Medical Geography

Osteoporosis

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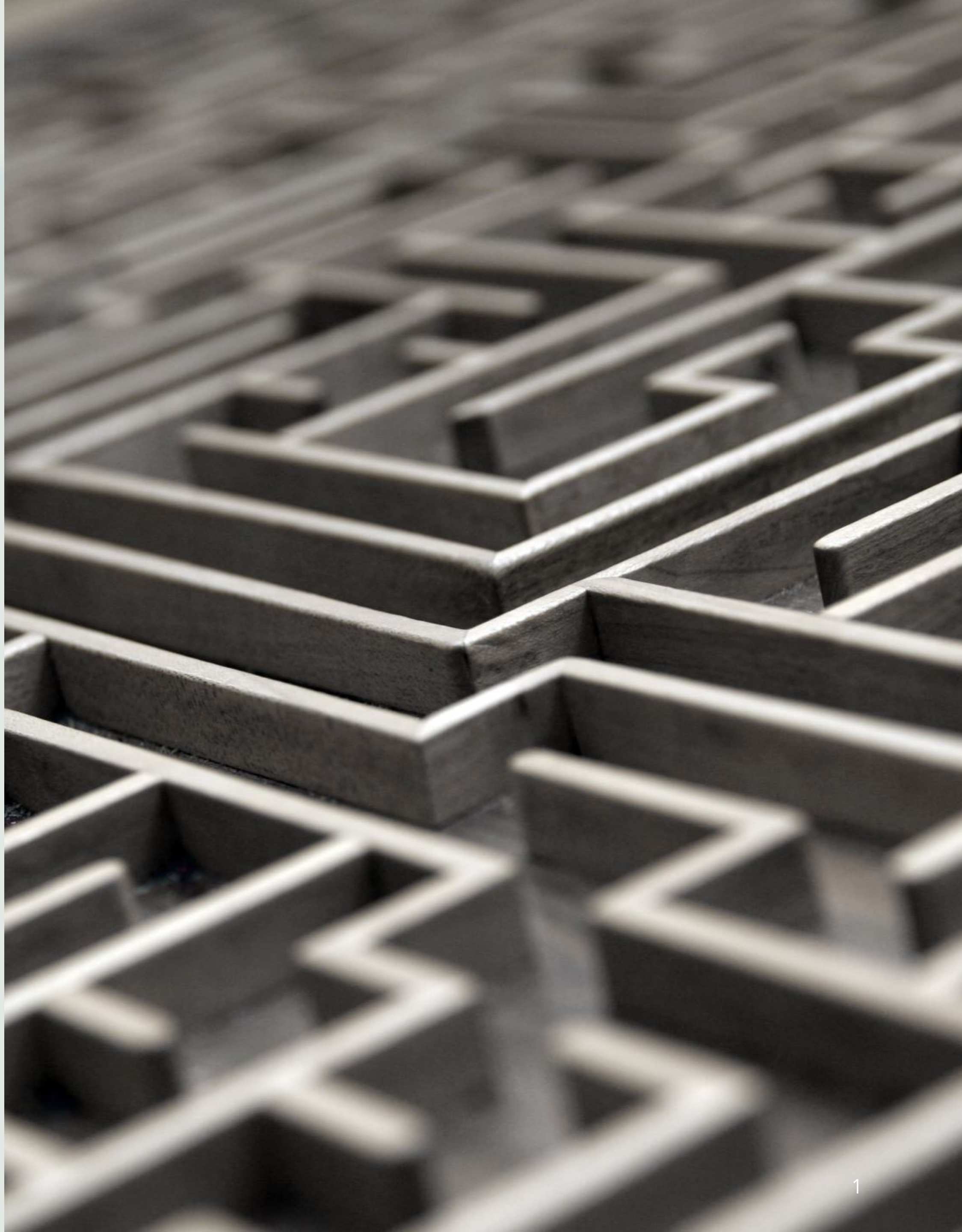
Outline

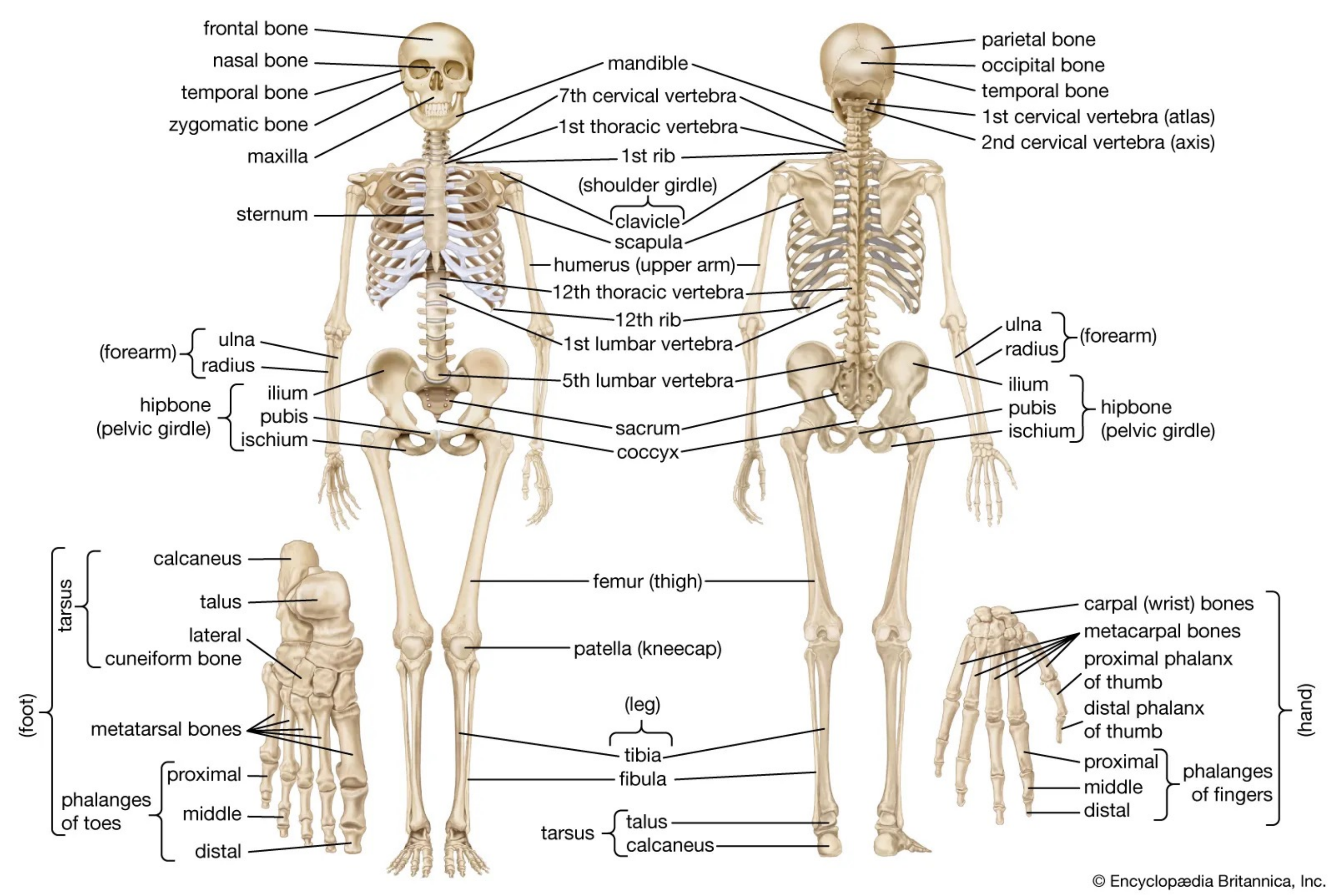
- Bone Structure
- Osteoporosis
- Bone Metabolism
- Osteoporosis Treatment
- Compression Fractures
- Osteoporosis Location
- The Characteristics of Osteoporosis
- Where is Trabecular Bone and Why it is Important
- Trabecular Imaging Techniques
- Quantitative Trabecular Microarchitecture Analysis
- Current Issues and Dilemma in Clinical Practice
- Remarks
- Spatial Perspective Discussion



Bone Structure

Source: https://en.wikipedia.org/wiki/Human_skeleton
Photo: https://www.britannica.com/science/human-skeleton

- The human skeleton is the internal framework of the human body. It is composed of around 270 bones at birth – this total decreases to around **206 bones** by adulthood after some bones get fused together.
- The bone mass in the skeleton makes up about **14% of the total body weight** (ca. 10–11 kg for an average person) and reaches maximum mass between the ages of **25 and 30**.
- The human skeleton can be divided into the **axial skeleton** and the **appendicular skeleton**.

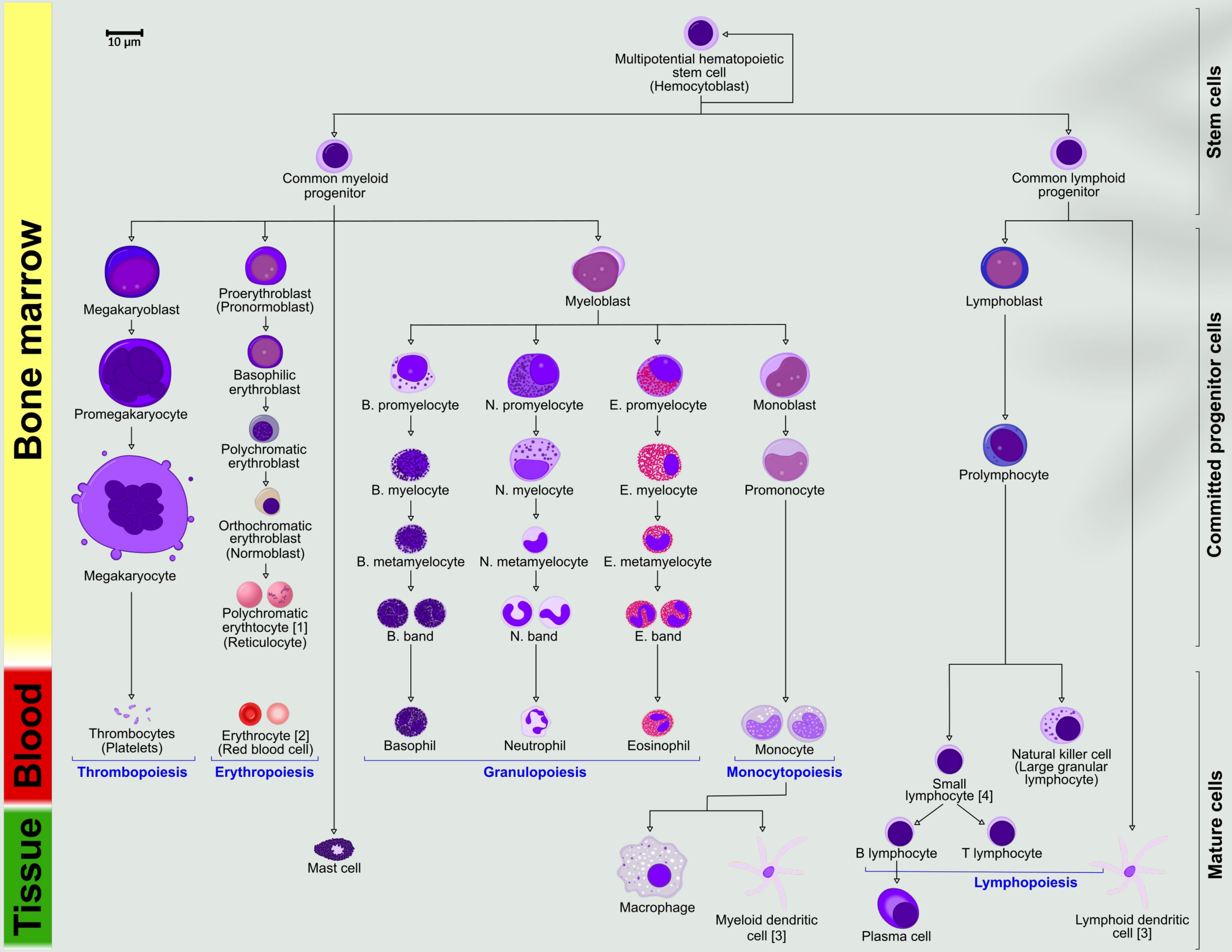


Bone Structure – Function

- **Support:** The skeleton provides the framework which supports the body and maintains its shape.
- **Movement:** The joints between bones allow movement, some allowing a wider range of movement than others.
- **Protection:** The skeleton helps to protect many vital internal organs from being damaged.
- **Blood cell production:** The skeleton is the site of haematopoiesis, the development of blood cells that takes place in the bone marrow.
- **Storage:** The bone matrix can store calcium and is involved in calcium metabolism, and bone marrow can store iron in ferritin and is involved in iron metabolism.
- **Endocrine regulation:** Bone cells release a hormone called osteocalcin, which contributes to the regulation of blood sugar (glucose) and fat deposition.

Source: https://en.wikipedia.org/wiki/Human_skeleton

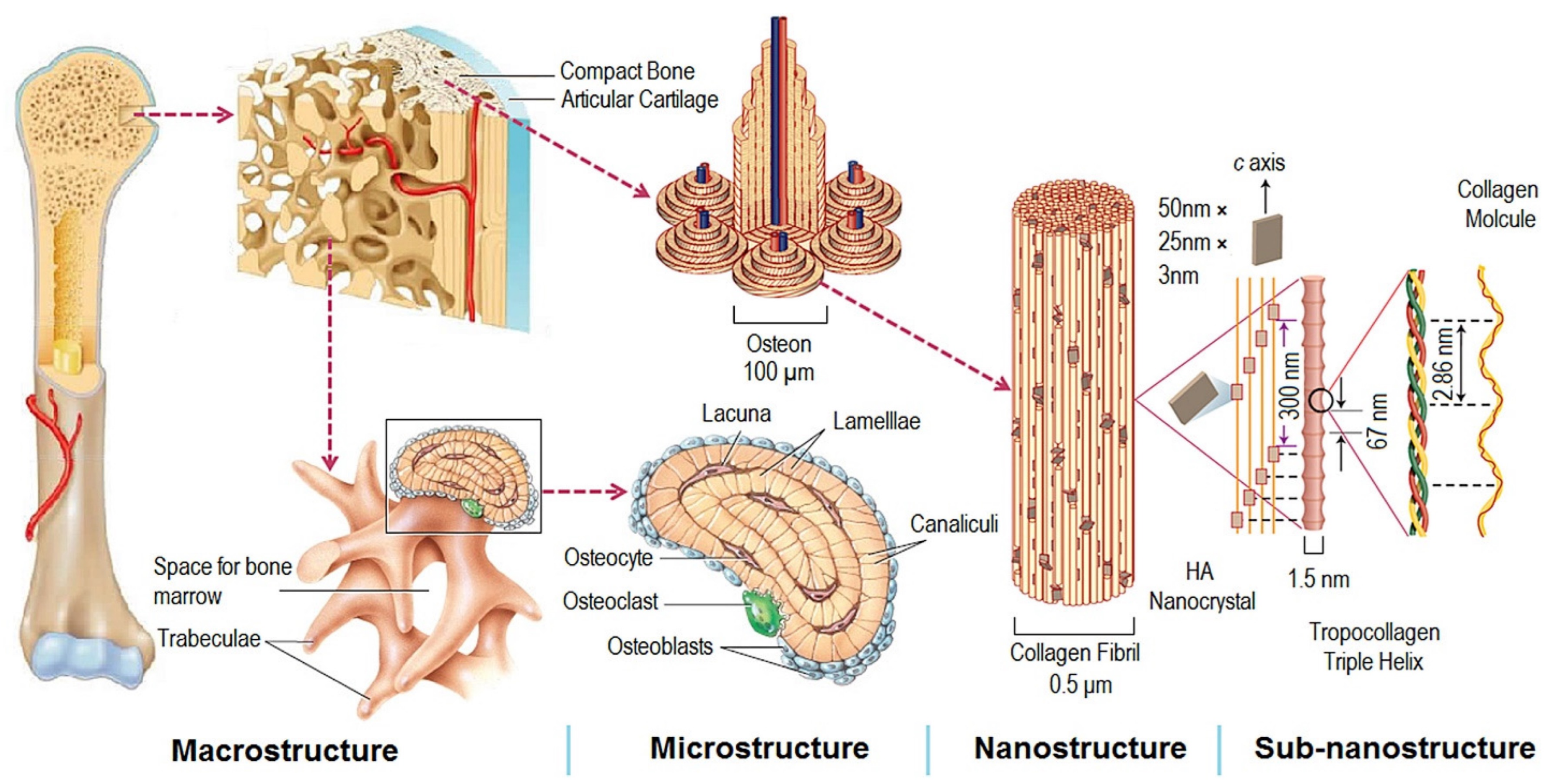
Haematopoiesis



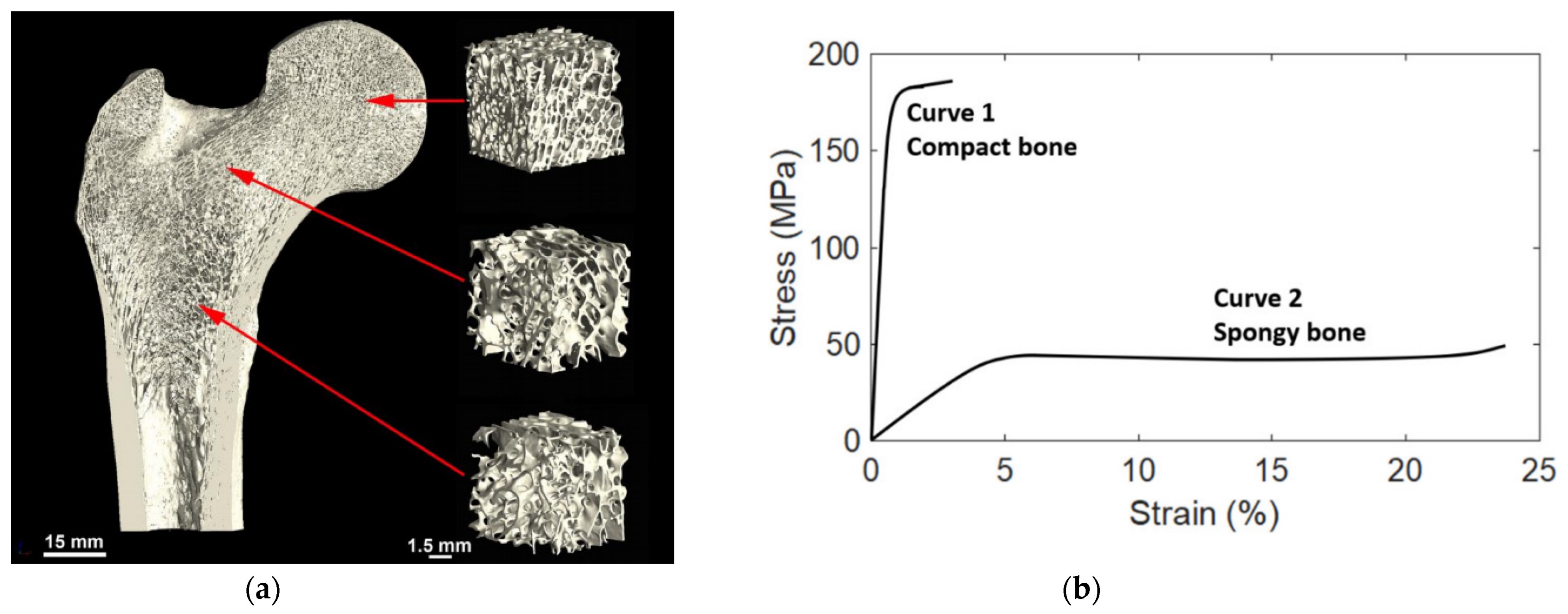
Source: https://en.wikipedia.org/wiki/Haematopoiesis#/media/File:Hematopoiesis_(human)_diagram_en.svg

Bone Structure

Wang, X.; Xu, S.; Zhou, S.; Xu, W.; Leary, M.; Choong, P.; Qian, M.; Brandt, M.; Xie, Y.M. Topological design and additive manufacturing of porous metals for bone scaffolds and orthopaedic implants: A review. Biomaterials 2016, 83, 127–141.



Bone Structure – Strength



Variation in the trabecular bone structure by location, in this example from the human femur of a 26-year-old male.

1.Yadroitsava, I.; du Plessis, A.; Yadroitsev, I. Bone Regeneration on Implants of Titanium Alloys Produced by Laser Powder Bed Fusion: A Review, in Titanium for Consumer Applications; Froes, F., Qian, M., Niinom, M.I., Eds.; Elsevier: Amsterdam, The Netherlands, 2019; pp. 197–233.

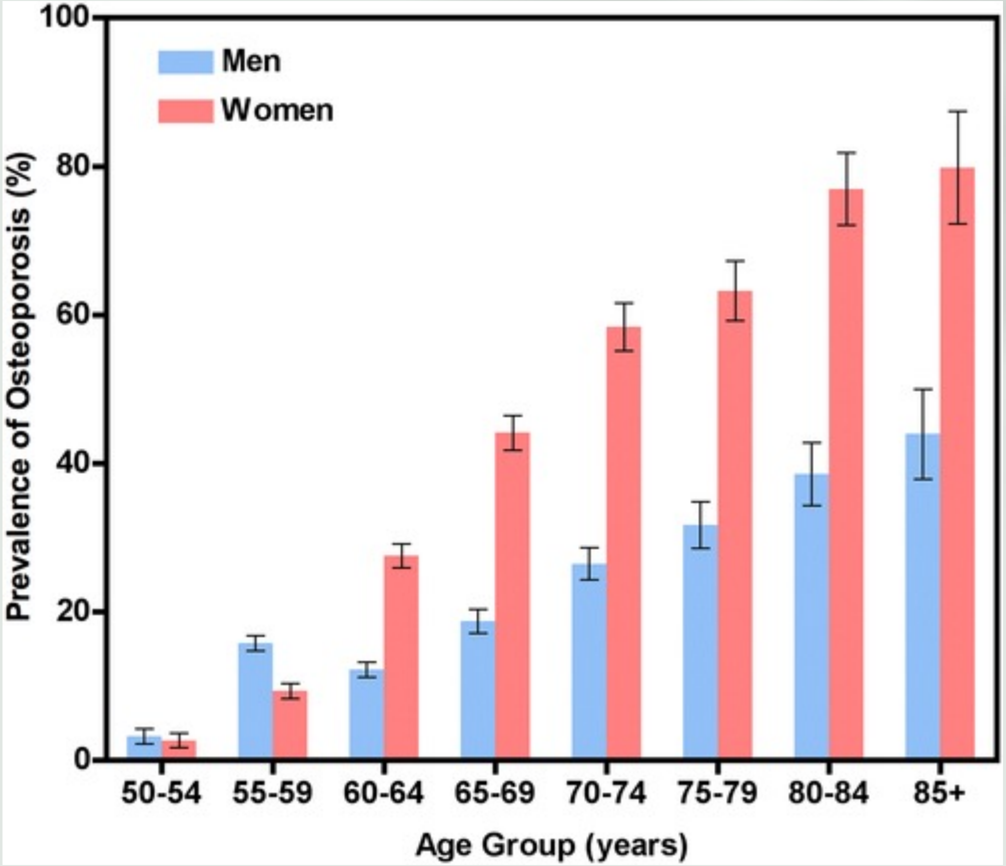
2.Lin, C.-Y.; Kang, J.-H. Mechanical Properties of Compact Bone Defined by the Stress-Strain Curve Measured Using Uniaxial Tensile Test: A Concise Review and Practical Guide. Materials 2021, 14, 4224.

Osteoporosis – Definition

- **Osteoporosis** is defined as a **systemic skeletal disease** characterized by low **bone mass** and **microarchitectural deterioration** of **bone tissue**, with a consequent increase in bone fragility and susceptibility to fracture.
- This well established definition, developed by international consensus in 1993, captures two important characteristics of the disease: its adverse effects on **bone mass** and **microstructure**, and the **clinical outcome of fracture**.
- The following year, diagnostic criteria were produced by WHO using SD scores of bone mineral density (BMD) related to peak bone mass in healthy young women, with osteoporosis being defined as a BMD T score of −2.5 or less and low bone mass (osteopenia) as a BMD T-score between −1 and −2.5.

Osteoporosis – Cause and Prevalence

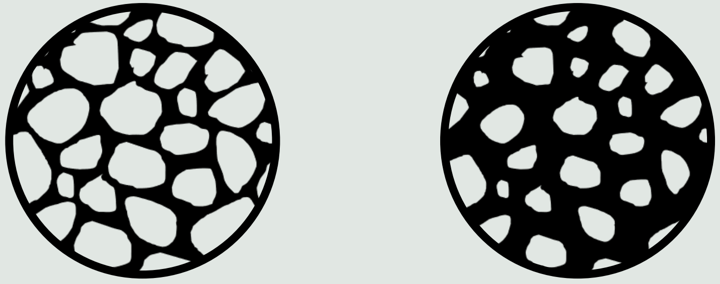
- WHO considers osteoporosis to be the second important epidemic in the world after coronary heart disease.
- Osteoporosis is a highly prevalent disease in older population, accounting 20 to 30% of people over 50 years old in Taiwan, and 80% of patients with osteoporosis are female.

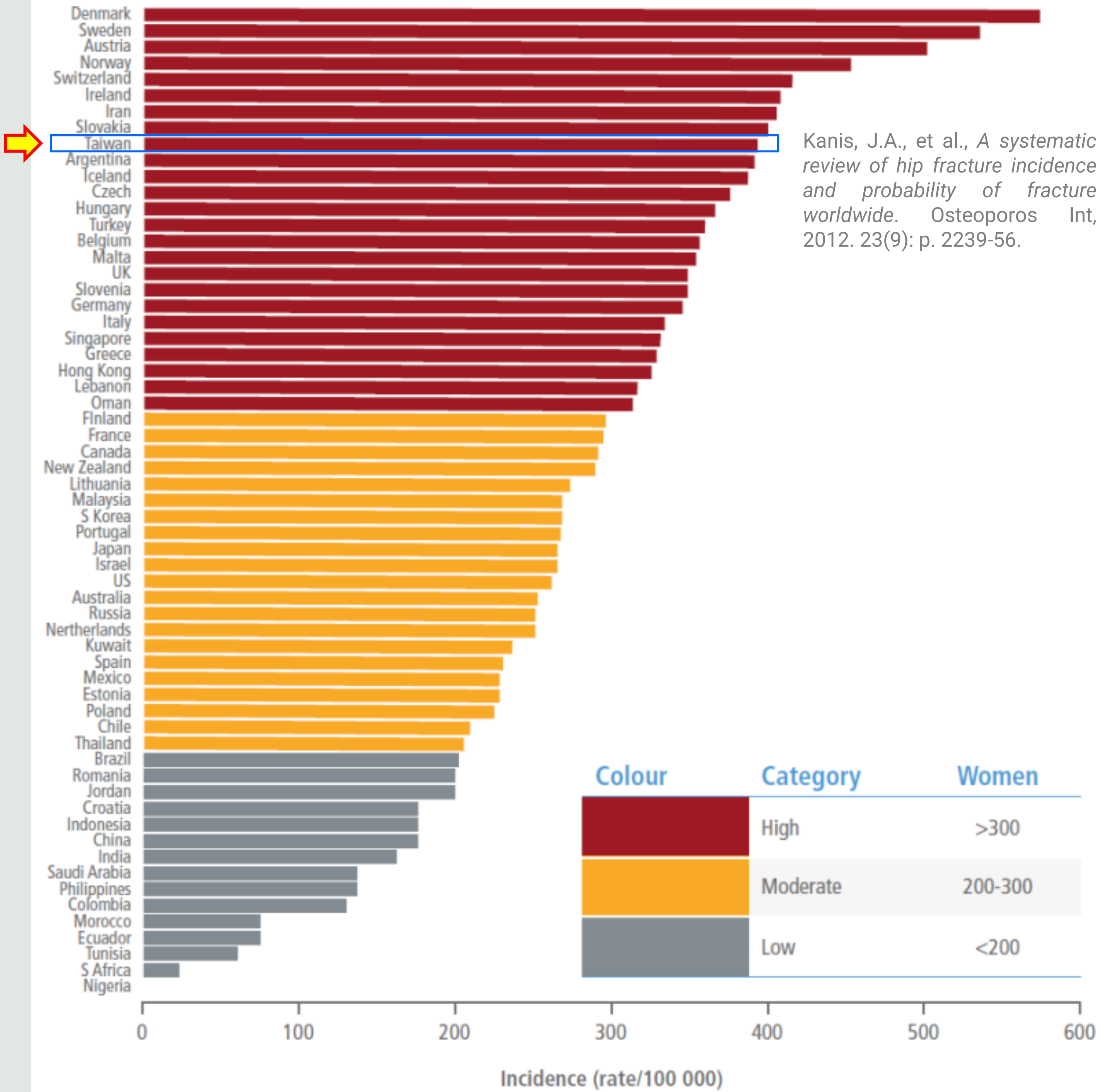


Cheng et al. (2010) Opportunistic Screening Using Low-Dose CT and the Prevalence of Osteoporosis in China: A Nationwide, Multicenter Study. Journal of Bone and Mineral Research. 36 (3) 427-435.

Outcome

- It is characterized by low bone strength, predisposing to an increased risk of fragility fracture and leading to a high probability of compression fracture, low quality of life, mobility reduction, and increased mortality.

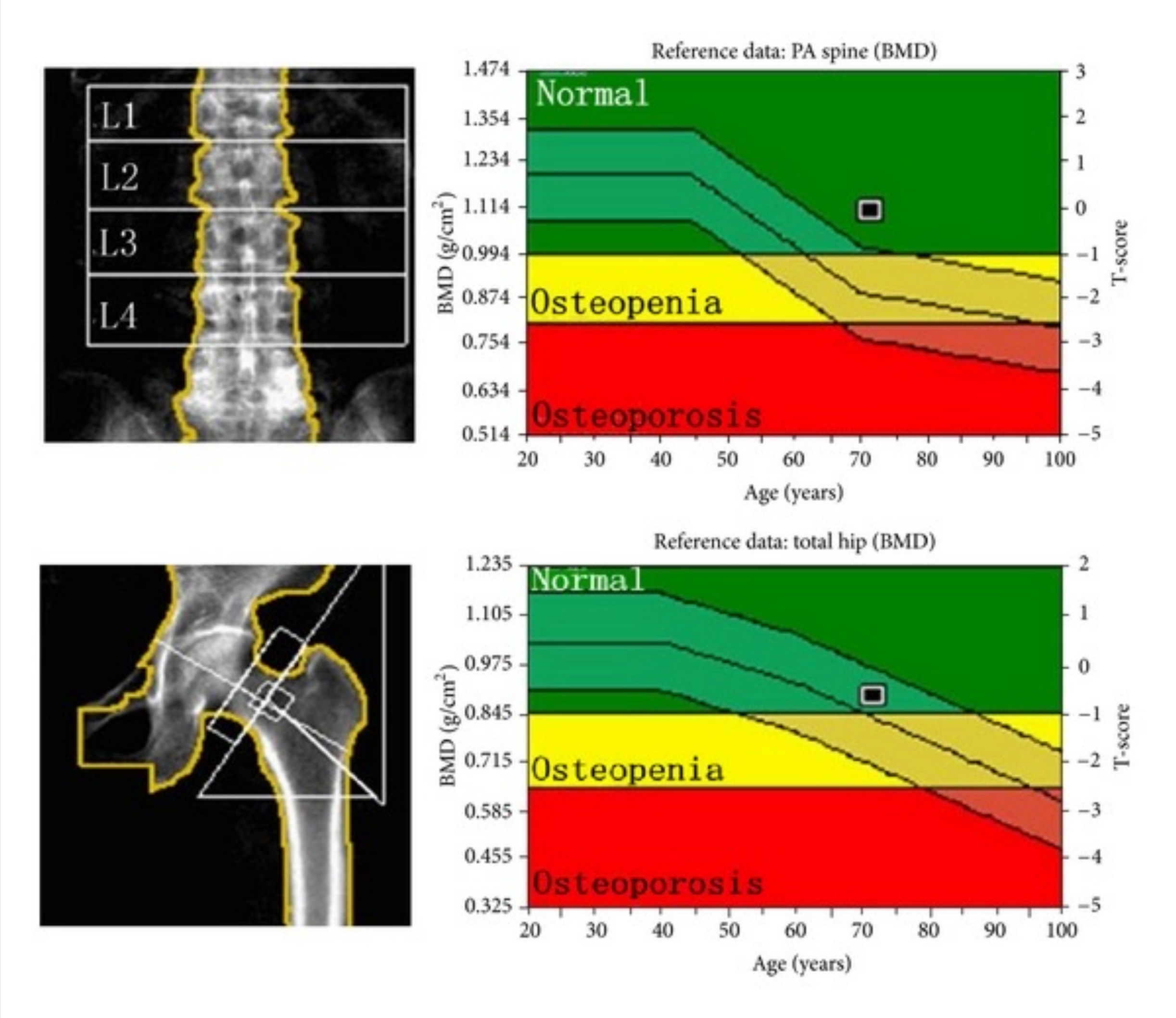




Kanis, J.A., et al., *A systematic review of hip fracture incidence and probability of fracture worldwide*. Osteoporos Int, 2012. 23(9): p. 2239-56.

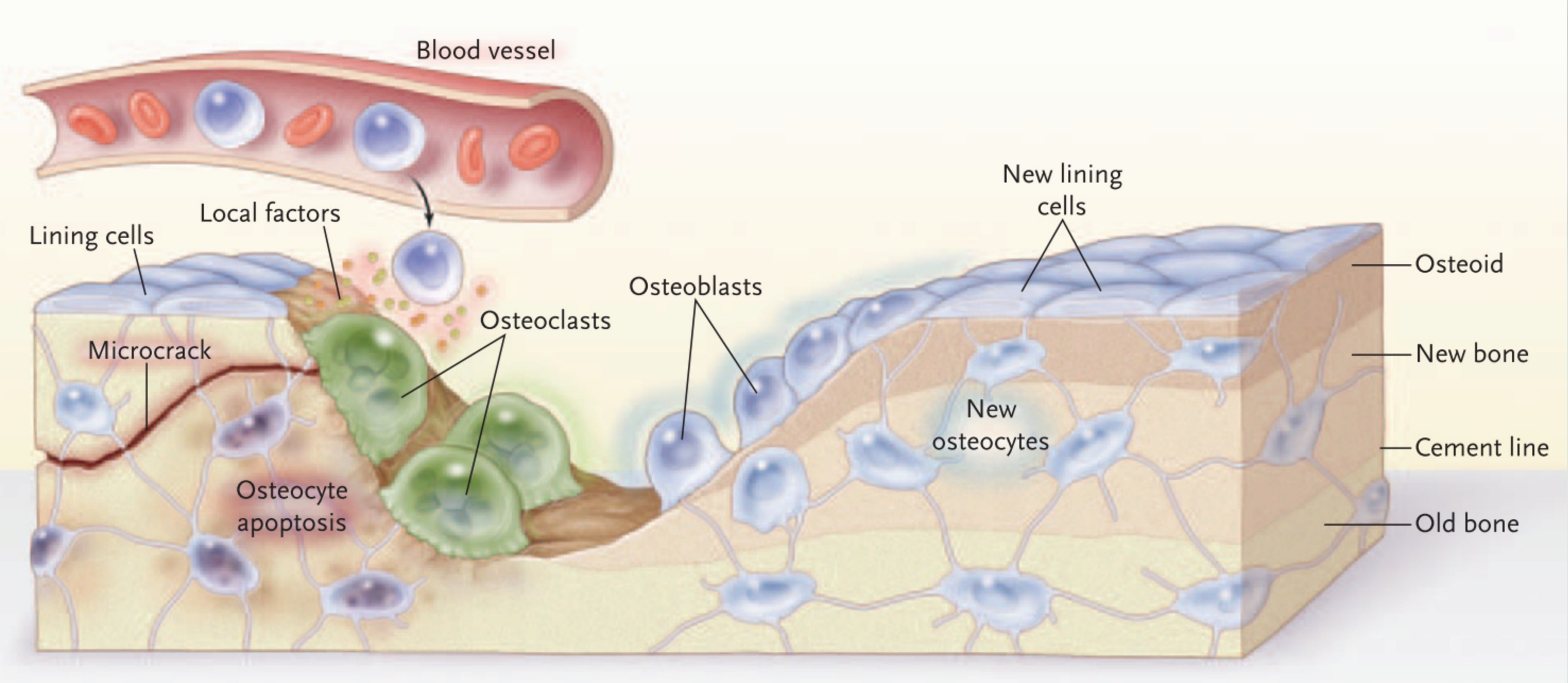
Osteoporosis Diagnosis

- Current osteoporosis diagnosis is based on bone mineral density (BMD), measured by dual X-ray absorptiometry (DXA).



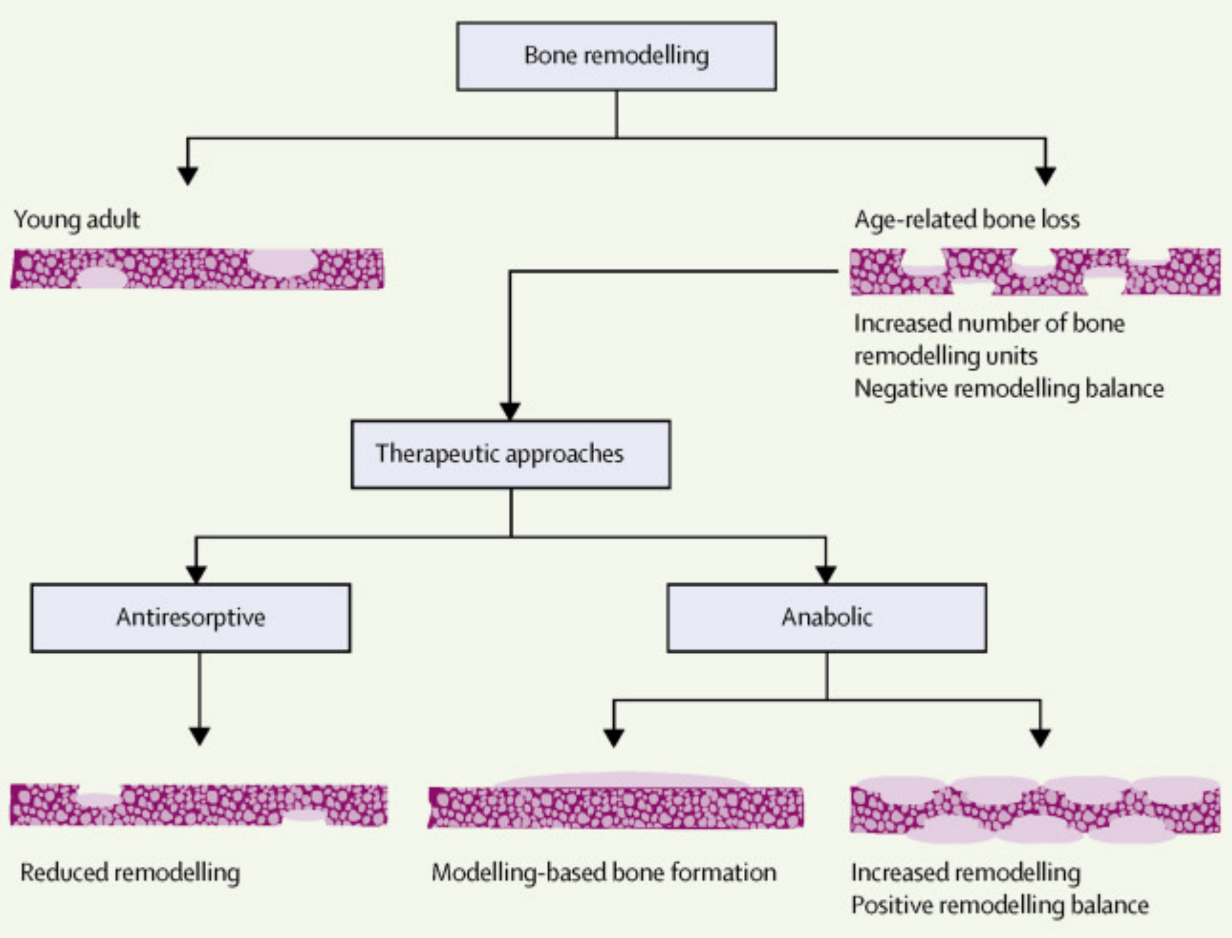
Bone Metabolism

Seeman, E., & Delmas, P. D. (2006). Bone quality—the material and structural basis of bone strength and fragility. *New England journal of medicine*, *354*(21), 2250-2261.

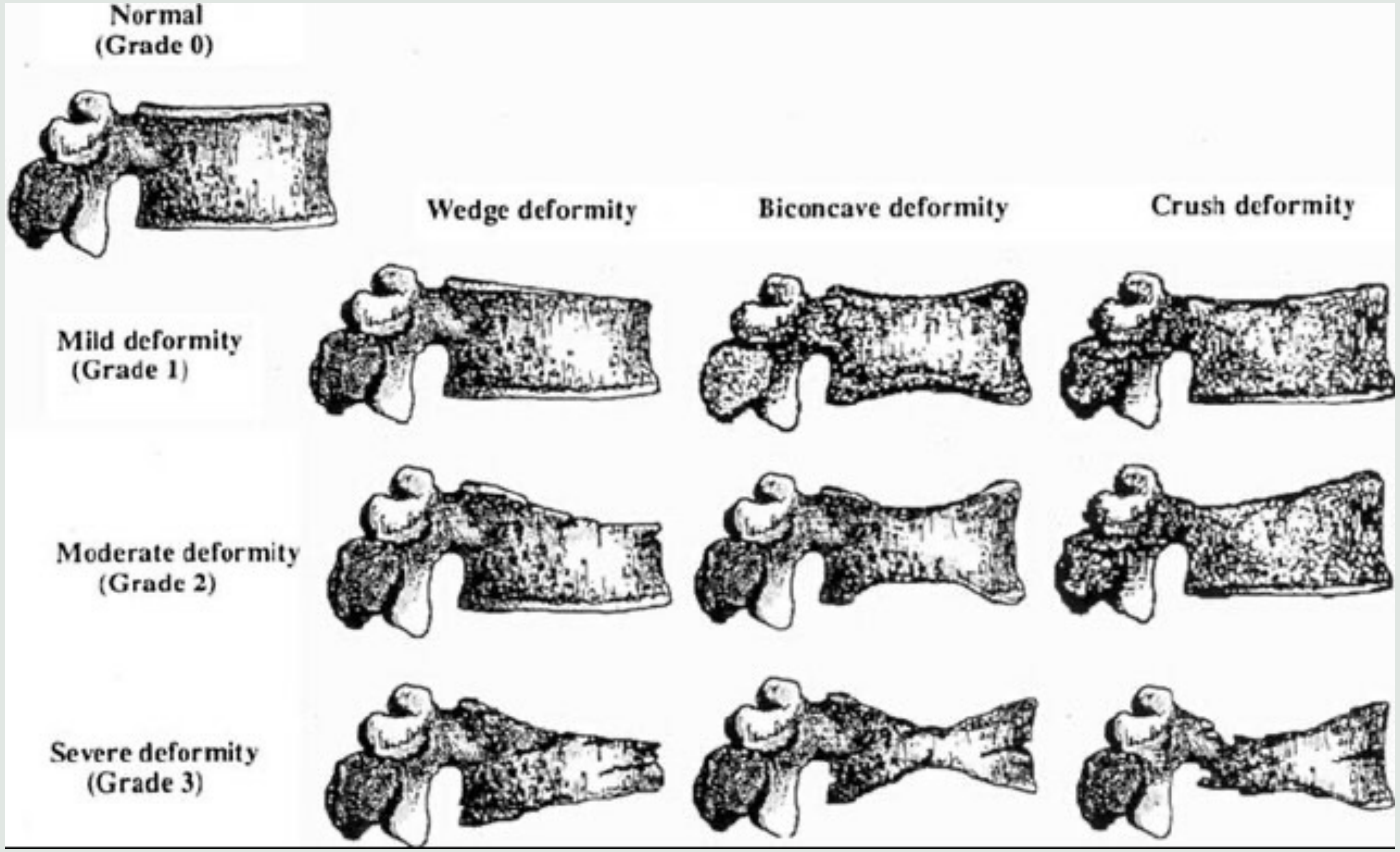


Osteoporosis Treatment

- Age-related bone loss is associated with an increase in remodeling and a negative remodeling balance in individual bone remodeling units.
- Antiresorptive agents act predominantly by reducing remodeling rate.
- Anabolic agents produce their effects by increasing remodeling in combination with a positive remodeling balance, or stimulating bone modelling.



Compression Fractures

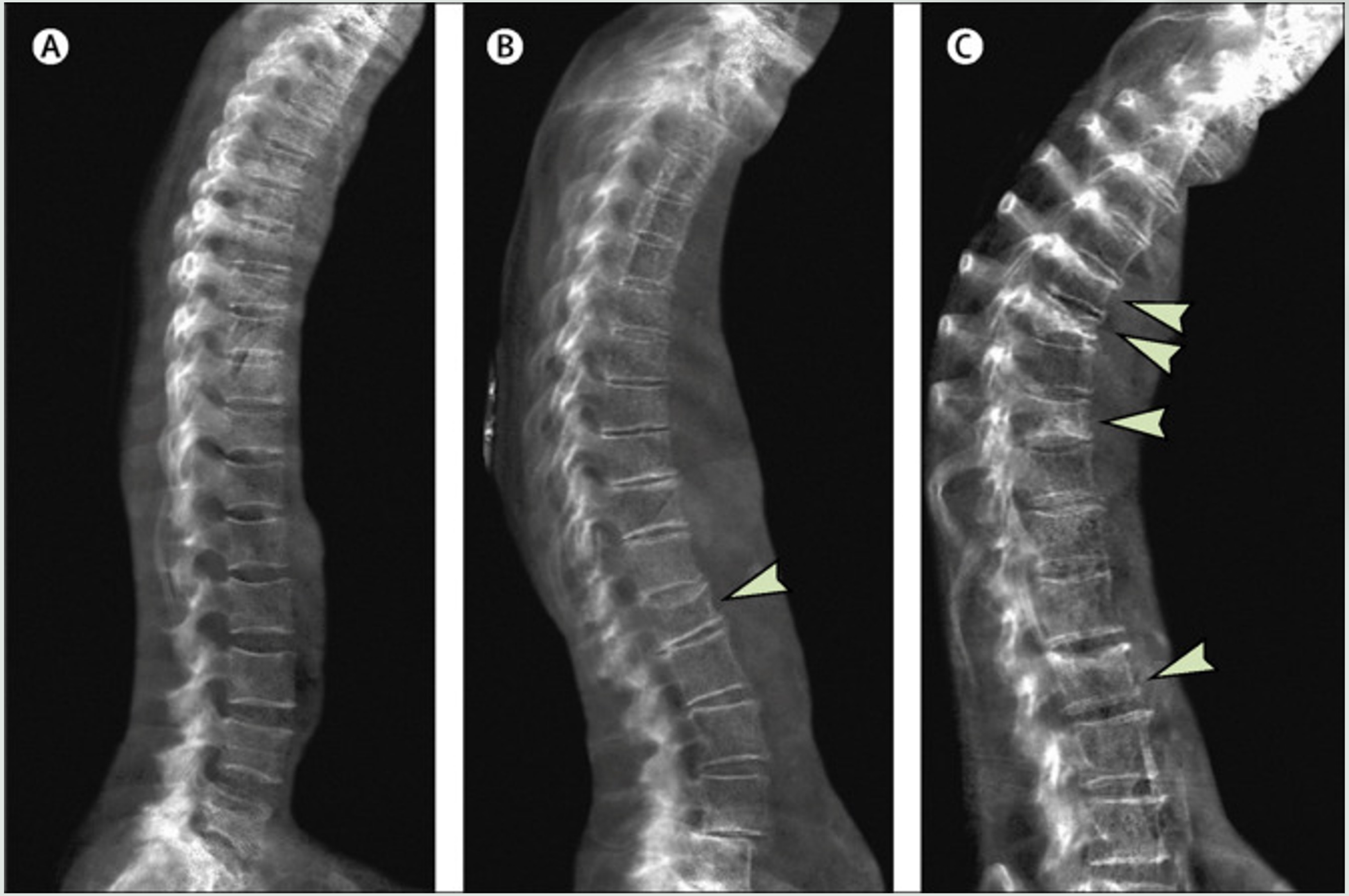


Semiquantitative (SQ) visual grading scheme for vertebral fractures. Genant's grading scheme for a semiquantitative evaluation of vertebral fracture. The drawings illustrate normal vertebrae (top row) and mild to severe fractures (respectively in the following rows). The size of the reduction in the anterior, middle, or posterior height is reflected in a corresponding to fracture grade, from 1 (mild) to 3 (severe)

Genant HK, Wu CY, van Kuijk C, Nevitt MC. Vertebral fracture assessment using a semiquantitative technique. J Bone Miner Res. 1993 Sep;8(9):1137-48. doi: 10.1002/jbmr.5650080915. PMID: 8237484.

Compression Fracture

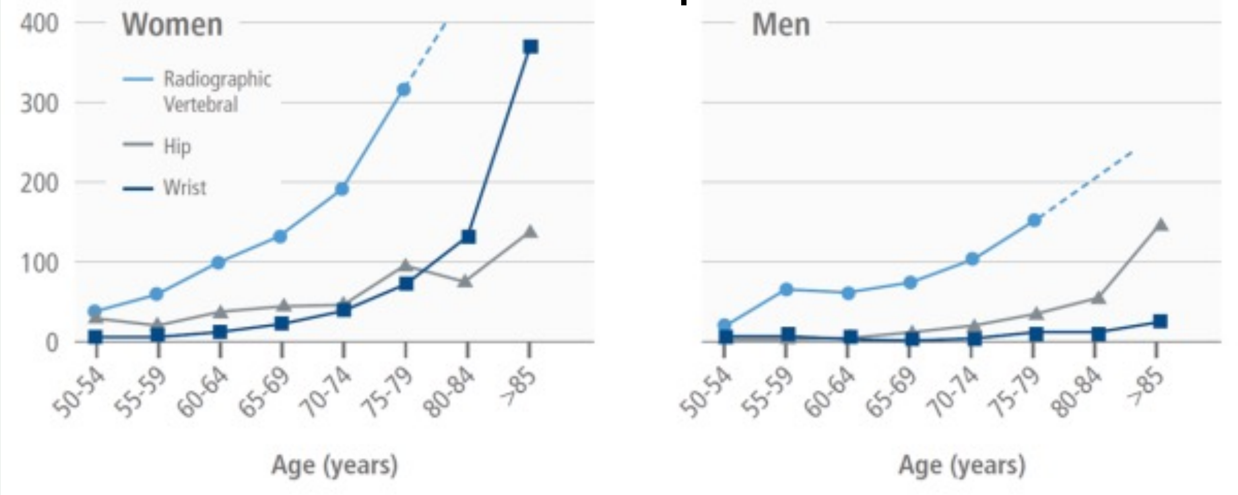
Vertebral fracture assessment can be done with the dual energy x-ray absorptiometry scanner at the time of bone mineral density assessment to identify unsuspected vertebral fractures. In the absence of an alternative cause, their presence indicates high fracture risk due to underlying osteoporosis and usually warrants treatment initiation. (A) Normal spine. (B) Single moderate fracture (L1). (C) Multiple vertebral fractures (T7 moderate, T8 severe, T10 mild, L2 mild). L=lumbar vertebra. T=thoracic vertebra. Arrows point to specific fractures.



Osteoporosis Location

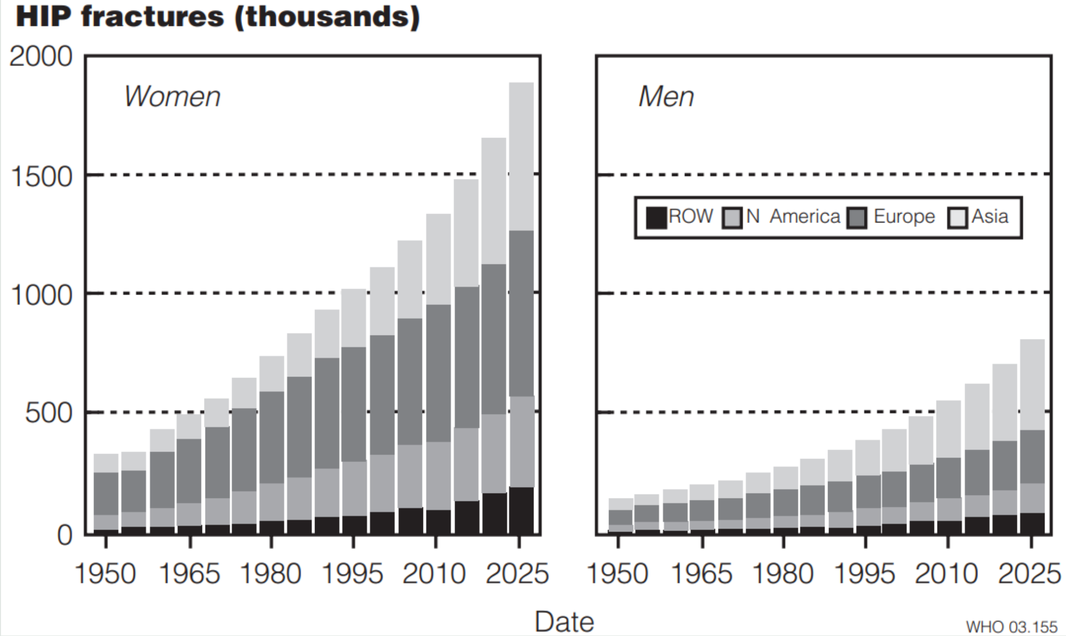
- Osteoporotic hip fracture is the most serious fracture.
- The lifetime risk of hip fracture lies between 14% and 20% among Caucasian women in Europe and the USA, and is likely to increase as mortality for other conditions declines.

Vertebral > Hip ~ Wrist



Age-specific and sex-specific incidence of radiographic vertebral, hip and distal forearm fractures

Sambrook, P. and C. Cooper, *Osteoporosis*. Lancet, 2006. 367(9527): p. 2010-8.

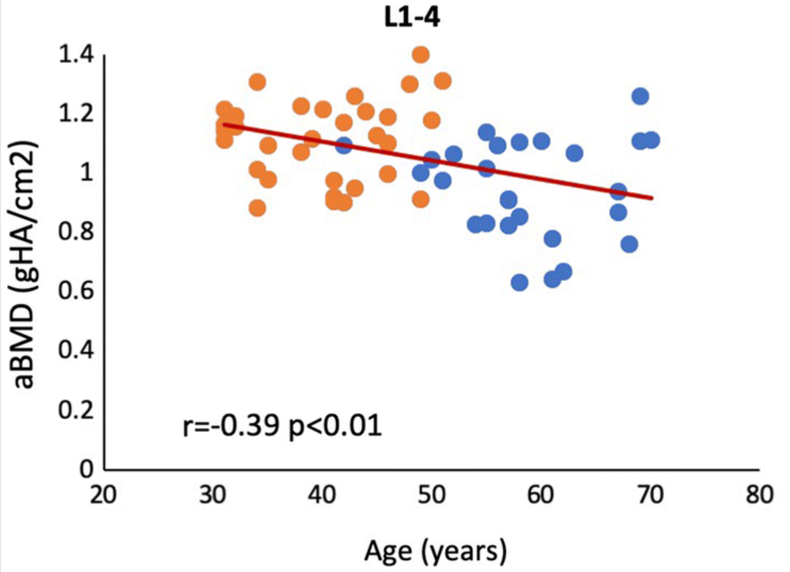


Estimates of the number of hip fractures between 1950 and 2025 by gender and region (ROW: rest of world)

Caverzasio J, Bonjour JP. Characteristics and regulation of Pi transport in osteogenic cells for bone metabolism. Kidney International, 1996, 49:975– 980.
WHO, Prevention and management of osteoporosis. WHO Technical Report Series, 2003, Geneva.

The Characteristics of Osteoporosis

- Osteoporosis is a disease that is characterized by <u>low bone mass</u>, <u>deterioration of bone tissue</u>, and <u>disruption of bone microarchitecture</u>.
- Current gold standard tool for screening and monitoring patients is dual-energy X-ray absorptiometry (DXA) by measuring areal bone mineral density (aBMD) of the spine (L1-L4) and proximal femurs.



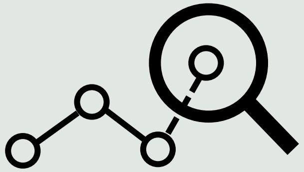
Scatter diagrams between age and aBMD measured by DXA. lumbar vertebrae L1-4 (orange plots: premenopausal women, blue plots: postmenopausal women)

DXA Problems

Low precision

➔ 2-3% variation

➔ 2-3 years follow-up



Low prediction rate

➔ 50%-60% prediction for fracture

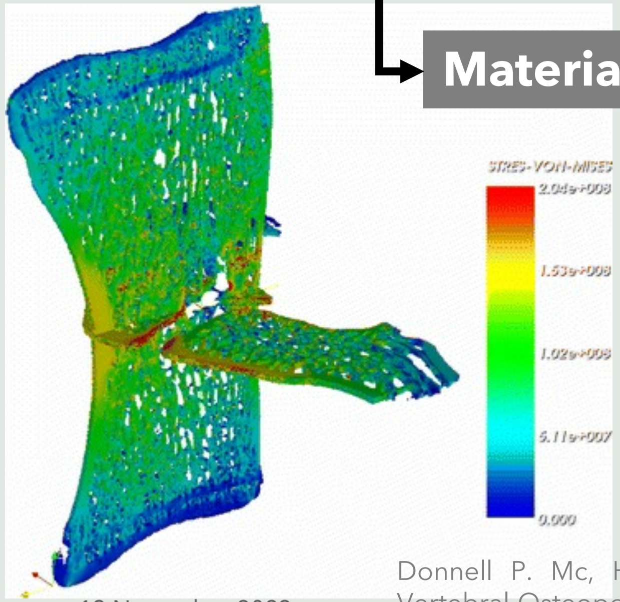
➔ <u>Cannot quantify 3D trabecular microarchitecture</u>

Kazuaki Yokota, Ko Chiba, Narihiro Okazaki, Choko Kondo, Mitsuru Doi, Shuta Yamada, Makoto Era, Yuichiro Nishino, Akihiko Yonekura, Masato Tomita & Makoto Osaki. (2020) Deterioration of bone microstructure by aging and menopause in Japanese healthy women: analysis by HR-pQCT. Journal of Bone and Mineral Research. 38, 826-838.

The Characteristics of Osteoporosis

Fracture → **Bone Strength**

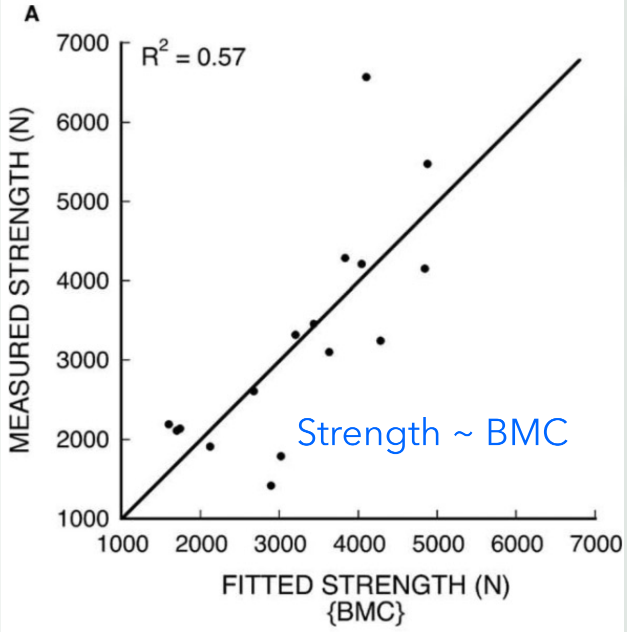
- → **Bone Mineral Density (BMD)**
  - ↳ **BMD from DXA**
- → **Trabecular Microarchitecture**
  - ↳ **???**
- → **Material Composition**



Stress contour plot for whole ovine vertebra under compression load, showing vertical and lateral sections (from the authors' laboratory at NCBES, NUI Galway).

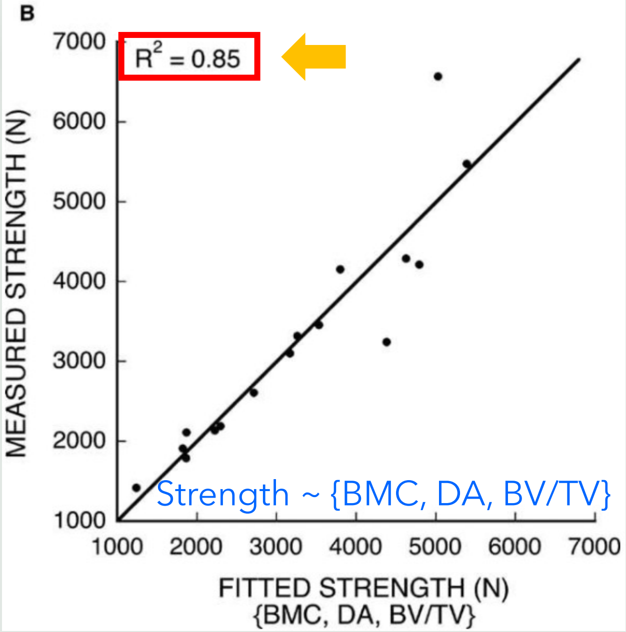
Donnell P. Mc, Hugn P. E. Mc, Mahoney D. O' (2007) Vertebral Osteoporosis and Trabecular Bone Quality. Annals of Biomedical Engineering, 35, 170-189.

Fitted vs. measured vertebral strength



(A) BMC as a single predictor of strength (Strength = BMC × 376–196).

Aaron J Fields, Senthil K Eswaran, Michael G Jekir, Tony M Keaveny (2009) Role of Trabecular Microarchitecture in Whole-Vertebral Body Biomechanical Behavior, Journal of Bone and Mineral Research. 24 (9)1 1523-1530.



(B) BMC, DA, and BV/TV as predictors of strength (Strength = BMC × 244 + DA × 7660 + BV/TV × 29,700–12,900).

Where is Trabecular Bone and Why it is Important

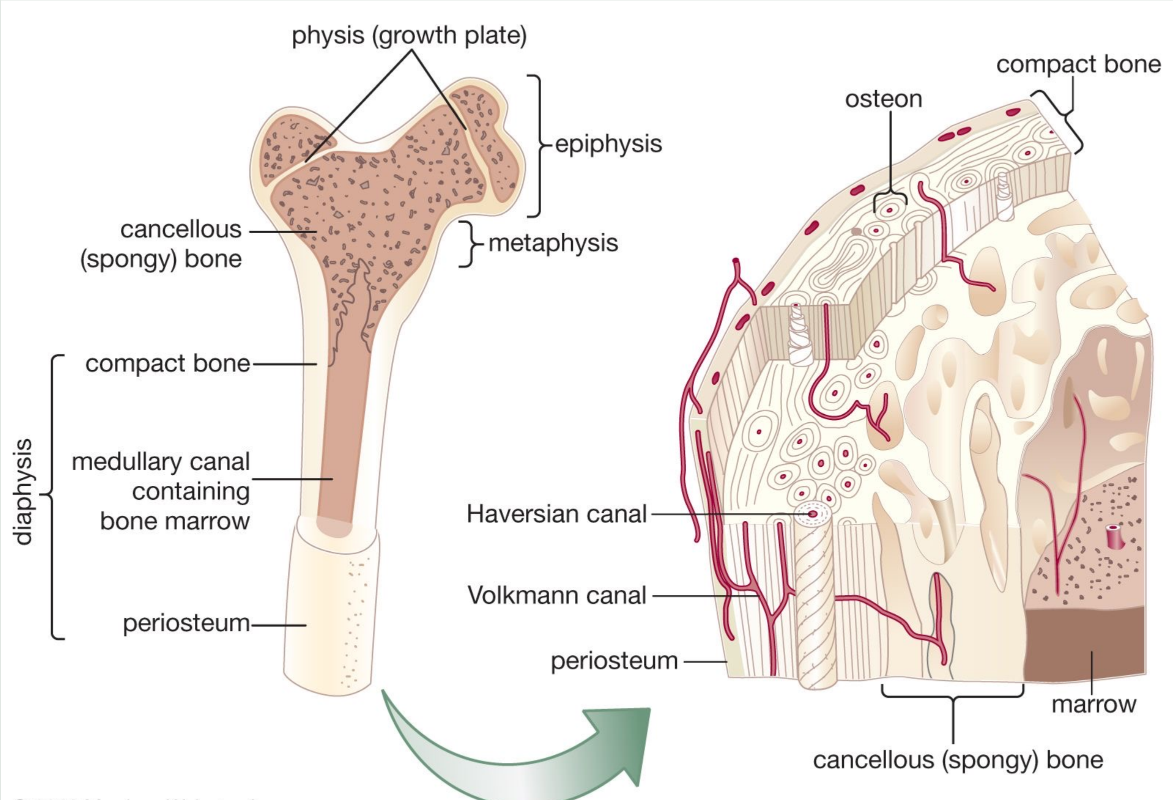
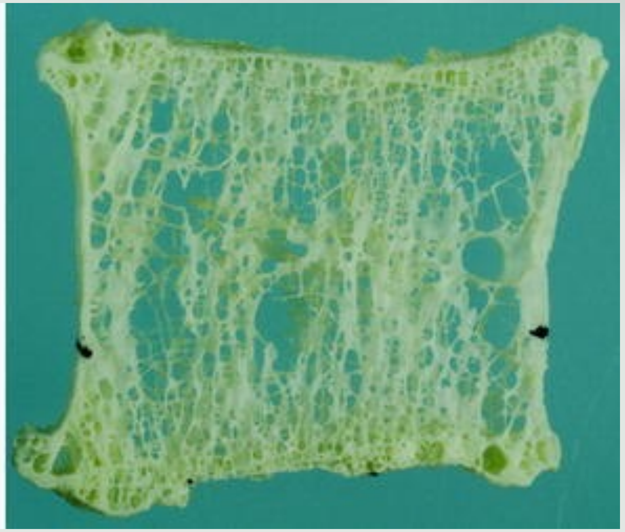


Photo: https://www.britannica.com/science/cancellous-bone

X-ray

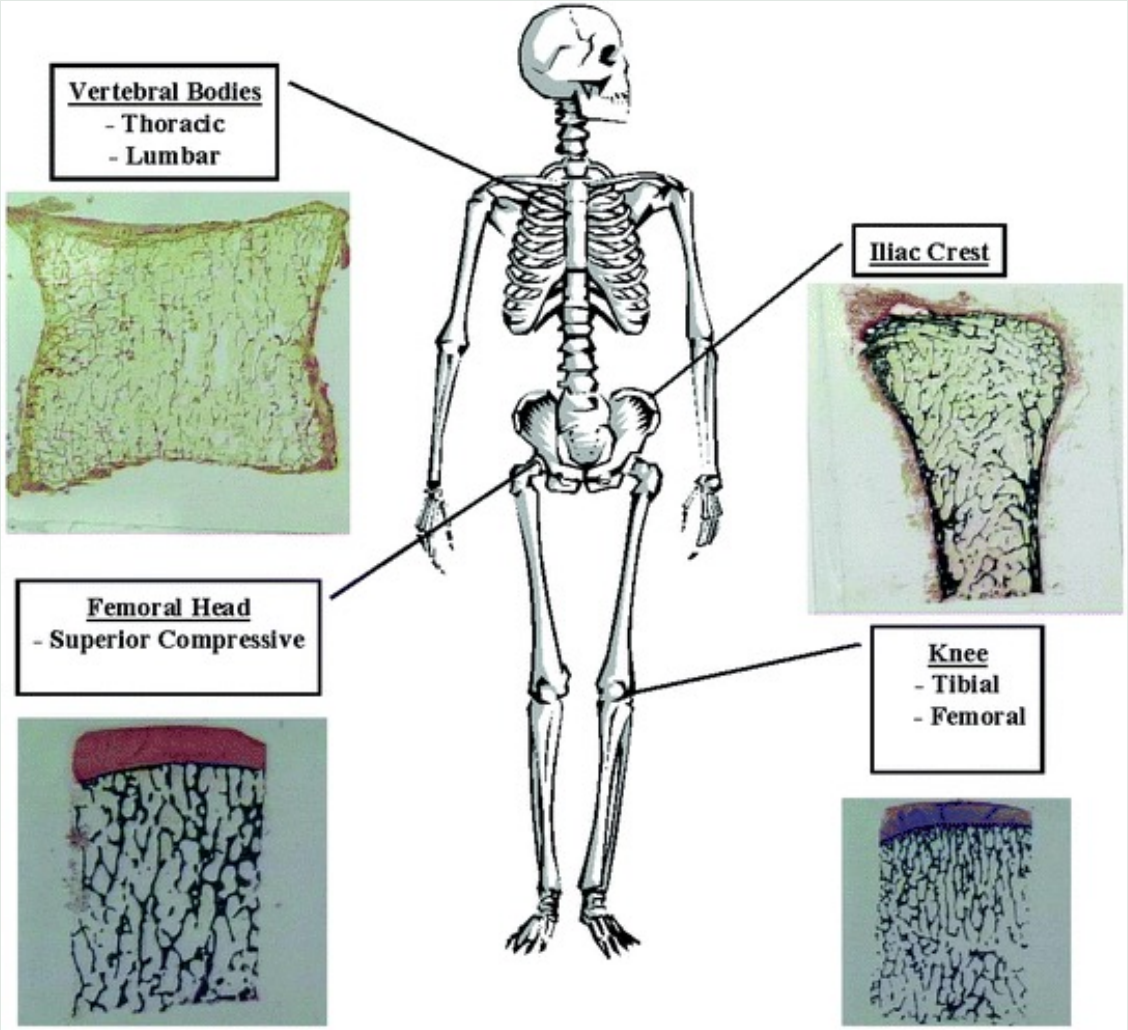
SEM



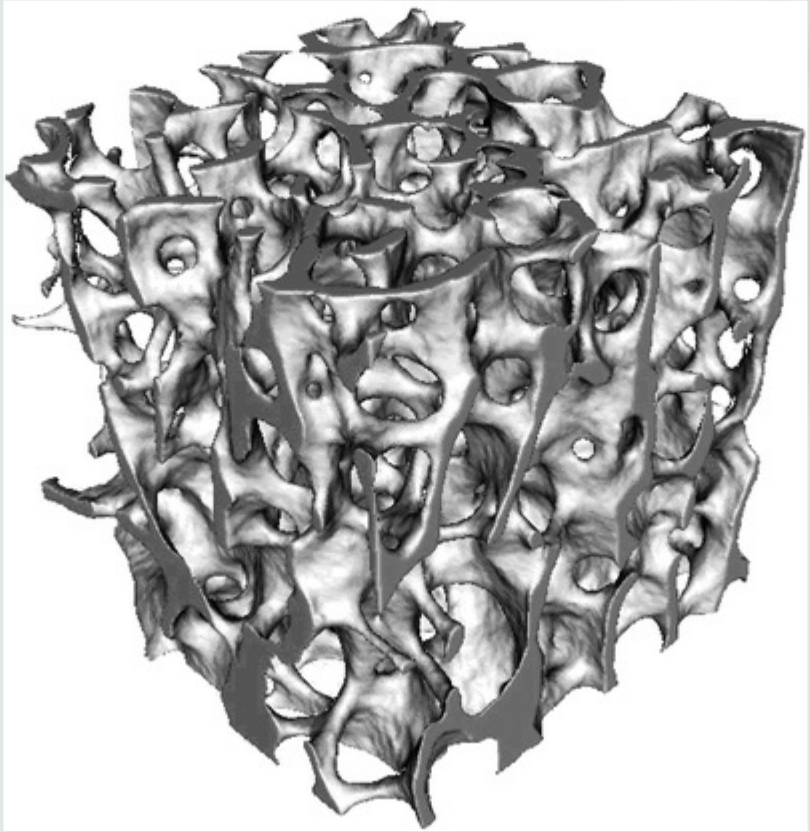
X-ray image of sagittal femoral head slice (*left*) in contrast to a macerated sagittal slice from a vertebral body (*right*) showing marked differences in the amount of bone and the arrangement of trabeculae

Parkinson Lan H., Fazzalari Nicola L. (2012) Characterization of Trabecular Bone Structure. In Skeletal Aging and Osteoporosis (31-51). Springer, Berlin, Heidelberg, 2013.

Where is Trabecular Bone and Why it is Important



Composite photomicrograph showing histological sections of trabecular bone from multiple skeletal sites



3D rendering of a bone cube from the L4 vertebral body of 66 years old male with BV/TV = 9.6%

Parkinson Lan H., Fazzalari Nicola L. (2012) Characterization of Trabecular Bone Structure. In Skeletal Aging and Osteoporosis (31-51). Springer, Berlin, Heidelberg, 2013.

Where is Trabecular Bone and Why it is Important

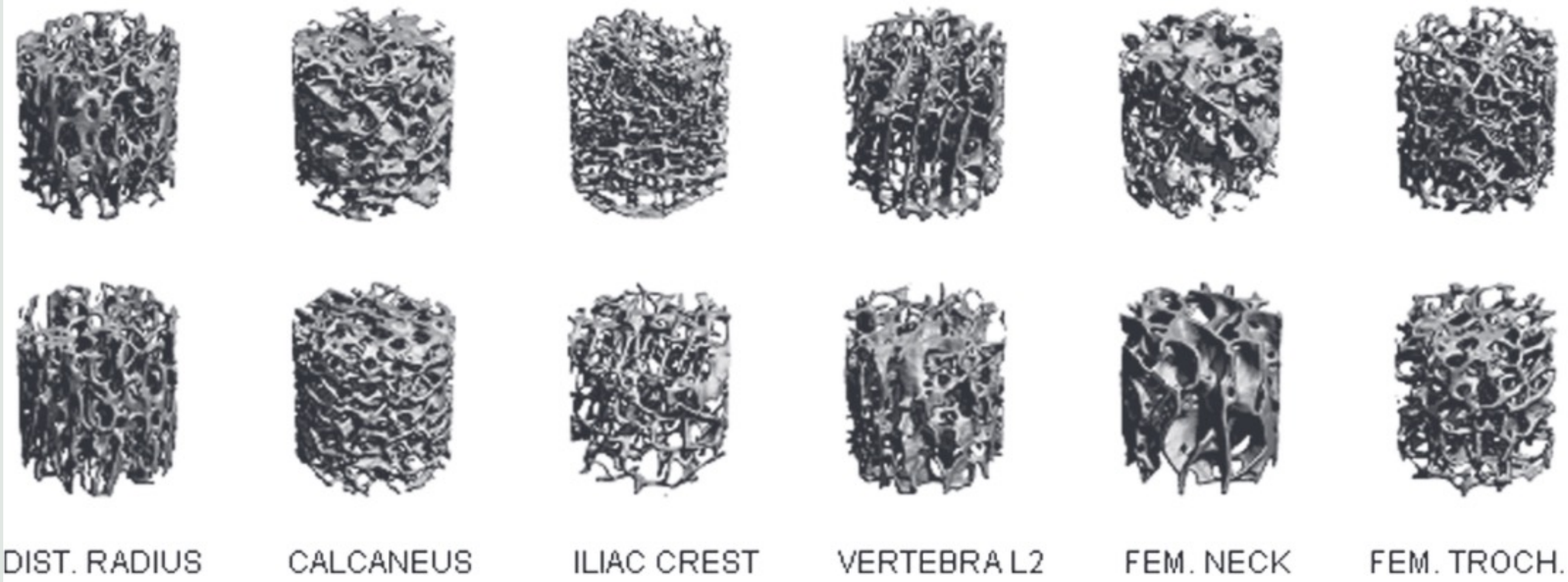


FIG. 1. Reconstructions of bone microstructure from μCT scans at the six skeletal sites studied, with examples of average properties shown for women (top) and men (bottom).

Eckstein et al. (2007)

Trabecular Modeling and Remodeling

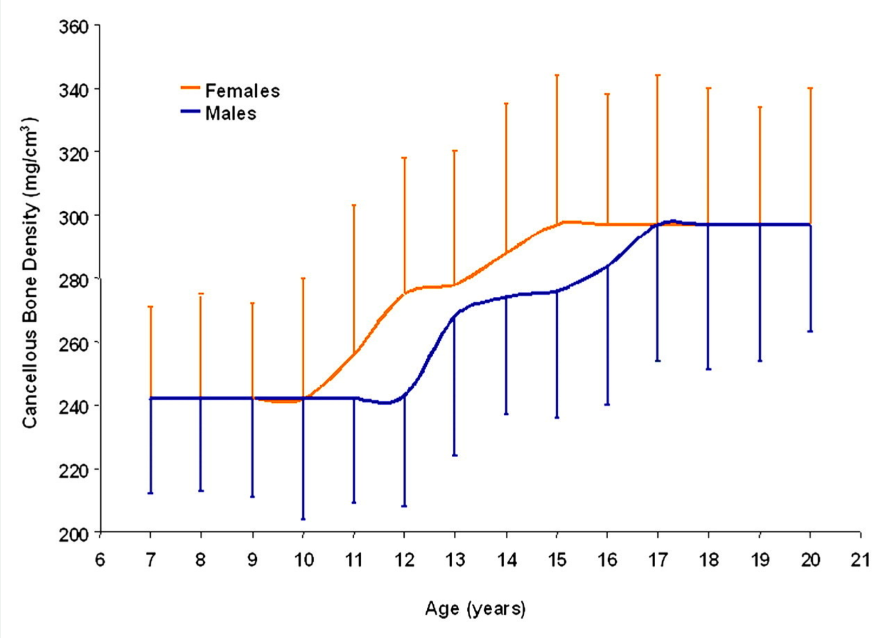
As a normal human subject, two major changes occur in trabecular bone: bone modeling and bone remodeling.

Modeling Process

- occurs in both children and young adults.
- is a growth process

Remodeling Process

- occurs in postmenopausal women or older men.
- occurs when trabecular bone needs to adapt to the different loadbearing directions

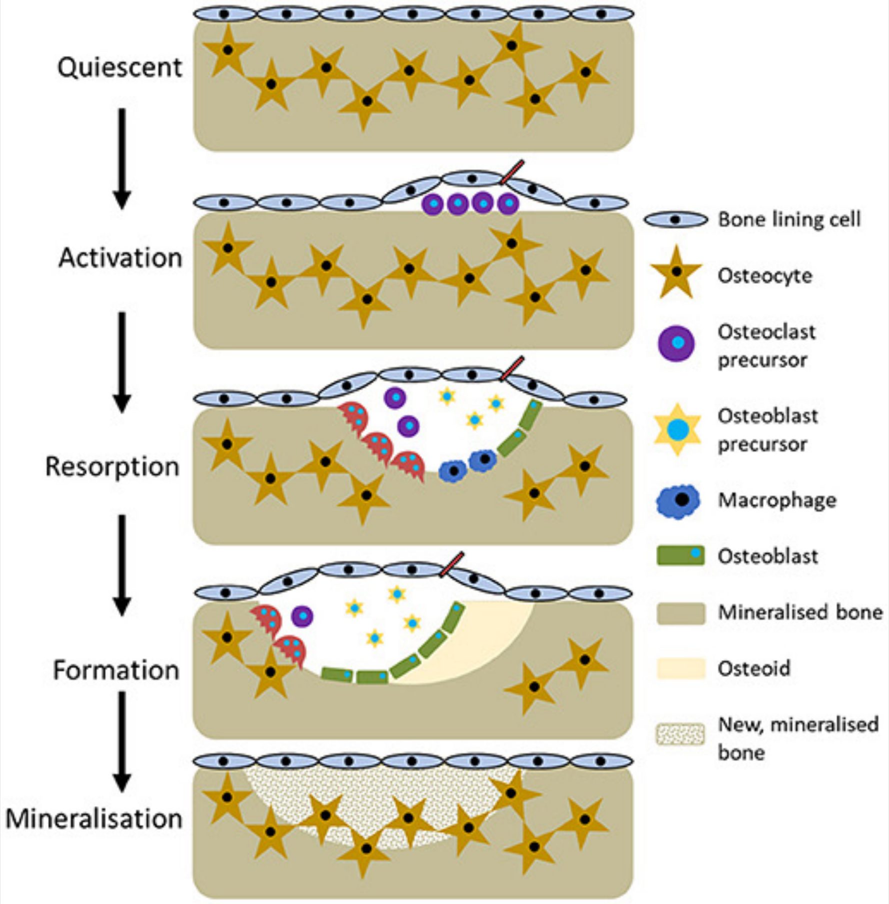


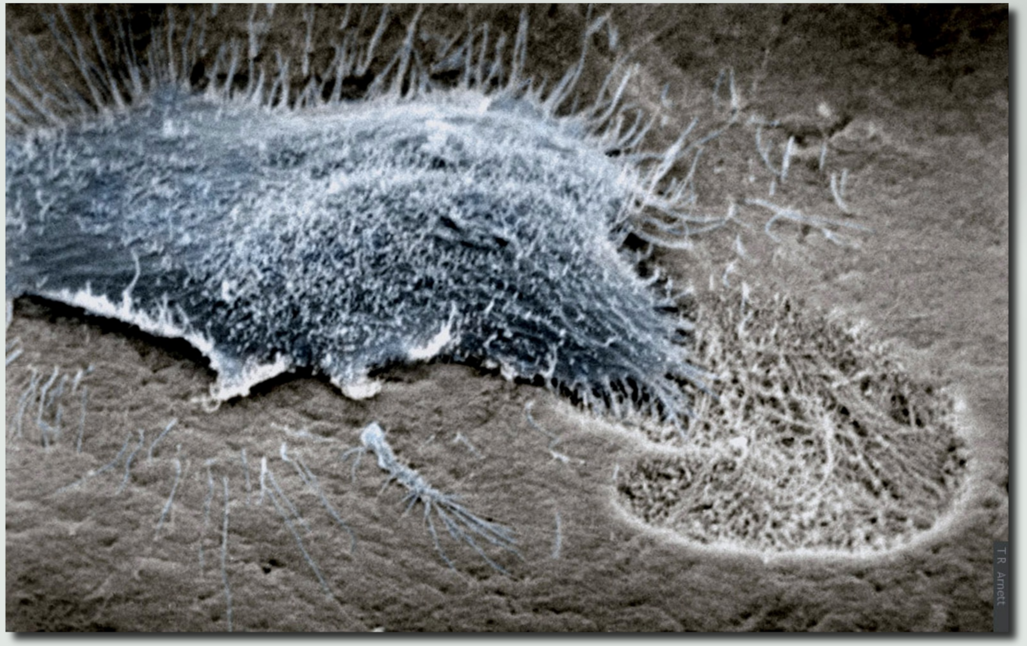
Mean and standard deviations of vertebral TBD in male and female subjects aged 7–20 years. TBD increased and reached peak values earlier in female than in male subjects. Because TBD did not correlate with age for male subjects aged 7–11 and 17–20 years and for female subjects aged 7–10 and 15–20 years, values for TBD in these age groups were equalized. Values at 7 and 20 years represent the mean for subjects 5–7 years of age and 20–21 years of age, respectively.

Vicente Gilsanz, Francisco J. Perez, Patricia P. Campbell, Frederick J. Dorey, David C. Lee, Tishya A. L. Wren. (2009) Quantitative CT Reference Values for Vertebral Trabecular Bone Density in Children and Young Adults. Radiology. 250 (1), 222-227.

Trabecular Modeling and Remodeling

The five stages of bone remodeling.



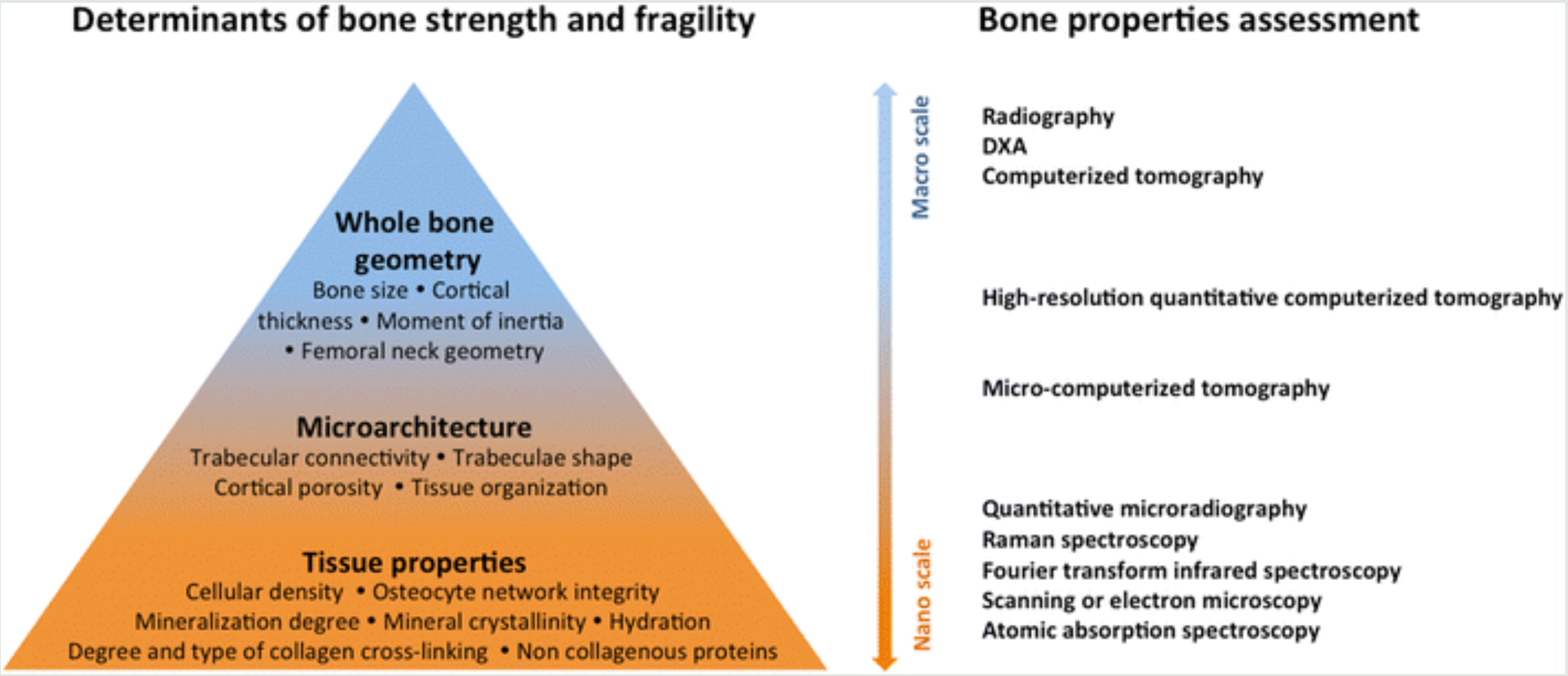


Scanning electron micrograph of a rat osteoclast and resorption pit on a bone surface

Photo: https://slideplayer.com/slide/8813563/

Robert Owen, Gwendolen C. Reilly (2018) In vitro Models of Bone Remodelling and Associated Disorders. Front Bioengineering Biotechnology. (11) 134.

Trabecular Imaging Techniques



The several traits influencing bone strength are schematically depicted in the *left* of the figure. The *base* of the pyramid is represented by the properties of bone tissue, which comprise the relative amount and biophysical properties of either the organic or the inorganic components. The *centre* of the pyramid shows the micro-architectural properties that are defined by the way the bone tissue is spatially organized inside the trabecular and cortical components. Finally, at the *top* of the pyramid, supported by the remaining determinants, the gross morphological traits that define whole bone geometry are represented, which are key determinants for the way the bones dissipate the stresses generated during loading periods. The *right half* of the figure lists some of the numerous laboratory methods, ranging from a nano-scale to the macro-scale, that can be used to investigate these bone properties. *DXA* dual-energy X-ray absorptiometry

Fonseca, H., Moreira-Gonçalves, D., Coriolano, HJ.A. et al. Bone Quality: The Determinants of Bone Strength and Fragility. Sports Med 44, 37–53 (2014).

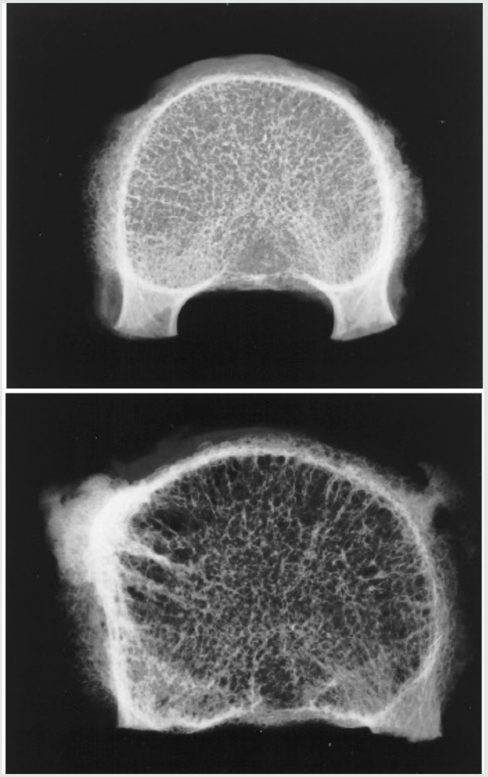
Trabecular Imaging Techniques

Low radiation dose

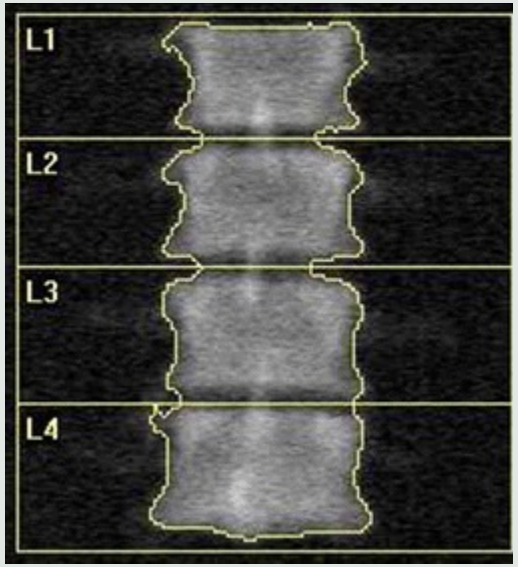
Radiograph | **DXA**

High Resolution

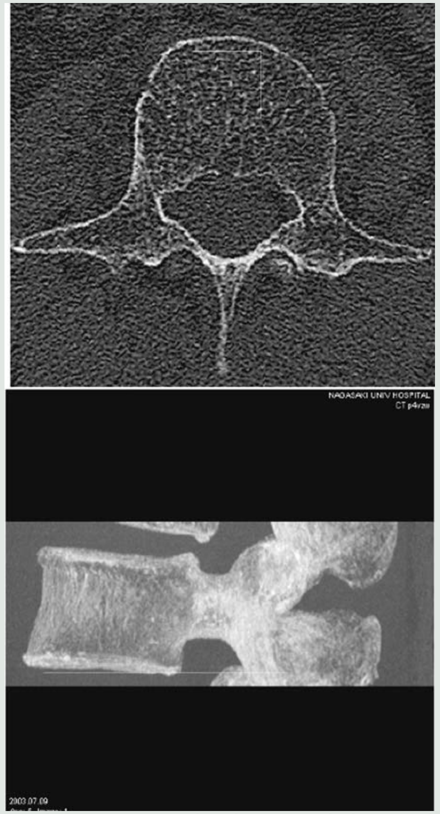
CT Fast | **MRI** Slow



Lis Mosekilde (1998) The effect of modelling and remodelling on human vertebral body architecture. Technology and Health Care



V. Bousson, C. Bergot, B. Sutter, P. Levitz, B. Cortet & the Scientific Committee of the GRIO (Groupe de Recherche et d'Information sur les Ostéoporoses) (2011) Trabecular bone score (TBS): available knowledge, clinical relevance, and future prospects. Osteoporosis International. 23, 1489–1501.

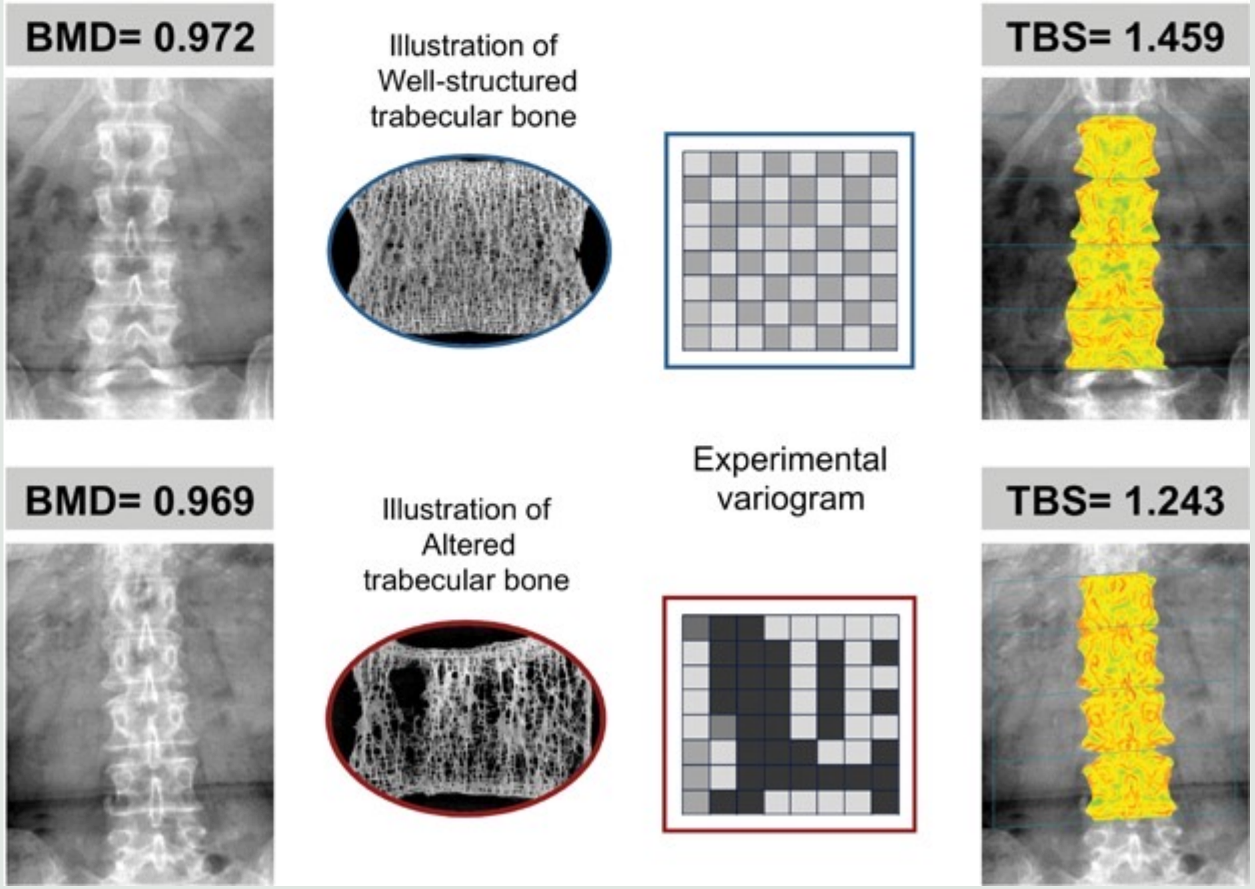


Masako Ito,Kyoji Ikeda,Masahiko Nishiguchi,Hiroyuki Shindo,Masataka Uetani,Takayuki Hosoi,Hajime Orimo. (2009) Multi-Detector Row CT Imaging of Vertebral Microstructure for Evaluation of Fracture Risk. Journal of Bone and Mineral Research. 20(10), 1828-1836.

Bauer Jan S., Link Thomas M. (2009) Advances in osteoporosis imaging. European Journal of Radiology. 71 (3), 440-449.

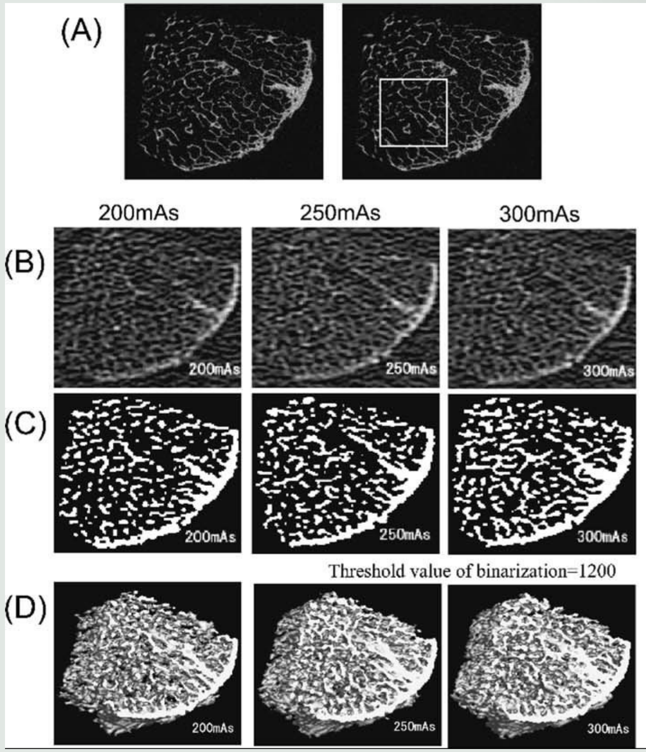
Trabecular Imaging Techniques

2D approach – DXA approach



Barbara C Silva,William D Leslie,Heinrich Resch,Olivier Lamy,Olga Lesnyak,Neil Binkley,Eugene V McCloskey,John A Kanis,John P Bilezikian. (2014) Trabecular Bone Score: A Noninvasive Analytical Method Based Upon the DXA Image. Journal of Bone and Mineral Research. 29 (3), 518-530.

3D approach – MDCT approach

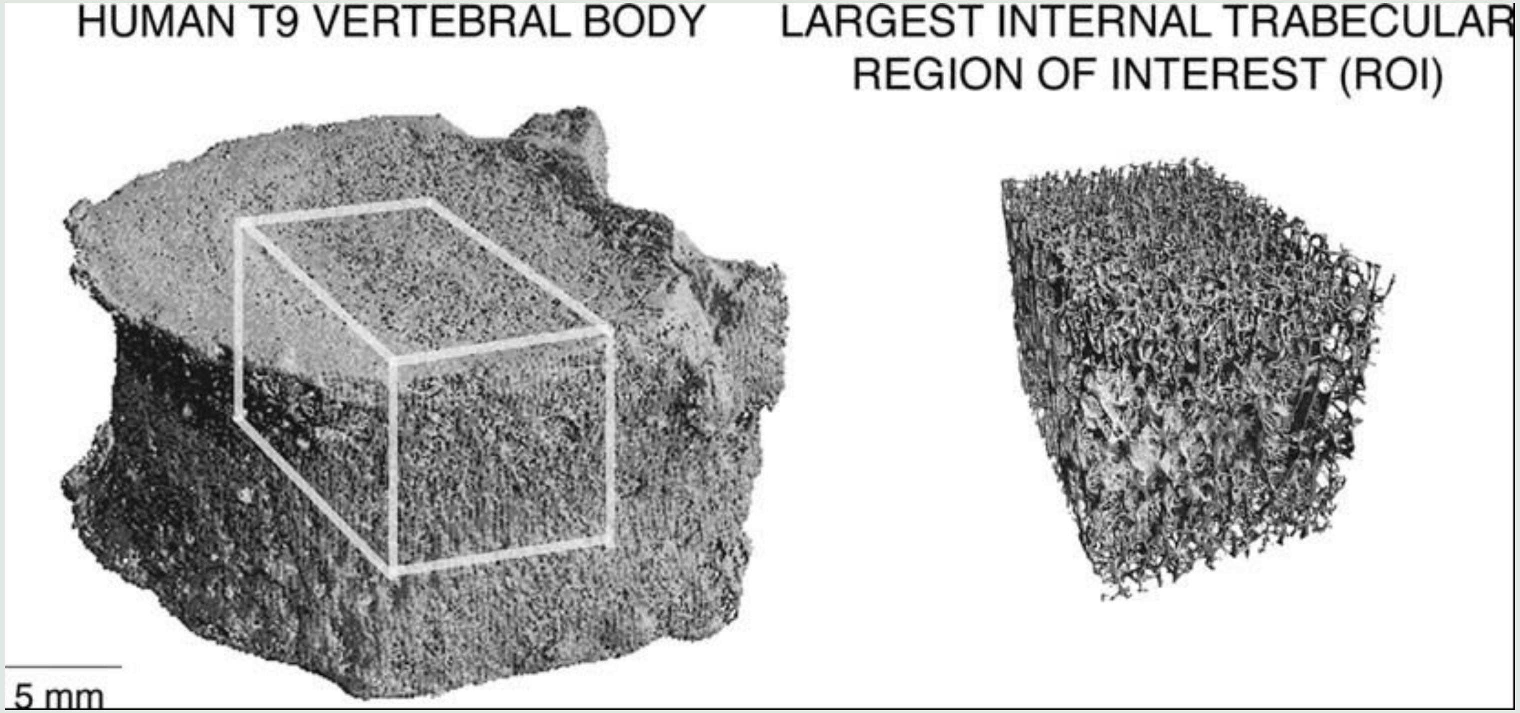


Threshold value	mAs	r	p
1120	200	0.656	ns
	250	0.487	ns
	300	0.959	< 0.01
1200	200	0.665	ns
	250	0.899	< 0.05
	300	0.979	< 0.005
1280	200	0.629	ns
	250	0.886	< 0.05
	300	0.959	< 0.05

Masako Ito,Kyoji Ikeda,Masahiko Nishiguchi,Hiroyuki Shindo,Masataka Uetani,Takayuki Hosoi,Hajime Orimo. (2009) Multi-Detector Row CT Imaging of Vertebral Microstructure for Evaluation of Fracture Risk. Journal of Bone and Mineral Research. 20 (10) 1828-1836.

Quantitative Trabecular Microarchitecture Analysis

Several studies leveraged various trabecular microarchitecture parameters to illustrate the morphological characteristics.



Example μCT rendering of a human T_9 vertebral body (left) with largest internal cuboid of trabecular bone isolated for microarchitecture analysis (right).

- **BV/TV**
- **Tb.Th**
- **Tb.N**
- **Tb.Sp**
- **D2D**
- **D3D**

Aaron J Fields, Senthil K Eswaran, Michael G Jekir,Tony M Keaveny. (2009) Role of Trabecular Microarchitecture in Whole-Vertebral Body Biomechanical Behavior. Journal of Bone and Mineral Research. 24 (9) 1523-1530.

Quantitative Trabecular Microarchitecture Analysis

Definition of common trabecular microarchitecture parameters

Parameter	Abbrev.	Meanings
Bone Volume/ Total Volume	**BV/TV**	The proportion of bone volume to total VOI.
Trabecular thickness	**Tb.Th**	The mean trabecular bone diameter
Trabecular number	**Tb.N**	The number of the trabeculae, measured as the inverse of the mean spacing between the midlines of the trabeculae
Trabecular separation	**Tb.Sp**	The mean distance between the boundaries of the segmented trabeculae
2D Fractal Dimension	**D2D**	Microarchitectural characteristics of trabecular bone on 2-D histological sections
3D Fractal Dimension	**D3D**	

Quantitative Trabecular Microarchitecture Analysis

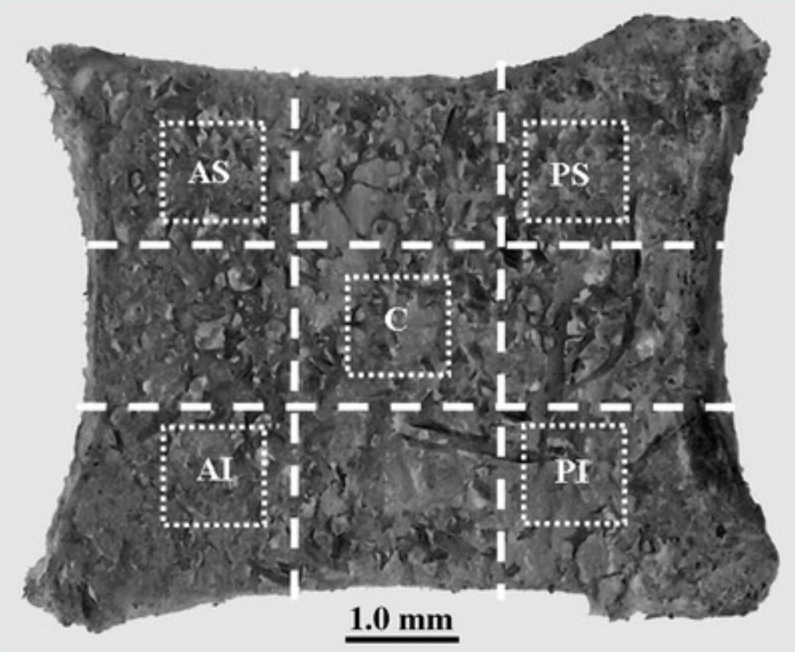
Pitfall: Volume of Interest Section

Chen, H., Shoumura, S., Emura, S. et al. (2008) Regional variations of vertebral trabecular bone microstructure with age and gender. Osteoporos Int 19, 1473–1483.

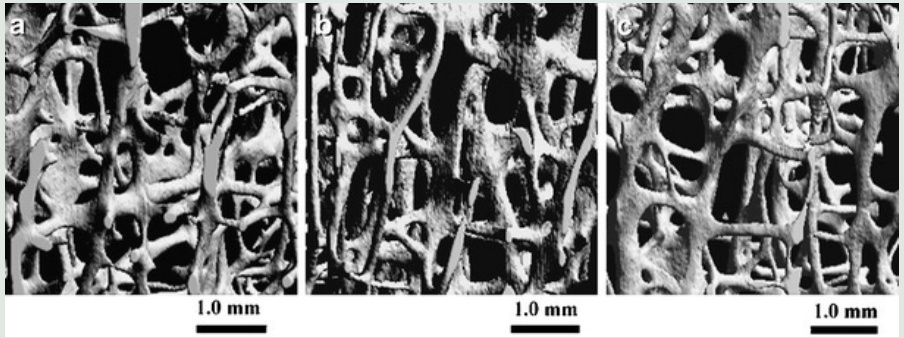
Microstructural parameters in the five regions

	AS	AI	C	PS	PI
BV/TV (%)	12.7 ± 1.1	13.8 ± 1.3	11.8 ± 1.0[b]	14.4 ± 1.2[c]	15.0 ± 1.2[a,c]
Tb.Th (mm)	110.7 ± 8.7	112.0 ± 9.2	114.8 ± 9.5	111.1 ± 10.3	110.2 ± 9.8
Tb.N (/mm)	1.13 ± 0.10	1.15 ± 1.17	1.09 ± 0.12	1.17 ± 0.09	1.22 ± 0.14[a,c]
Tb.Sp (mm)	834.1 ± 78.6	809.8 ± 77.0	860.8 ± 81.4	797.7 ± 75.9	768.3 ± 72.4[a,c]
SMI	2.22 ± 0.21	2.21 ± 0.23	2.32 ± 0.25	2.18 ± 0.20	2.14 ± 0.19
Conn.D (/mm^3)	2.96 ± 0.27	3.04 ± 0.25	2.89 ± 0.30	3.14 ± 0.28	3.23 ± 0.33[a,c]
DA	1.63 ± 0.16	1.62 ± 0.19	1.61 ± 0.15	1.62 ± 0.17	1.59 ± 0.14

1.Values are mean ± SD. a: $p < 0.05$, vs. AS; b: $p < 0.05$, vs. AI; c: $p < 0.05$, vs. C



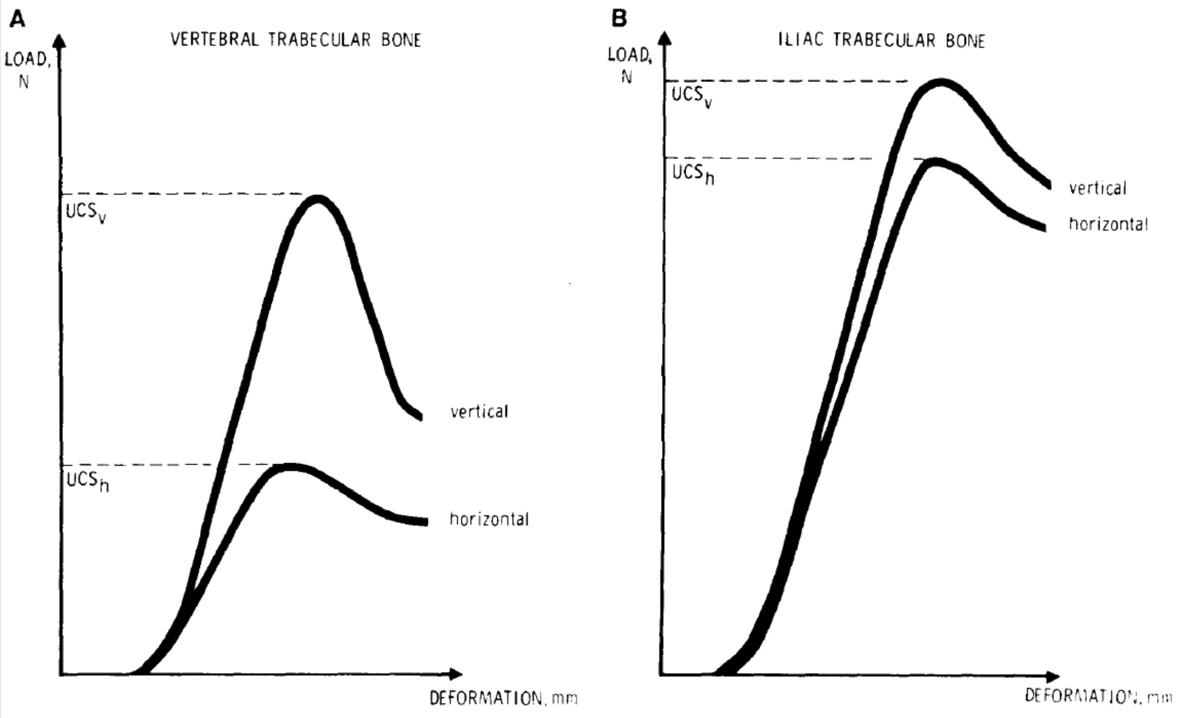
Stereomicroscopic image of the sagittal section from the fourth lumbar vertebral body. Five regions (AS, AI, C, PS and PI) of the vertebral body for micro-CT scanning are shown



Three-dimensional micro-CT image reconstructions in different regions of the vertebral body from a woman aged 78 years: anterosuperior (**a**), anteroinferior (**b**), central (**c**), posterosuperior (**d**) and posteroinferior (**e**) regions. The trabecular bone is higher in the posterosuperior and posteroinferior regions than that of the central and anterosuperior regions

Quantitative Trabecular Microarchitecture Analysis

Loadbearing effect → trabecular remodeling



Typrcal load-deformation curves for the vertebral body (A) and iltac crest (B) trabecular bone UCSv, and UCSh, indicate vertrcal and horrzontal ultimate compressive strength

Mosekilde Lis, Viidik A., Mosekilde Leif (1985) Correlation Between the Compressive Strength of Iliac and Vertebral Trabecular Bone in Normal Individuals. Bone. 6, 291-295.

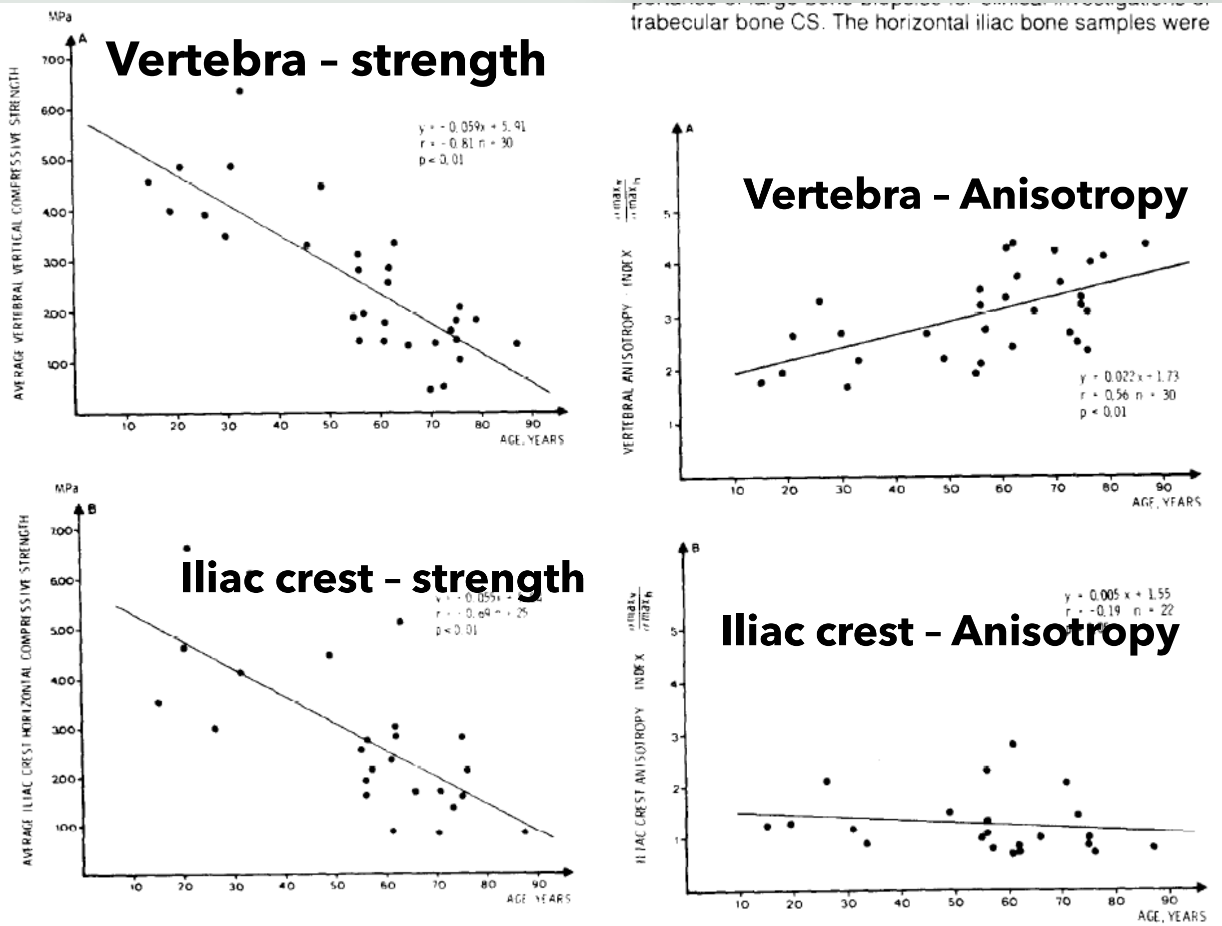
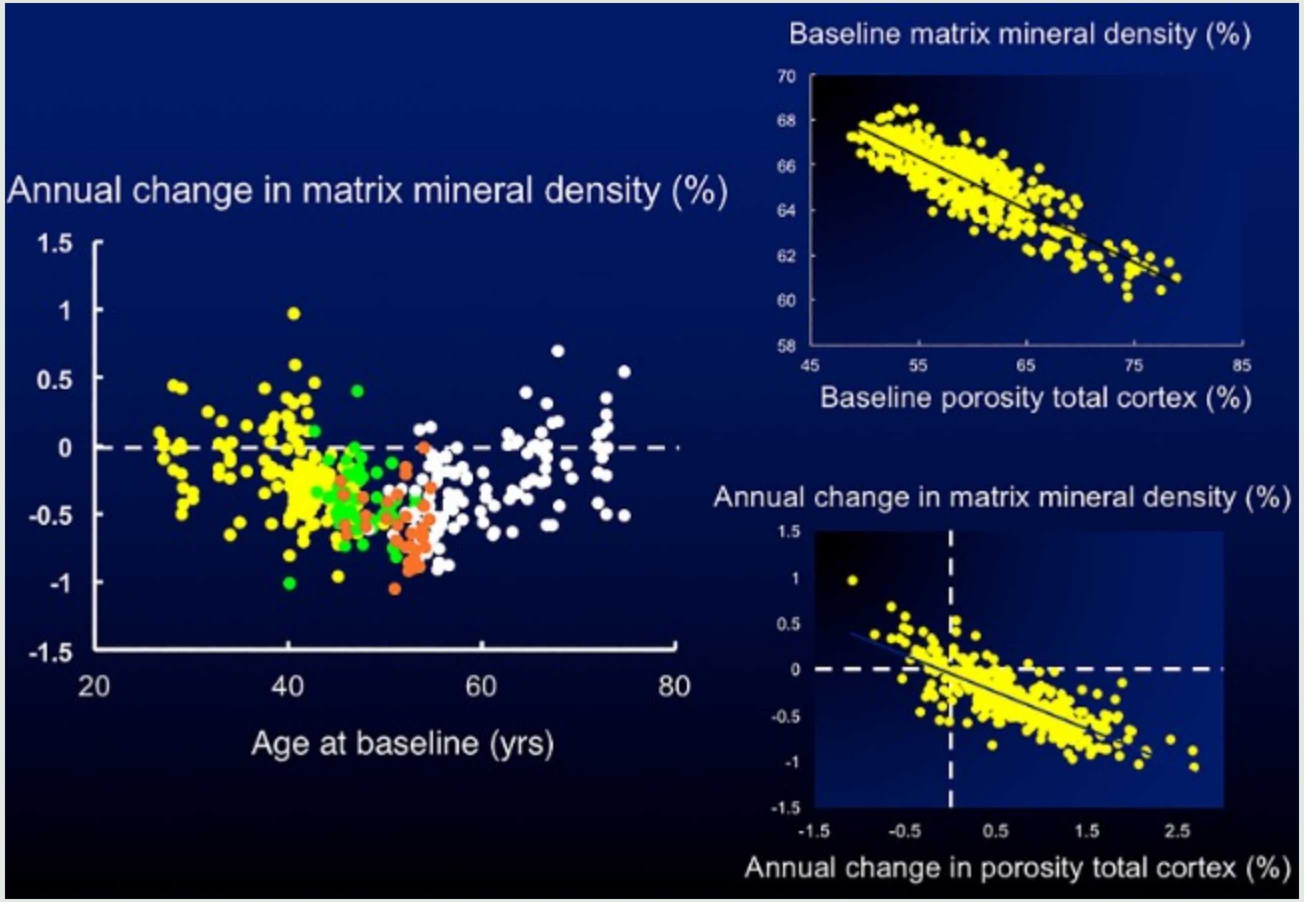


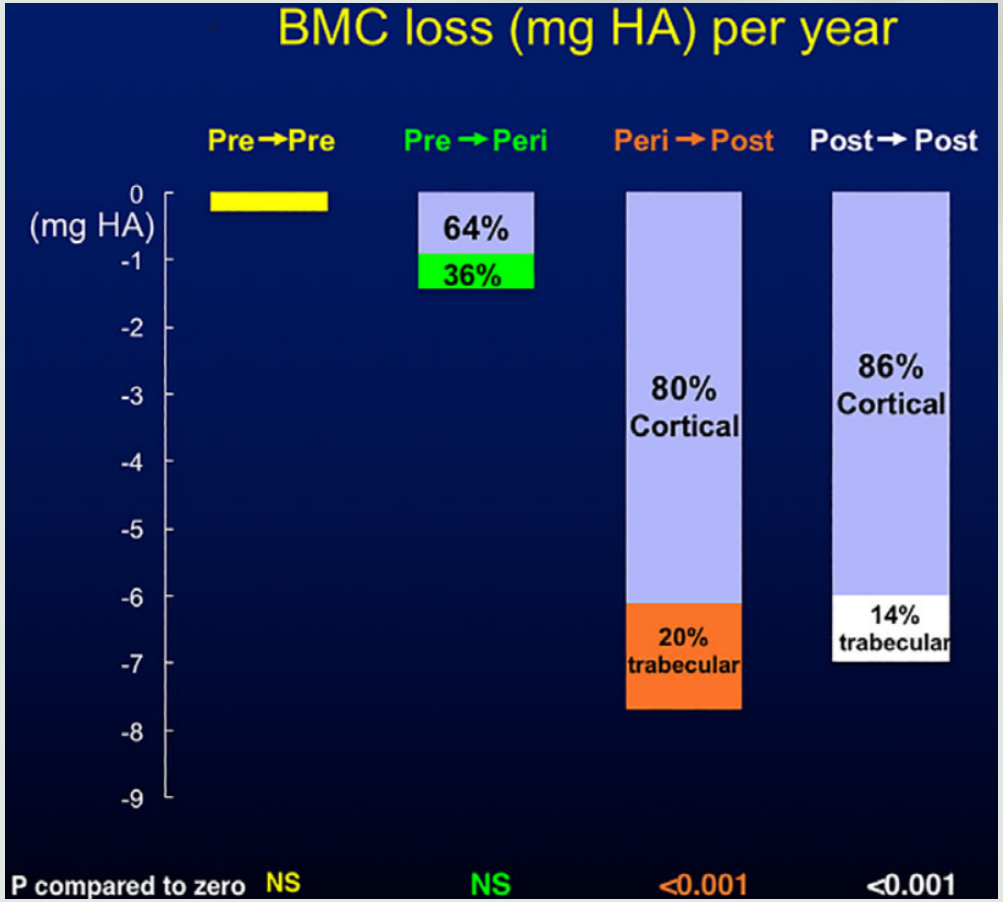
Fig. 4. Age-related decrease in trabecular bone compressive strength in the vertebral body in vertical direction **(A)** and in the iliac crest in horizontal direction **(B)**. The regression lines are almost parallel.

Fig. 5. Variation in AI with age. The index is increasing in the vertebral trabecular bone with age **(A)**. in the iliac crest no significant difference is observed **(B)**.

Quantitative Trabecular Microarchitecture Analysis

Age- and sex-related aging



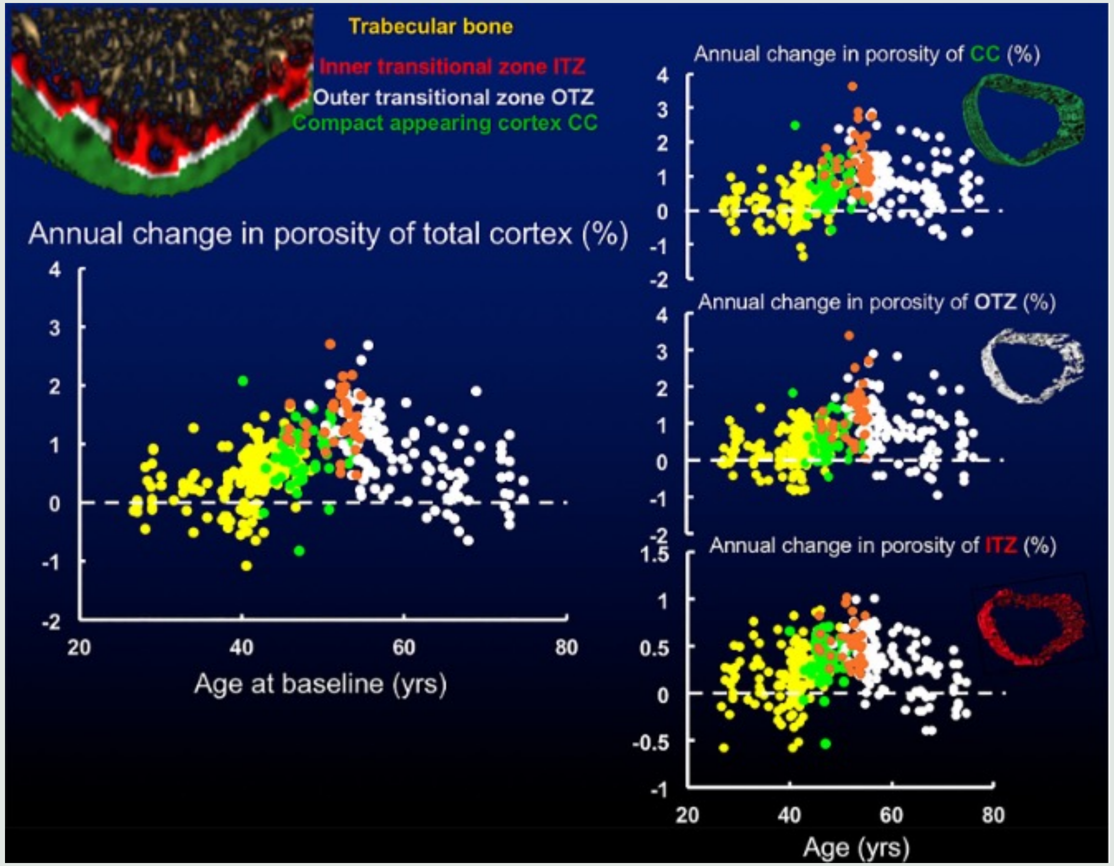


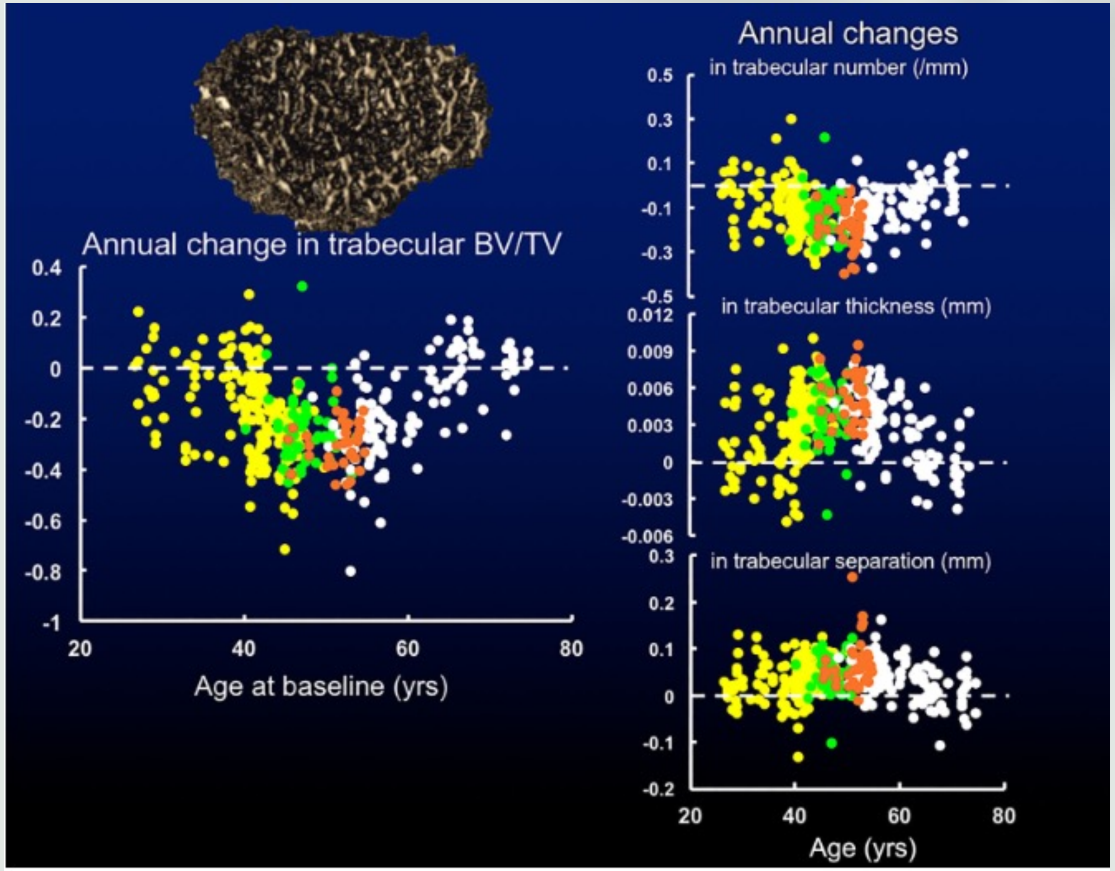
Amount of tibial cortical and trabecular bone loss as a percentage of annual loss of total (BMC) (mg HA) in women Pre to Pre, Pre to Peri, and Post to Post. Values of *p* with in each group tested whether the to total annual losses were different from zero. BMC-bone mineral content; HA-hydroxyapatite; Pre to Pre-premenopausal remaining premenopausal; Pre to Peri-premenopausal becoming perimenopausal; Post to Post-postmenopausal remaining postmenopausal

Bjørnerem, Å., Wang, X., Bui, M., Ghasem-Zadeh, A., Hopper, J. L., Zebaze, R., & Seeman, E. (2018). Menopause-related appendicular bone loss is mainly cortical and results in increased cortical porosity. Journal of Bone and Mineral Research, 33(4), 598-605.

Quantitative Trabecular Microarchitecture Analysis

Age- and sex-related aging





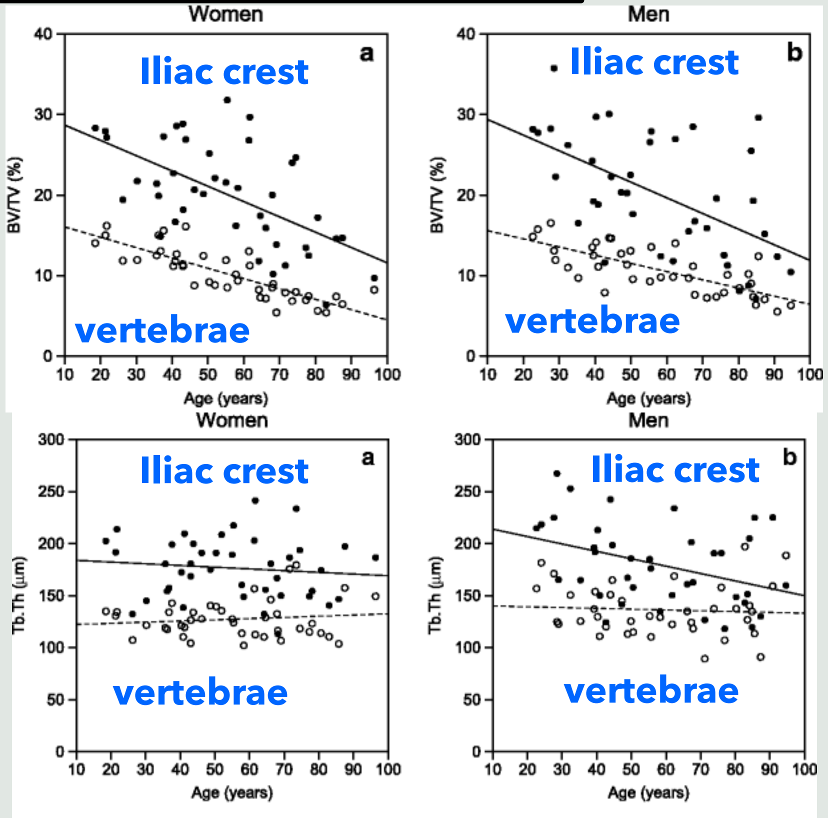
Annual changes of the distal tibia trabecular BV/TV, trabecular number, trabecular thickness, and trabecular separation by baseline age in women remaining premenopausal (yellow dots), becoming perimenopausal (green dots), becoming postmenopausal (orange dots), and remaining postmenopausal (white dots). BV/TV¼bone volume/tissue volume.

Bjørnerem, Å., Wang, X., Bui, M., Ghasem-Zadeh, A., Hopper, J. L., Zebaze, R., & Seeman, E. (2018). Menopause-related appendicular bone loss is mainly cortical and results in increased cortical porosity. Journal of Bone and Mineral Research, 33(4), 598-605.

Thomsen, J.S., Jensen, M.V., Niklassen, A.S. *et al.* (2015) Age-related changes in vertebral and iliac crest 3D bone microstructure-differences and similarities. *Osteoporos Int* **26,** 219–228

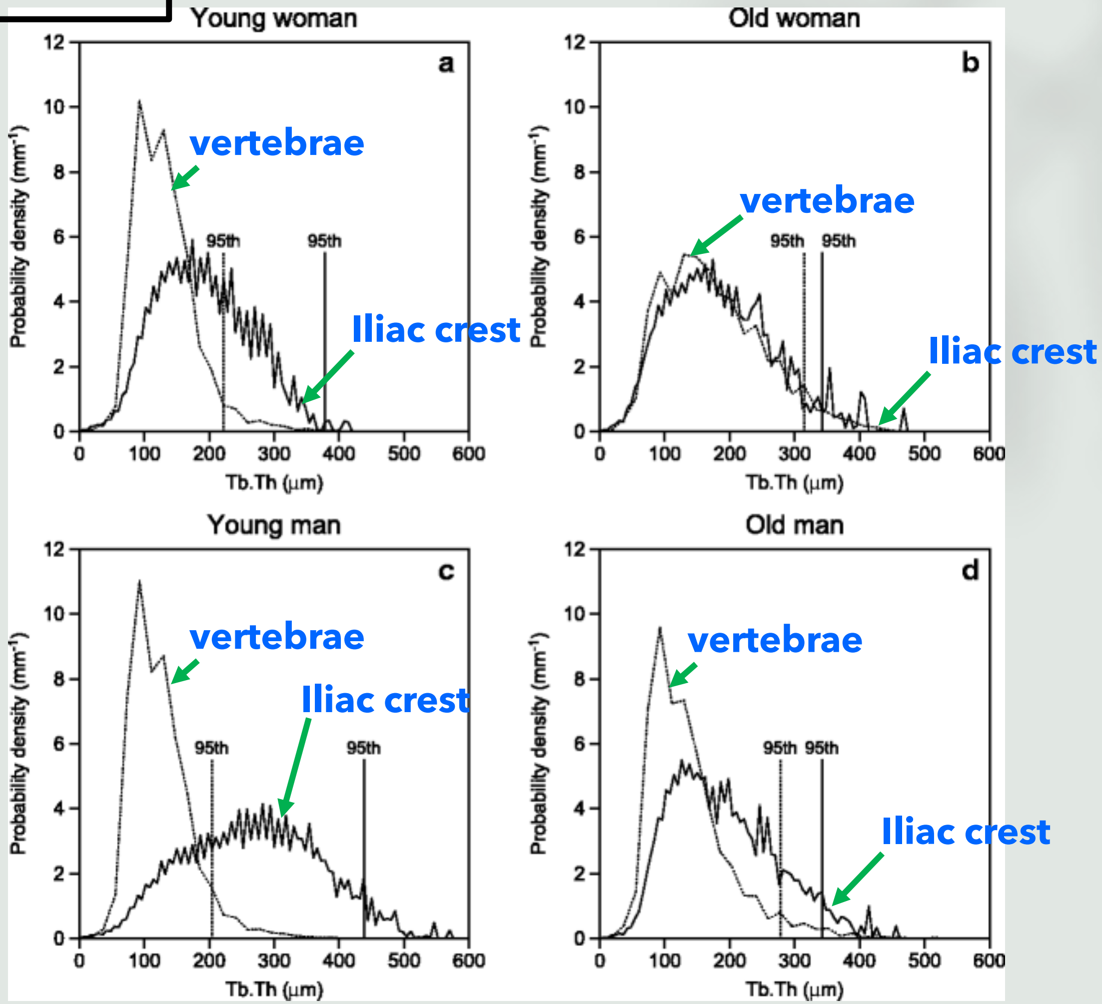
Quantitative Trabecular Microarchitecture Analysis

Age- and Sex-related Aging



Microstructural measures as functions of age for the following: trabecular bone volume fraction for **a** women and **b** men; structure model index for **c** women and **d** men. Data for _iliac crest_ are shown with filled circles and solid fit lines, while data for _vertebral bodies_ are shown with open circles and dashed fit lines.

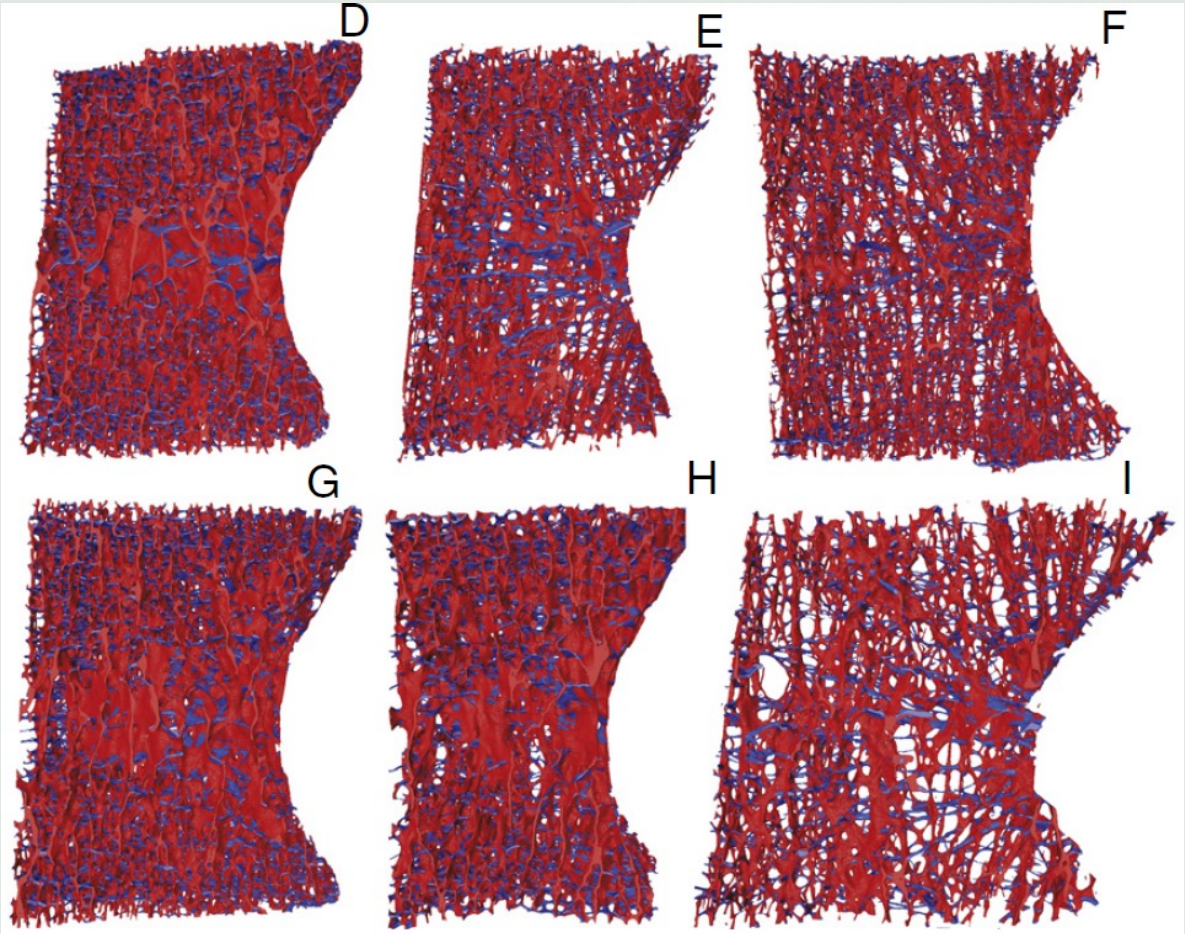
Thickness



Trabecular thickness probability density functions for **a** a 21-year-old woman (*OVL* = 0.60), **b** a 71-year-old woman (*OVL* = 0.89), **c** a 28-year-old man (*OVL* = 0.34), and **d** a 73-year-old man (*OVL* = 0.70). Data from iliac crest are shown with a *solid curve*, while vertebral bodies are shown with a *dashed curve*.

Quantitative Trabecular Microarchitecture Analysis

As abovementioned, weightbearing plays an important role in remodeling process.
If we classify all trabeculae into Vertical and Horizontal trabeculae …

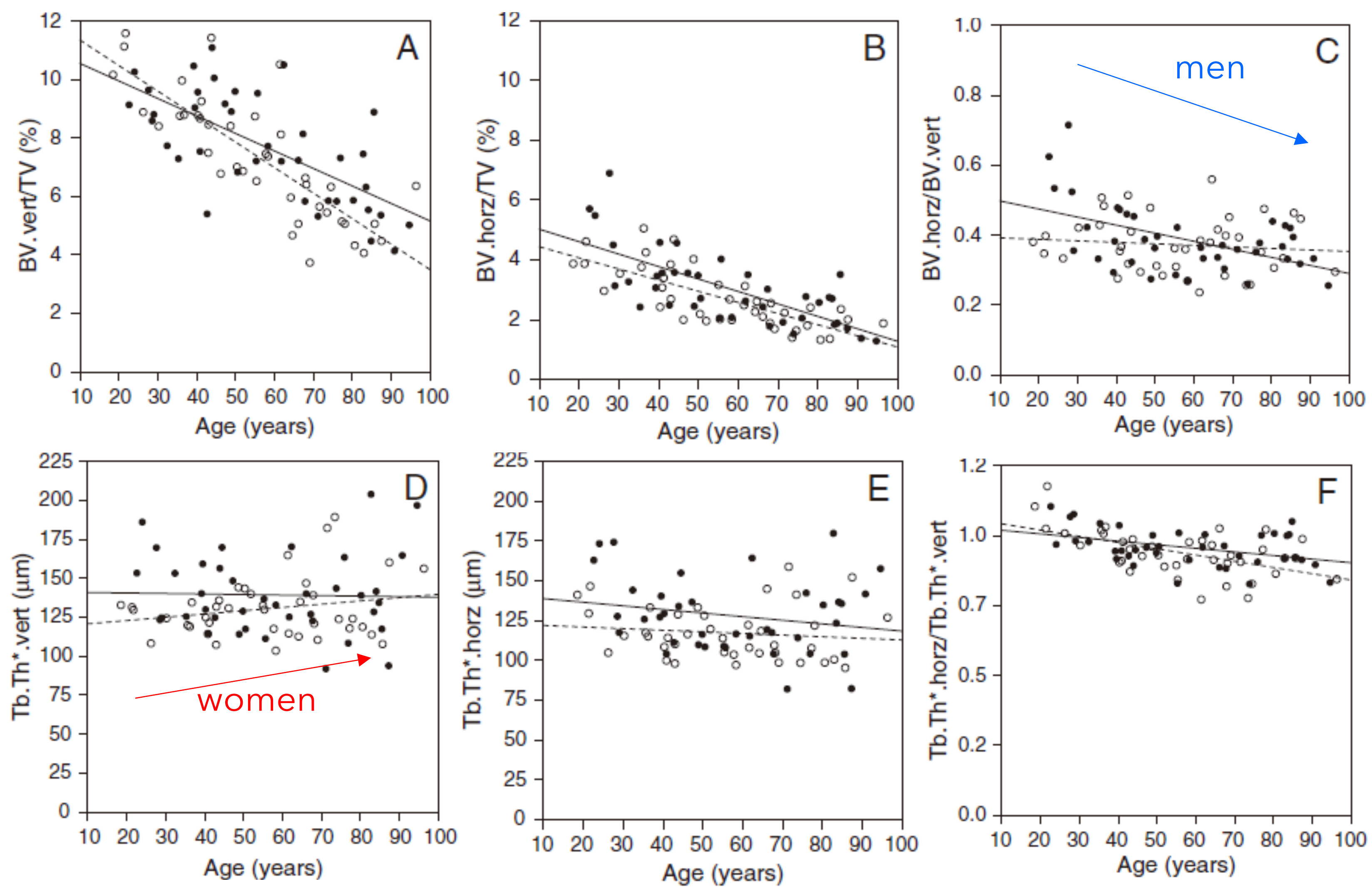


3D visualization of the trabecular network subdivided into horizontal (blue) and vertical (red) voxels. (A) 27-year-old man. (B) Magnification of the region shown with a box in (A) without median filtration (see text for detail). Arrowheads indicates regions with small specs of voxels that have been classified as the opposite orientation as the surrounding voxels. (C) Same as (B) but with median filtration applied. Examples of the trabecular orientation algorithm: (D) 36-year-old woman, (E) 66-year-old woman, (F) 83-year-old woman, (G) 32-year-old man, (H) 66-year-old man, and (I) 90-year-old man.

Jesper Skovhus Thomsen, Andreas Steenholt Niklassen, Ebbe Nils Ebbesen , Annemarie Brüel (2013) Age-related changes of vertical and horizontal lumbar vertebral trabecular 3D bone microstructure is different in women and men. Bone (57) 47-55

Quantitative Trabecular Microarchitecture Analysis

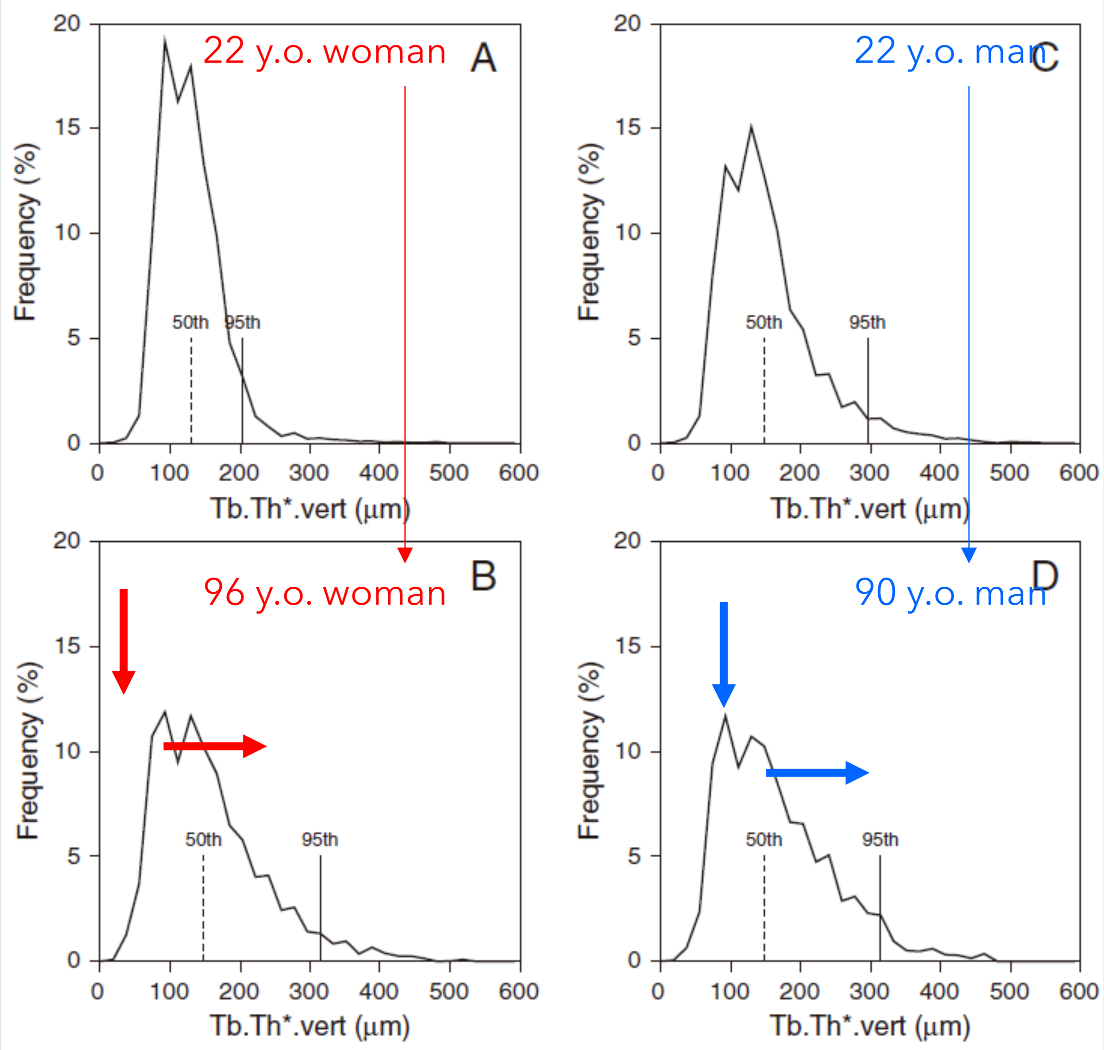
Jesper Skovhus Thomsen, Andreas Steenholt Niklassen, Ebbe Nils Ebbesen , Annemarie Brüel (2013) Age-related changes of vertical and horizontal lumbar vertebral trabecular 3D bone microstructure is different in women and men. Bone (57) 47-55



men women

Age-related changes of horizontal and vertical trabeculae. (A) Vertical trabecular bone volume. (B) Horizontal trabecular bone volume. (C) Ratio between horizontal and vertical bone volume. (D) Vertical trabecular thickness. (E) Horizontal trabecular thickness. (F) Ratio between horizontal and vertical trabecular thickness. <u>Women are shown with open circles and dashed fit-lines</u>, while <u>males are shown with filled circles and solid fit-lines.</u>

Quantitative Trabecular Microarchitecture Analysis



Frequency distribution of Tb.Th*.vert for (A) a 22-year-old woman, (B) a 96-year-old woman, (C) a 22-year-old man, and (D) a 90-year-old man. The 50th percentile (median) is indicated with a dashed line and the 95th percentile is indicated with a solid line.

Jesper Skovhus Thomsen, Andreas Steenholt Niklassen, Ebbe Nils Ebbesen , Annemarie Brüel (2013) Age-related changes of vertical and horizontal lumbar vertebral trabecular 3D bone microstructure is different in women and men. Bone (57) 47-55

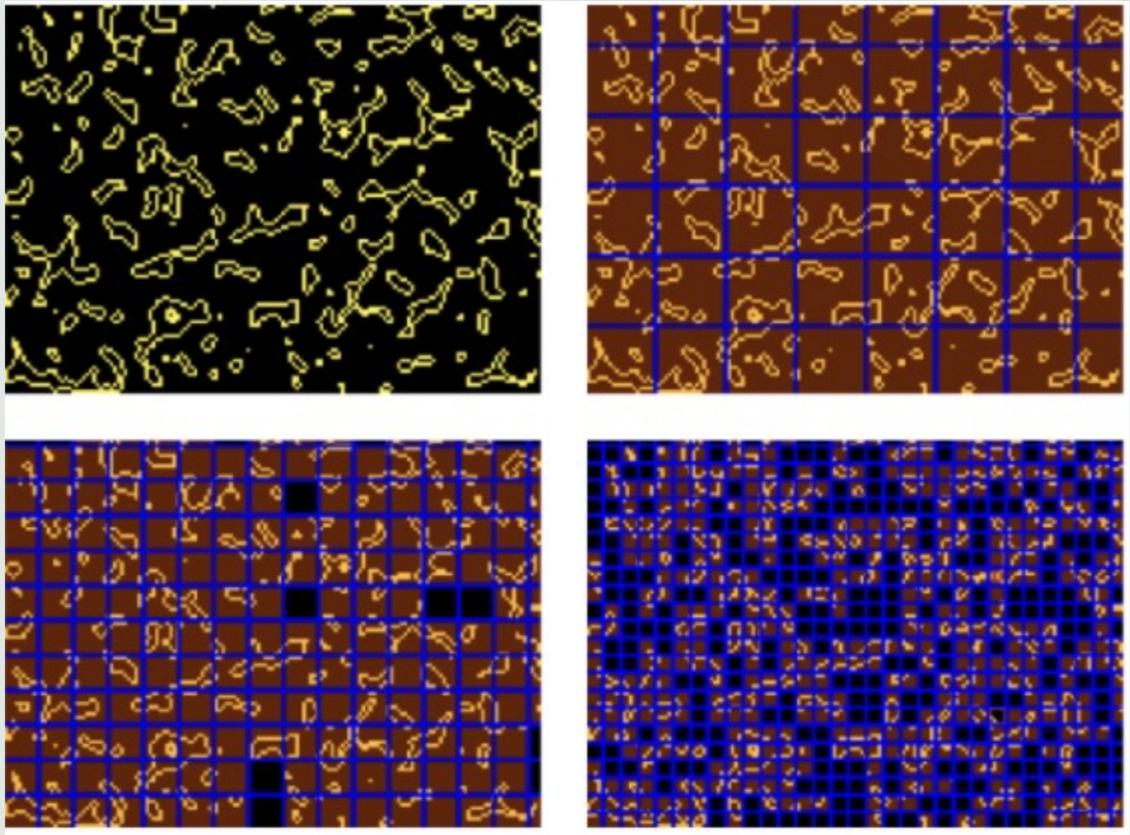
It is not a normal distribution!

Quantitative Trabecular Microarchitecture Analysis

D2D & D3D Fractal Dimension Parameters

The counting box calculates the 2D and 3D fractal dimensions and the voxel method, respectively. The software conducts several different resolutions of boxes to fit the following equations:

$$log(N) = -D2Dlog(\lambda) + k,$$
$$log(N) = -D3Dlog(\lambda) + k\,.$$



Current Issues and Dilemma in Clinical Practice

Trabecular imaging dilemma

- **Imaging sources**
  - ➔ The resolution of X-ray and DXA is too low.
  - ➔ MRI is not time-efficient method
  - ➔ CT has high resolution but needs to be aware of dose

Routine CT slice thickness usually is larger than 2 mm; however, trabecular thickness is only 50-200 μm.

Current Issues and Dilemma in Clinical Practice

- **Trabecular analysis tools**

→ Most of tools are for micro-CT or micro-MR.

→ Calculation bases (2D or 3D)

Trabecular analysis pitfalls

- **VOI selection**: location, size, and shape
- **Sample statistic selection?** mean & standard deviation
- **Horizontal and vertical directions?**

Remarks

- Trabecular microarchitecture could enhance the power of bone strength explanation and the prediction of future fracture.
- However, implementing trabecular microarchitecture analysis into clinical practice still has several problems that should be clarified in advance.
- Trabecular imaging leveraging with microarchitecture parameters might be an important future direction to predict fracture and routine trabecular monitoring method.

Spatial Perspective Discussion

- After understanding the importance and progress of osteoporosis, if you are a medical data scientist, what will you do?

- What kind of spatial analysis methods could be used in the context of osteoporosis?

The End

Thank you for your attention!

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Web: toodou.github.io

SCAN ME