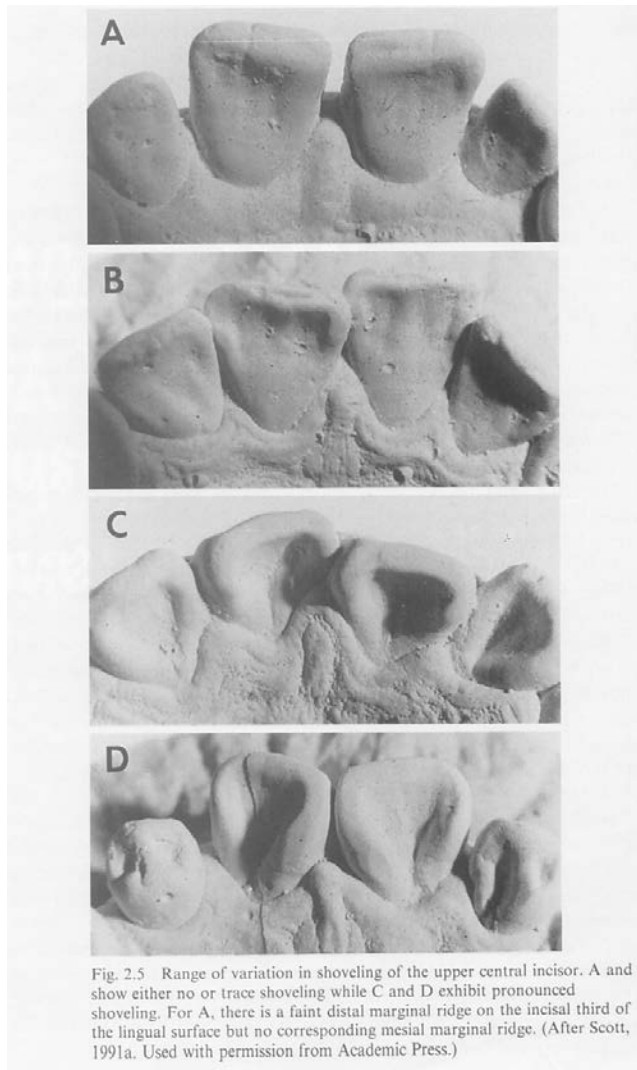
Fig. 2.9 Winging of the upper central incisors shown from lingual (A) and occlusal (B) views. Note the unusual adze-shaped upper lateral incisors.

SHOVELLING - The presence of lingual marginal ridges.

TOOTH: UI1
UI2
UC
LI1
LI2

PLAQUE: #2 (UI1 shovelling)
#3 (UI2 shovelling)
#14 (LI shovelling)

SCORING:	0 – Absent.	Lingual surface is flat.
	1 – Faint.	Very slight elevations can be seen and/or palpated.
	2 – Trace.	Elevations can be easily seen.
	3 – Semishov.	Stronger ridging is present; tendency for ridging to converge at cingulum.
	4 – Semishov.	Convergence and ridging are stronger than in grade 3.
	5 – Shovel.	Strong development of ridges, which almost contact at cingulum.
	6 – Marked.	Strongest development, with medial and distal ridges sometimes in contact at cingulum.
	7 – Barrel.	UI2 ONLY!!!! Expression exceeds grade 6; is not a result of a hypertrophied tuberculum dentale.
	99 – Unobserv.	This tooth is damaged to the extent the trait cannot be assessed.



DOUBLE SHOVELLING – The presence of lingual AND labial marginal ridges. Only assess a grade 6 double shovel on teeth that are heavily worn.

TOOTH: UI1
 UI2
 UC
 UP1
 LI1
 LI2

PLAQUE: #4 (UI)

SCORING: 0 – Absent. Labial surface is smooth.
 1 – Faint. Mesial ridging can be seen in strong contrasting light. In this and stronger grades, distal ridge may be present or absent.
 2 – Trace. Ridging is more easily seen and palpated.
 3 – Semishov. Ridging can be readily palpated.
 4 – DoubShov. Ridging is pronounced on at least ½ of the total crown height.
 5 – Marked. Ridging is very prominent and may occur from the occlusal surface to the crown-root junction.
 6 – Extreme. Even more than grade 5.
 99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.

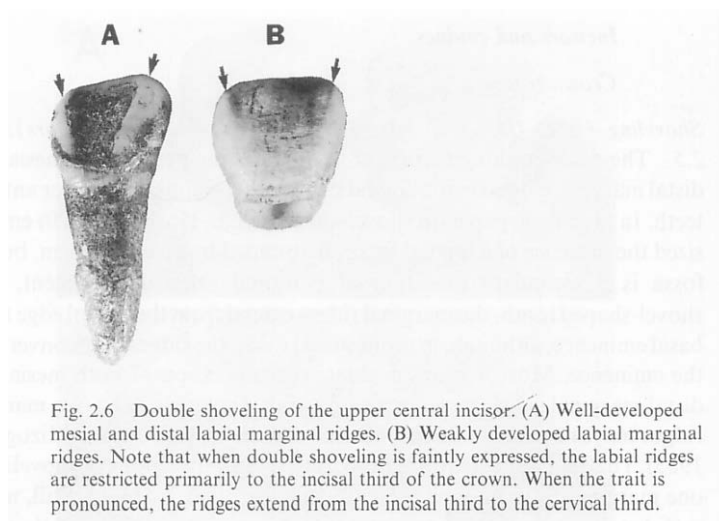


Fig. 2.6 Double shovelling of the upper central incisor. (A) Well-developed mesial and distal labial marginal ridges. (B) Weakly developed labial marginal ridges. Note that when double shovelling is faintly expressed, the labial ridges are restricted primarily to the incisal third of the crown. When the trait is pronounced, the ridges extend from the incisal third to the cervical third.

LABIAL CONVEXITY – When viewed from the occlusal aspect, the labial surface of the upper incisors can range from essentially flat to a marked degree of convexity. Observe the MEDIAL 2/3rds of the tooth, and try to observe a point about 1/3rd of the way down from the occlusal surface. This trait and double shovelling are inversely correlated.

TOOTH: UI1
 UI2

PLAQUE: #1

SCORING: 0 – Absent. Labial surface is flat.
 1 – Trace. Labial surface exhibits trace convexity.
 2 – Weak. Labial surface exhibits weak convexity.
 3 – Moderate. Labial surface exhibits moderate convexity.
 4 – Marked. Labial surface exhibits marked convexity.
 99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.

INTERRUPTION GROOVE – Grooves which cross the cingulum and often continue down the root. More often seen on lateral incisors.

TOOTH: UI1
UI2

PLAQUE: none

SCORING: 0 – Absent. The mesial, distal, and medial areas of the lingual surface are smooth and continuous, and show no disruption groove, either vertical to near-horizontal in direction.
1 – Mesial. An interruption groove occurs on the mesiolingual border.
2 – Distal. An interruption groove occurs on the distolingual border.
3 – Both. An interruption groove occurs on BOTH the mesio- and disto-lingual borders.
4 – Medial. An interruption groove occurs in the medial area of the cingulum.
99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.



Fig. 2.8 Interruption grooves of the upper lateral incisors. Both upper lateral incisors exhibit interruption grooves (*dens invaginatus*), but expression is more pronounced on the right antimere. Such grooves, which often involve the root to a greater extent than shown here, can be manifest on the upper central incisor, but less frequently than on upper lateral incisor.

TUBERCULUM DENTALE – On the lingual surface of the upper incisors and canines, ridges or varying degrees of expression of an extra cusp may occur in the cingular region. Strength of expression, not number of ridges, should be scored. Any presence of lingual shoveling should be ignored when assessing this trait. Turner says that the lateral incisor shows the most trait variation, and should be used in analyses.

TOOTH: UI1
UI2
UC

PLAQUE: #5 (UI1)
#s 5 and 7 (UI2, UC)

- SCORING:
- 0 – Absent. Cingular region of lingual surface is smooth.
 - 1 – Faint ridge. Grade 1 of ASU plaque #5.
 - 2 – Trace ridge. Grade 2 of ASU plaque #5.
 - 3 – Strong ridge. Grade 3 of ASU plaque #5.
 - 4 – Pronounced. Grade 4 of ASU plaque #5.
 - 5 – Weak cusp. A weakly developed cuspule, WITHOUT A FREE APEX, is attached to either the mesio- or disto-lingual marginal ridge. Interpolate between plaque #5 grade 4 and plaque #7 grade 4.
 - 6 – Weak apex. A weakly developed cuspule, WITH A FREE APEX, is attached to either the mesio- or disto-lingual marginal ridge. Size approximately corresponds to grade 4 on plaque #7.
 - 7 – Strong apex. A strongly developed cuspule, WITH A FREE APEX, is attached to either the mesio- or disto-lingual marginal ridge. Size is equal to or greater than grade 5 of plaque #7.
 - 99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.

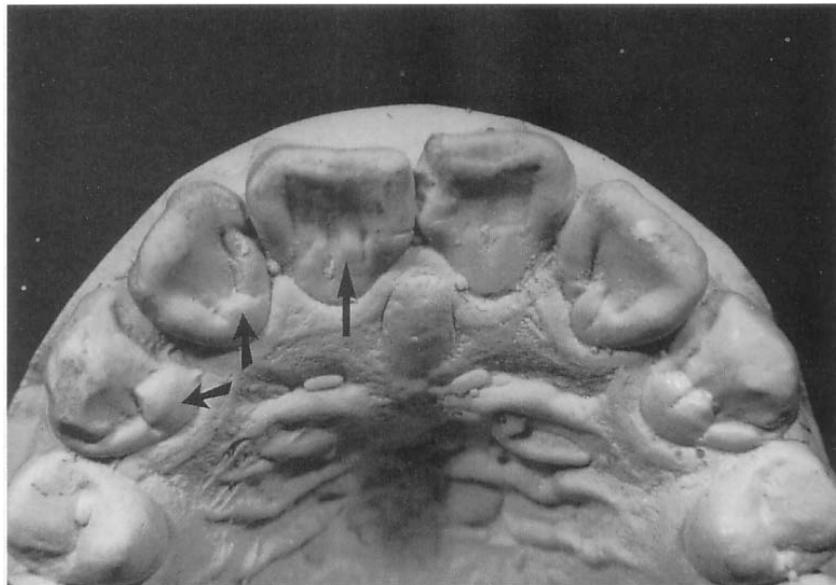


Fig. 2.7 *Tuberculum dentale* of the upper incisors and canines. Arrows point to three moderate to pronounced tuberculum projections on the right upper central incisor, upper lateral incisor, and upper canine but the projections are also evident on the left antimeres (showing some asymmetry in expression).

PEG-SHAPED INCISOR – A tooth that is very reduced in size and lacking the normal crown morphology. A continuum probably exists that ends with the congenital absence of the tooth, the peg form being near the absence threshold.

TOOTH: UI2

PLAQUE: none

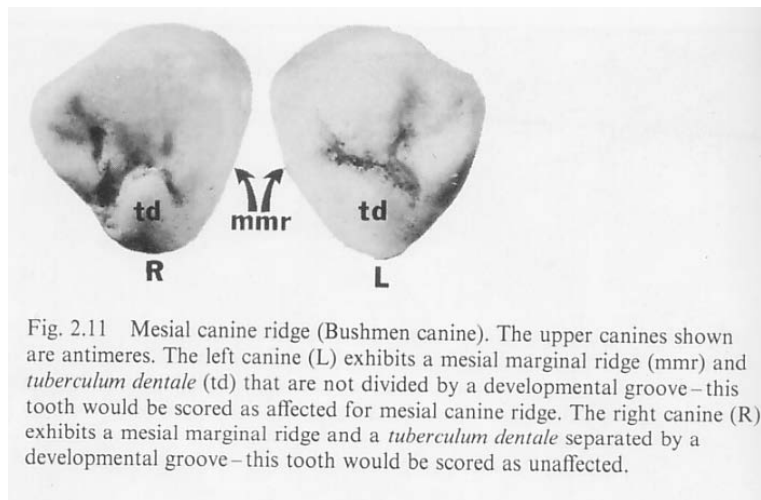
- SCORING:
- 0 – Absent. Lateral incisor is normal in size and crown form.
 - 1 – Reduced. Incisor reduced in size, but having normal crown form.
 - 2 – Peg. Incisor is reduced in size and lacks normal crown morphology.
-

CANINE MESIAL RIDGE/BUSHMAN CANINE – Normally, the mesiolingual marginal ridge of the upper canine is similar in size to the distolingual marginal ridge. Occasionally, the mesial ridge is larger than the distal. and. in pronounced cases, it possesses a distal deflection approximately 2/3rds of the way down from the occlusal surface due to its attachment to the tuberculum dentale. This trait is strongly asymmetrical on the lingual surface when it reaches grade 3 or more. My take on this trait is that it measures the degree to which the tuberculum dentale is removed from the mesial marginal ridge by a groove.

TOOTH: UC

PLAQUE: #6

SCORING: 0 – Absent. Mesial and distal lingual ridges are the same size. Neither is attached to the tuberculum dentale, if it is present.
 1 – Weak. Mesiolingual ridge is larger than the distolingual, and is weakly attached to the tuberculum dentale.
 2 – Moderate. Mesiolingual ridge is larger than the distolingual, and is moderately attached to the tuberculum dentale.
 3 – Strong. Mesiolingual ridge is much larger than the distolingual, and is fully incorporated into the tuberculum dentale.
 99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.



CANINE DISTAL ACCESSORY RIDGE – Located in the distolingual fossa between the tooth apex and the distolingual marginal ridge. There is no dentin involvement in this trait, so it can be worn off without leaving any trace of its presence. This trait appears to be sexually dimorphic, so consider NOT pooling sexes in analyses.

TOOTH: UC
LC

PLAQUE: #7

SCORING: 0 – Absent. Distal accessory ridge is absent.
 1 – Faint. Distal accessory ridge is very faint.
 2 – Weak. Distal accessory ridge is weakly developed.
 3 – Moderate. Distal accessory ridge is moderately developed.
 4 – Strong. Distal accessory ridge is strongly developed.
 5 – Extreme. Distal accessory ridge is very pronounced.
 99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.

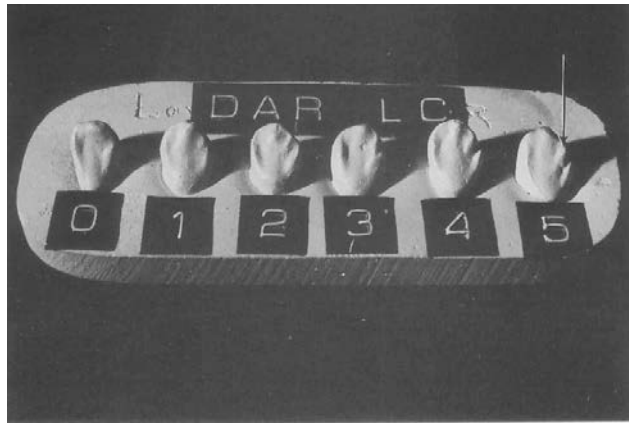


Fig. 2.12 Canine distal accessory ridge. Distal accessory ridges can be present on either the upper or lower canines. Illustrated is the 6-grade scale used to rank lower canine distal accessory ridge expression. An arrow points to the maximal form of trait expression on the lower canine.

PREMOLAR MESIAL AND DISTAL ACCESSORY CUSPS – Small accessory cusps are sometimes seen at the mesial and/or distal ends of the sagittal grooves of the upper premolars. These cusps are defined by a strong separation from both the buccal and lingual cusps. If a small cusp is still attached to the buccal or lingual cusps, it **SHOULD NOT** be considered an accessory cusp.

TOOTH: UP1
UP2

PLAQUE: none

SCORING: 0 – Absent. No accessory cusps occur.
1 – Mesial. At least one accessory cusp appears on the mesial end.
2 – Distal. At least one accessory cusp appears on the distal end.
3 – Both. Accessory cusps appear on both the mesial and distal ends.
99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.



Fig. 2.15 Premolar accessory marginal tubercles. A large marginal tubercle, triangular in shape, is noted along the mesial marginal ridge of the upper second premolar.

TRICUSPID PREMOLARS – VERY RARE variant (1/8000) that occurs almost exclusively in prehistoric SW Native American populations. The third cusp is located distally, and is the hypocone.

TOOTH: UP1
UP2

PLAQUE: none.

SCORING: 0 – Absent. No third cusp.
1 – Present. A third cusp of equal size to the normal lingual cusp is present.
99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.

DISTOSAGITTAL RIDGE/UTO-AZTECAN PREMOLAR – Occurs when a pronounced ridge from the apex of the buccal cusp extends to the distal occlusal border at or near the sagittal sulcus. There is also a mesial rotation of the buccal surface and a buccolingual expansion of the buccal cusp. Could represent a weak expression of the tricuspid premolar described above. Common in Native American populations, but nowhere else in the world.

TOOTH: UP1

PLAQUE: #8

SCORING: 0 – Absent. No distosagittal ridge.
1 – Present. A distosagittal ridge is present.
99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.

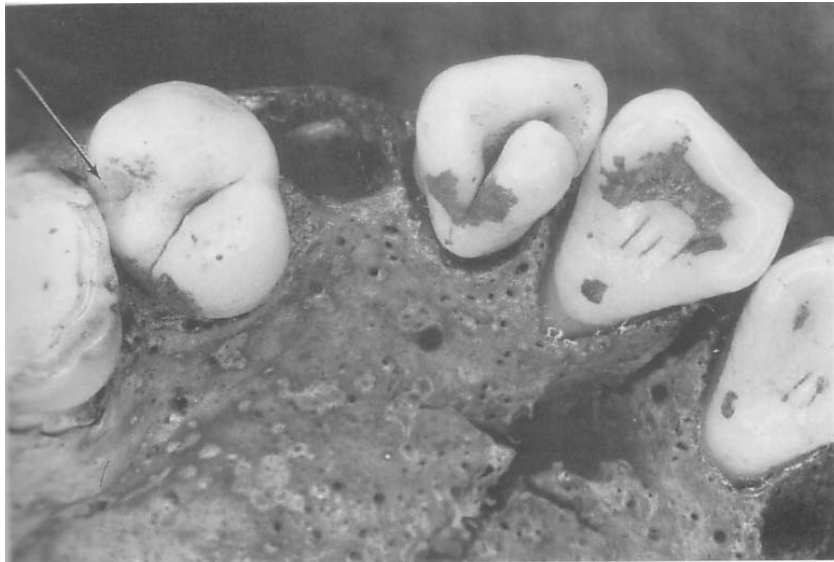


Fig. 2.17 Distosagittal ridge (Uto-Aztecan premolar). Only upper first premolars exhibit this rare geographically restricted trait. The distobuccal displacement of the buccal cusp and a fossa adjacent to the distal marginal ridge (arrow) are the key characteristics of the distosagittal ridge. Note also another form of upper lateral incisor variant.

ODONTOME – Any pin-sized, spike-shaped enamel and dentin projection occurring on the premolar occlusal surface. These are very fragile structures, but since they have a dentin component, they can often be recognized even in slightly worn teeth. They often occur in or near the sagittal sulcus. Use a 10x hand lens to inspect premolar surfaces.

TOOTH: UP1
UP2
LP1
LP2

PLAQUE: none

SCORING: 0 – Absent. Odontome not present.
1 – Present. Odontome present.
99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.



Fig. 2.16 Premolar odontomes. Occlusal tubercles, or odontomes, are found in close association with the median occlusal ridge of the premolars. On unworn teeth, odontomes are typically conical in form. The large odontome shown on the lower second premolar has been worn to the point where dentine is visible.

METACONE/CUSP3 – Distobuccal cusp. Absence or weak expression of this cusp is very rare on UM1 and UM2. Note that the ASU plaque is of the UM3, but can be used for any molar if only size is considered. Also note that the grade 3.5 was added after field testing, but is not represented on the plaque. It is NOT half a grade between 3 and 4; rather, it represents a full grade difference.

TOOTH: UM1
UM2
UM3

PLAQUE: #9

SCORING: 0 – Absent. Metacone is absent.
1 – Not free. An attached ridge is present at the metacone site, but there is no free apex.
2 – Faint. A faint cusplule with a free apex is present.
3 – Weak. Weak cusp is present.
3.5 – Intermed. An intermediate-sized cusp is present.
4 – Large. Metacone is large.
5 – Very large. Metacone is very large; equal in size to a large M1 hypocone.
99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.

HYPOCONE – The distolingual cusp and cusp4. Absence and severely reduced forms of this cusp are more common on M1 and (especially) M2 than the same forms of the metacone. As with the metacone, a full interval grade had to be added to the plaque after development, again labeled 3.5. The plaque works well with UM1 and UM2, but requires judgment to be used with UM3, since many distal accessory cusps can be present, and cusp 5 can be larger than the hypocone.

TOOTH: UM1
 UM2
 UM3

PLAQUE: #10

SCORING: 0 – Absent. No hypocone. Site is smooth.
 1 – Ridging. Faint ridging present at the site.
 2 – Faint. Faint cusplule present.
 3 – Small. Small cusp present.
 3.5 – Mod. Moderate-sized cusp present.
 4 – Large. Large cusp present.
 5 – Very large. Very large cusp present.
 99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.

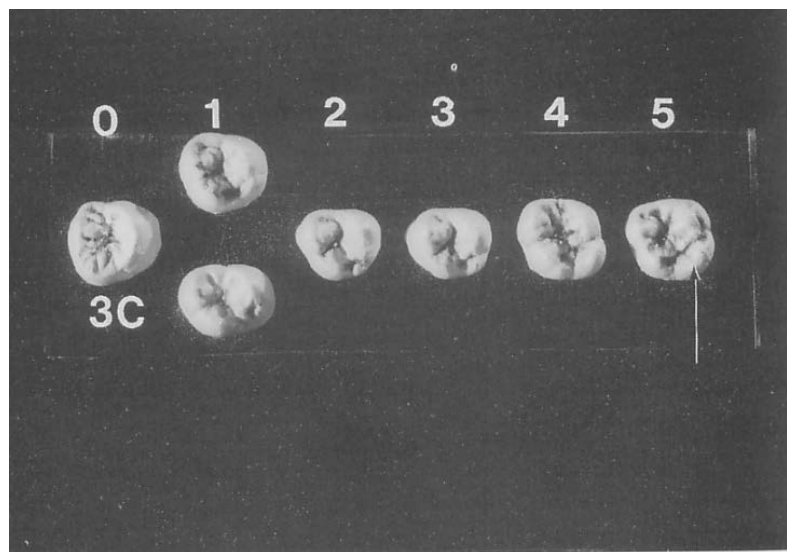


Fig. 2.21 Hypocone of the upper molars. The standard plaque for the hypocone (Turner *et al.*, 1991) shows the range of variation in the distolingual cusp of the upper molars. An arrow points to the largest grade of hypocone expression while 3C denotes a three-cusped upper molar lacking a hypocone. For grade 1, the hypocone is indicated only by an outline on the protocone. After this plaque was developed, it became apparent that the difference in expression between grades 3 and 4 was too marked so another grade (3.5) was added to smooth the transition.

CUSP 5/METACONULE – A 5th cusp, the metaconule, may occasionally be present in the distal fovea of the upper molars between the metacone and hypocone. When present, cusp 5 usually has two adjacent distal grooves, which can be useful when the tooth is highly worn. This plaque **SHOULD NOT** be used in UM3, where multiple distal grooves are common.

TOOTH: UM1
 UM2
 UM3

PLAQUE: #11

SCORING: 0 – Absent. Site of cusp 5 is smooth, there being only a single distal groove present, which separates cusps 3 and 4.
 1 – Faint. Faint cuspule is present.
 2 – Trace. Trace cuspule is present.
 3 – Small. Small cuspule is present.
 4 – Sm. cusp. Small cusp is present.
 5 – Medium. Medium-sized cusp present.
 99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.

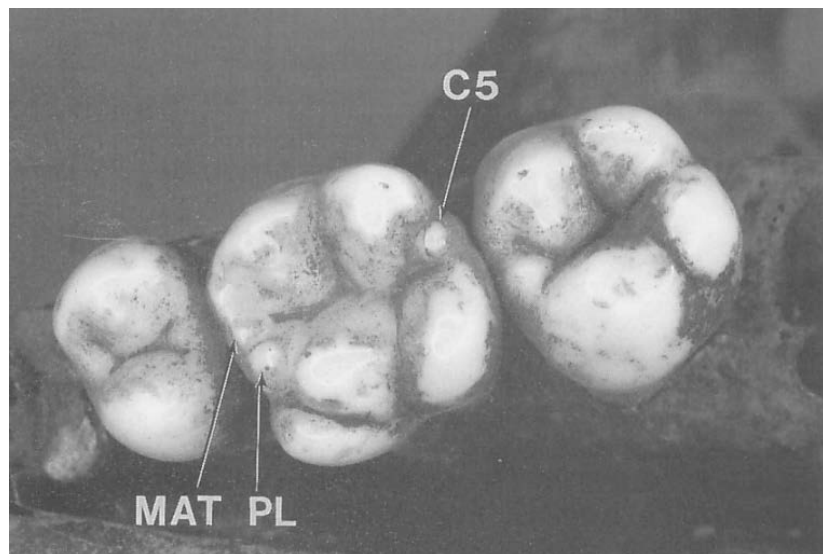


Fig. 2.23 Accessory marginal tubercles of the upper molars. The mesial and distal marginal ridge complexes of the upper molars can both exhibit accessory tubercles. On the upper first molar, there is an accessory tubercle on the distal marginal ridge (C5, or cusp 5) and two accessory tubercles on the mesial marginal ridge, a protoconule (PL) and mesial accessory tubercle (MAT). The mesial accessory tubercle is also expressed on the second molar (but not PL or C5). Two additional upper molar accessory tubercles, the mesial paracone tubercle and lingual paracone tubercle, are illustrated in Fig. 2.36.

CARABELLI'S TRAIT – Occurs on the lingual surface of the mesiolingual cusp (cusp 1/protocone) of the upper molars.

TOOTH: UM1
 UM2
 UM3

PLAQUE: #12

SCORING:	0 – Absent.	The mesiolingual aspect of cusp 1 is smooth.
	1 – Groove.	A groove is present.
	2 – Pit.	A pit is present.
	3 – Small Y.	A small Y-shaped depression is present.
	4 – Large Y.	A large Y-shaped depression is present.
	5 – Sm. cusp.	A small cusp without a free apex occurs (although see caption to picture below). The distal border of the cusp does not contact the lingual groove separating cusps 1 and 4.
	6 – Med. cusp.	A medium-sized cusp with an attached apex making contact with the medial lingual groove is present.
	7 – Free cusp.	A large free cusp is present.
	99 – Unobserv.	This tooth is damaged to the extent the trait cannot be assessed.

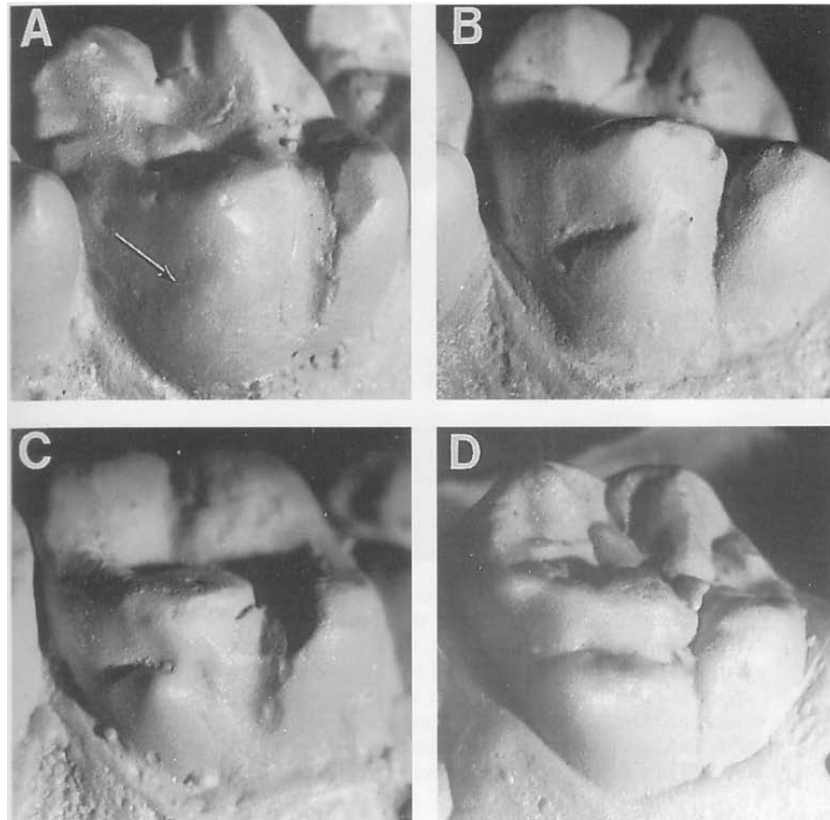


Fig. 2.22 Carabelli's trait of the upper molars. (A) The arrow points to an extremely subtle manifestation of Carabelli's trait that borders on 'threshold expression' (i.e., just barely visible); (B) a form of intermediate trait expression (grade 4); (C) a small tubercle with a free apex (grade 5); (D) a large cusp with a free apex that contacts the lingual groove separating the protocone and hypocone (grade 7). Because workers have scored intermediate grades of Carabelli's trait expression using different standards, we focus on distinct tubercle and cusp forms (grades 5–7) in our population comparisons.

PARASTYLE – A paramolar cusp that most commonly occurs on the buccal surface of the mesiobuccal cusp (the paracone/cusp 2) of UM3, although it can occur in the same place on the other molars. A similar structure can be found on the buccal surface of cusp 3 in the upper molars, which may or may not be related. According to Scott and Turner, the relative rarity of the parastyle is reason to score any additional cusp on the buccal surface as present for the parastyle.

TOOTH: UM1
 UM2
 UM3

PLAQUE: #13

SCORING: 0 – Absent. The buccal surfaces of cusps 2 and 3 are smooth.
 1 – Pit. A pit is present in or near the buccal groove between cusps 2 and 3.
 2 – Sm. cusp. A small cusp with an attached apex is present.
 3 – Med. cusp. A medium-sized cusp with a free apex is present.
 4 – Lg. cusp. A large cusp with a free apex is present
 5 – Very Lg. A very large cusp with a free apex is present, usually involving the buccal surface of both cusps 2 and 3.
 6 – Peg. An effectively peg-shaped crown attached to the root of UM3 is present. This condition is extremely rare, and not shown on the plaque.
 99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.

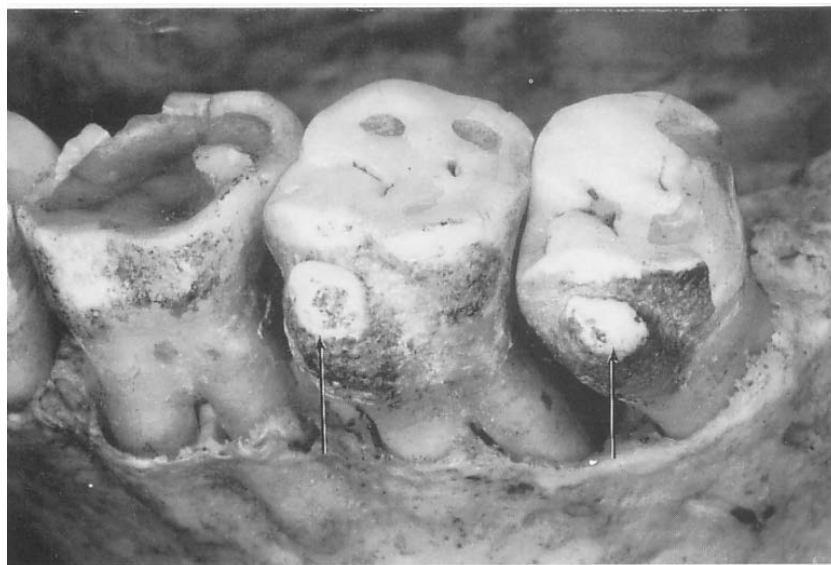


Fig. 2.24 Parastyle of the upper molars. Despite moderate crown wear, distinctive parastyles (arrows) are expressed on the buccal surfaces of the upper second and third molars. Forms of this magnitude are likely equivalent to paramolar tubercles.

ENAMEL EXTENSIONS – Projections of the enamel border in an apical direction. Any of the four grades may have an enamel pearl at or near the site of the extension, even when there is no extension. Enamel pearls are NOT scored by ASU. In premolars, extensions almost never exceed grade 2, and are almost always on roots with a strong expression of the buccal developmental groove, but can occur on the lingual side of teeth, as well. If an enamel extension is interrupted or discontinuous, only that portion that is in contact with the crown is used for scoring length.

TOOTH: UP1
 UP2
 UM1
 UM2
 UM3

PLAQUE: none

SCORING: 0 – Absent. The enamel border is straight or curved upwards to the crown (rare). Any extensions that may be present are NOT attached to the crown.
 1 – Faint. A faint, approx. 1mm-long extension projecting toward and along the root.

- 2 – Medium. A medium-sized, approx. 2mm-long extension is present.
- 3 – Lengthy. A lengthy extensions, generally > 4mm in length, is present. It may extend all the way to root bifurcation on molars.
- 99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.

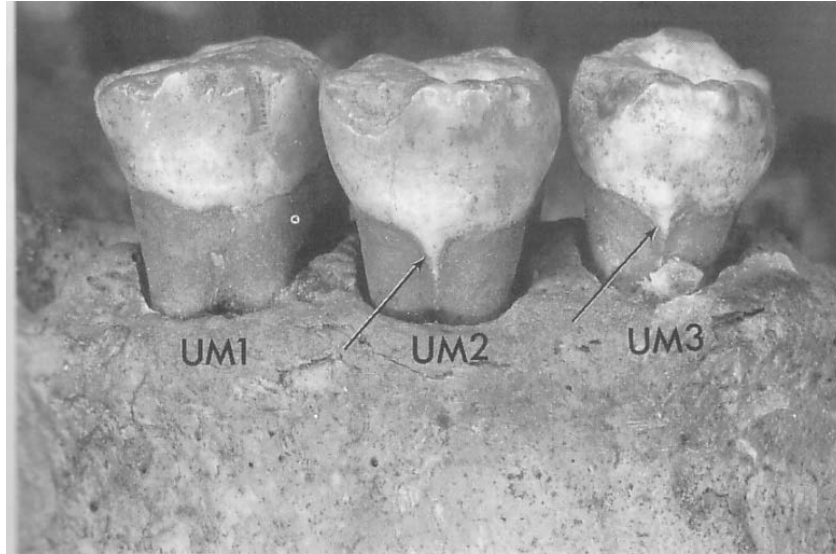


Fig. 2.25 Enamel extensions of the upper molars. These three upper molars (UM) illustrate the range of variation in enamel extension expression: UM1 exhibits no enamel extension, UM2 shows a distinct extension toward the root bifurcation, and UM3 exhibits a moderate extension.

PEG-SHAPED MOLAR – A small tooth lacking appropriate crown morphology.

- TOOTH: UM3
- PLAQUE: none
- SCORING: 0 – Absent. UM3 has a full-sized crown with normal third molar morphology.
 1 – Reduced. UM3 reduced in size to 7 to 10mm buccolingual diameter. Crown form is near normal or somewhat shriveled.
 2 – Peg. UM3 is < 7mm in buccolingual diameter. The crown is peg or cone-shaped with rarely more than 2 rounded cusps lacking secondary morphology. Root is simple and straight.
 99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.
-

CONGENITAL ABSENCE – Failure of a tooth to form at the bud stage. Should be assessed only on individuals > 17 years of age. Be wary of gaps in the incisor or premolar sites (usually indicating antemortem loss), and look for wear facets on M2 if M3 is missing in case of antemortem removal of the M3.

- TOOTH: UI2
 UP2
 UM3
 LI1
 LP2
 LM3
- PLAQUE: none
- SCORING: 0 – Present. Tooth is present, or at least shows sign of impaction.
 1 – Absent. Tooth is congenitally absent.

99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.

PREMOLAR LINGUAL CUSP VARIATION – ASU system considers the number of lingual cusps and their relative size. Note that this classification is very sensitive to wear. Do NOT consider odontomes when scoring for lingual cusp variation.

TOOTH: LP1
LP2

PLAQUE: #16 (LP1)
#17 (LP2)

SCORING: 0/A – Absent. No lingual cusp is present. A ridge may be present, which suggests a much reduced structure without a free tip, but this is scored as cusp absent.
0 – One. One lingual cusp present. Size and form may vary, but tip can be seen.
1 – One/Two. One or two lingual cusps. Do not use this class on worn teeth; instead, score as missing.
2 – Two. Two lingual cusps; MESIAL cusp is MUCH LARGER than distal cusp.
3 – Two. Two lingual cusps; MESIAL cusp is LARGER than distal cusp.
4 – Two. Two lingual cusps; MESIAL cusp is EQUAL in size to distal cusp.
5 – Two. Two lingual cusps; DISTAL cusp is LARGER than mesial cusp.
6 – Two. Two lingual cusps; DISTAL cusp is MUCH LARGER than mesial cusp.
7 – Two. Two lingual cusps; DISTAL cusp is VERY MUCH LARGER than mesial cusp.
8 – Three. Three lingual cusps, each about equal in size.
9 – Three. Three lingual cusps; MESIAL cusps is MUCH LARGER than medial and/or distal cusps.
99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.

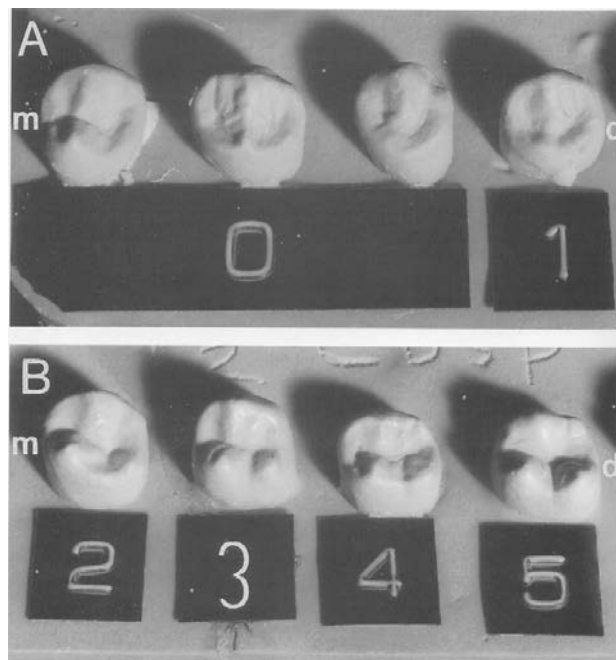


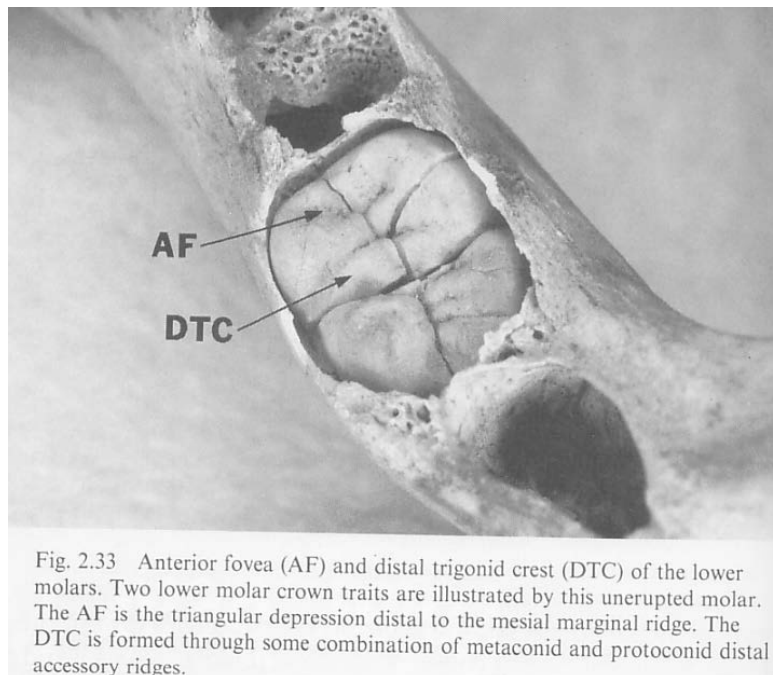
Fig. 2.18 Lower premolar multiple lingual cusps. In contrast to the stable lingual cusps of the upper premolars, the lower first and second premolars exhibit lingual cusps that vary in form and number. For lower second premolars, the teeth in row A exhibit single lingual cusps while those in B illustrate two distinct lingual cusps. In most cases, when multiple lingual cusps occur, the mesial cusp is larger than the distal cusp. m: mesial, d: distal.

ANTERIOR FOVEA – Located on the anterior occlusal surface. This trait is VERY easily worn off, especially in LM1, which erupts early on. In Pleistocene populations, it has been known to occur in LM3 as well, but this is rare in modern populations. Note that age-related wear and caries can erode this trait rapidly, and Turner suggests that in non-industrial populations, individuals over the age of 12 should not be scored.

TOOTH: LM1
LM2
LM3

PLAQUE: #19

SCORING: 0 – Absent. Anterior fovea is absent. The sulcus between cusps 1 and 2 continues without interruption from the center of the occlusal surface to the mesial border.
1 – Weak. A weak ridge connects the mesial aspects of cusps 1 and 2, producing a faint groove.
2 – Medium. The connecting ridge is larger and the resulting groove deeper than in grade 1.
3 – Longer. The groove is longer than in grade 2.
4 – Robust. The groove is very long and the mesial ridge is robust.
99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.



GROOVE PATTERN – Even with advanced attrition, groove pattern is often recognizable, although caries and dental casts may create unreliable circumstances. Use a 10x hand lens to ascertain the pattern. When LM3 has many supernumerary cusps, determination of groove pattern can be difficult.

TOOTH: LM1
LM2
LM3

PLAQUE: none

SCORING: 1 – Y Cusps 2 and 3 are in contact.
2 – + Cusps 1,2,3, and 4 are in contact.
3 – X Cusps 1 and 4 are in contact.

99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.

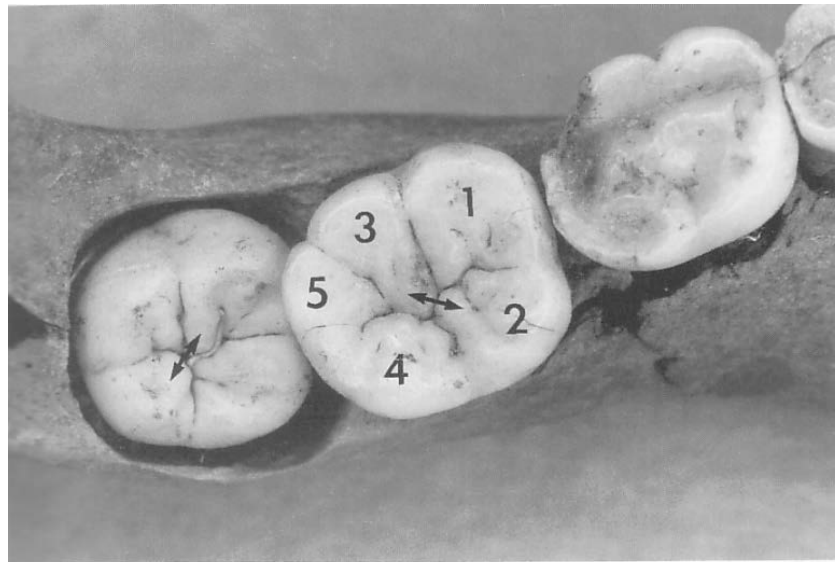


Fig. 2.28 Groove pattern of the lower molars. Gregory's famous *Dryopithecus* Y5 pattern is evident on the lower first molar. The cusps are numbered to emphasize the point that lower molar groove pattern is determined by cusp contact. When cusps 2 and 3 are in contact (as arrowed), the result is a Y pattern. Contact between cusps 1 and 4, shown by the partially erupted lower second molar, results in an X pattern.

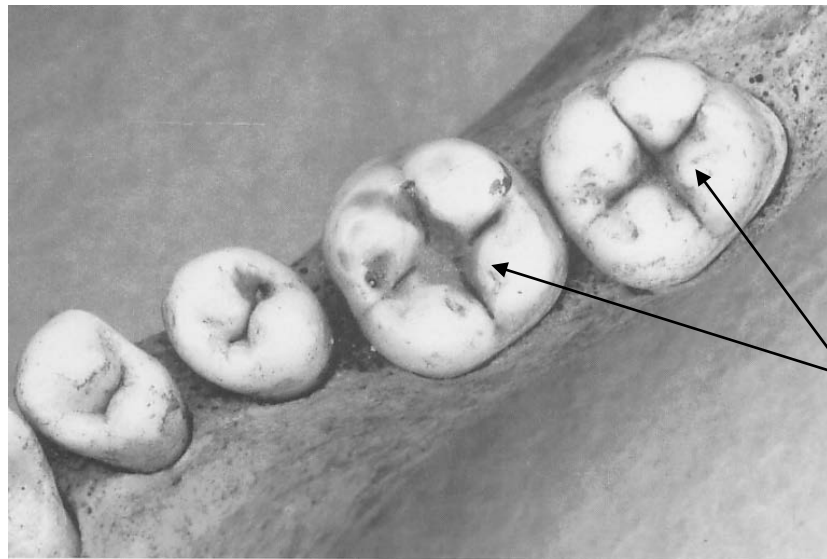
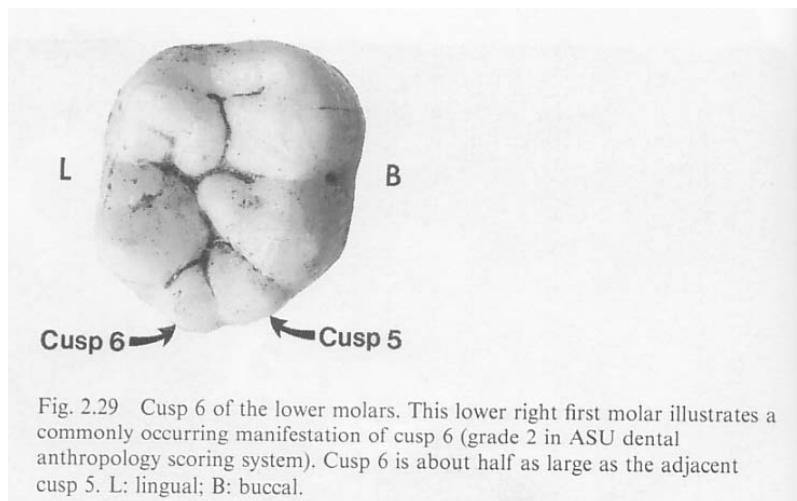


Fig. 2.27 Hypoconulid of the lower molars. The hypoconulid, or cusp 5, of the lower molars is illustrated in Figs. 2.2, 2.28, and 2.29 so the lower molars in this plate illustrate absence rather than presence of the hypoconulid. In this dentition, the lower first and second molars are both 4-cusped teeth. In our population comparisons, we focus on 4-cusped lower molars.

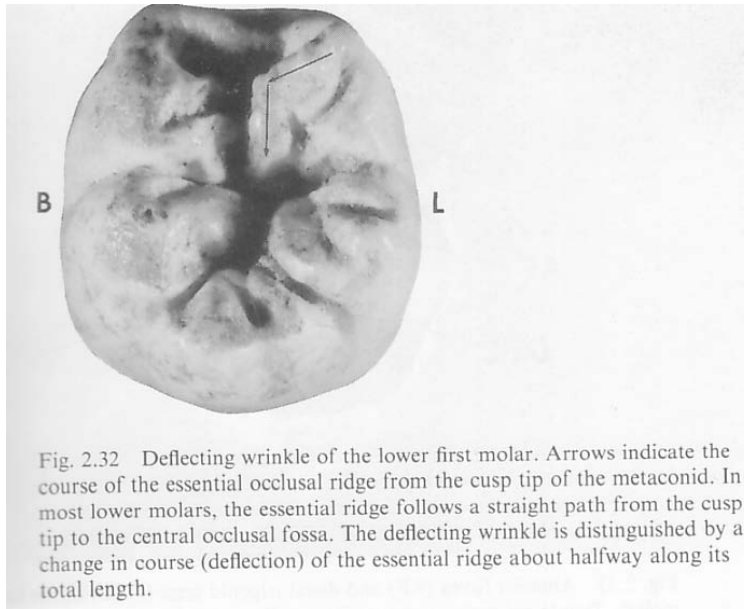
CUSP NUMBER – Score cusps as present regardless of size. Do not confuse cusp 7 in this classification with cusps 2 or 4; ASU does not use cusp 7 to avoid confusion of cusp homologies. If cusp 5 exists, but the presence of cusp 6 is uncertain, score the tooth as having more than 4 cusps, so that a dichotomy of 4 versus more than 4 can be set up for analysis. Note that cusp 3 in LM3 can be small.

TOOTH:	LM1 LM2 LM3
PLAQUE:	none
SCORING:	4 – Four. Cusps 1(protoconid), 2 (metaconid), 3 (hypoconid), and 4 (entoconid) are the only cusps present. 5 – Five. Cusp 5 (hypoconulid) is also present. 6 – Six. Cusp 6 (entoconulid) is also present. 8 - >4. When unsure of cusp 6's presence, score this tooth as having more than 4 cusps. 99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.



DEFLECTING WRINKLE – Variation of the medial ridge on cusp 2 of LM1. Very rarely occurs in LM2 or LM3, and since there is no apparent involvement of dentin in this trait, it is easily worn away and therefore questionable for scoring in individuals > 12 years of age.

TOOTH:	LM1
PLAQUE:	#20
SCORING:	0 – Absent. Deflecting wrinkle is absent; medial ridge of cusp 2 is straight. 1 – Midpoint. Cusp 2 medial ridge is straight, but shows a midpoint constriction. 2 – Distal. Medial ridge is deflected distally, but does not make contact with cusp 4. 3 – L-shaped. Medial ridge is deflected distally, forming an L-shaped ridge. The medial ridge contacts cusp 4. 99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.



DISTAL TRIGONID CREST – A ridge or loph bridging cusps 1 and 2 that is rare in permanent molars (the plaque shows deciduous molars). When present, it is usually found on the first molar. Even slight wear can completely obliterate this trait.

TOOTH:	LM1 LM2 LM3	
PLAQUE:	#21	
SCORING:	0 – Absent.	Distal borders of cusps 1 and 2 are not connected by a crest or loph.
	1 – Present.	Distal borders of cusps 1 and 2 are connected by a crest or loph.
	99 – Unobserv.	This tooth is damaged to the extent the trait cannot be assessed.

PROTOSTYLID – A paramolar cusp found on the buccal surface of cusp 1. It is normally associated with the buccal groove separating cusps 1 and 3, and is most commonly seen on LM1 and LM3. The buccal pit characteristic of grade 1 of the protostylid is often the site of a carious lesion; only score as a protostylid if the protostylid can be observed in the caries. In modern populations, the protostylid is often filled by dentists as a preventive measure.

TOOTH:	LM1 LM2 LM3	
PLAQUE:	#22	
SCORING:	0 – Absent.	Protostylid is absent. Buccal surface is smooth and shows no pits.
	1 – Pit.	A pit occurs in the buccal groove.
	2 – Distal.	The buccal groove is curved distally.
	3 – Faint 2.	A faint secondary groove extends medially from the buccal groove.
	4 – Medium 2.	The secondary groove is slightly more pronounced.
	5 – Strong 2.	The secondary groove is stronger and can easily be seen.
	6 – Sm. cusp.	The secondary groove extends across most of the buccal surface of cusp 1. This is considered a weak or small cusp.
	7 – Free apex.	A cusp with a free apex is present.
	99 – Unobserv.	This tooth is damaged to the extent the trait cannot be assessed.



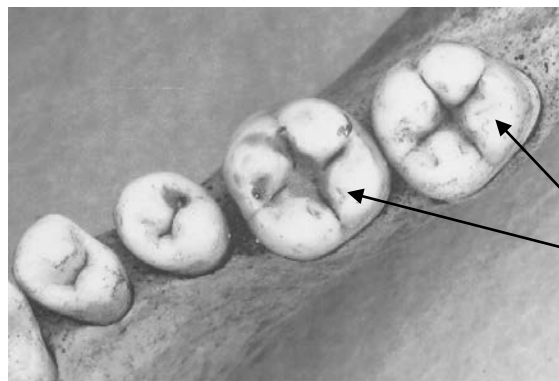
Fig. 2.31 Protostylid of the lower molars. This cingular variant, indicated by arrows, is expressed on the mesiobuccal cusps of all three lower molars. The protostylid, while showing some parallels to Carabelli's trait of the upper molars, is not expressed as commonly, nor to such pronounced degrees as its maxillary cingular counterpart.

CUSP 5 – The hypoconulid occurs on the distal occlusal aspect of the lower molars. It is graded in terms of size only in the absence of cusp 6. There is no way to know if a single distal cusp is number 5 or 6.

TOOTH: LM1
LM2
LM3

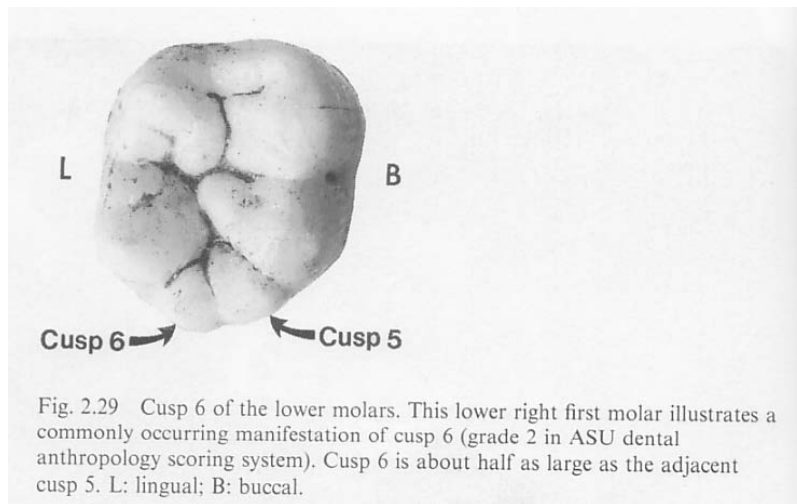
PLAQUE: #23

SCORING: 0 – Absent. Cusp 5 is not present. The molar only has 4 cusps (cusps 1, 2, 3, and 4).
1 – V. small. Cusp 5 is present and very small.
2 – Small. Cusp 5 is present and small.
3 – Medium. Cusp 5 is present and medium-sized.
4 – Large. Cusp 5 is present and large.
5 – V. large. Cusp 5 is present and very large.
99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.



Trait ABSENCE

Fig. 2.27 Hypoconulid of the lower molars. The hypoconulid, or cusp 5, of the lower molars is illustrated in Figs. 2.2, 2.28, and 2.29 so the lower molars in this plate illustrate absence rather than presence of the hypoconulid. In this dentition, the lower first and second molars are both 4-cusped teeth. In our population comparisons, we focus on 4-cusped lower molars.

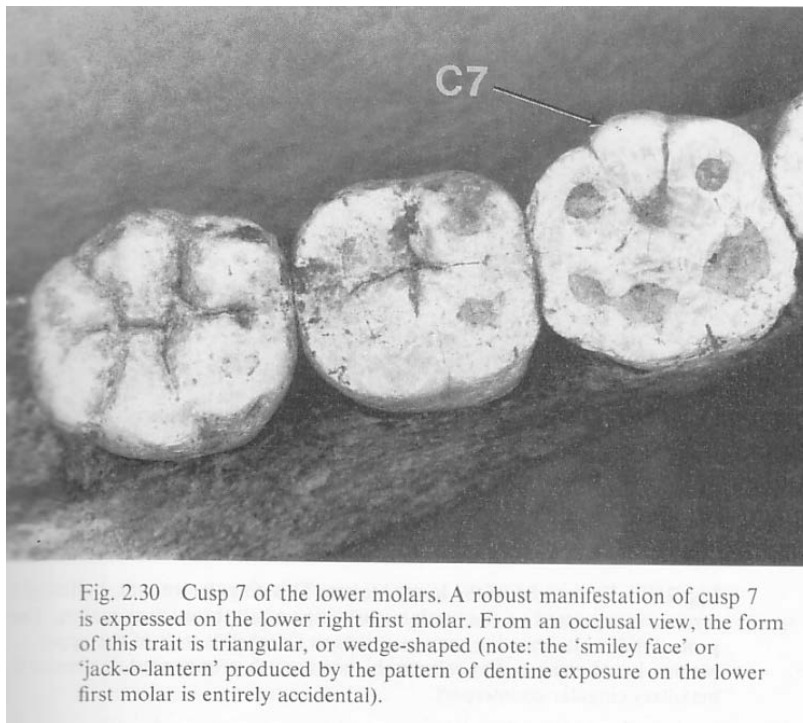


CUSP 6 – The entoconulid occurs in the distal fovea of the lower molars lingual to cusp 5. It is scored based on its relative size to cusp 5.

TOOTH:	LM1 LM2 LM3	
PLAQUE:	#24	
SCORING:	0 – Absent.	Cusp 6 is absent.
	1 – V. small.	Cusp 6 is much smaller than cusp 5.
	2 – Small.	Cusp 6 is smaller than cusp 5.
	3 – Equal.	Cusp 6 and cusp 5 are equal in size.
	4 – Large.	Cusp 6 is larger than cusp 5.
	5 – V. large.	Cusp 6 is much larger than cusp 5.
	99 – Unobserv.	This tooth is damaged to the extent the trait cannot be assessed.

CUSP 7 – The metaconulid occurs in the lingual groove between cusps 2 and 4 of the lower molars, especially LM1. Cusp 7 is NEVER used in determining lower molar cusp number, as it can appear without the presence of either cusp 5 or cusp 6.

TOOTH:	LM1 LM2 LM3	
PLAQUE:	#25	
SCORING:	0 – Absent.	Cusp 7 is absent.
	1 – Faint.	A faint cusp is present, and two weak lingual grooves are present instead of one.
	1A – Tipless.	A faint but tipless cusp 7 occurs displaced as a bulge on the lingual surface of cusp 2.
	2 – Small.	Cusp 7 is small.
	3 – Medium.	Cusp 7 is medium-sized.
	4 – Large.	Cusp 7 is large.
	99 – Unobserv.	This tooth is damaged to the extent the trait cannot be assessed.



MIDDLE TRIGONID CREST – A ridge or loph that connects the middle aspect of cusps 1 and 2 on the lower molars.

TOOTH: LM1
LM2
LM3

PLAQUE: #26

SCORING: 0 – Absent. Middle trigonid crest is absent. The middle aspect of cusps 1 and 2 is smooth.
1 – Sharp. A sharp crest connects cusps 1 and 2.
2 – Wide. A wide ridge that forms a small, rounded elevation connects cusps 1 and 2.
99 – Unobserv. This tooth is damaged to the extent the trait cannot be assessed.