КУНСТКАМЕРА

РОССИЙСКАЯ АКАДЕМИЯ НАУК

МУЗЕЙ АНТРОПОЛОГИИ И ЭТНОГРАФИИ
ИМЕНИ ПЕТРА ВЕЛИКОГО (КУНСТКАМЕРА)

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при поддержке фонда
Династия

30 АПРЕЛЯ – 5 МАЯ 2012
САНКТ-ПЕТЕРБУРГСКИЙ СЕМИНАР ПО ГЕОМЕТРИЧЕСКОЙ МОРФОМЕТРИИ ДЛЯ АНТРОПОЛОГОВ, БИОЛОГОВ И АРХЕОЛОГОВ

DR. GERMAN MANRIQUEZ. Lecture

"WHY GMM ARE USEFUL IN ANTHROPOLGY AND ARCHAEOLOGY?

EXCELLENCE IN SCIENCE
THE ROYAL SOCIETY

PROYECTO ANILLO ACT-96
Programa de Investigación Asociativa de CONICYT

Saint Petersburg Workshop on GMM

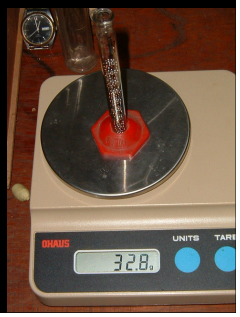
Definitions

What does mean to make measurements?

Why we need to make measurements?

Research program of GM

WHAT DOES MEAN TO MEASURE?



1. Our perception of the universe is directly related to the estimation of tha main parameters describing change: space, time, matery and energy.

2. These parameters are understood through the notions of “entity” and “object”.

3. To measure consists in estimating the parameters of space, time, matery and/or energy

4. The estimation can be discrete or continuous

5. … and based on instruments that optimyze the perception we have about the object.

6. Measurements should be: Operational (unambiguous and clear computational algorithms), reproducible (increasing precision), testable (based on statistical hypotheses) and systematic (based on population sampling)

WHY TO MAKE MEASUREMENTS?

We make measurements in order to know the properties of the objects of the Universe.
…to compare them
…To analyse them and to understand the causes of the processes where those objects are participating as biological entities.

To establish the significance of the differences between and within groups (populations) through **hypothesis testing**

HΣ

•**Statistical hypotheses**: Allow to make decissions about the problem: are the observed differences explained by chance?

Hβ

•**Biological (anthropological, archaeological) hypotheses**, allow to make decissions about the problem: there is any causal factor different to chance which could explain the observed results? (sex, age, origin, genetic variation, etc.)

WHY TO MEASURE HUMAN POPULATIONS?

To know the causes of their:

VARIABILITY: Role played by evolutionary factors such as natural selection, genetic drift, and migration, among others, in the generation of genetic and phenotypic changes

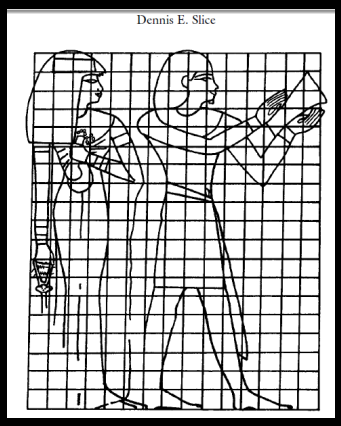
COMPLEXITY: Nature and type of the relationships established between the parts of any structure as well as between the functions derived from those parts.

HISTORY: Individual (ontogenetic) and supraspecific (phyilogenetic) changes of populations during time.

Quantitative methods have been used for a long time in Anthropology, Biology and Archaeology to assess the type of relationship between multiple variables and thus allowing the estimation of populational parameters.

Howell data base (skulls)
Goldman data set (long bones)
Decorated skulls from Austria

www.paleoanth..org



Structure of the matrix with raw data obtained from measurement of interlandmark distances (or geometric distances)

CAUSAL VECTORS (DISCRETE, CONTINOUS IND. VARS)				DEPENDENT VARIABLES (INTERLANDMARK DISTANCES OR SHAPE COMPONENTS					
PLM3	ND	-2	-1	-0.0043	-0.0146	0.0192	-0.0024	0.0153	0.0067
ARICA	ND	-2	-1	-0.0075	-0.0061	0.0159	0.0167	0.0269	0.0003
PLM3	ND	-2	-1	-0.0099	0.0216	0.0068	-0.0099	-0.0327	0.0037
PLM3	CO	0	-1	0.0327	0.0321	0.0327	-0.0089	0.0053	-0.0153
PLM3	ND	-2	-1	-0.0054	0.0182	0.0226	0.0055	0.0045	0.0049
PLM3	TO	2	-1	0.0332	0.0004	0.0346	-0.005	0.0133	-0.0008
CHLL5	ND	-2	-1	-0.0253	0.0024	0.013	0.0215	-0.0019	0.0049
PLM4	ND	-2	-1	-0.0495	-0.0069	-0.0031	0.0238	-0.0023	-0.006
ARICA	ND	-2	-1	-0.0342	-0.0155	0.0116	0.0155	0.0059	-0.0046
CAM8	ND	-2	-1	-0.0092	-0.0027	0.0151	-0.0158	0.0285	0.0042
PLM3	ND	-2	-1	-0.0369	0.0086	0.0264	0.0177	-0.0296	-0.0047
CAM9	ND	-2	-1	-0.0442	0.0259	-0.0368	0.0038	0.0124	0.0063
PLM4	CO	0	-1	0.0752	0.0603	-0.0141	0.0165	-0.0041	0.01
AZ105	CO	0	-1	0.0203	0.0197	0.0242	-0.0047	-0.0052	0.001
SR	CO	0	-1	0.0508	0.005	0.0121	-0.0093	0.0078	-0.0052
SR	TE	1	-1	-0.0069	-0.0391	-0.0051	0.0349	0.0151	0.0044
PLM3	ND	-2	-1	-0.0047	0.0015	0.003	-0.0049	0.0107	-0.01
CAM9	ND	-2	-1	-0.0314	0.0193	0.0272	-0.0177	-0.0359	0.0135
CAM9	CO	0	-1	0.0159	0.0546	0.0027	0.0139	0.009	-0.0026
CHLL5	ND	-2	-1	-0.0484	0.0315	-0.0067	0.0288	-0.0112	-0.0046
PLM3	ND	-2	-1	-0.0332	-0.0091	0.0114	-0.0076	-0.021	0.0011
PLM3	ND	-2	-1	-0.0431	0.0034	0.0134	0.0041	0.0076	-0.0026

¿Why GMM are useful in Anthropolgy and Archaeology?

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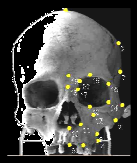
Approaches

Linear and geometric morphometrics



LINEAR MULTIVARIATE MORPHOMETRICS

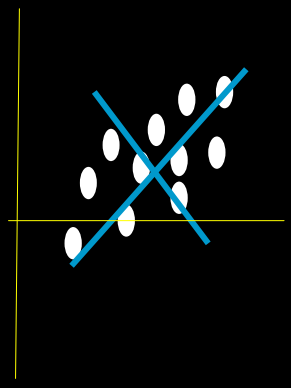
Exploratory analyses (PCA) a posteriori

Multivariate analysis reduces the number of original dependent variables to a few new variables resuming jerarchically the overall variance of the sample

When the number of variables is higher than two the resulting graphs represent a morphometric space

Confirmatory analyses (DA, REG) a priori

Uses categorical (discrete) independent variables in order to test the statistical significance of the observed differences between groups

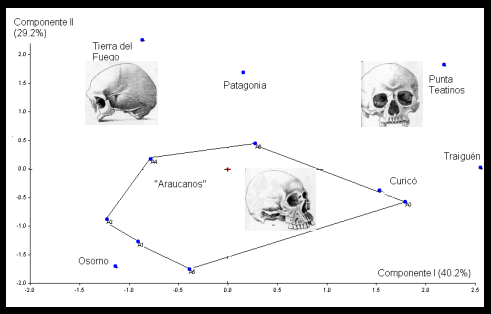


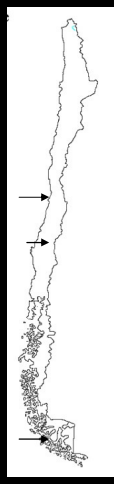
Original raw data: interlandmark distances

↓

Indeces → Principal component analysis

Tabla 1	Indices	
Procedencia	1) AAF/DOF	2) DBM/DFO
Araucano	0.68**	1.41*
Araucano	0.62	1.56
Araucano	0.77*	1.44
Araucano	0.71	1.31
Araucano	0.69	1.38**
Araucano	0.73	1.45
Traiguén	0.73	1.30
Osorno	0.69**	1.24
Curicó	0.77*	1.23
Pta. Teatinos	0.67**	1.42*
Patagonia	0.66	1.39**
Chonos	0.67**	1.26
T. del Fuego	0.65	1.66





Skull shape variation in prehispanic chilean population from Central a nd Southern Chile. Original data (Medina, 1882),

GEOMETRIC MORPHOMETRICS

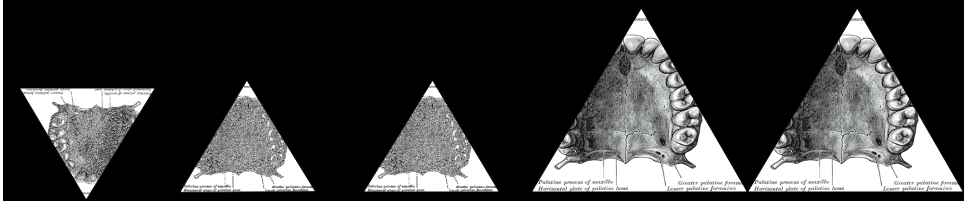
Morfometry: Analysis of shape changes due to growth, experimental treatment and/or evolution in a finite group of organisms (Rohlf & Marcus, 1993).

Statistical analysis of covariance between shape and its causal factors (Bookstein, 1991)

Geometric Morphometrics: The suit of methods for the adquisition, processing, and analysis of shape variables that retain all of the geometric information obtained within the data (Slice, 2007)

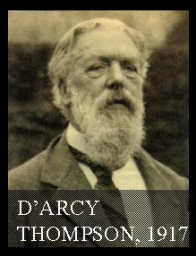
Shape: the **geometric properties** of an object that are **invarant to** location, scale, and orientation (Slice, 2007)

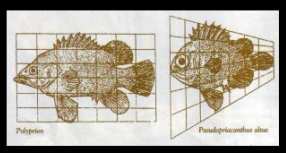
Form: Size + Shape (Uniform, Non-uniform)

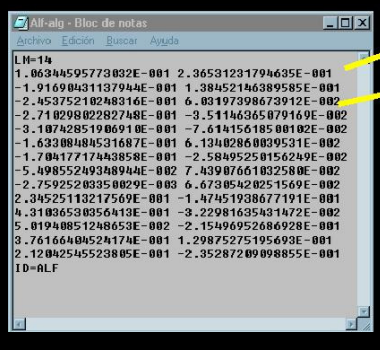


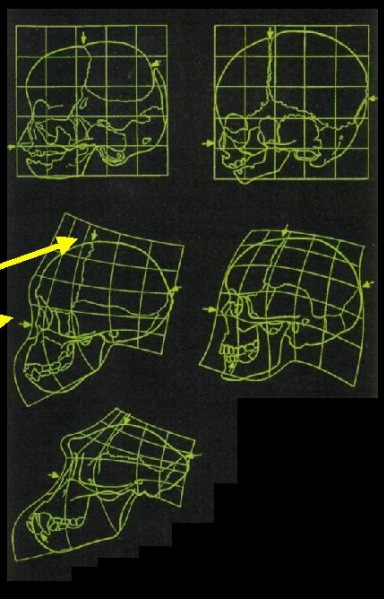
Theory of transformation of cartesian grids

Saint Petersburg Workshop on GMM



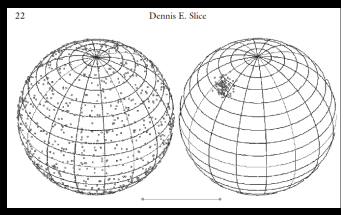






Research program of geometric morphometrics (after Bookstein, 1991, with modifications)

1) Create matrices of homologous landmarks as raw data (2D, 3D)
2) Obtain an estimator of size which is independent of scaling effect (centroid size)
3) Possing classical and new problems in biometry: there is any covariation between the variables, and if any, which is the cause of that covariartion?
4) Testing statistical and biological hypothesis using procrustes analysis and multivariate statistics for the resulting linear vectors (shape components)
5) To describe and analyse differences between groups using thin plate spline function
6) Explaining and understanding the causal factors of shape variation

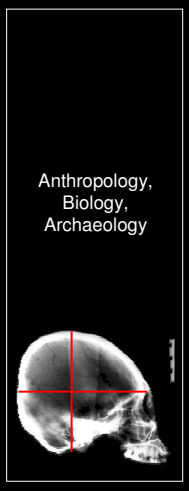


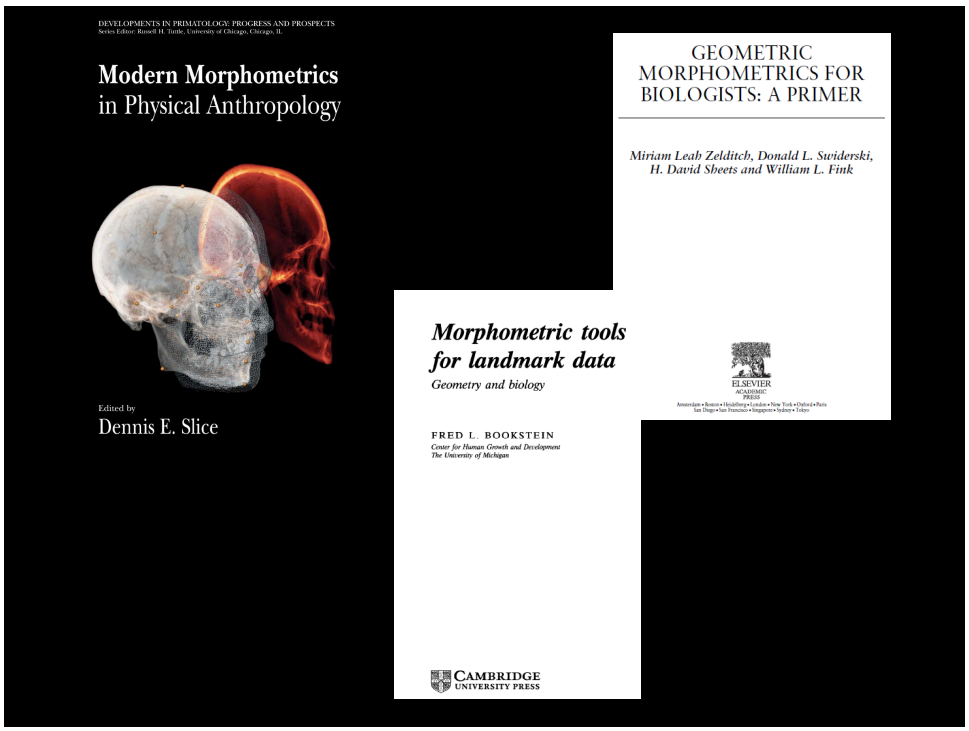
Why GMM are useful in Anthropolgy and Archaeology?

Saint Petersburg Workshop on Geometric Morphometrics for Anthropologists, Biologists and Archaeologists, 30 April – 05 May 2012

Examples

Anthropology,
Biology,
Archaeology





Contribution of geometric morphometrics to the study of biological affinities between Fueguian populations: a three dimensional analysis of skull shape variation. (Grant Fondecyt 1020375)

The current state of the knowledge about the biological affinities among the first inhabitants of Tierra del Fuego (Selknam, Kaweskar, Yamana and Aonikenk), and the Amerindian populations of southern Chile (Mapuches, Huilliches, Chonos) deals with classic problems of Physical Anthropology and Population Genetics: 1) what factors do explain the morphological variation of these populations? and 2) Which is the pattern of genetic variation that characterizes them?

Although these problems are common to every research on the causality of human biodiversity, the case of the fueguians is particularly interesting due to the knowledge that has been obtained about their anatomical atributes, the extreme environmental conditions in which they lived and the rol that those conditions played in the early peopling of Southamerica (Massone, 1989, Manríquez & Llop, 2004).

Figura 1: Ubicación de los territorios de origen de las muestras de cráneos utilizadas en este estudio (O= Kaweskar, Δ= Yaghan □= Selknam, en recuadro, ★ = Mapuche, ●= Chono).

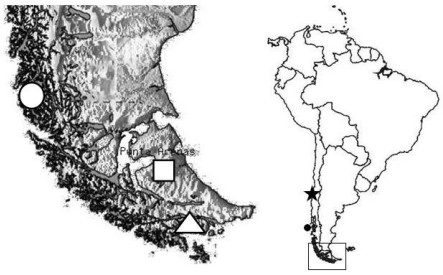
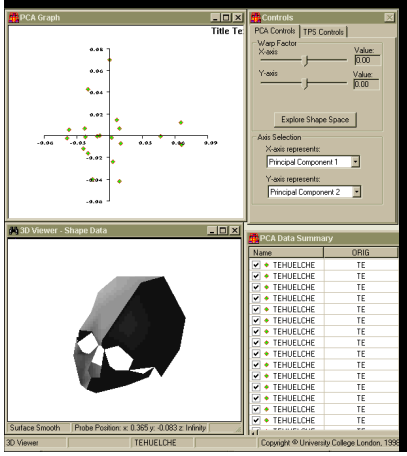
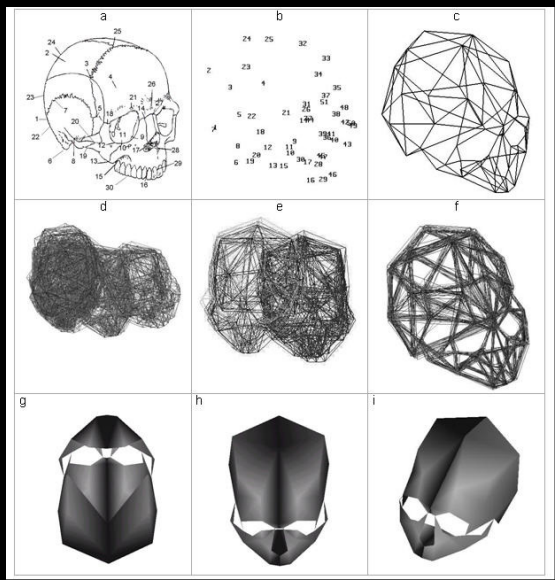


Figura 2: a) Hitos utilizados en el análisis de la variación de la forma del cráneo mediante morfometría geométrica 3D (Los hitos 31-51 se ubican simétricamente en el lado izquierdo, según definición en Tabla 1), b) Ubicación de los hitos en 3D, c) red de polígonos, d-e) Muestra de cráneos antes de eliminar diferencias de tamaño, rotación y traslacion, f) Cráneos alineados luego de efectuar el análisis de procrustes, g-i) vistas tridimensionales de la configuración de consenso de la muestra utilizada en este estudio



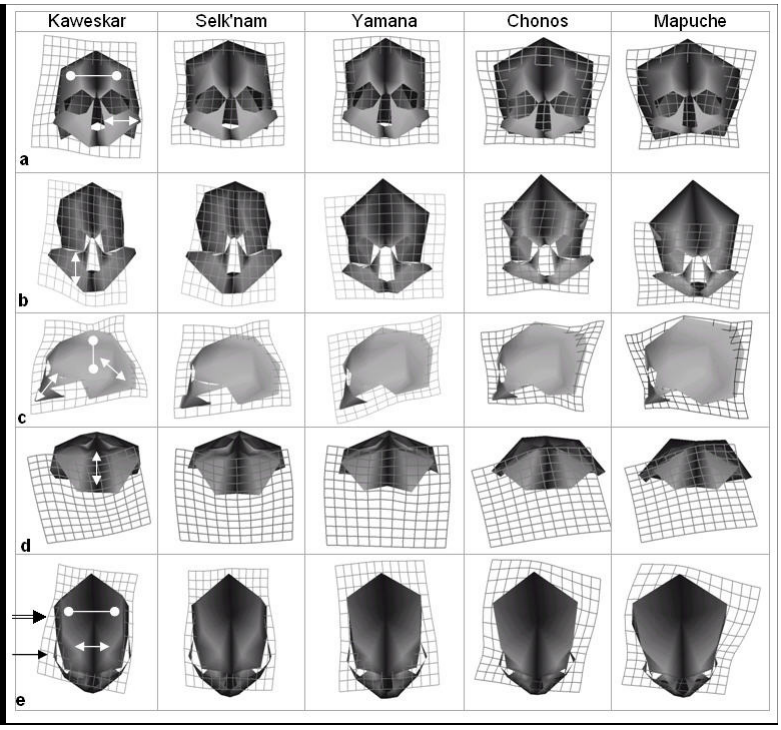


↔= expansión,

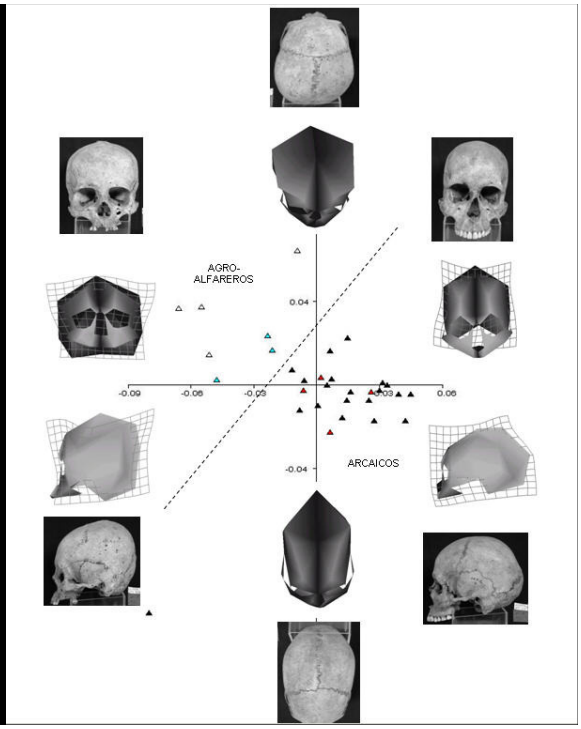
o---o= contracción,

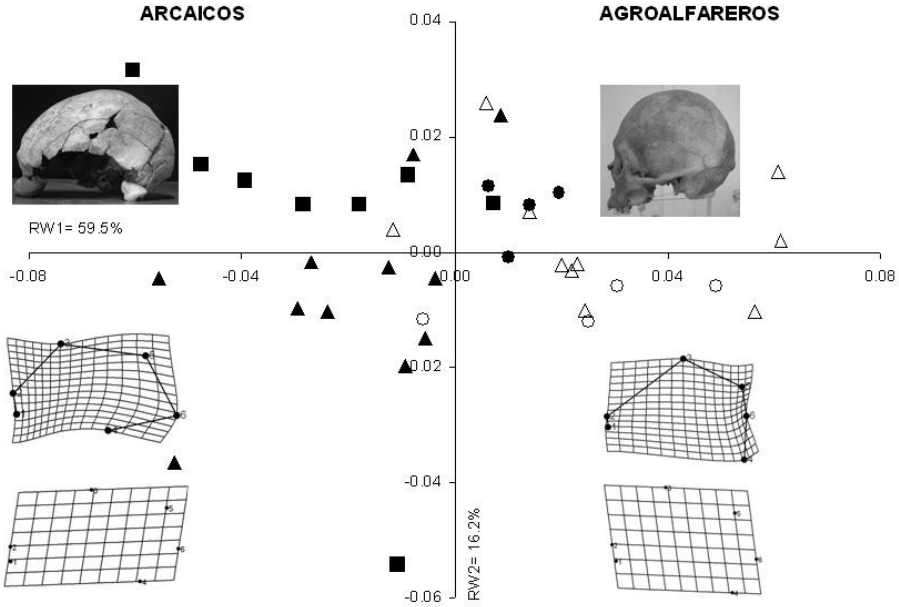
→= zona de inserción del músculo pterigoideo lateral en el proceso cigomático del temporal,

⇒ = línea temporal inferior



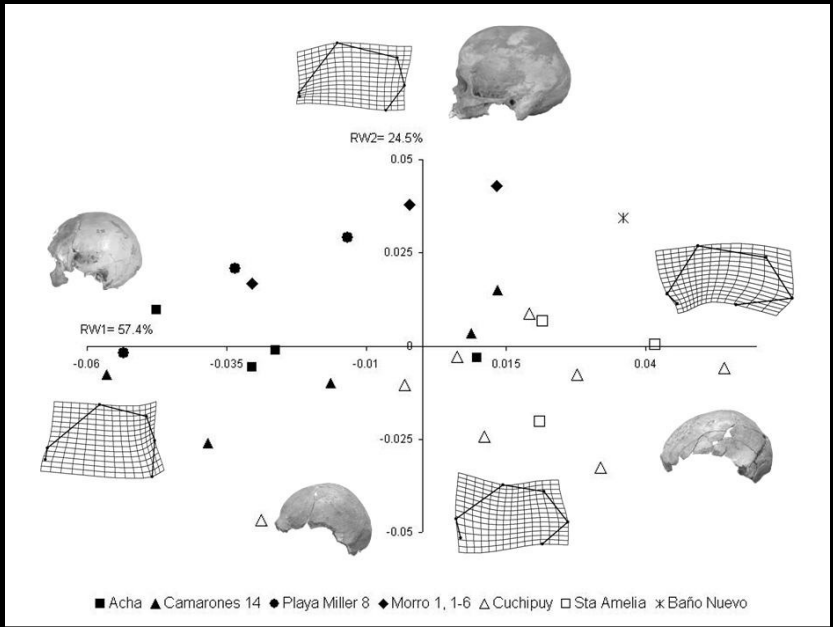
Analysis of skull shape variation in archaic and non-archaic prehispanic populations of Central Chile using 3D and 2D geometric morphometrics



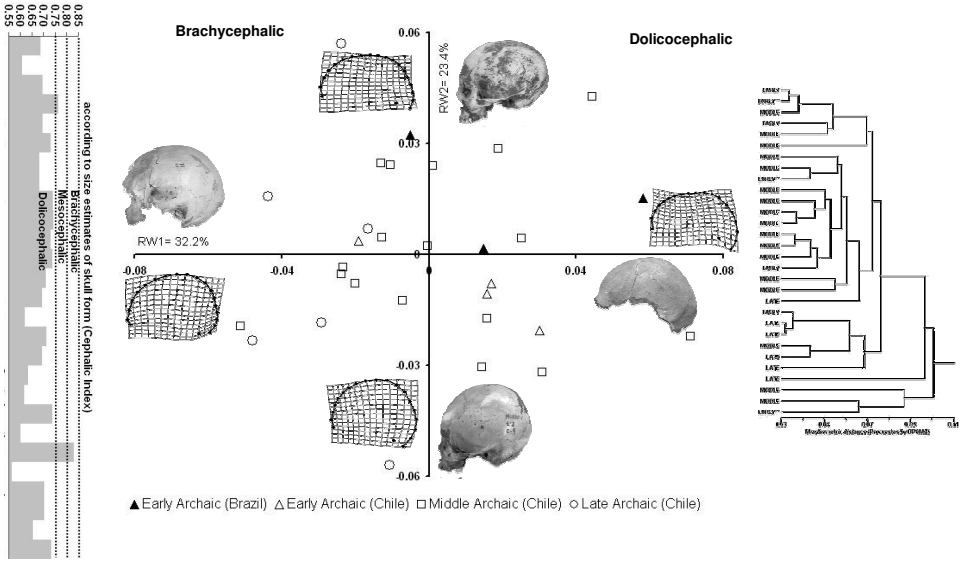


■ Cuchipuy ▲ La Herradura ● El Peral/Arc. ○ El Peral/Agro △ Cia. Baja-Peñuelas

Analysis of skull shape variation in archaic prehispanic populations of Northern (Acha, Camarones, Playa Miller 8, Morro 1, 1-6), Central (Cuchipuy, Sta. Amelia), and Southern (Baño Nuevo) Chile using 2D geometric morphometrics



Size and shape components of morphological variation in archaic samples from Chile,and Brazil, according to lineal and geometric morphometrics approaches. The grids represent the pattern of shape variation at positive and negative extreme values (x3) of the first two principal shape componentes in relation to the "consensus", non deformed configuration.



[redacted]

[redacted]ysis of skull shape variation in different ethnic origin

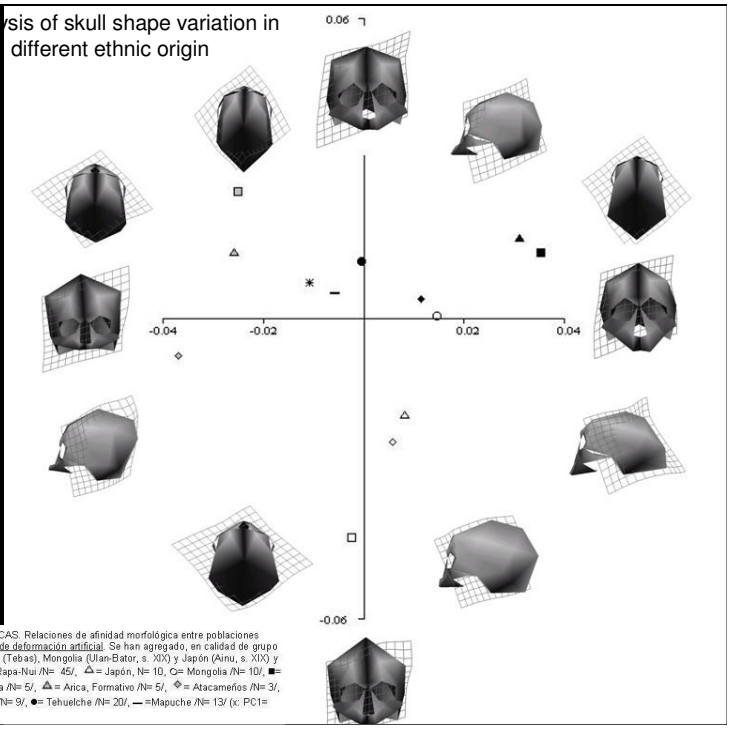
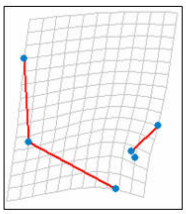
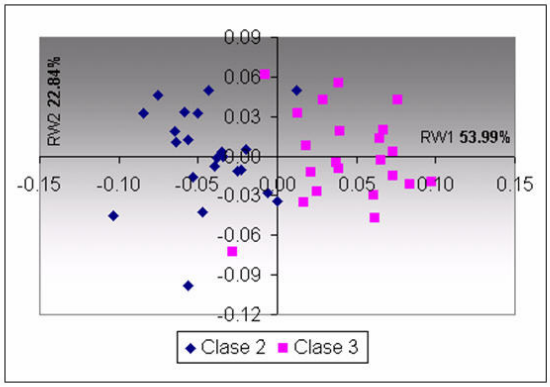
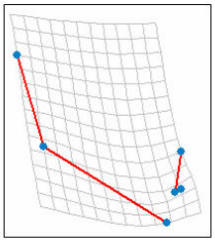


Figura 9: MUESTRA POBLACIONES PREHISPANICAS. Relaciones de afinidad morfológica entre poblaciones prehispánicas de Chile, no afectadas por la práctica de deformación artificial. Se han agregado, en calidad de grupo externo, los promedios de cráneos de Egipto antiguo (Tebas), Mongolia (Ulan-Bator, s. XIX) y Japón (Ainu, s. XIX) y Rapa-Nui (s. XIX) (□= Egipto antiguo /N= 10/, ◇= Rapa-Nui /N= 45/, △= Japón, N= 10, ○= Mongolia /N= 10/, ■= Selknam /N= 7/, ▲= Kaweskar /N= 16/, ◆= Yamana /N= 5/, ◬= Arica, Formativo /N= 5/, ◈= Atacameños /N= 3/, ▨= Agroalfareros Chile central /N= 10/, ✳= Chono /N= 9/, ●= Tehuelche /N= 20/, ▬ =Mapuche /N= 13/ (x: PC1= 24.4%, y: PC2= 19.7% de la varianza total).

[redacted]







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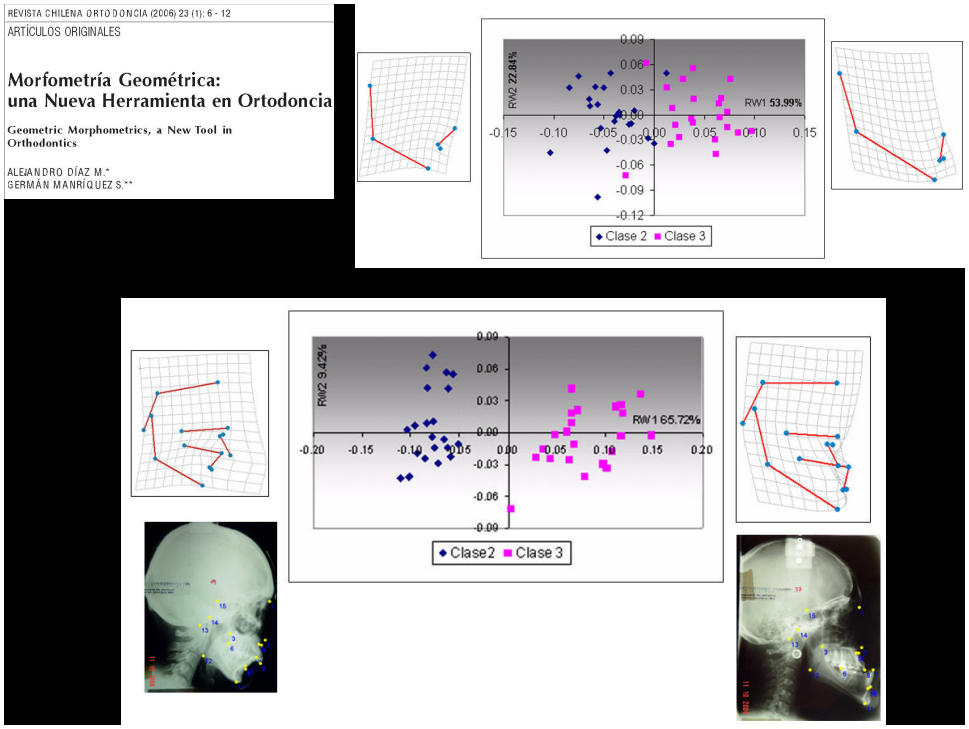
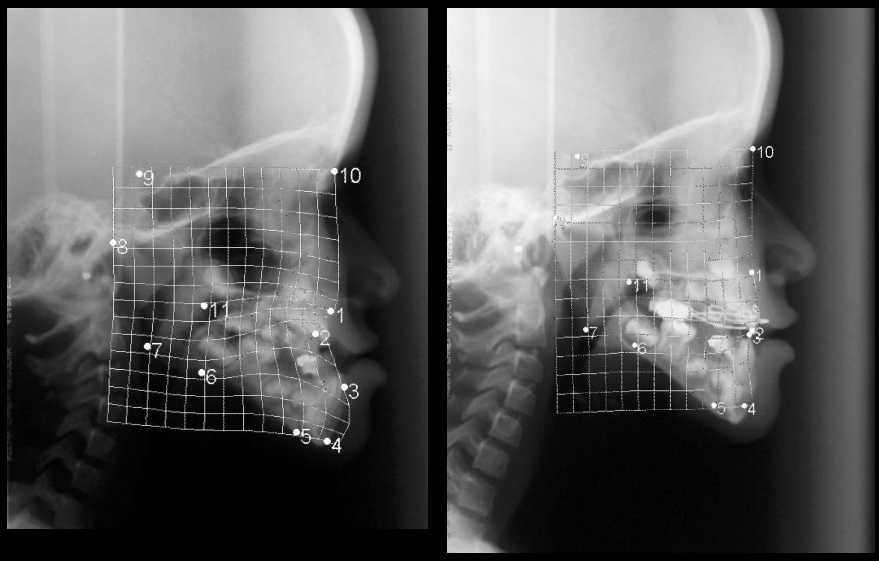

REVISTA CHILENA ORTODONCIA (2006) 23 (1): 6 - 12
ARTÍCULOS ORIGINALES

Morfometría Geométrica: una Nueva Herramienta en Ortodoncia

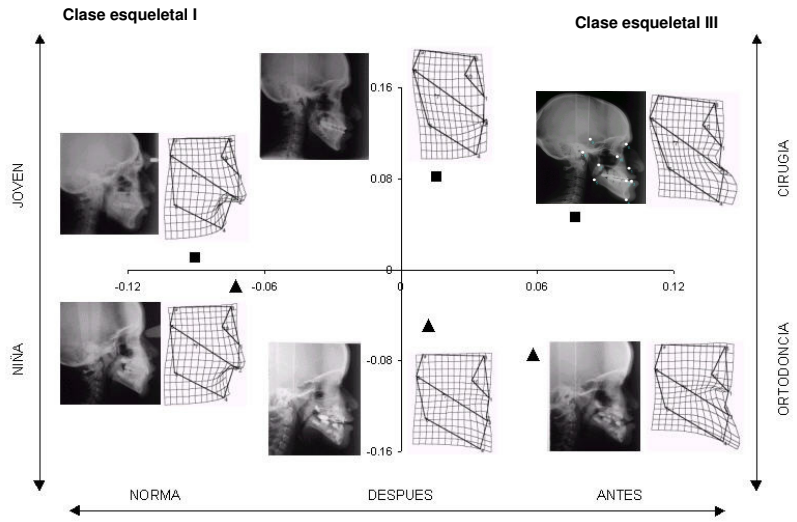
Geometric Morphometrics, a New Tool in Orthodontics

ALEJANDRO DÍAZ M.*
GERMÁN MANRÍQUEZ S.**

APLICACION CLINICA: VECTORES BIOMECANICOS EN UN CASO DE HIPERPLASIA MAXILAR

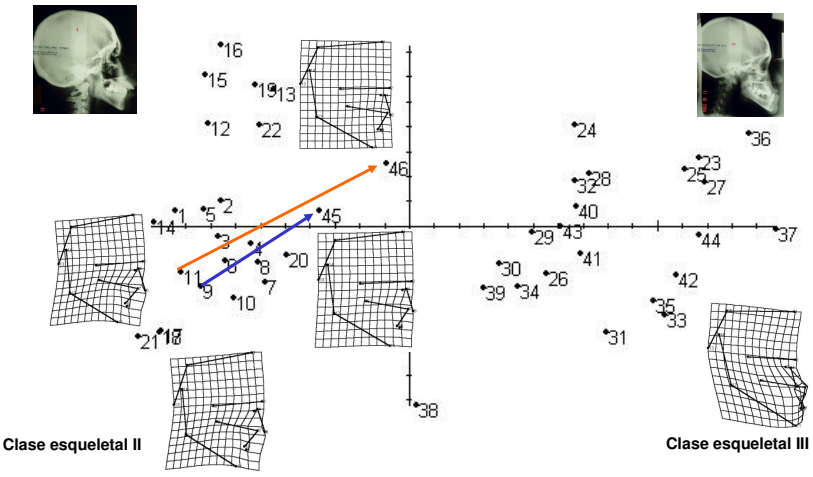


G. Manríquez, F. González, Servicio DentoMaxilo Facial Hosp. Clínico U. de Chile.

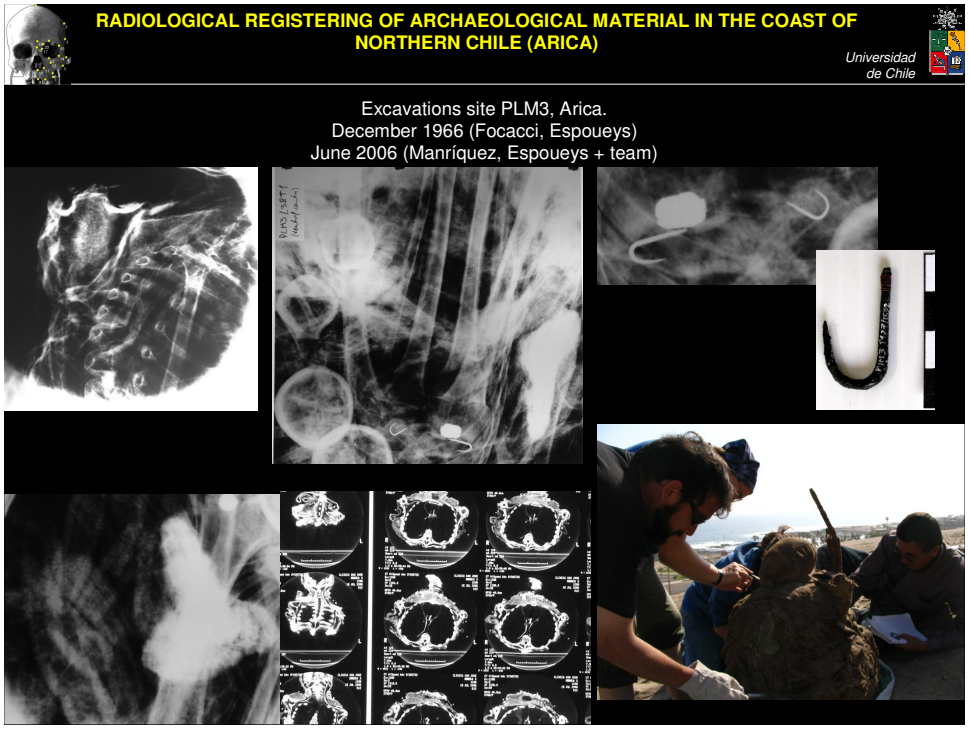


Pacientes, Servicio Dento Máxilofacial, Hosp. Clínico U. de Chile. Análisis, Dr. Fermín González.
Niña 6 años (▲▲), tratamiento ortopédico. Joven 20 años (■), tratamiento ortodóncico-quirúrgico, crecimiento óseo terminado. Ambos de clase esqueletal III

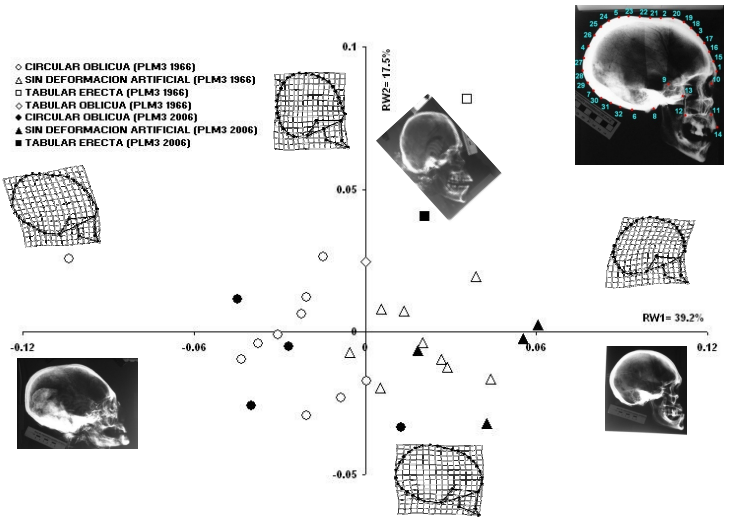
Variación de la Forma Facial Post-tratamiento Ortopedico-quirurgico:Análisis de Telerradiografías Craneofaciales Mediante Morfometría Geométrica.
F. González, JC Salinas y G. Manríquez
XVII Reunión Anual International Association for Dental Research Sección Chile, Concepción, Nov. 2004



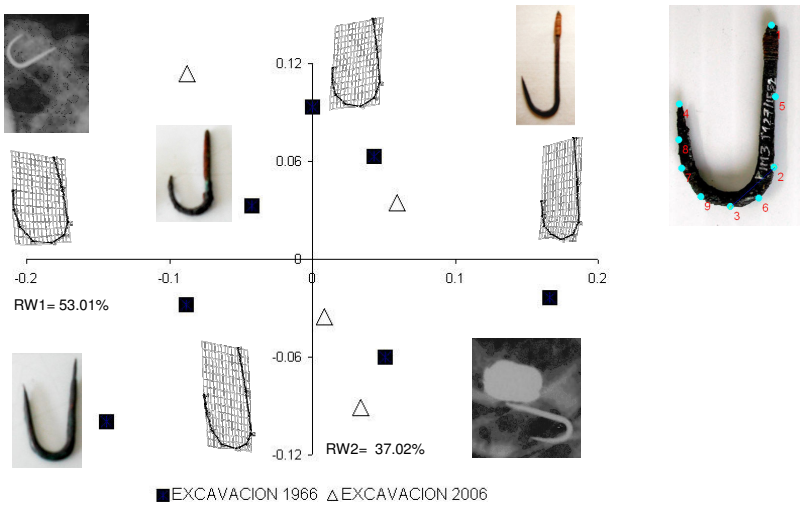
Pacientes, Unidad de Cirugía Máxilofacial Hospital San Borja Arriarán, Análisis (Dr. Alejandro Díaz M.)
Clases esqueletales II (izquierda), I (centro) y III (derecha) y reubicación de dos pacientes en el espacio morfométrico de Clase esqueletal I luego de la cirugía



Análisis morfométrico de los componentes arqueológicos del cementerio Playa Miller 3



(PLM3_1966 vs PLM3_2006) (análisis de regresión /Prueba de F según Goodall F = 0.9069, df = 58, 1682 : P = 0.6737



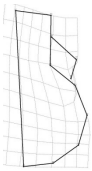
(PLM3_1966 y PLM3_2006) (análisis de regresión /Prueba de F según Goodall/: F = 0.2389, df = 14, 126 : P = 0.9979;

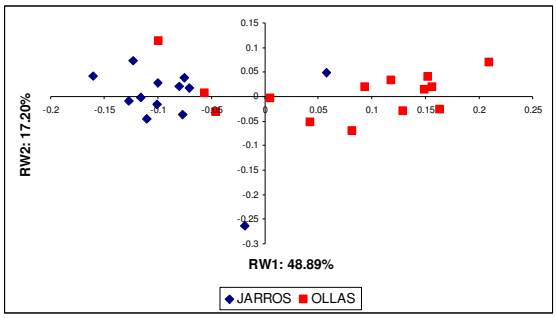
Figueroa, V. y G. Manríquez, XVI Congreso Nacional de Arqueología Argentina (San Salvador de Jujuy, 8-12 de Octubre, 2007)

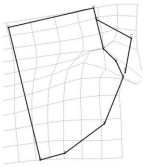
Poblaciones cerámicas de Rancagua /Itaci Correa, alumna Arqueología, Fac.Soc. U Chile/.
Confeccion de mapa de homologías y digitalizacion y con uso de tpsdig

1. Punto medio del borde
2. Borde lateral derecho
3. Unión cuello-cuerpo
4. Diámetro Máximo
5. Base
6. Punto medio de la base
7. Punto medio entre hitos 3 y 4
8. Punto medio entre hitos 4 y 5
9. Alto Superior del asa
10. Bajo alto inferior del asa
11. Punto más lateral del asa

Análisis Exploratorio: Jarros V/S Ollas (tpsRelw)







Efectos de la domesticación y origen del cuy (*Cavia porcellus*)

Ancient and modern steps during the domestication of guinea pigs (*Cavia porcellus* L.)

A. E. Spotorno[1], J. C. Marín[1], G. Manríquez[1], J. P. Valladares[1], E. Rico[2] & C. Rivas[2]

1 Laboratorio de Genómica Evolutiva de Mamíferos, ICBM, Facultad de Medicina, Universidad de Chile, Santiago, Chile
2 Proyecto MEJOCUY, Universidad Mayor de San Simón, Cochabamba, Bolivia

Journal of Zoology **270** (2006) 57–62

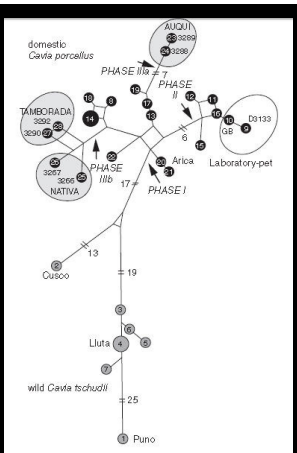


Figure 4 Median joining network representing the relationships between 28 mitochondrial cytochrome *b* gene haplotypes of wild and domestic guinea pigs. The number within each circle corresponds to haplotype number; circle size is proportional to frequency, where the smallest circles represent single copy sequences and the largest ones represent two copies. Numbers on branches are mutational steps. Arrows mark inferred domestication phases.

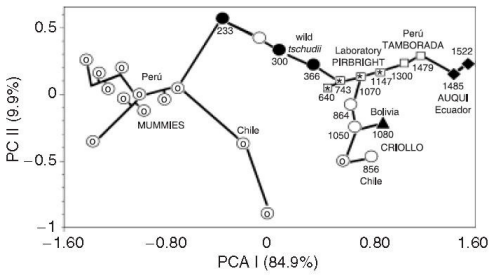
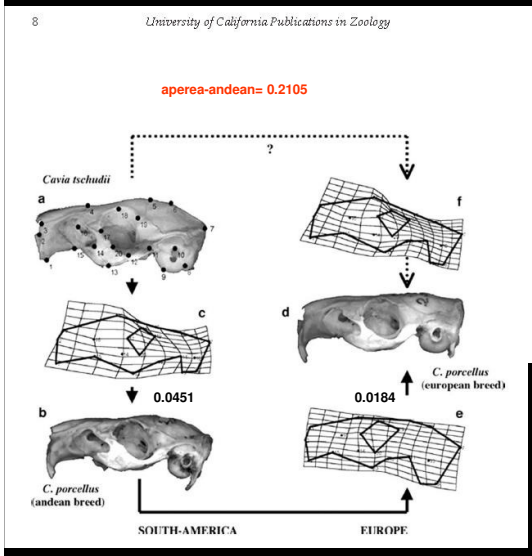


Figure 2 Minimum spanning tree in the principal component analysis of six cranial and post-cranial measurements from four domestic guinea pig breeds, 13 mummies and three wild cavies. Percentages are per cent of total variance explained by each axis. Numbers below specimens are weights (in g).

Efectos de la domesticación y origen del cuy (*Cavia porcellus)*



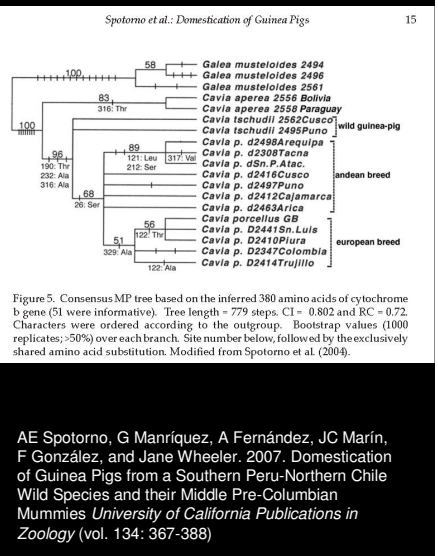
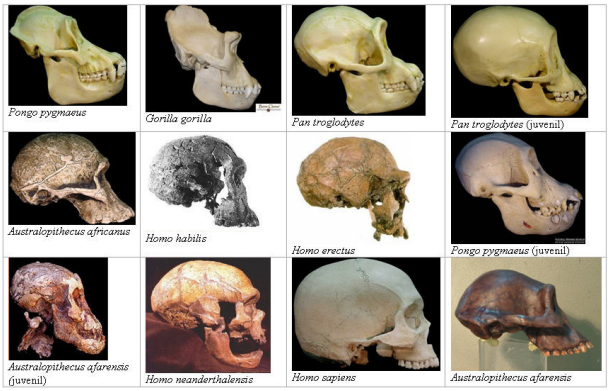


Figure 5. Consensus MP tree based on the inferred 380 amino acids of cytochrome b gene (51 were informative). Tree length = 779 steps. CI = 0.802 and RC = 0.72. Characters were ordered according to the outgroup. Bootstrap values (1000 replicates; >50%) over each branch. Site number below, followed by the exclusively shared amino acid substitution. Modified from Spotorno et al. (2004).

AE Spotorno, G Manríquez, A Fernández, JC Marín, F González, and Jane Wheeler. 2007. Domestication of Guinea Pigs from a Southern Peru-Northern Chile Wild Species and their Middle Pre-Columbian Mummies *University of California Publications in Zoology* (vol. 134: 367-388)

LA NEOTENIA COMO FACTOR EVOLUTIVO DE LOS HOMINIDOS

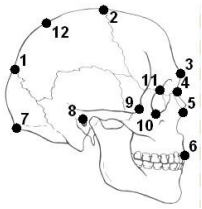
1. En este seminario se aplicarán técnicas de Morfometría Geométrica (MG). La morfometría tiene como objeto de estudio la descripción anatómica y el análisis numérico de la variación de los seres vivos en forma (desarrollo) y tamaño (crecimiento), así como el conocimiento de las causas que explican dicha variación



2. La MG se caracteriza por capturar y conservar la información espacial (geométrica) de la estructura que se estudia mediante la sobreposición de matrices de coordenadas para dos (*x, y*) o tres dimensiones (*x, y, z*), eliminando las diferencias de rotación y traslación, y ajustando la escala. Se obtienen componentes de la forma de los espécimenes, independientemente del tamaño.

3. Los puntos definidos por cada par de coordenadas x e y corresponden a hitos anatómicos (landmarks) comparables entre dos o más objetos biológicos, y se establecen según los criterios de homología a nivel ontogenético, estructural y/o evolutivo, conformando un mapa de homologías.

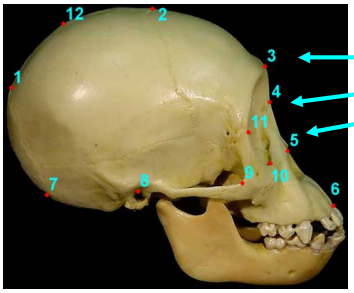
HITOS HOMOLOGOS
1. Lambda, 2. Bregma, 3. Glabella, etc



MAPA DE HOMOLOGIAS

COMPONENTES DE LA FORMA, CON INDEPENDENCIA DEL TAMAÑO

ANALISIS DE PROCUSTO
(EXTRACCION DE DIFERENCIAS DEBIDAS A ROTACION, TRASLACION Y ESCALA)

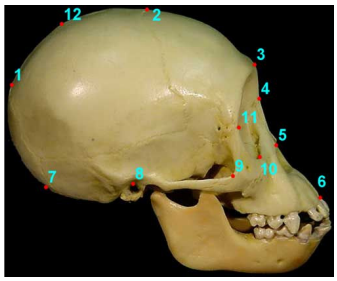


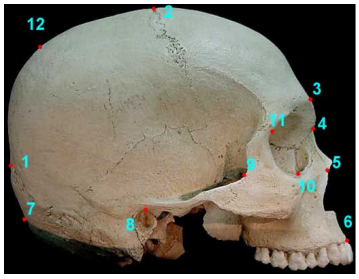
Matriz de 12 hitos anatómicos

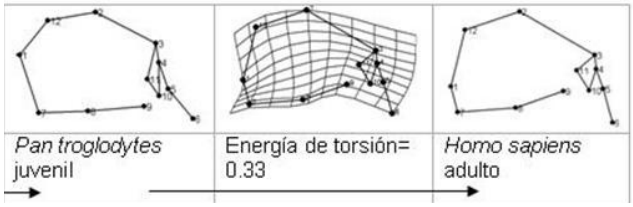
X	Y
14.00000	301.00000
190.00000	439.00000
323.00000	381.00000
341.00000	329.00000
379.00000	277.00000
482.00000	219.00000
55.00000	216.00000
126.00000	217.00000
298.00000	230.00000
357.00000	270.00000
307.00000	328.00000
73.00000	403.00000

IMAGE=Pongo_pygmaeus_juv_LATD.jpg

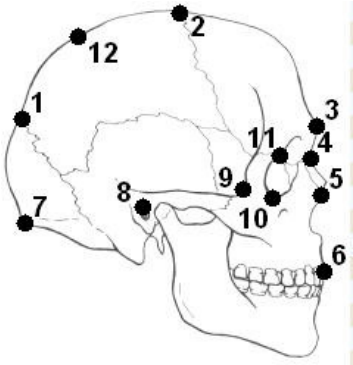
Los cambios se muestran como grillas de deformación cuyos vectores tienen origen en los hitos anatómicos de cada especimen en estudio. En este caso, chimpancé juvenil sobrepuesto a humano adulto. El "costo" del cambio evolutivo se expresa mediante el valor de la "energía de torsión", sumatoria de la variación vectorial entre especimenes







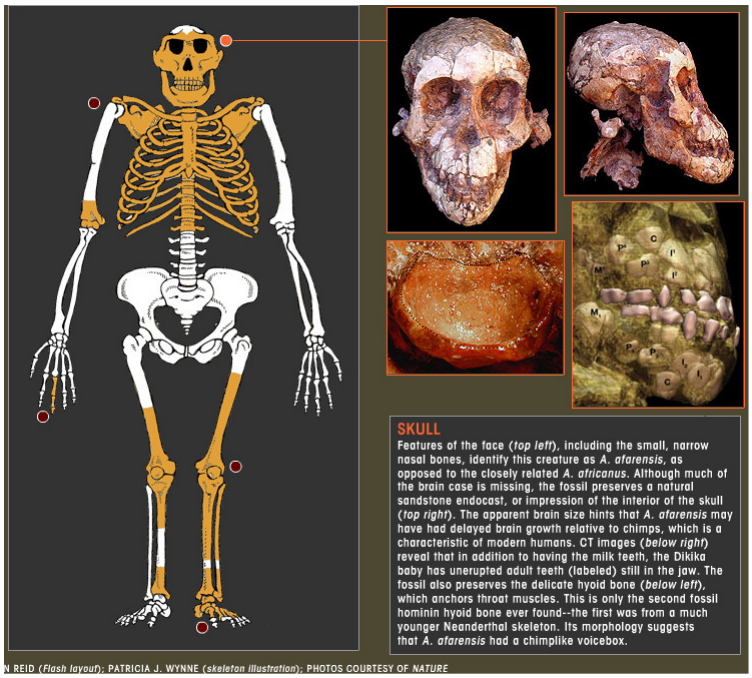
ACTIVIDAD 1 a) En grupos organizados por su Prof. Ayudante, nombre y defina los hitos anatómicos de la Figura 1. b) Discuta y responda ¿Qué condiciones deben cumplirse para que estos hitos sean de utilidad en un análisis filogenético? Fundamente. Compare la Figura 1 con la imagen que se muestra (*Australopithecus africanus*) y con la réplica de un cráneo de homínido ¿Hay hitos que no cumplan con el criterio de sinapomorfía? ¿Por qué?



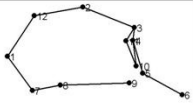
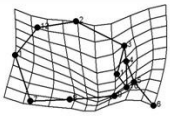
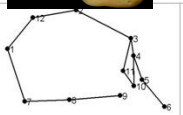
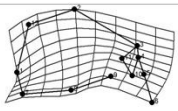
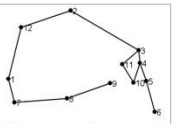
HITOS HOMOLOGOS

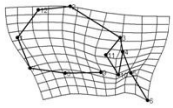
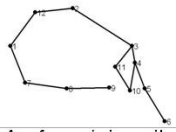
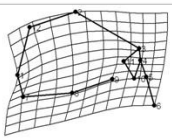
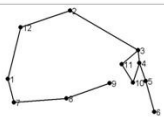
1.Lambda,
2.Bregma
3.Glabella
4.Nasion,
5. Maxilo-nasal,
6. Incisal superior,
7. Inion,
8. Porion,
9. Angulo más anterior del arco cigomatico,
10. Punto más inferior de la orbita,
11. Punto más anterior de la sutura fronto–maxilar,
12. Proyección a bóveda del punto medio del trazo lambda bregma.

Material publicado en *Nature,* 21 Septiembre de 2006, Describe hallazgo de restos fósiles de niño *A. afarensis* (el "hijo" de Lucy)



ACTIVIDAD 3.

				
Pan troglodytes adulto →	Energía de torsión= 1.17 →	*Pan troglodytes* juvenil →	Energía de torsión= 0.33 →	*Homo sapiens* adulto

				
A. afarensis adulto →	Energía de torsión= 1.06 →	*A. afarensis* juvenil →	Energía de torsión= 0.014 →	*Homo sapiens* adulto

Actividad 4. Las grillas corresponden a proyecciones sobre el eje x, que recoge la mayor varianza de los componentes de la forma (Relative Warps= RW).