

# Craniometry and Functional Craniology

## Part II: Functional Craniology: Kinematics and Dynamics

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## Lecture outline

1. Introduction: definition, scope, and objectives
2. Kinematics and dynamics
3. Biomechanics: forces, deformation, stresses, strains
4. Form and Function
5. Bone remodeling and growth directions
6. Moss' Hypothesis: Functional Matrix Hypothesis
7. Clinical applications

## Functional Craniology

- **Definition:** The study of the craniofacial complex in relation to the fields of functional anatomy, comparative anatomy, embryology, and growth and development.
- **Scope:** anatomy, embryology, histology, physiology, growth and development of the head and neck regions; theories of craniofacial growth; craniometry and cephalometry; and others
- **Objectives:** 1) to relate the function to the morphology of the craniofacial complex.  
2) to apply the theories of craniofacial growth and biomechanics to better understand the morphology, ontogeny and phylogeny of the craniofacial complex  
3) to provide the scientific basis for the clinical applications in the treatment of craniofacial anomalies.

## *Kinematics*

**The measurement and description of the changes in size, shape, and location of the craniofacial complex.**

## *Dynamics*

**The interpretation and description of the biological processes of the changes in size, shape, and location of the craniofacial complex.**

## *Kinematics*

The description of measurement.

The description of the changes in size, shape, and location based on observations and measurements.

The why, who, how, which and where, and what in measurement.

- 1) The history, scope, definition, and objectives of anthropometry
- 2) Introduction to craniometry and cephalometry
- 3) Define anatomical landmarks
- 4) Define anthropometric, craniometric, cephalometric measurements
- 5) Measuring devices and technical assessments
- 6) Data analysis, result descriptions
  - a) qualitative vs quantitative
  - b) absolute vs relative
  - c) statistical analysis

## *Dynamics*

What is the true meaning of a measurement?

How to see beyond the numbers? And what are we looking for?

What makes the changes in size, shape, and location of an organism or a structure (the transformation)?

What are the modern hypotheses, paradigms, and syntheses in understanding these kinematic changes?

- 1) Introduction to functional craniometry
- 2) Basic principles in growth and development, especially in osteology and biomechanics.
- 3) The functional, biological, and mechanical interpretations of the transformation of an organism or a structure.
- 4) The evolutionary significance: the adaptation and the selection
- 5) Clinical applications

## Terminology used in Biomechanics

**Force**: compression, tension, bending, shear, and torsion

**Deformation**: Change of form due to the loading of forces

**Stress**: the force per unit area

**Strain**: the dimensional change expressed as a fraction (ratio) of the subject's original size

## Force

### *Compression, Tension, Shear, Bending, Torsion*

- 1) Two basic forces: **Compression & Tension**
- 2) A combination of compression and tension: **Shear & Bending**
- 3) A combination of the above four forces: **Torsion**

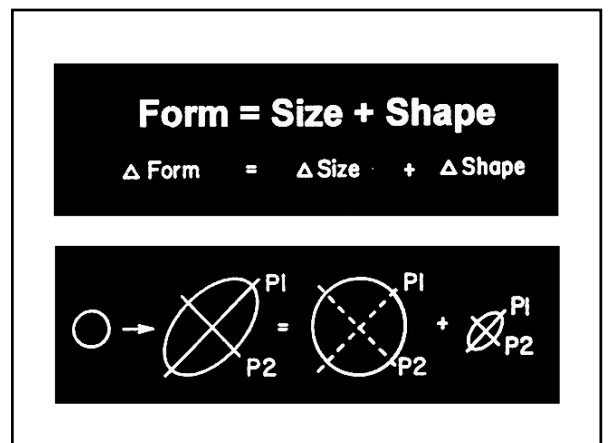
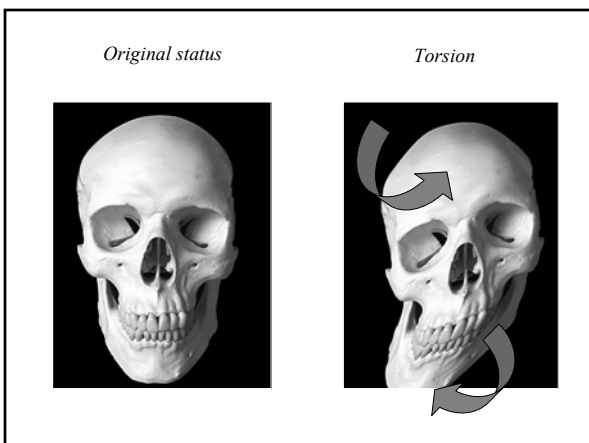
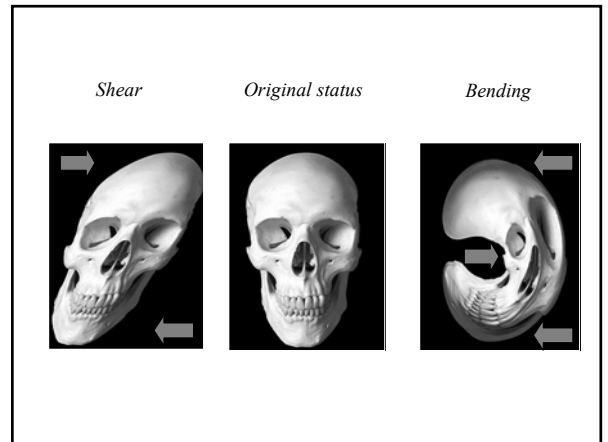
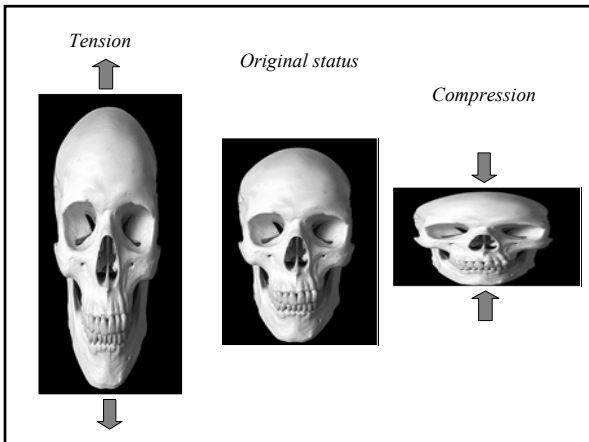
*Compression*: compression is the direct expression of the force, which pushes everything towards the center of an object.

*Tension*: the opposite of compression; the force which pulls everything away from the center, where there is a compressive force, there must be a tensile force.

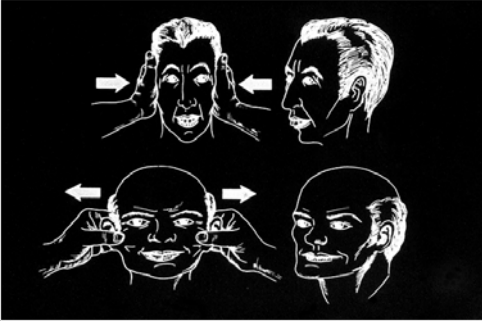
*Shear*: shear is present, when two forces are thrusting in opposite directions but offset and slide past each other.

*Bending*: is found between the pulling of tension and the pushing of compression.

*Torsion*: a result of all the other four forces. Torsion is twist. Torsion is actually a specialized bending, a circular bending.



## Facial Deformation



## Facial Deformation



Skeletal Class III, concave profile

Source: Dr. Wisanu Charoenkul



Skeletal Class II, convex profile

Source: Dr. Sonia Abraham

## Cephalic Form, Facial Form, and Arch Form

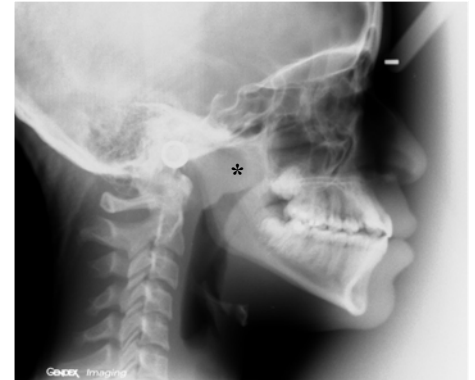


Dolichocephalic (long and narrow head)  
Leptoprosopic (long and narrow face)  
Dolichuronic (V shape, narrow maxillary arch)



Source: Dr. Christel Hummert

FM, female, 13y 6m



FM  
Female  
13y 6m

Source: Dr. Christel Hummert

Mouth breather; Enlarged pharyngeal tonsil (adenoid)

## Form (Structure) and Function

*Form (structure) follows Function.*

*Function determines form (structure).*

*Function controls form (structure).*

*Function regulates form (structure).*

**Form (structure) is the realization of information and the product of the functional attributes.**

## Cranial Sutures

1. Edge-to-edge suture  
⇒ No force loading
2. Beveled suture  
⇒ Shear force [Squamosal suture]
3. Serrated suture  
⇒ Intermittent tension force [Sagittal suture]
4. Beveled and serrated suture  
⇒ Intermittent tension and shear force
5. Butt-ended sutures  
⇒ Intermittent compressive force

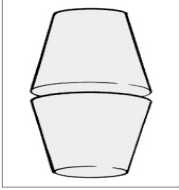


***“Form Follows Function”***

## Synovial Joints (I)

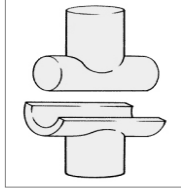
1. Plane (gliding) joint  
⇒ Sliding motion of all directions

[ Intermetatarsal joint ]



2. Hinge joint  
⇒ Flexion/extension

[ Humeroulnar joint ]



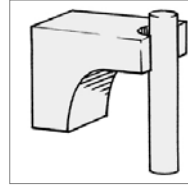
**“Form Follows Function”**

Illustrations: <http://www.science.ubc.ca/~biomania/tutorial/bonejt/intro.htm>

## Synovial Joints (II)

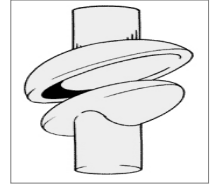
3. Pivot joint  
⇒ Rotation

[ Radioulnar joint ]



4. Ellipsoidal (condyloid) joint  
⇒ flexion/extension, adduction/abduction, circumduction, but no rotation

[ Temporomandibular joint ]



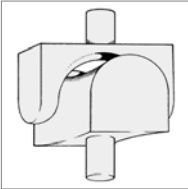
**“Form Follows Function”**

Illustrations: <http://www.science.ubc.ca/~biomania/tutorial/bonejt/intro.htm>

## Synovial Joints (III)

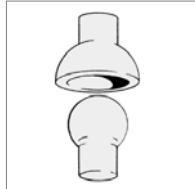
5. Saddle joint  
⇒ Similar to ellipsoidal joint, but freer

[ First carpometacarpal joint ]



6. Ball and socket joint  
⇒ flexion/extension, adduction/abduction, circumduction, and rotation

[ Glenohumeral joint ]



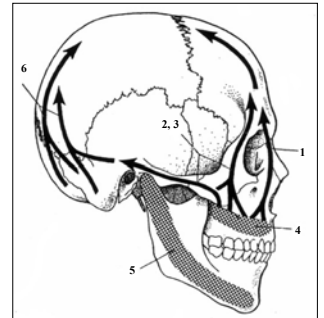
**“Form Follows Function”**

Illustrations: <http://www.science.ubc.ca/~biomania/tutorial/bonejt/intro.htm>

## Functional Structure of Skull (From a mechanical point of view)

In the force loading areas, pillar-like struts serve as mechanically efficient reinforcements to resist and dissipate pressure and traction, especially to the masticatory force.

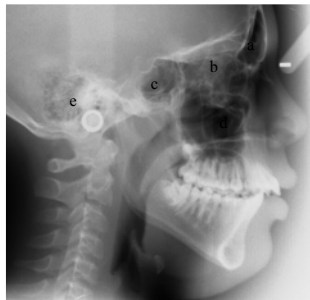
- 1) Fronto-nasal pillar
- 2) Zygomatic arch pillar with vertical branch
- 3) Zygomatic arch pillar with horizontal branch
- 4) Basal arch in upper jaw
- 5) Basal arch in lower jaw
- 6) Occipital pillar
- 7) Pterygoid-palate pillars



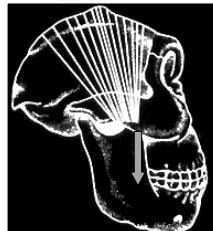
## Functional Structure of Skull (From a mechanical point of view)

• In the non- or less force loading areas, adipose tissue and pneumatic cavities fill those mechanically neutral areas.

- 1) Paranasal sinuses
  - a) Frontal sinus
  - b) Ethmoid sinus
  - c) Sphenoid sinus
  - d) Maxillary sinus
- 2) Accessory tympanic spaces
  - e) Mastoid air cells



## Sagittal crests and temporal muscle orientations Hominids compared to pongids



**Hominid: Australopithecine**

Temporal muscle fibers oriented towards the posterior teeth; emphasis on the posterior teeth in mastication and dietary adaptation



**Pongid: male gorilla**

Temporal muscle fibers oriented towards the anterior teeth; emphasis on the anterior teeth in mastication and dietary adaptation

## Bone remodeling

**Deposition:** the biological process of laying down the bone

**Resorption:** the biological process of removing the bone

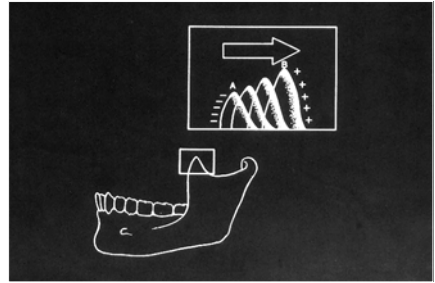
**Remodeling:** A basic part of bone growth involves simultaneous deposition and resorption on all inner and outer surfaces of the entire bone. It provides regional changes in shape, dimensions, and proportions.

**Drift:** Growth movement of an enlarging portion of a bone by the remodeling. The combinations of deposition and resorption result in growth movement toward the depository surface.

**Displacement:** The growth movement of a whole bone as a unit. The bone is carried away from its articulation in relation to other bones.

**Direction of growth:** 1) the direction of drift  
2) the direction of displacement  
3) the net direction of drift and displacement.

## The Growth of the Coronoid Process



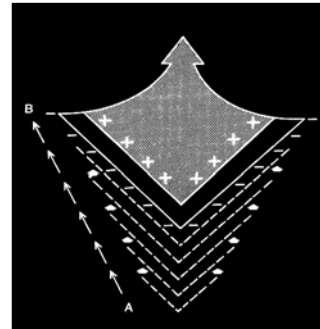
Deposition (+); Resorption (-); Direction of growth (arrow)

## The Growth of Mandible

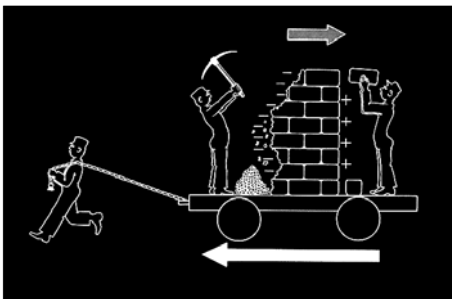


Deposition (blue arrow); resorption (white arrow)

## The Remodeling (Growth) Direction: The "V" Principle



## Drift vs Displacement



Drift: the growth movement of an enlarging portion of a bone by the remodeling.  
Displacement: The growth movement of a whole bone as a unit.  
Direction of growth: the net growth direction of drift plus displacement.

Head (craniofacial complex) is a region, where a series of functions are carried out.

These functions include *vision, hearing, speech, mastication, swallowing & digestion, respiration, neural integration, and others.*

The successful execution of a function requires biomechanical protection and support.

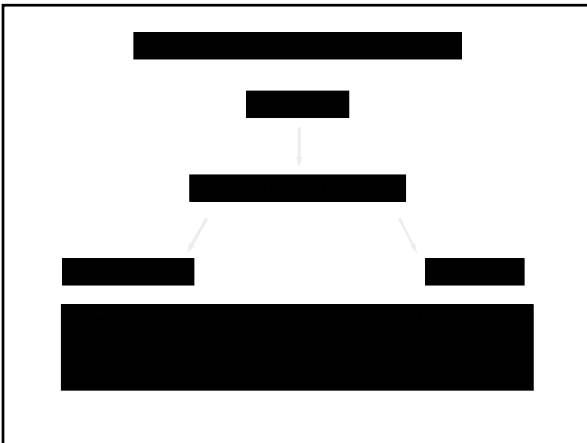
Moss' craniofacial growth theory:  
Function of the craniofacial complex region is performed by the Functional Cranial Components (F.C.C).

## Functional Matrix Hypothesis (Moss' Hypothesis)

“The functional matrix is primary and the presence, size, shape, spatial position, and growth of any skeletal unit is secondary, compensatory, and mechanically obligated to changes in the size, shape, spatial position of its related functional matrix” (Moss, 1968)

## Functional Matrix Hypothesis (Moss' Hypothesis)

“The origin, development and maintenance of all skeletal units are secondary, compensatory and mechanically obligatory responses to temporally and operationally prior demands of related functional matrices.”



### Types of Functional Matrix

- |   |   |
|---|---|
| 1. Periosteal matrix<br>(e.g., muscles)<br>Active growth<br>Deposition and resorption<br>Affect size and/or shape | 2. Capsular matrix<br>(e.g., brain, oral cavity)<br>Passive growth<br>No deposition<br>No resorption<br>Affect location |
|---|---|

### Growth

Active growth (Periosteal)  
+  
Passive growth (Capsular)  
=  
Total growth

### Craniofacial Growth

#### Active growth process

- 1) Sutural growth
- 2) Bone remodeling
- 3) Cephalic cartilage growth

#### Passive growth process

- 1) The growth of neural, orbital, CSF, and other masses and real substances
- 2) The expansion of oro-naso-pharyngeal and other functioning spaces

### Use of the “Functional Matrix” in the therapy of orthodontics, dentofacial orthopedics, and orthognathic and craniofacial surgery

#### 1. Orthodontics

Periosteal Matrix -----> Skeletal Unit  
[Teeth] [Alveolar Bone]

#### 2. Dentofacial Orthopedics and Orthognathic Surgery

Capsular Matrix -----> Multiple Skeletal Units  
[Functional Appliances] [Jaw Bones]  
Capsular Matrix -----> Multiple Skeletal Units  
[Distraction osteogenesis: e.g., hemifacial microsomia] [Jaw Bones]

#### 3. Craniofacial surgery

Capsular Matrix -----> Multiple Skeletal Units  
[Craniotomy: e.g. Crouzon Syndrome] [cranial bones]  
[Distraction osteogenesis: e.g., Treacher Collin Syndrome] [facial and jaw bones]

Introduction: definition, scope, and objectives

Kinematics and dynamics

Biomechanics: forces, deformation, stresses, strains

Form and Function

Bone remodeling and growth directions

Moss' Hypothesis: Functional Matrix Hypothesis

Clinical applications

## References

Enlow, D.H. (1990). *Handbook of Facial Growth* (3<sup>rd</sup> edition). Philadelphia, Pennsylvania: W.B. Saunders Company.

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