



Biomechanics of the Immature Ribs and Vertebra

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Disclosures

(a) (b) K2M

- a. Grants/Research Support
- b. Consultant
- c. Stock/Shareholder
- d. Speakers' Bureau
- e. Other Financial Support
- f. Over \$10,000

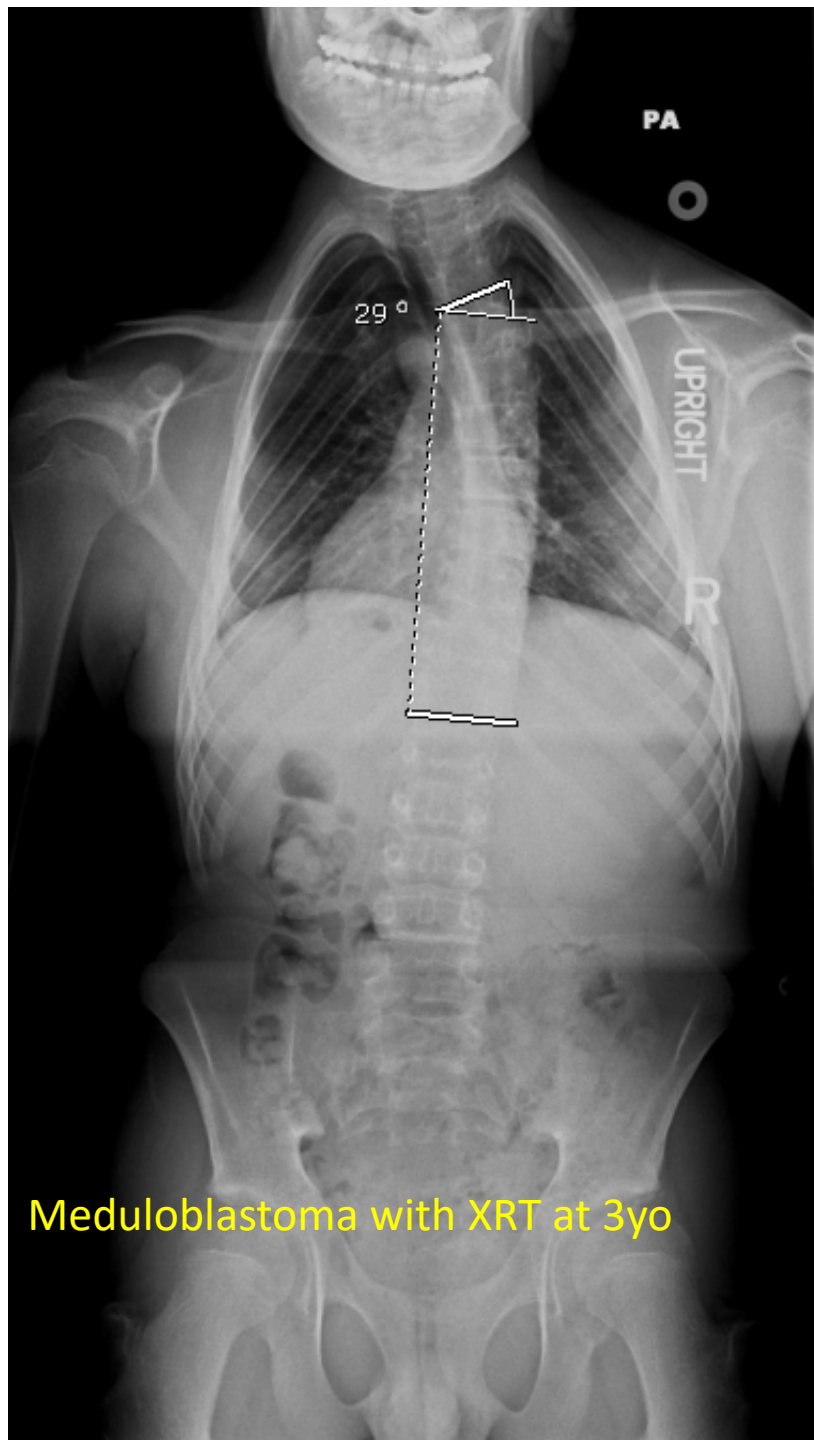
Funded by the Complex Spine Study Group (CSSG)

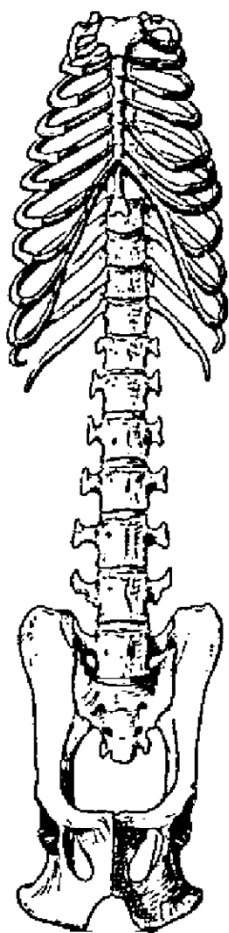


What we will cover

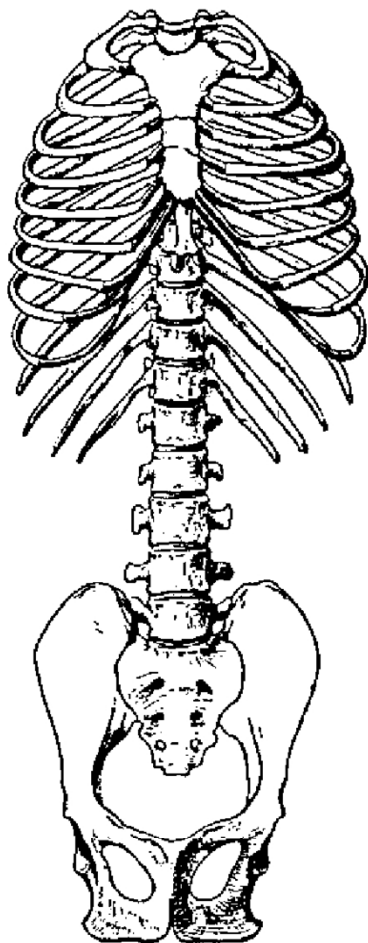
- CT data of rib growth
- Rib growth from Hamann Todd Collection
- Functional implications of rib growth
- Biomechanics



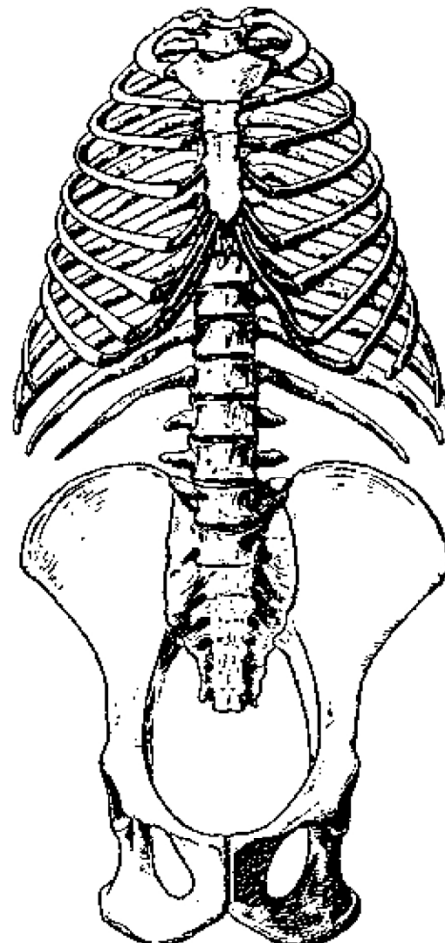




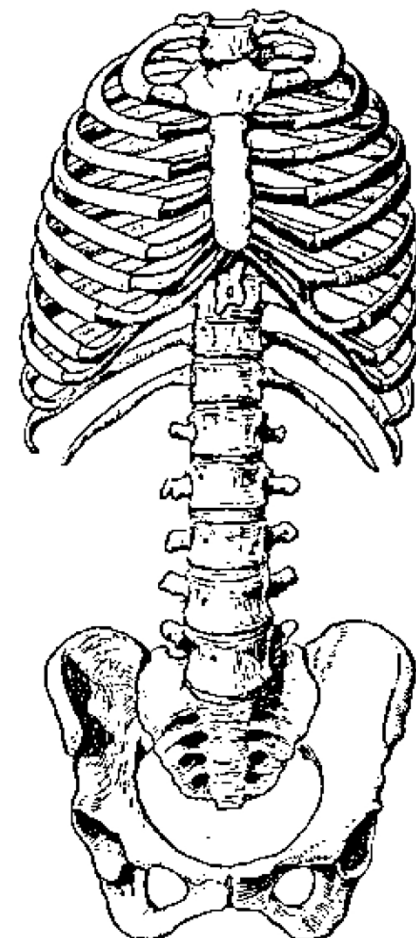
**Old world
monkey
(Macaque)**



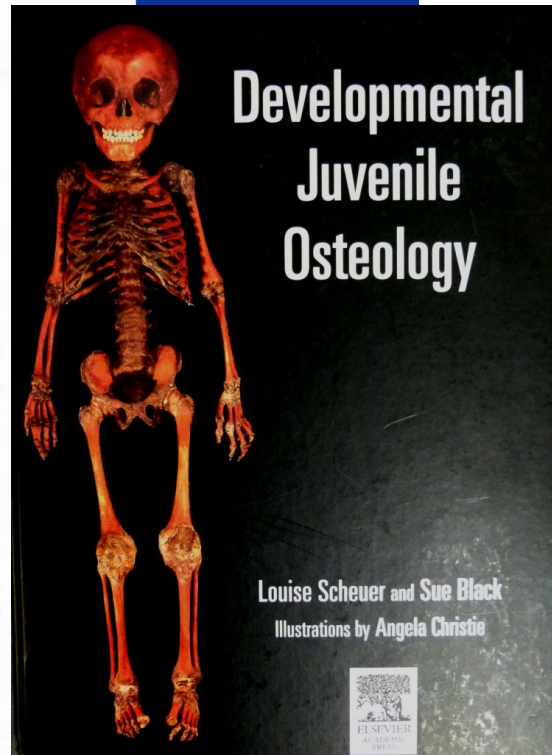
**Lesser Ape
(Gibbon)**



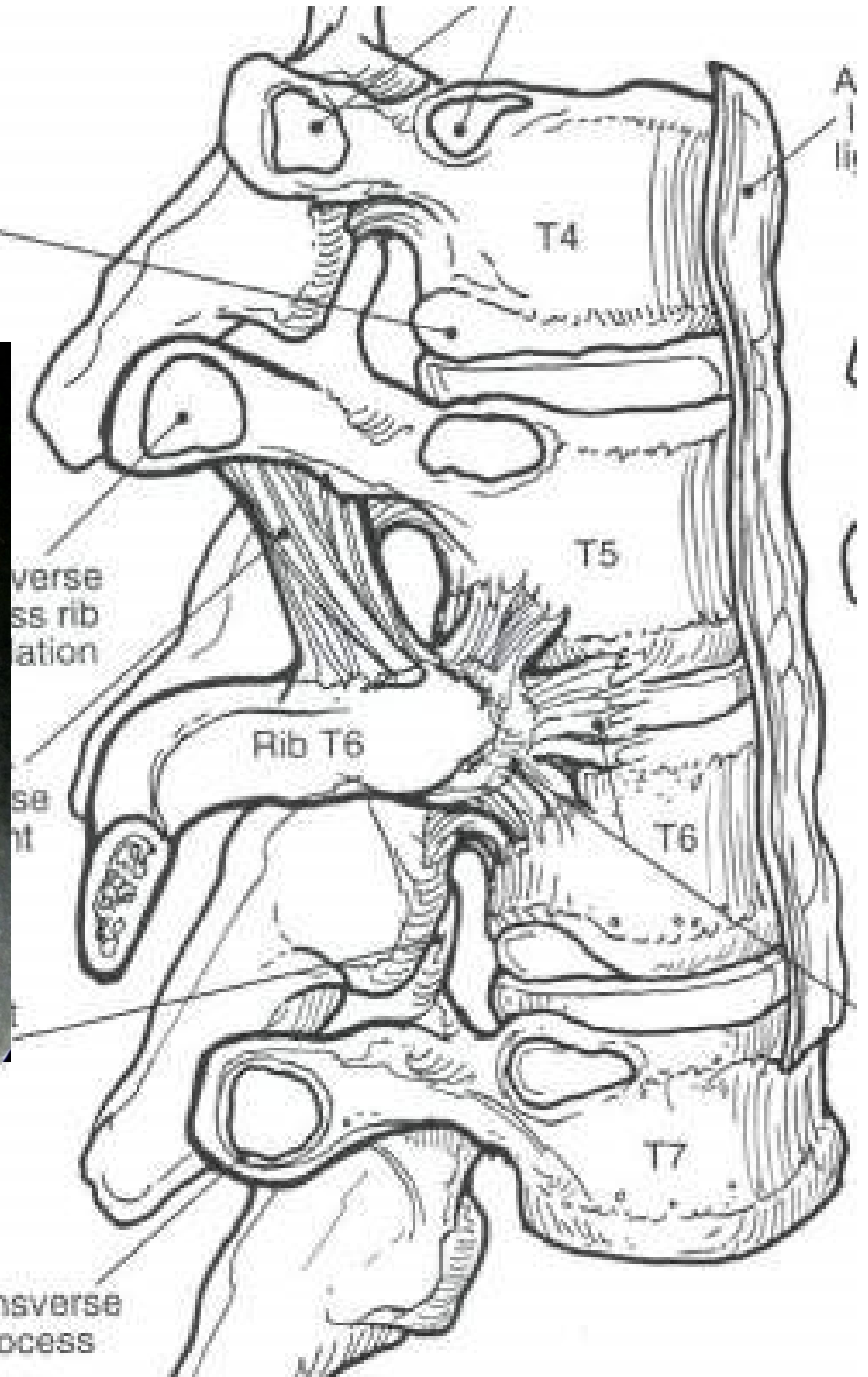
**Great Ape
(Chimpanzee)**

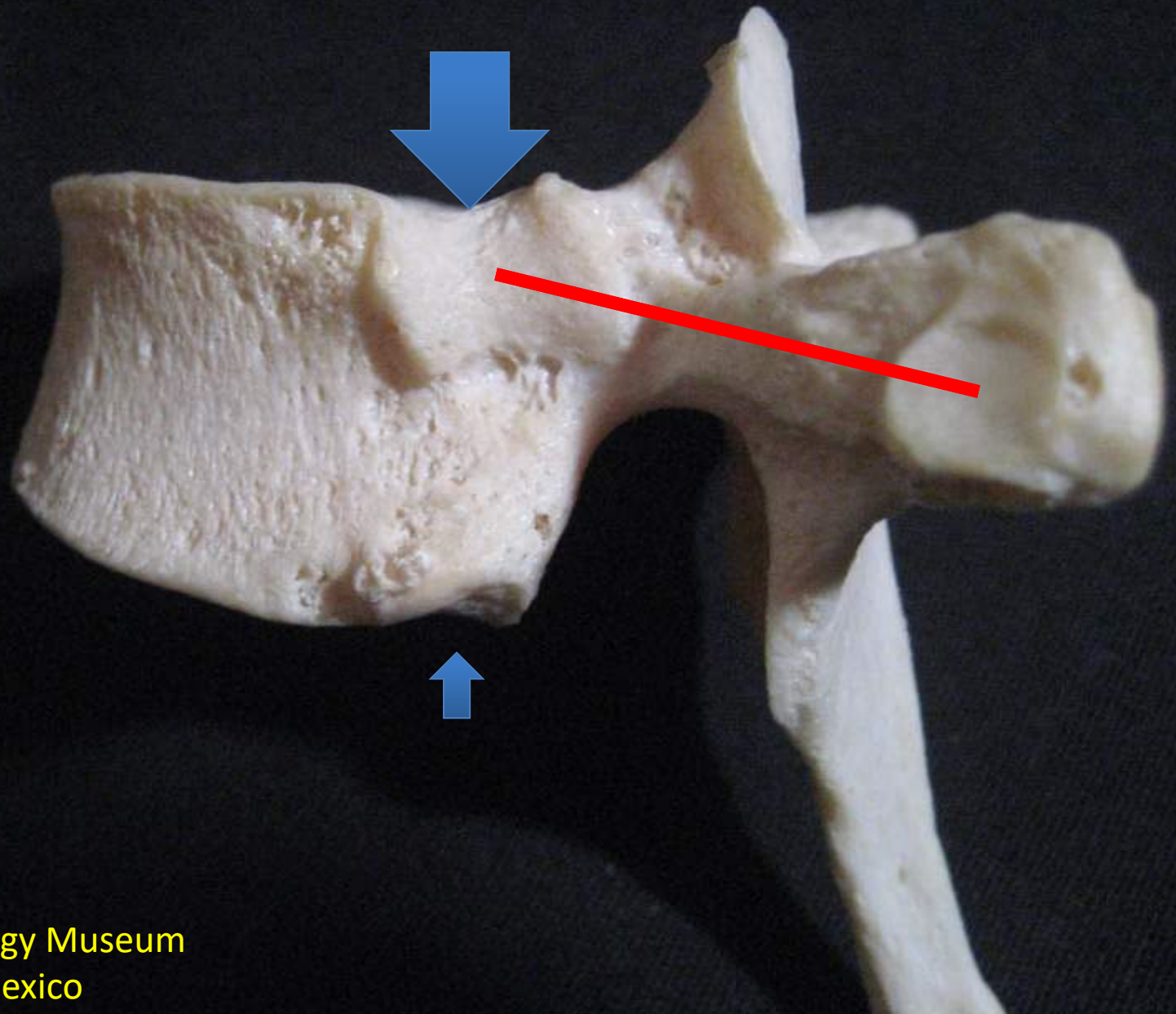


Human



Demi facet



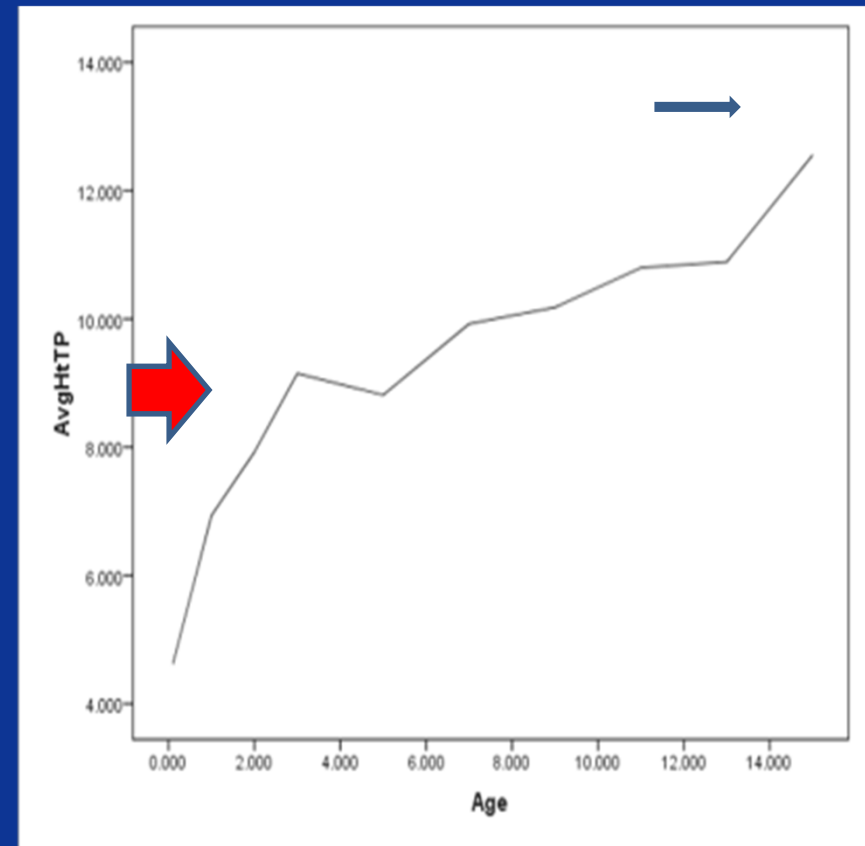


T7. Maxwell Osteology Museum
University of New Mexico

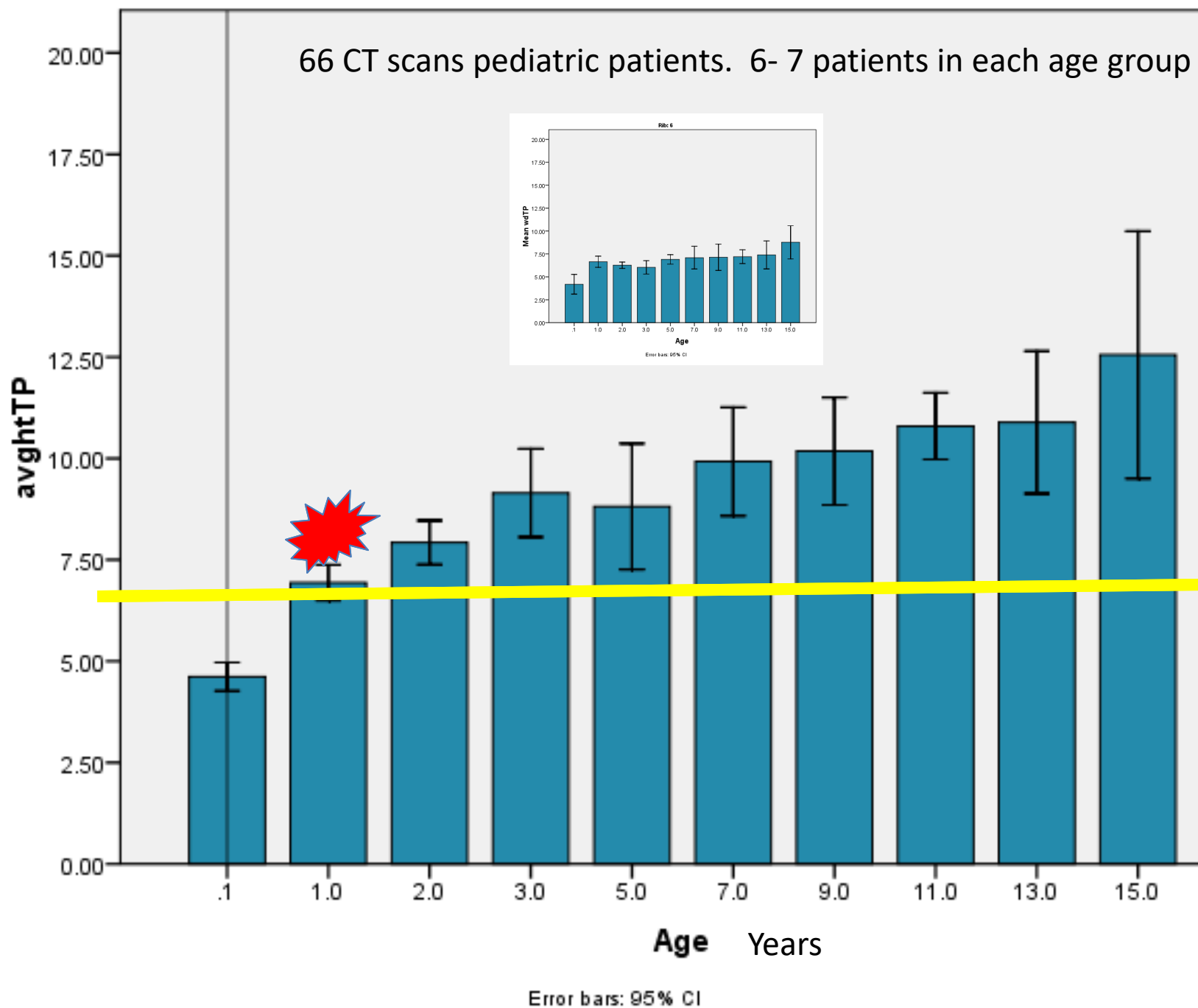


Results: Average Rib Heights

- CT 66 patients, 7 subjects in each of 10 age groups-NB, 1, 2, 3, 5, 7, 9, 11, 13, 15 years.
- No spine or chest wall deformity.
- By 1 year, average rib height 7mm- **1/2 the average adult rib height** (12.6mm).
- Average rib height reaches nearly **3/4 the average adult rib height by age 3 years**, and continues growth to reach adult rib height by approximately age 15 years.
- AAP Annual Meeting, San Francisco, 2010



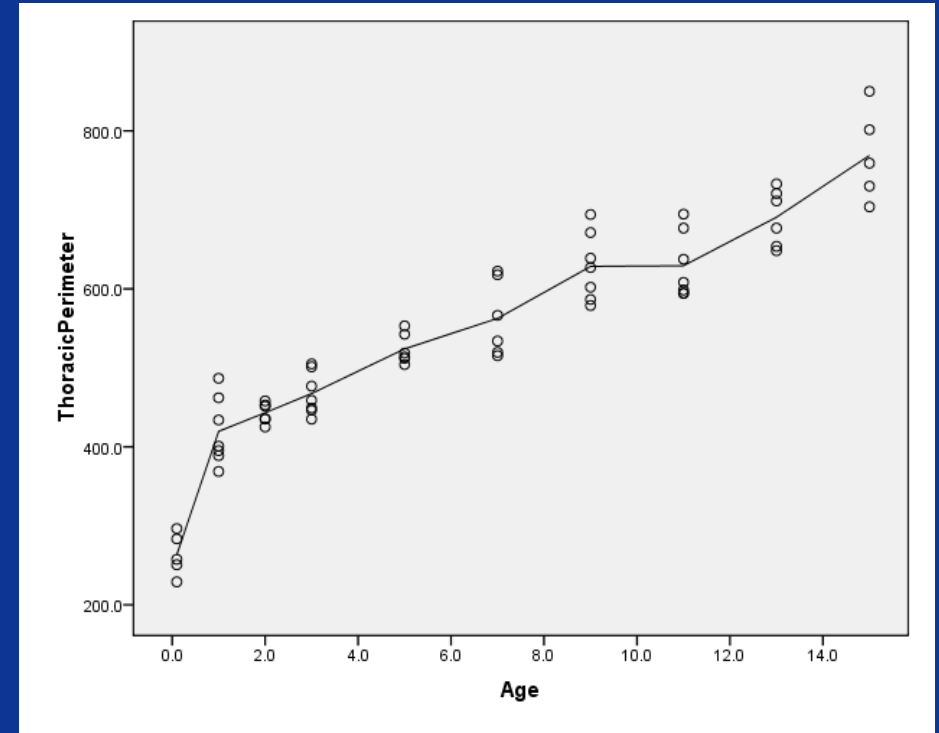
AVERAGE RIB HEIGHT GROWTH WITH AGE



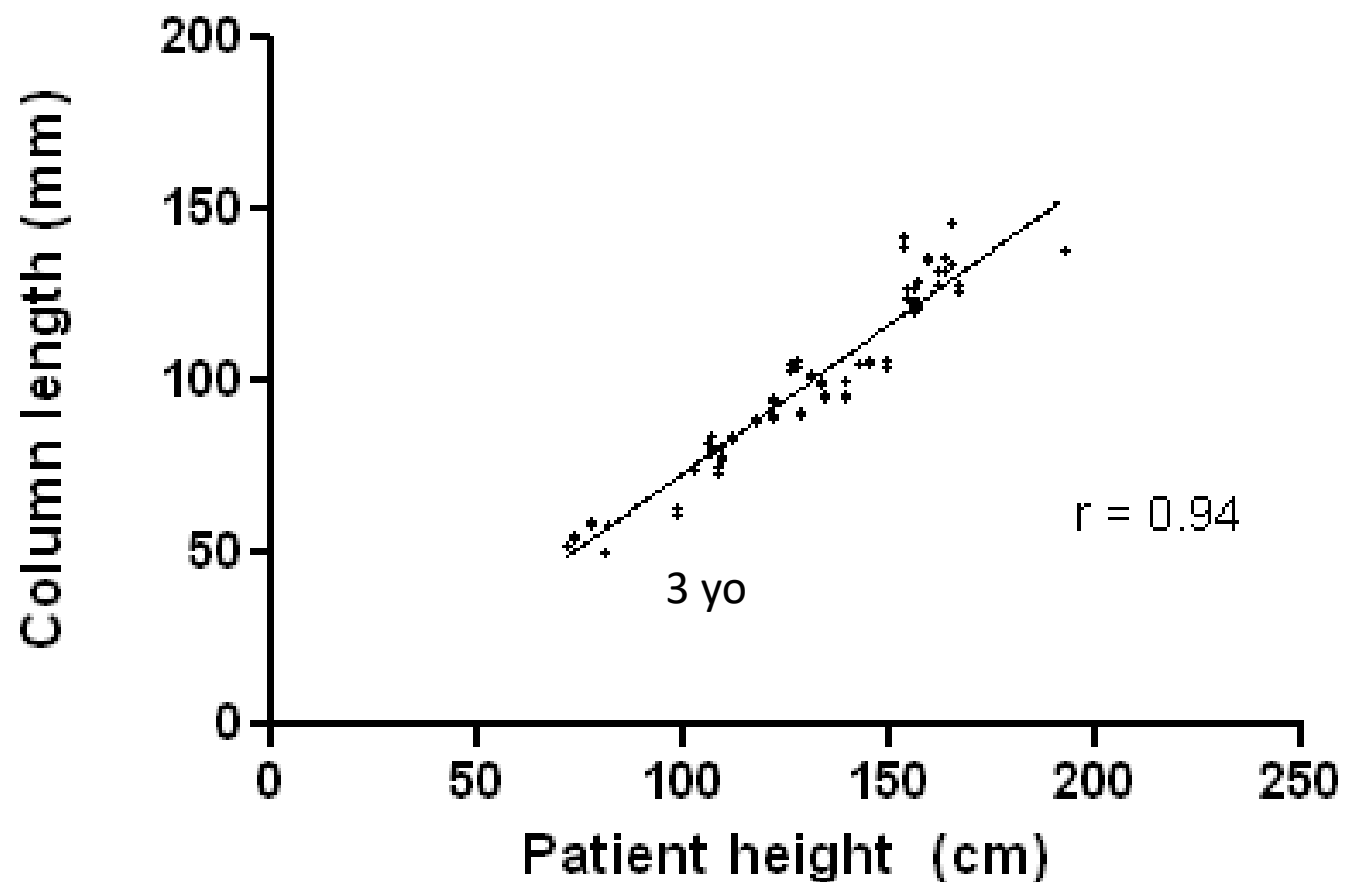


Results: Thoracic Perimeter

- Similar to growth in the rib height, thoracic perimeter increases rapidly during the first year of life
- Thoracic perimeter at the level of the xiphoid process can be used as a surrogate for sitting height (Charles, 2008)



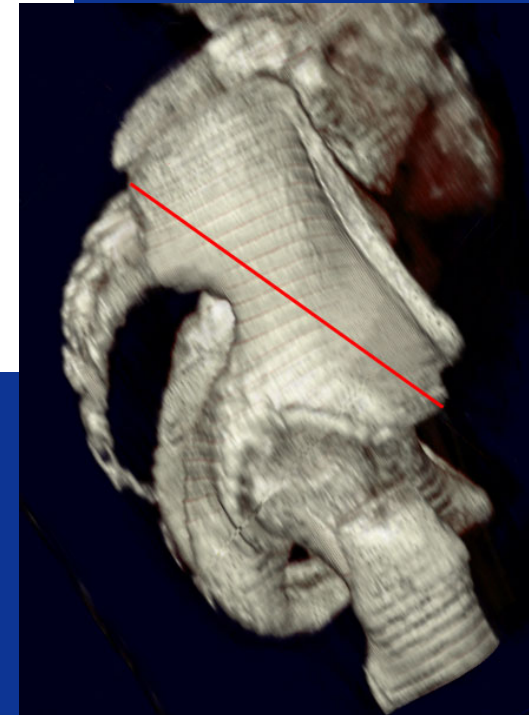
Iliac Column Length vs Patient Height



Schwend RM et al. SRS 2009

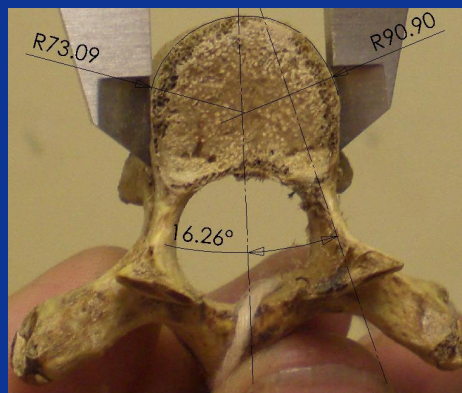
CT Data. N=40

Iliac column length is $\frac{1}{2}$ adult by age 3 years





Scalar Measurements of Pediatric Spine and Ribs from the Hamann-Todd (H-T) Collection

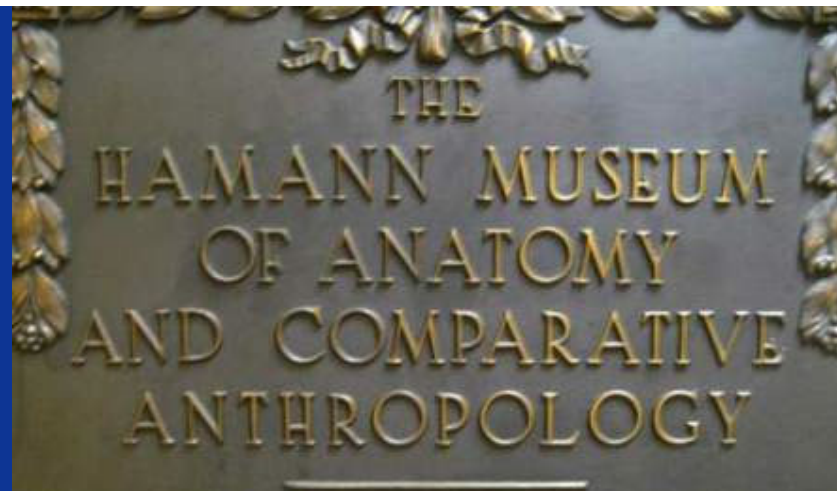


Richard M. Schwend, MD; Behrooz A. Akbarnia, MD; Laurel C. Blakemore, MD;
Kevin R. Strauss, ME; John Schmidt, PhD

4th International Congress on Early Onset Scoliosis and Growing Spine (ICEOS)
Toronto, Canada – November 19-20, 2010



Significance

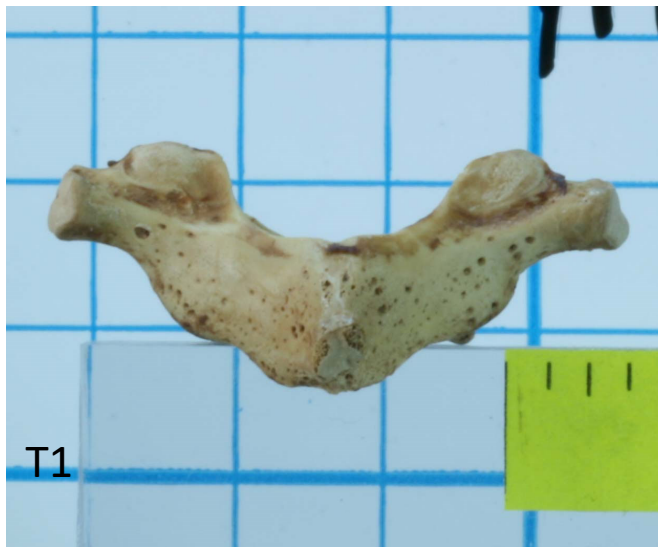


- The Hamann-Todd collection is a valuable resource available to researchers to evaluate osteology in the growing child.
- Purpose: With a total of 63 pediatric specimens of various ages, normative and comparative data can be obtained and used to reach new understanding and insight of the growing skeleton.

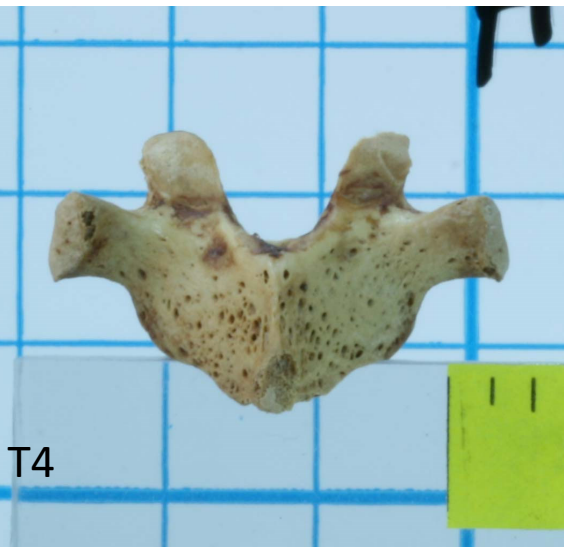


Methods and Materials

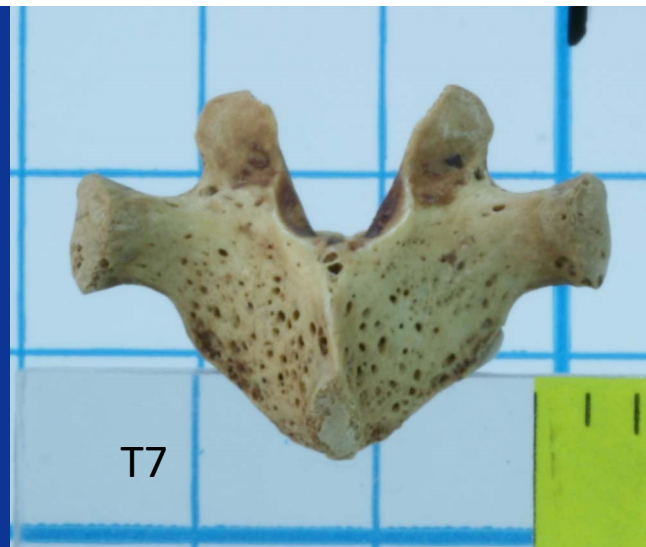
- General Demographics for each child were collected. Specifics such as height, weight, or prior trauma were unknown.
- Measurements from vertebral bodies, ribs, and long bones were obtained on 16 (1-18 year old) skeletons. Ages 2 and 9 years were not available.
- 46 measurements from the VBs and ribs at T1, T4, T7, T10, and L3



T1



T4



T7



T10

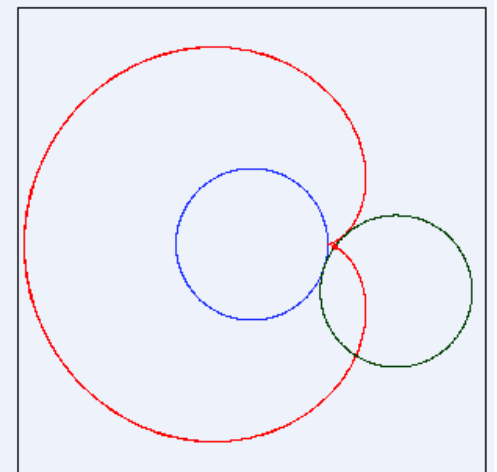
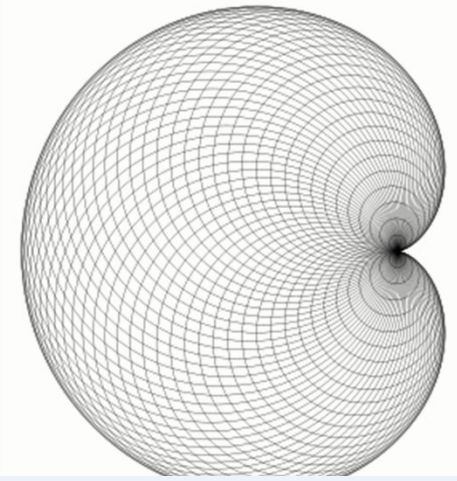


L3



Summary of Results

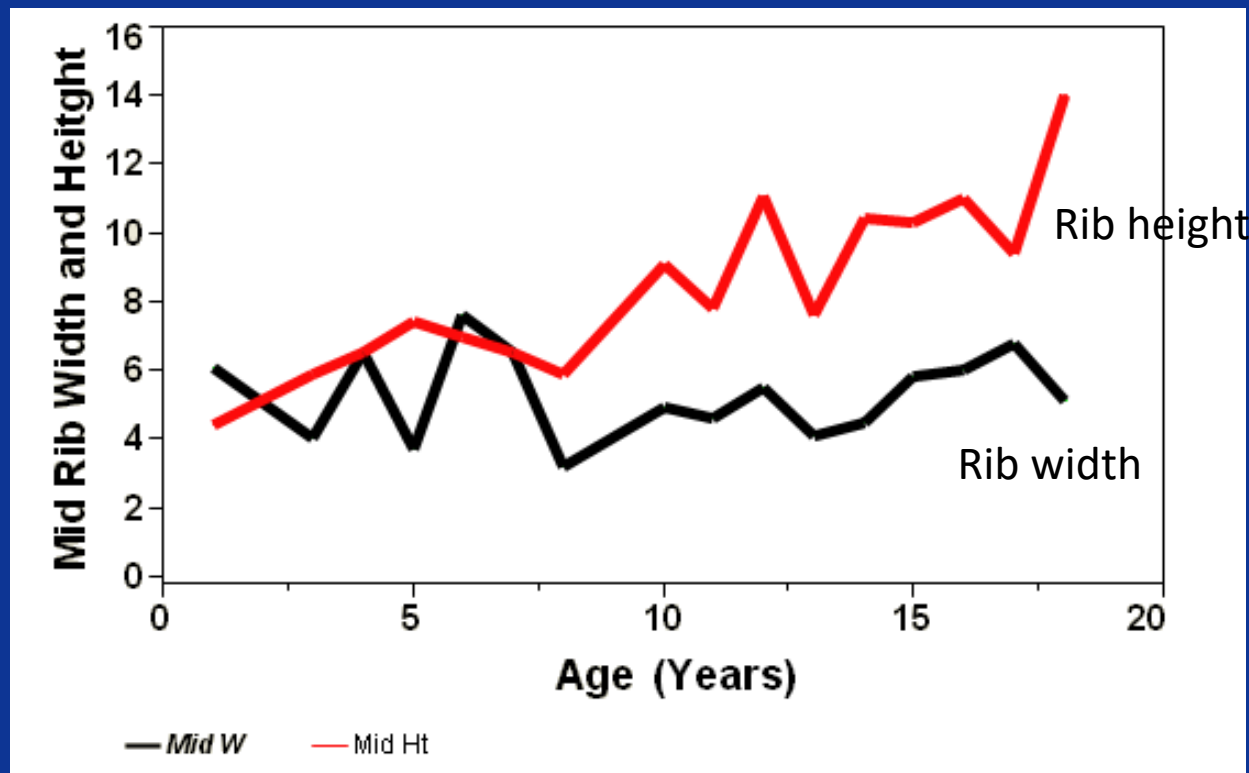
- At mid position: Rib width does not change with age but height increases (1/2 adult height by 1 yo)
- AP canal: no change with age
- Neurocentral synchondrosis fusion varies with age, level
- Handedness: Iliac Column Width Left and Right is Not Equal
- Rib linear growth (length) follows the Golden Spiral with greater growth of middle ribs
- Transverse process angles vary with vertebral level, determining axis of rib motion
- VB shape follows a cardioid





Results: Ribs

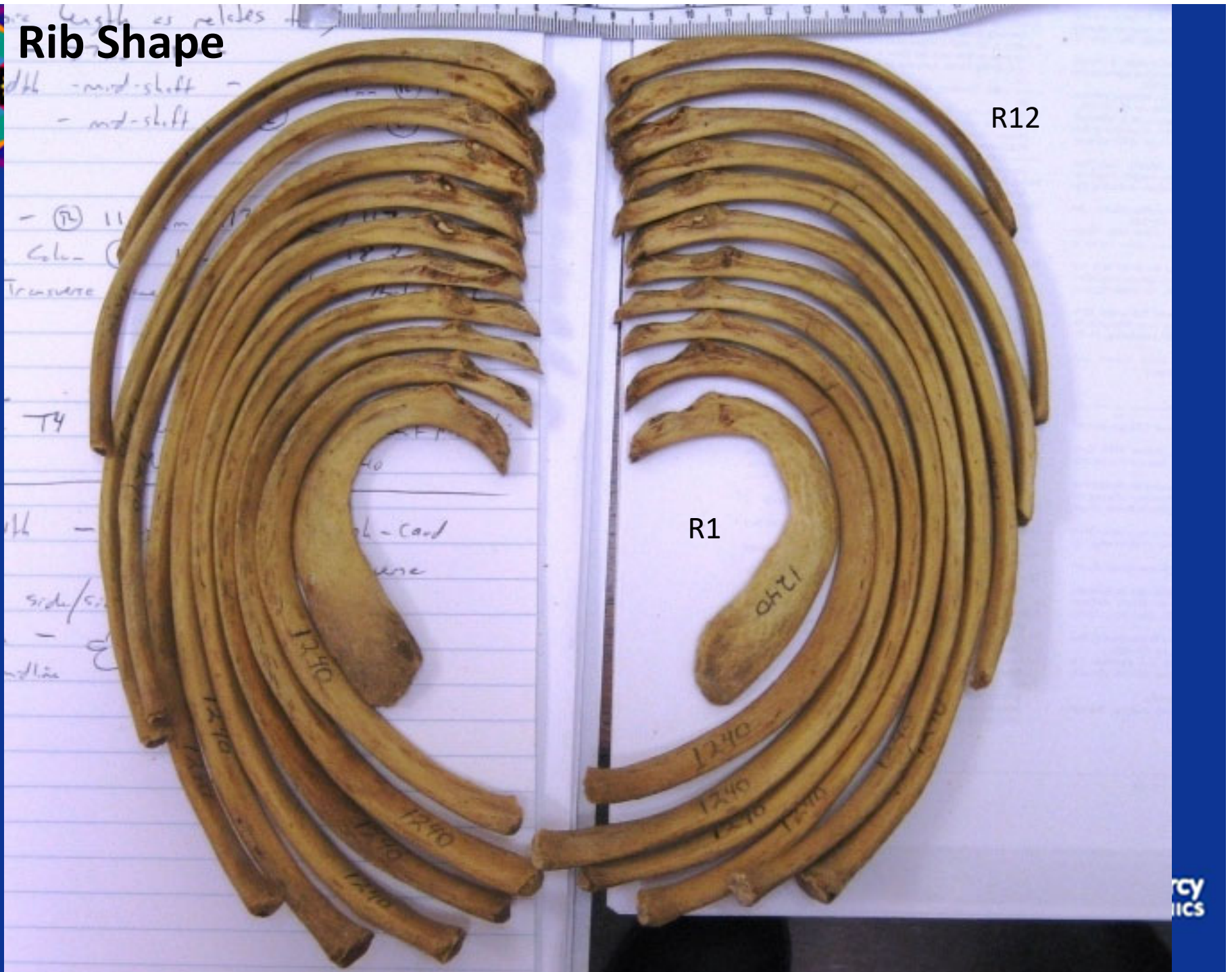
**At Middle of Rib: Width does not change with age.
However, height does and is $\frac{1}{2}$ adult height by 1 yo
Represents early preferential vertical thoracic growth.**



Data for T4 Left Rib.

Data is similar for the Right Rib and for T7 and T10.

Rib Shape



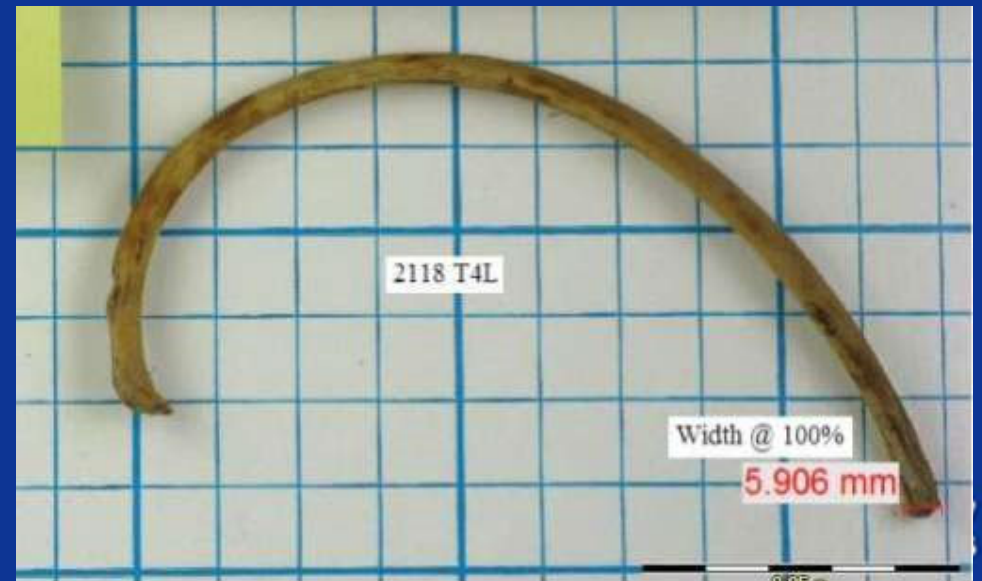
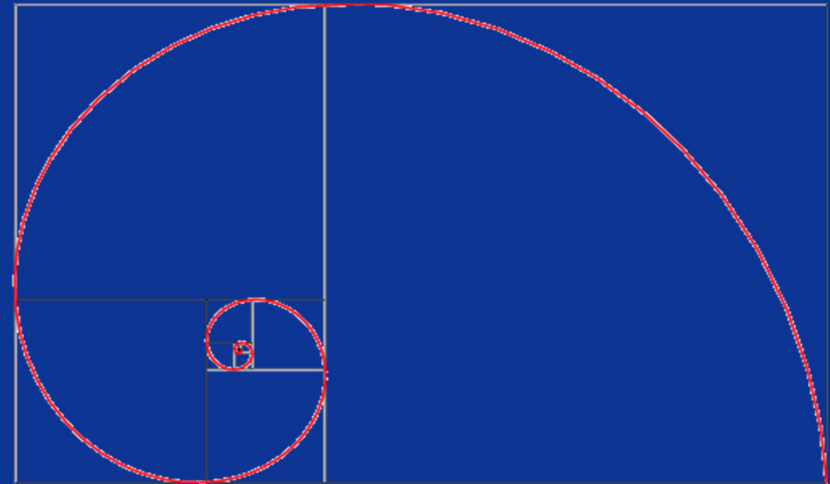


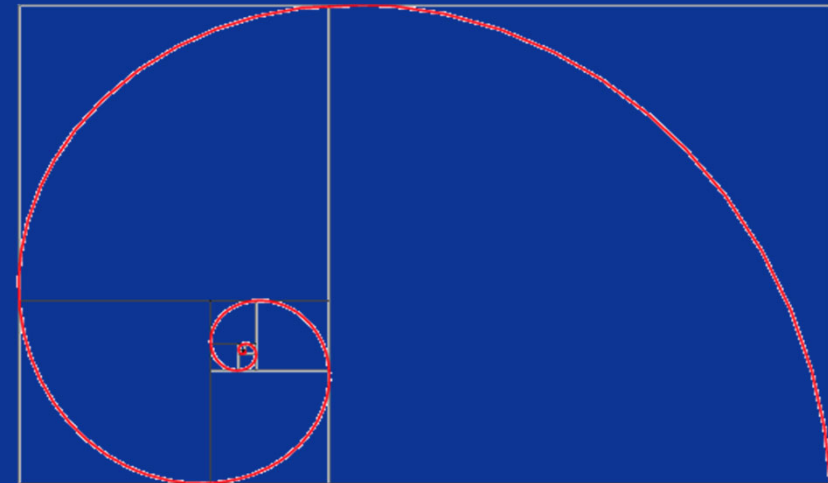
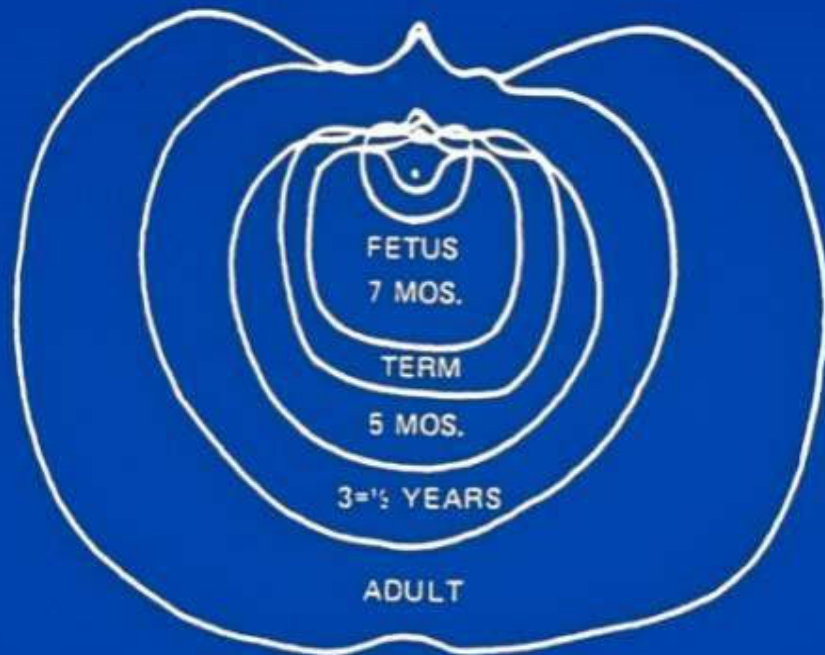
Golden Rectangle
Ratio of 1.618 to 1.0
Is found throughout nature

Ribs follow it
(<10% error)

Fibonacci (AD 1202) series:
0,1,1,2,3,5,8,13,21,34,55,89,144

John Schmidt, PhD





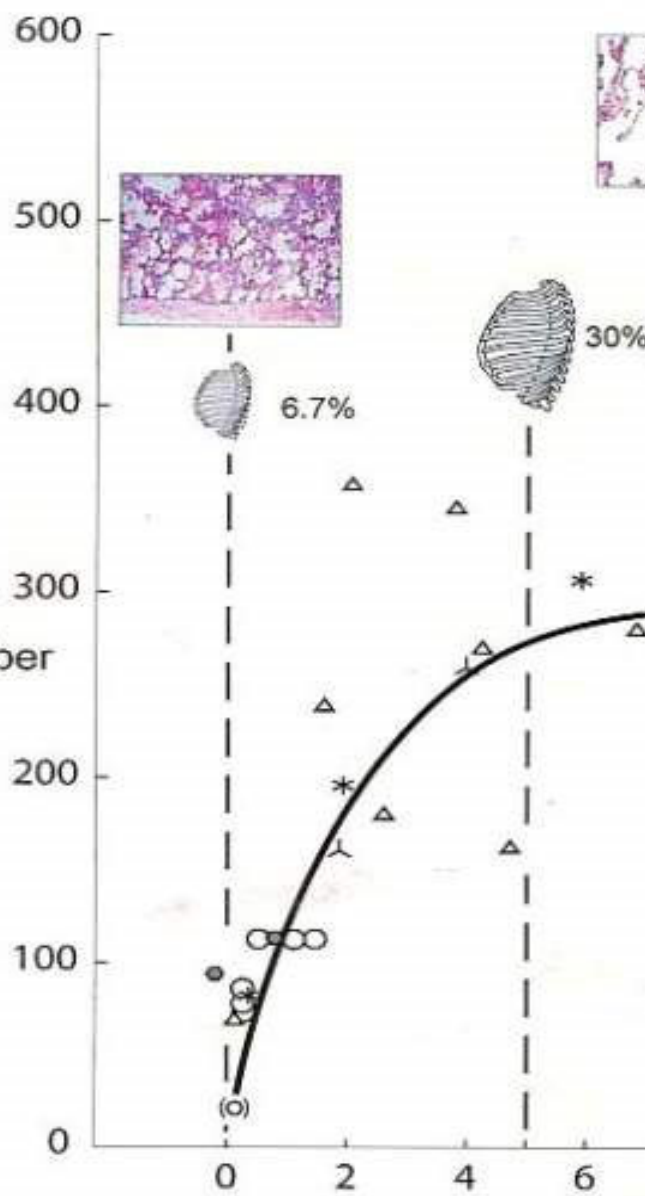
How does chest volume double from age 8- 10 years to adulthood?

Rib grows at costal end.

Middle ribs appear to grow more than the end ribs. At mid section, more than doubles in length between 1 year and maturity. About 1 cm/year, similar to the distal femur.



Total Number
of Alveoli
($\times 10^6$)



○ Du

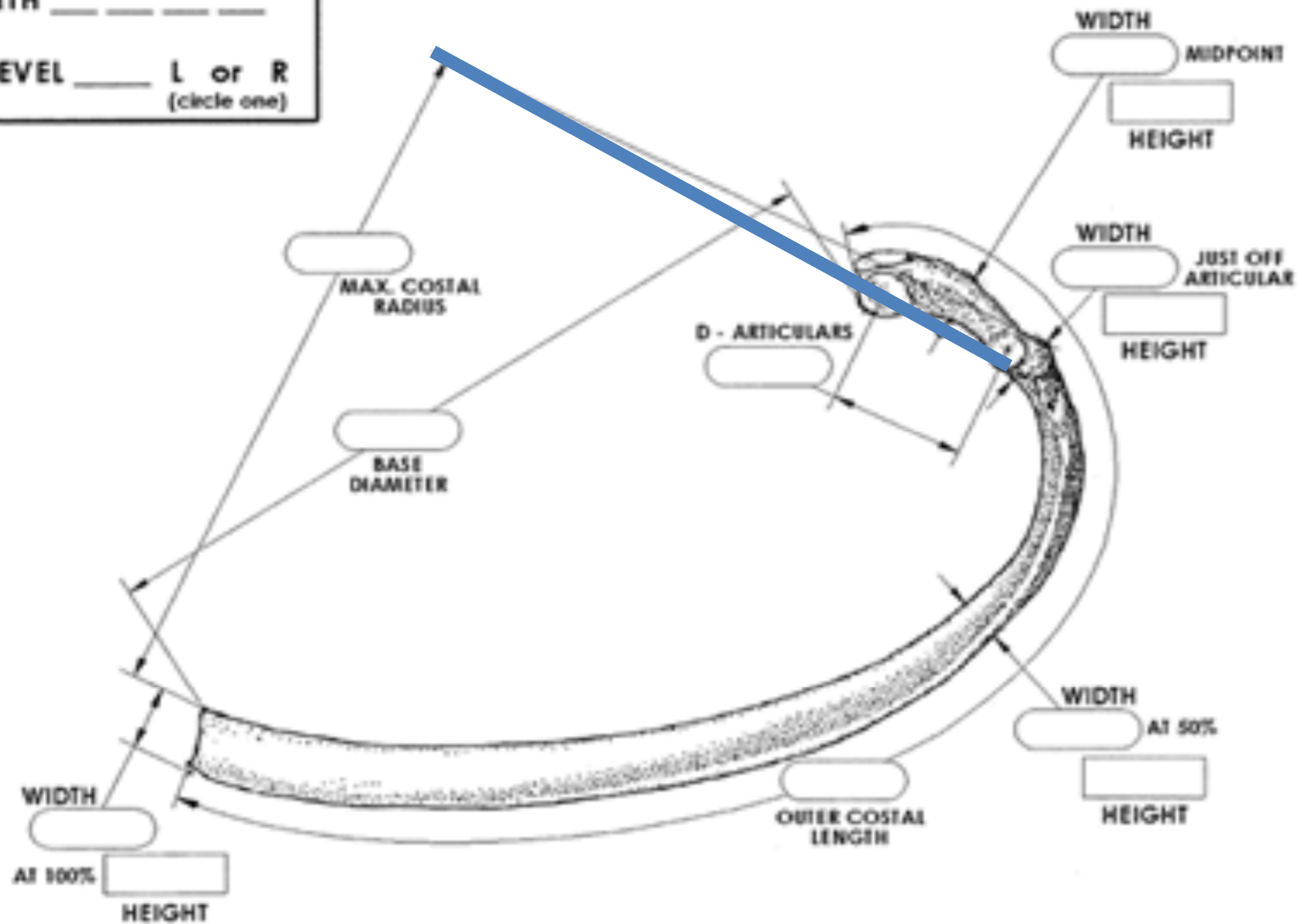


○ Age (yrs)

Dimeglio^{54,55}

HTH _____

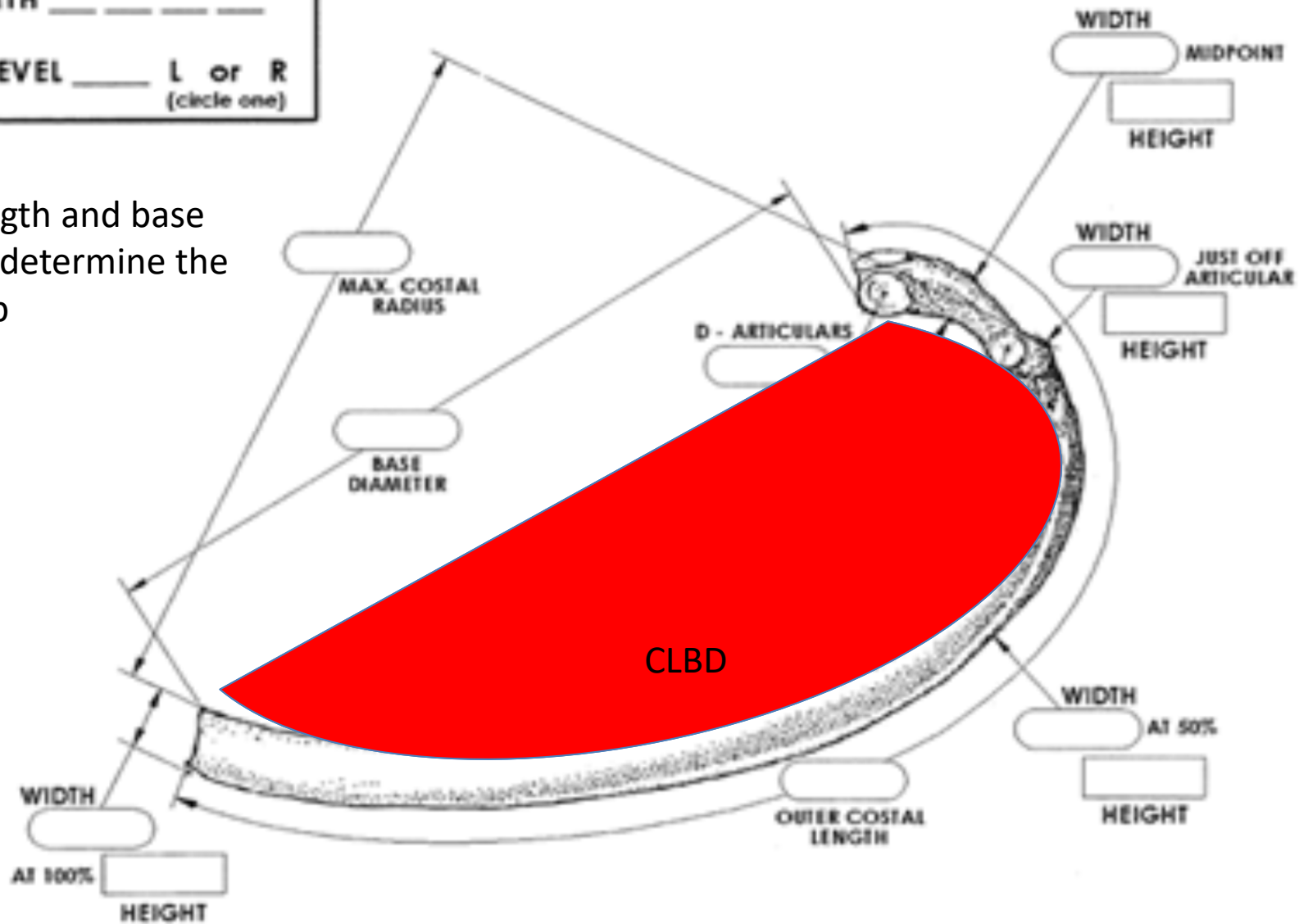
LEVEL _____ L or R
(circle one)



Rib measurements

HTH _____
 LEVEL _____ L or R
 (circle one)

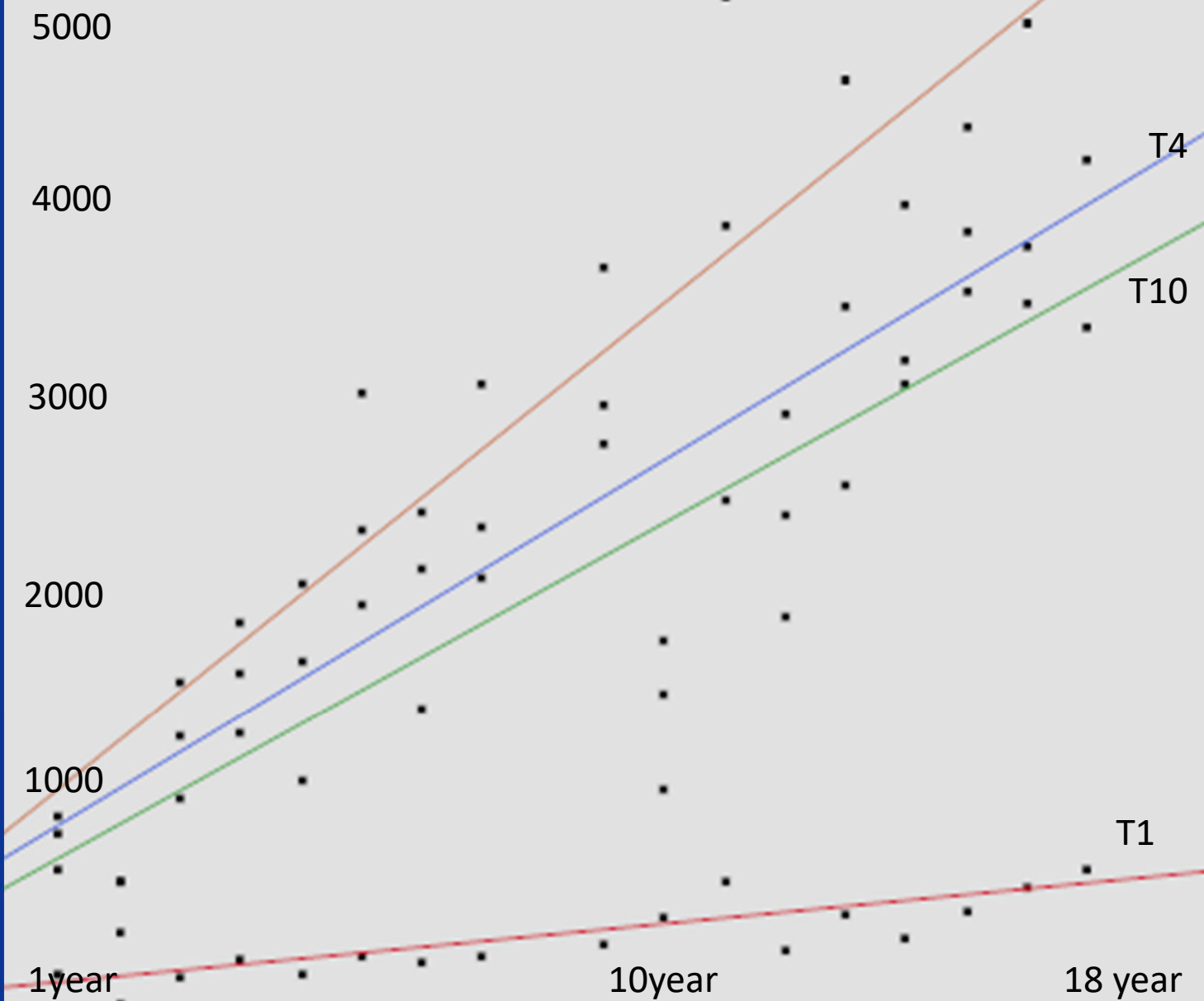
Costal length and base diameter determine the area of rib

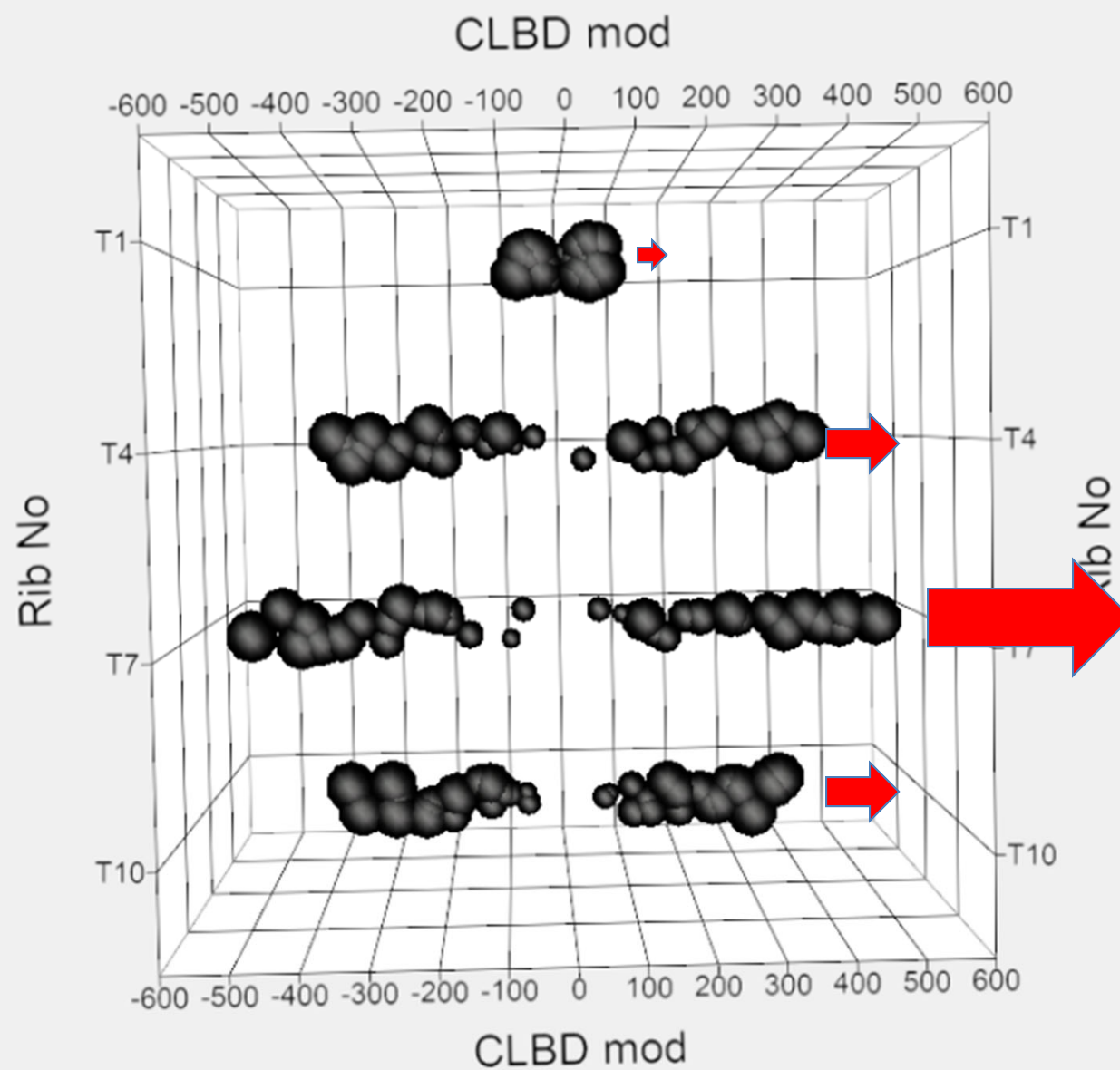


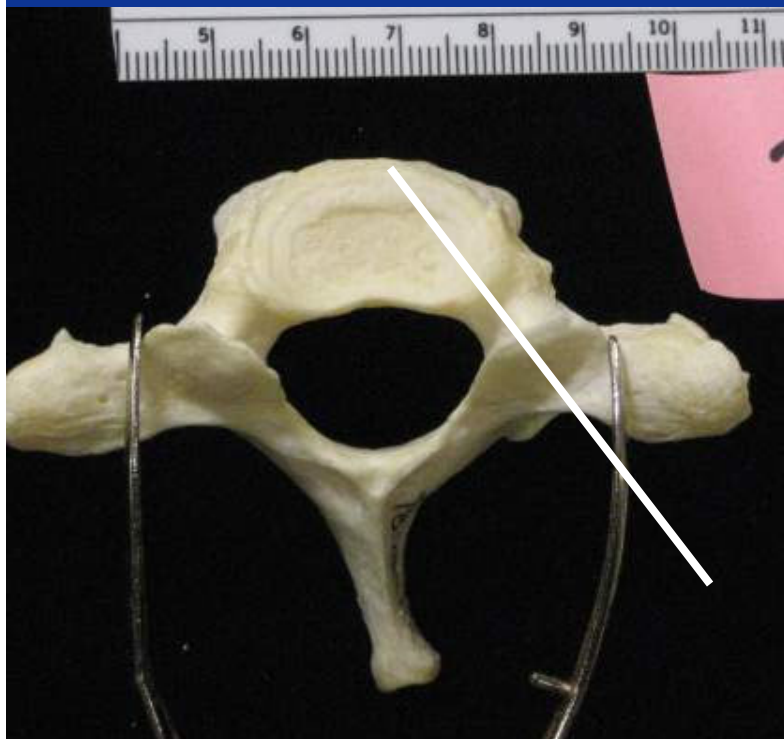
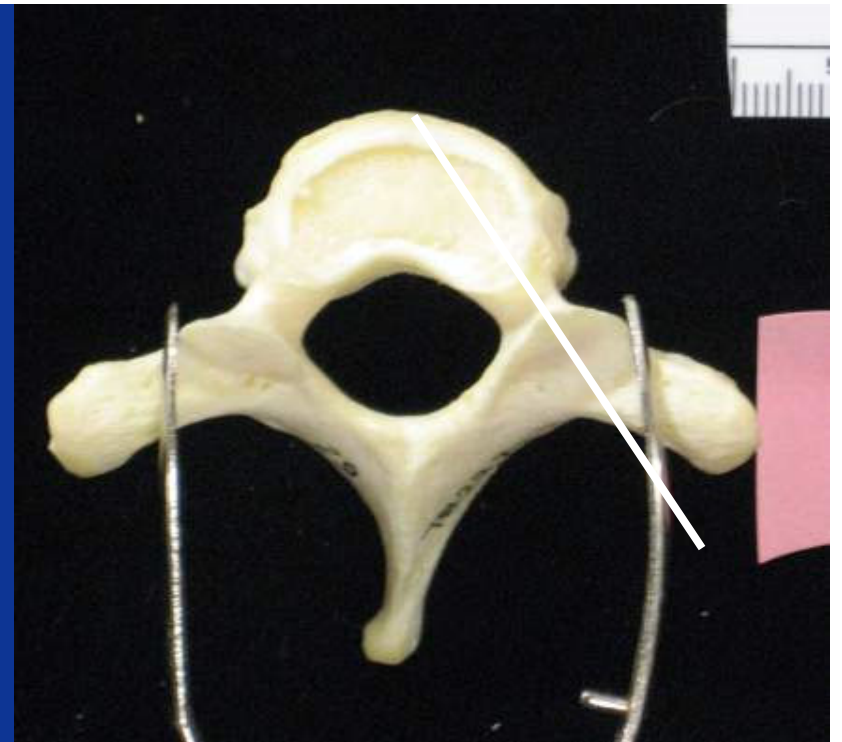
Rib measurements



Rib Area (CLBD)
HT Collection. 16 specimens

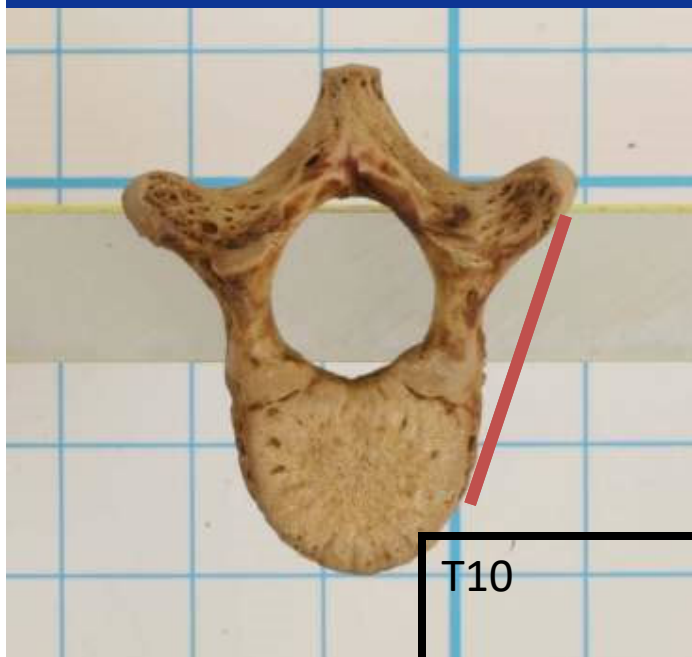
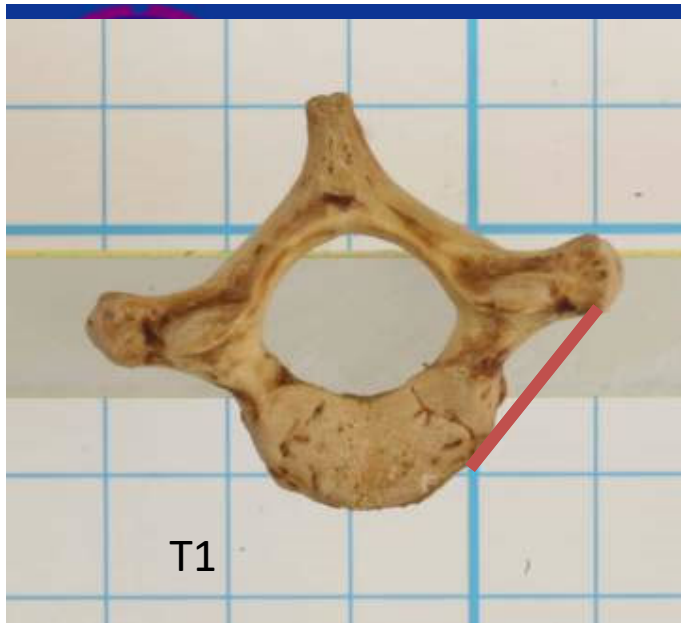






4 different
T1 vertebra
Similar pedicle
angles



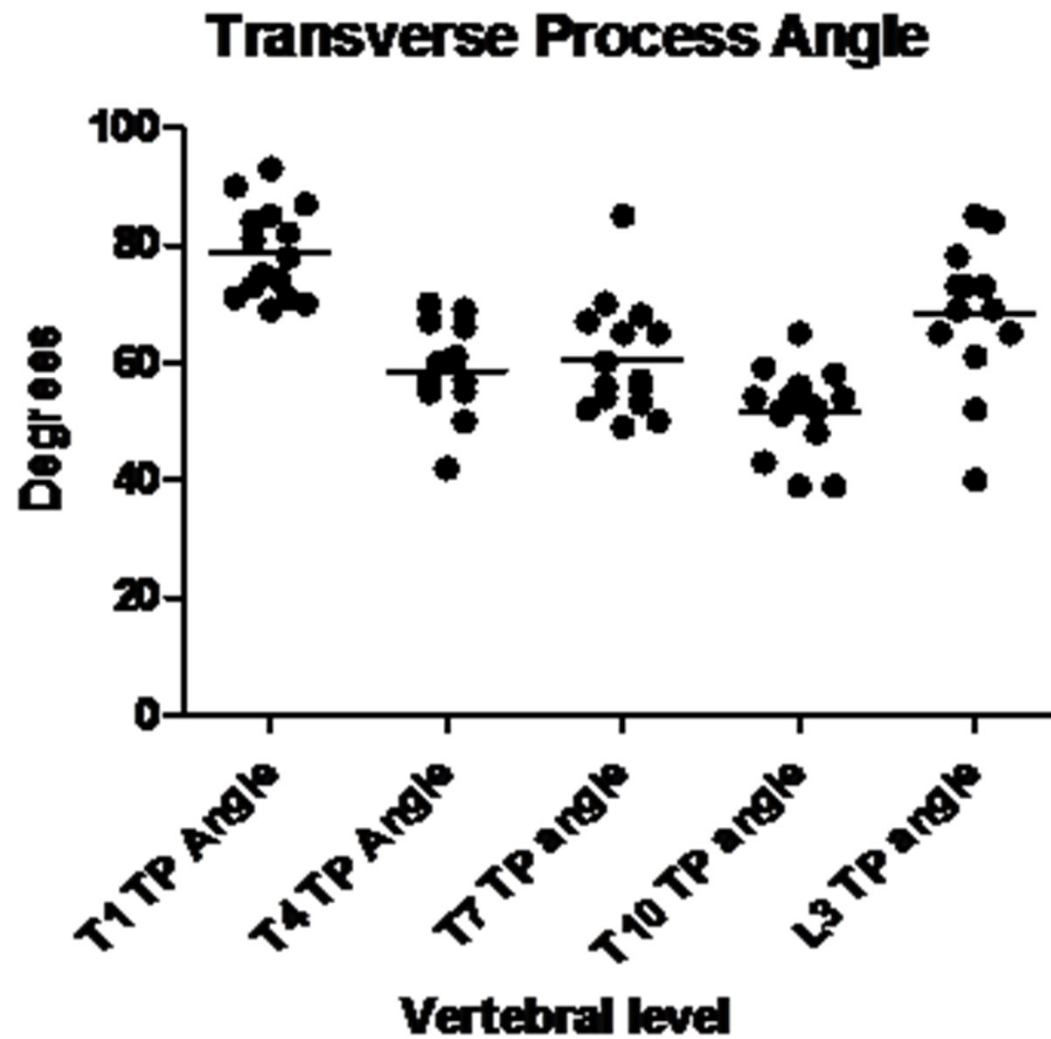


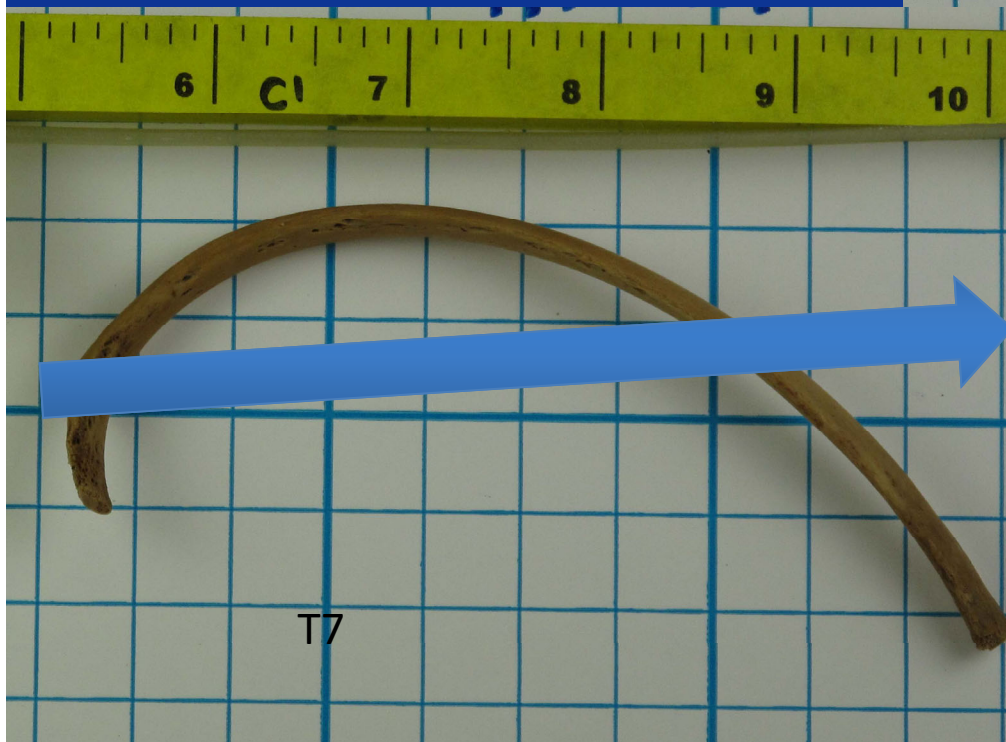
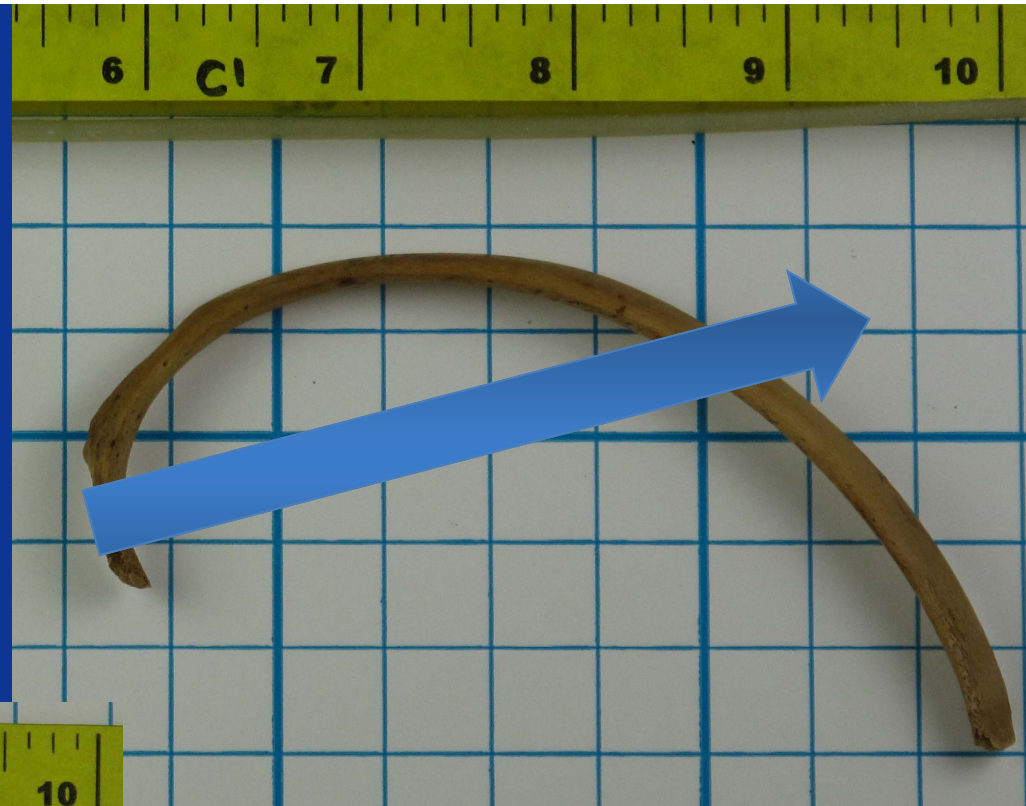
What does this mean?

Transverse process
angle varies with
thoracic level



HT Data





Each rib has its own unique axis of rotation



Rib elevation **INCREASES** simultaneously the transverse diameter of the lower thorax and the anteroposterior diameter of the upper thorax.

In the midthoracic region, the joints of the costal heads have an axis Running obliquely at roughly 45 deg to the sagittal plane so that both the transverse and the anterior-posterior diameters are increased.

Foreword by Professor Gerard Sallat

A. I. KAPANDJI

The Physiology of the Joints

Volume Three THE SPINAL COLUMN, PELVIC GIRDLE AND HEAD

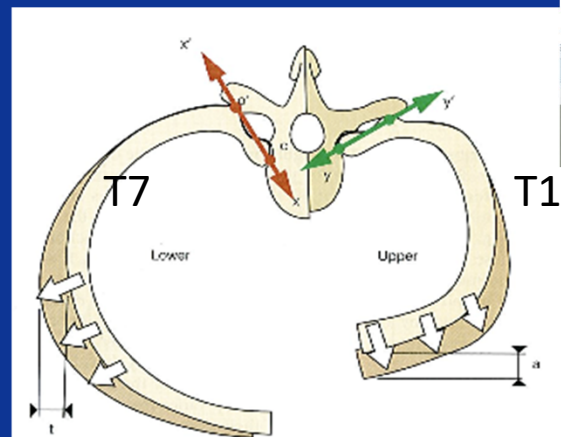
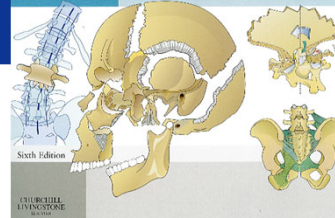


Figure 15

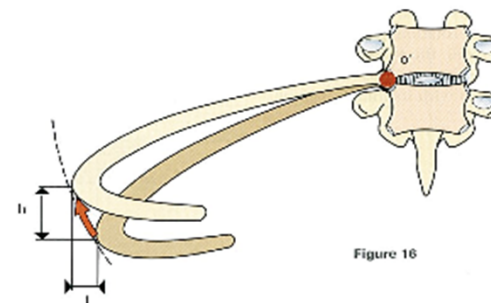


Figure 16

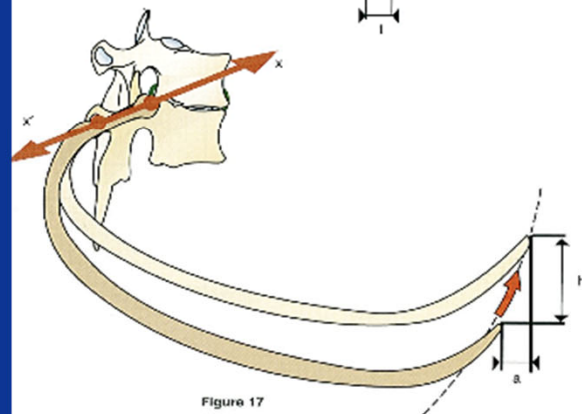


Figure 17



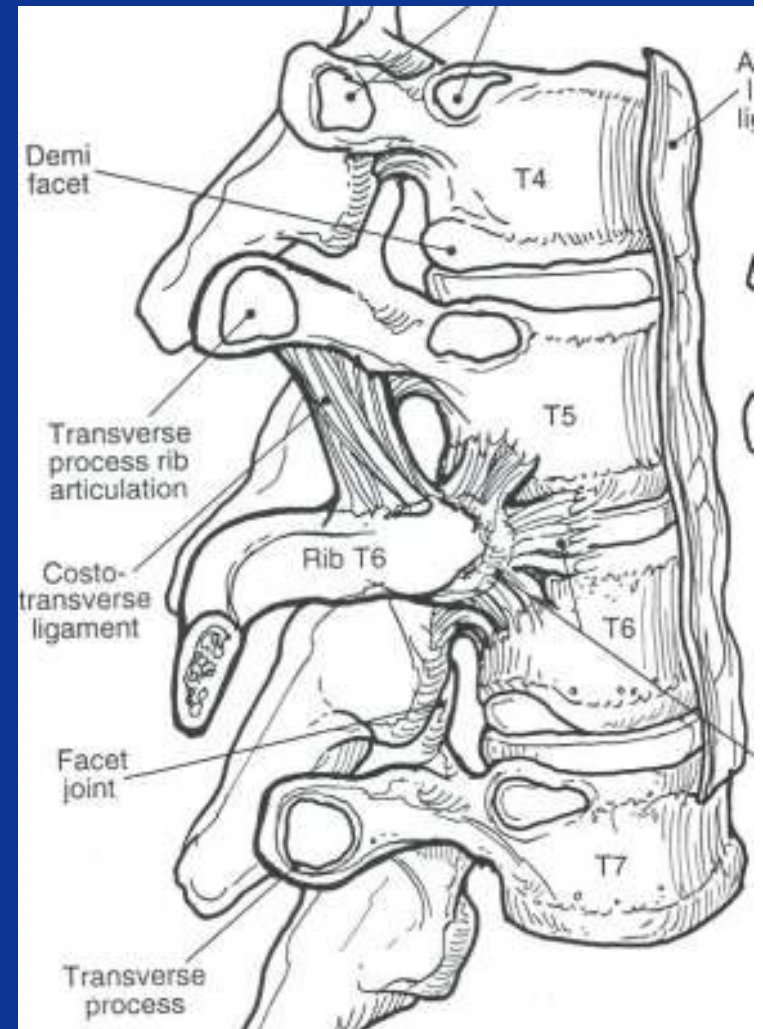
Biomechanics- My Summary

Few studies of releases of intact thorax,
none pediatric.

Sternum gives F/E stability to the thoracic
spine (42% decrease stability with
fracture) (Watkins R 2005)

With rib cage present- combination of disc
and rib articulation are BOTH important
to 3D spine stability (Takeuchi T 1999,
Feiertag MA 1995)

Convex thoracoplasty- not as effective as
rib head resection.





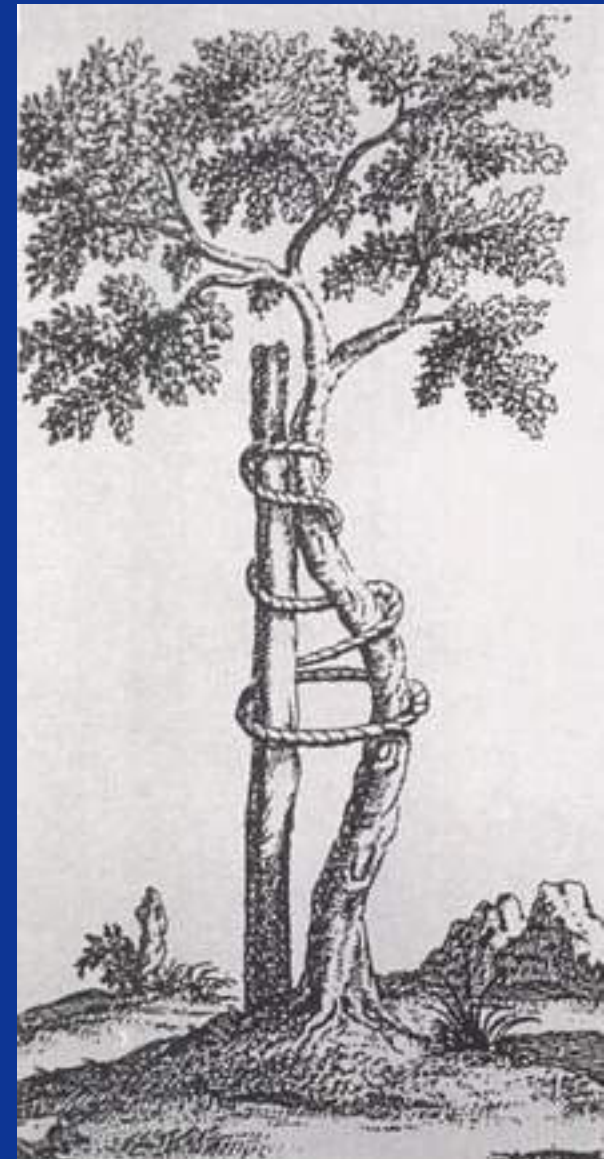
Conclusions

- 63 Pediatric skeletal specimens were available to study spinal and rib comparative anatomy.
- Rib height is approximately one half adult height by one year of age, increases more than width, preferential early vertical growth of the thorax compared to lower segments.
- Linear/area growth is greater in the midsection, creating barrel shape thorax. Linear growth follows golden spiral to provide large increase in volume with growth.
- TP angles determine axis of rib rotation.



Implications for future

- Entire thorax needs consideration when evaluating spine growth, function and stability
- Better understanding of rib anatomy , implications for implant design and use.
- Research on basic developmental thoracic anatomy and function
- Pathologic conditions compared to normal





Axial view from inferior

PEEK zip ties from China. Low profile, lowest cost implant

