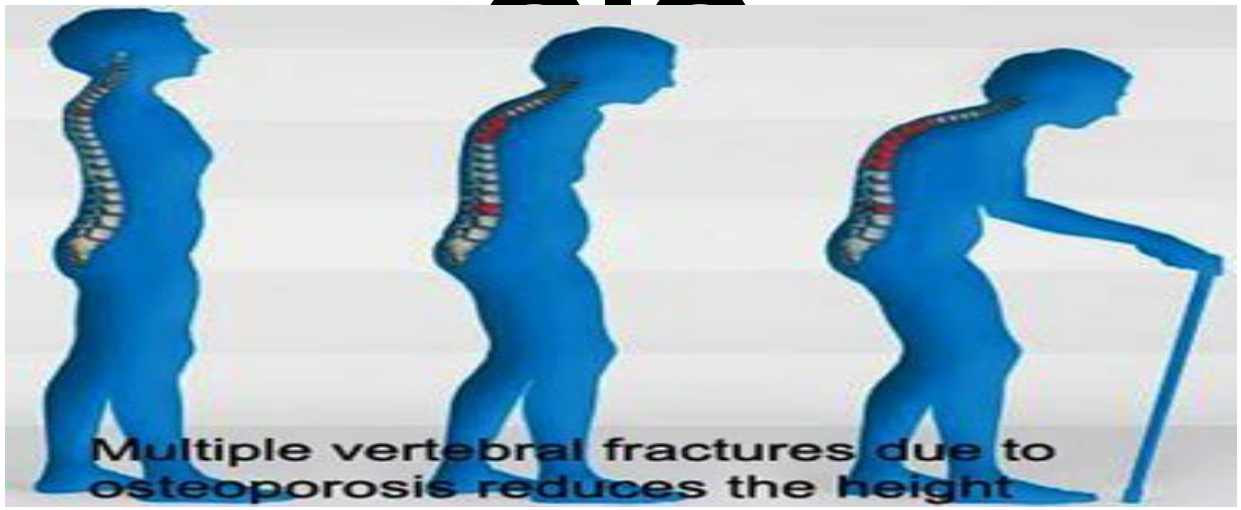
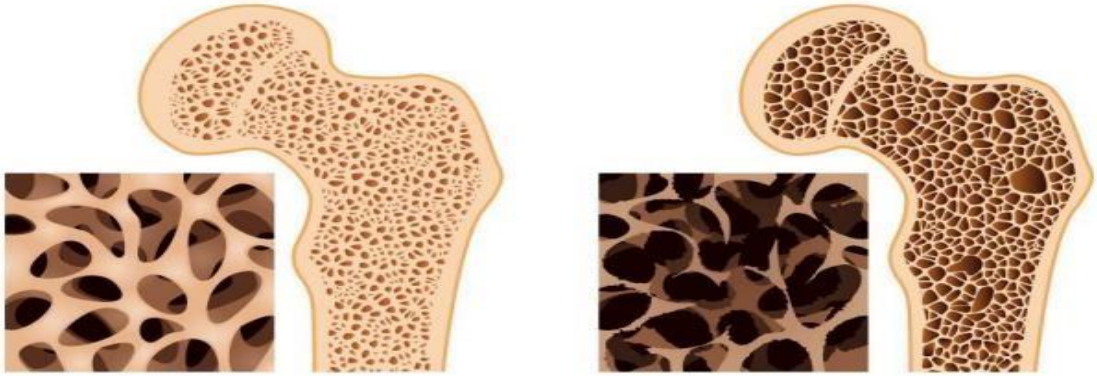
FARMAKOTERAPI

OSTEOPOROSIS



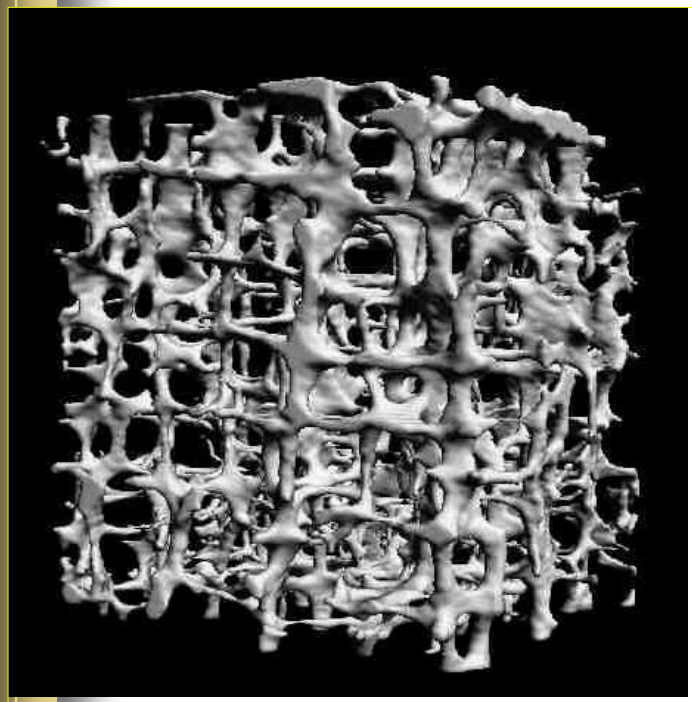
Definisi

- *osteo* = tulang, *porous* = berlubang-lubang atau keropos.
- ialah peny metabolik - me↓ massa tulang, krn matriks dan mineral tulang ↓ disertai kerusakan mikroarsitektur jar tulang.
- T.u pd tulang trabecular (proses resorpsinya lbh cpt drpd tulang lain)
- Dampak : kekuatan tulang ↓, tulang mdh patah
- Wanita > pria, percepatan menjelang menopause

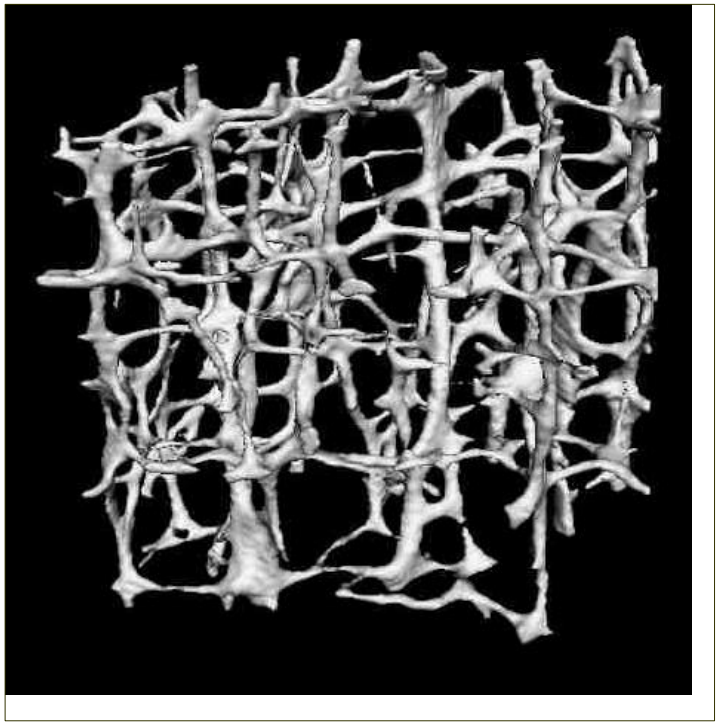


Hilangnya arsitektur trabekulasi vertebra dalam Micro CT-3 Dimensi

Wanita normal

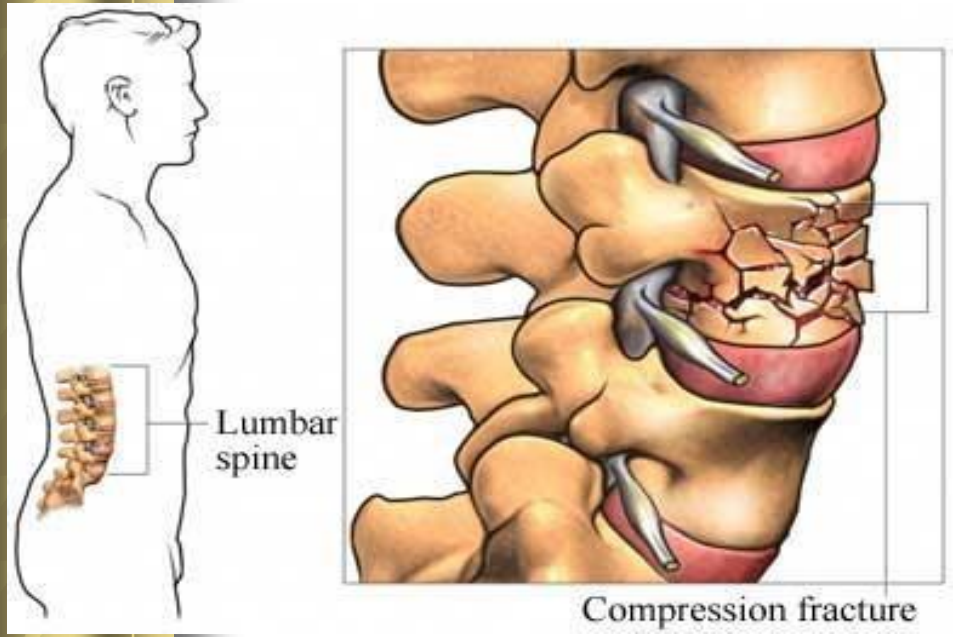


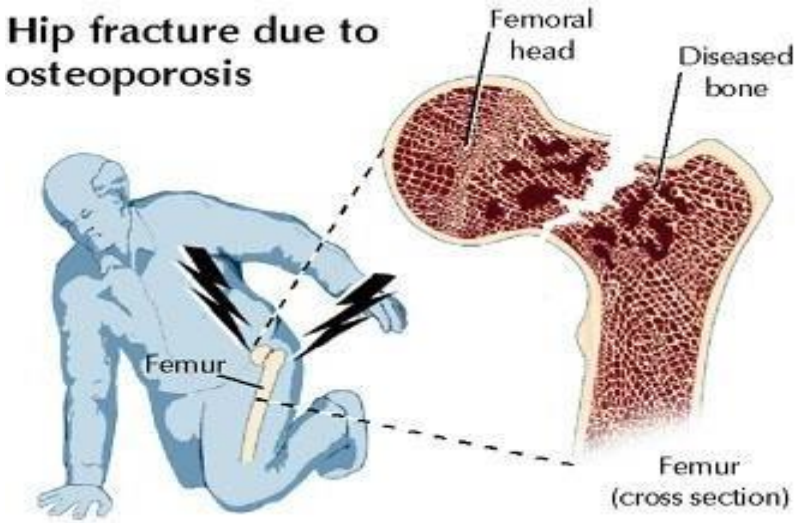
Wanita Osteoporosis (dg. fraktur vertebra)

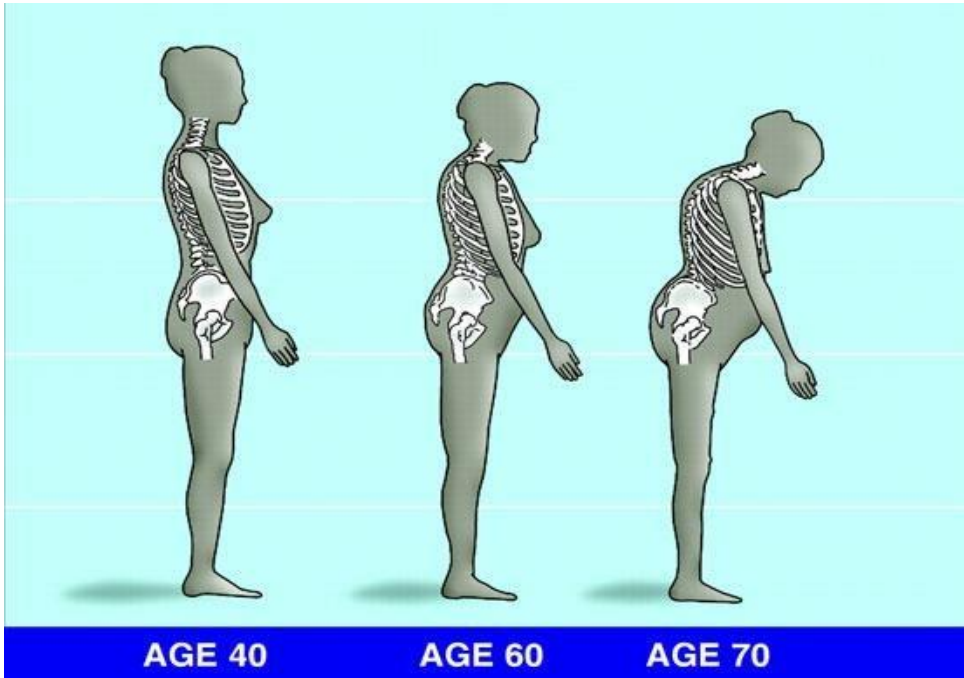


Loss of bone mass and horizontal trabeculae

Borah, et al. Anat. Rec. 2001


Lumbar spine
Compression fracture


Hip fracture due to osteoporosis
Femoral head
Diseased bone
Femur
Femur (cross section)


AGE 40
AGE 60
AGE 70

BMD

- **berkurang dg pertamb usia**

karena :

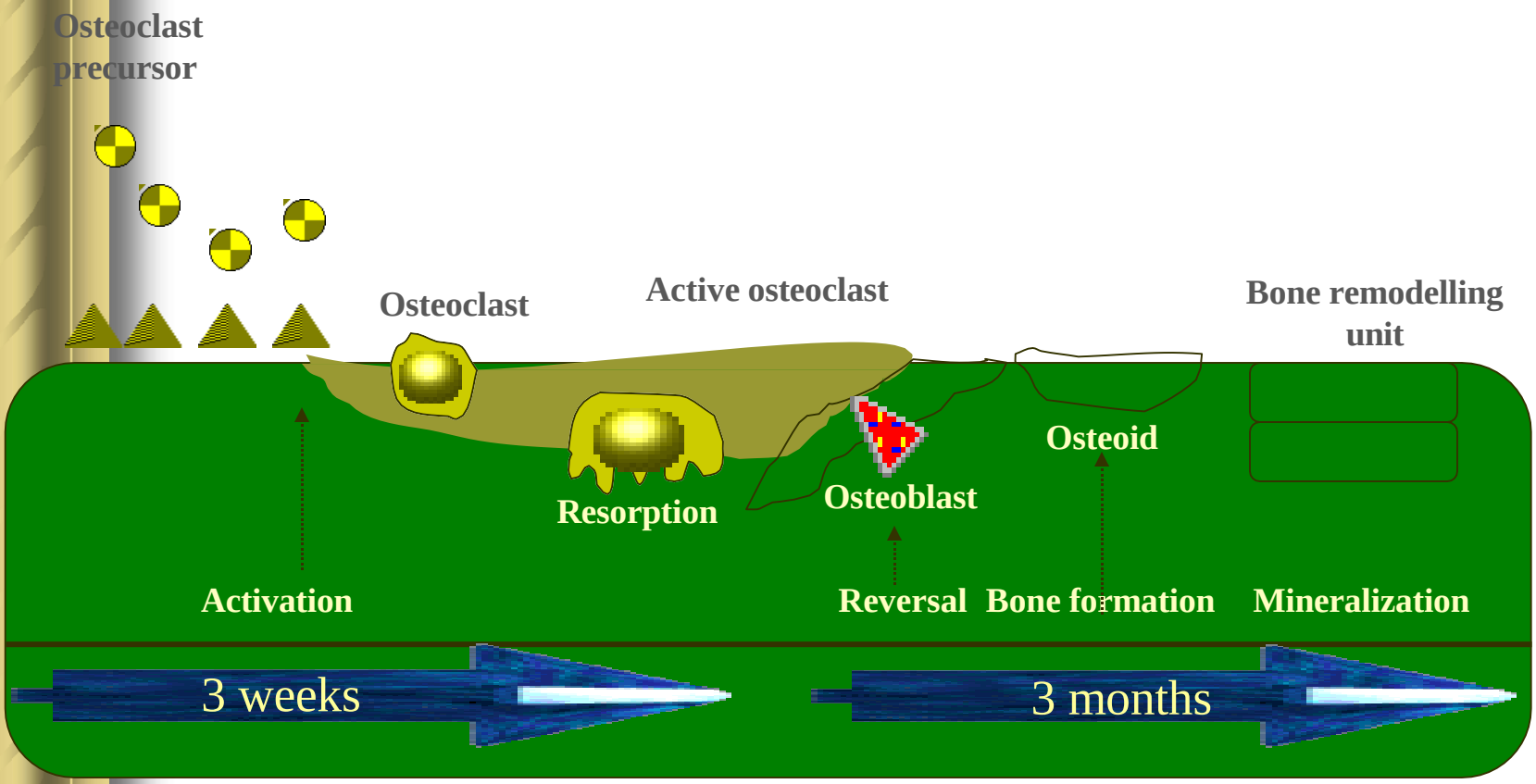
- Absorbsi kalsium di usus dan penggunannya ↓
- me↑ kadar horman paratiroid di serum
- Aktivasi vit D ↓
- Diet rendah kalsium, rendah vit D

Sumber Vitamin D = brokoli, kacang-kacangan, ikan teri, ikan salmon, susu, kuning telur, hati, sardine, sinar matahari

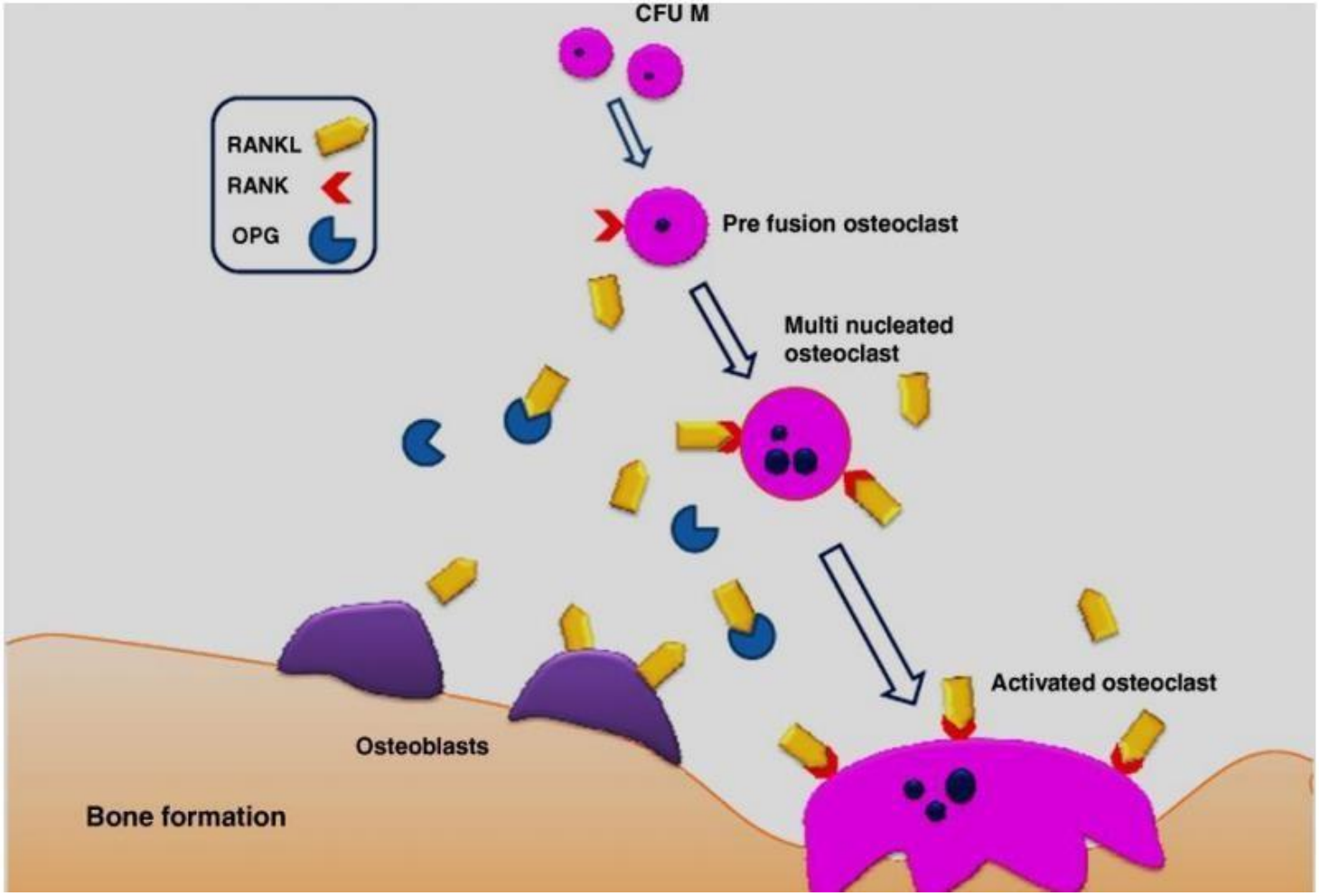
Remodelling Tulang

- Osteoblast = bertanggung jwb pd pembent tulang (bone formatio n)
- Osteoklast = bertanggung jwb pd penyerapan tulang (bone resorption)
- Osteoporosis = Abn bone turnover. Bone resoption > bone formation
- Tulang organ dinamis, selalu berubah dan mengalami pembaruan
- Pembaruan mulai dgn proses pengeroposan tulang (sel osteoclast) diikuti proses pembentukan tulang (sel osteoblast) ditempat pengeroposan, dilanjutkan mineralisasi shg diganti oleh tulang baru yg kuat

Remodeling Cycle

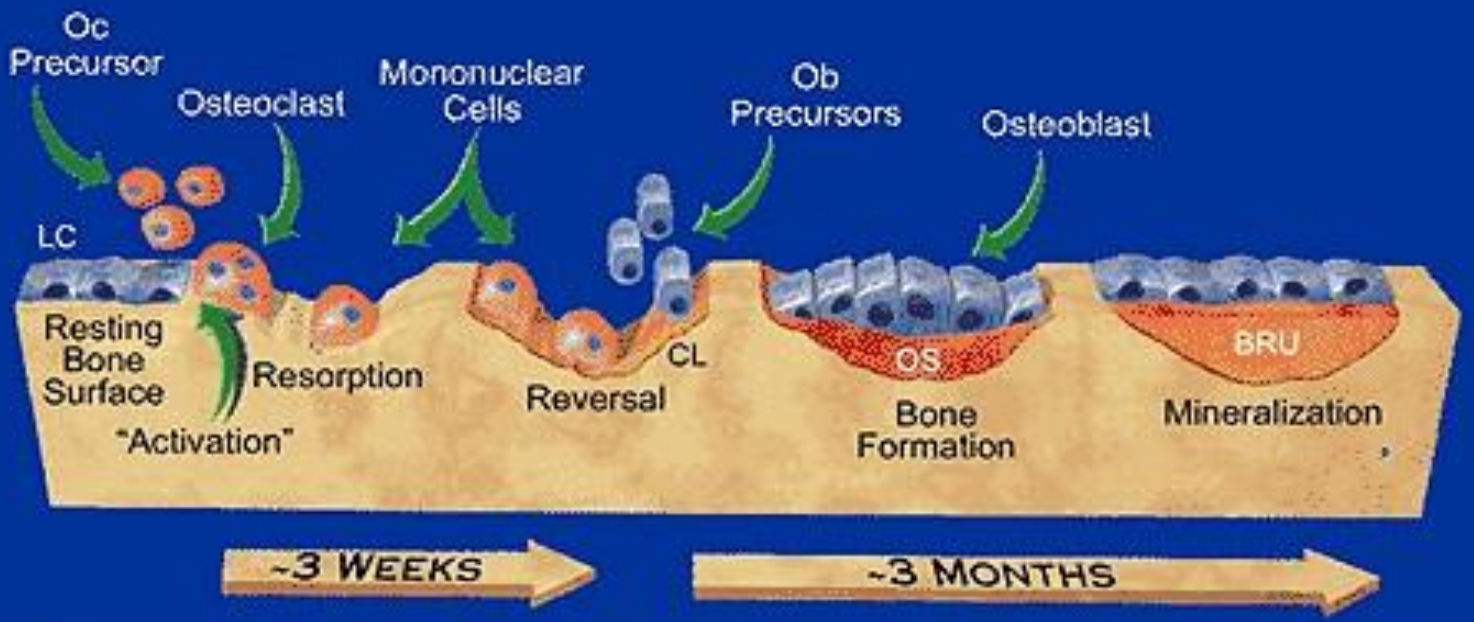


- *Receptor activator of nuclear factor kappa B ligand* (RANKL) adalah sitokin terkait TNF yang diproduksi oleh osteoblast, sel T, dan sel stromal.
- RANKL menstimulasi osteoclastogenesis dan sitokin seperti TNF-α, IL-1, atau IL-11, semua diproduksi oleh aktivasi sel T, yang mengarah ke destruksi tulang
- Osteoprotegerin (OPG) adalah anggota dari TNF *receptor super family* dan diproduksi oleh osteoblast. OPG adalah faktor inhibisi osteoclastogenesis yang mencegah fungsi dari RANKL.
- Sistem keseimbangan dari RANKL/OPG mengatur metabolisme tulang


CFU M
RANKL
RANK
OPG
Pre fusion osteoclast
Multi nucleated osteoclast
Activated osteoclast
Osteoblasts
Bone formation

OSTEOPOROSIS

Bone destruction>formation



LC = Lining Cells CL = Cement Line OS = Osteoid BRU = Bone Remodeling Unit

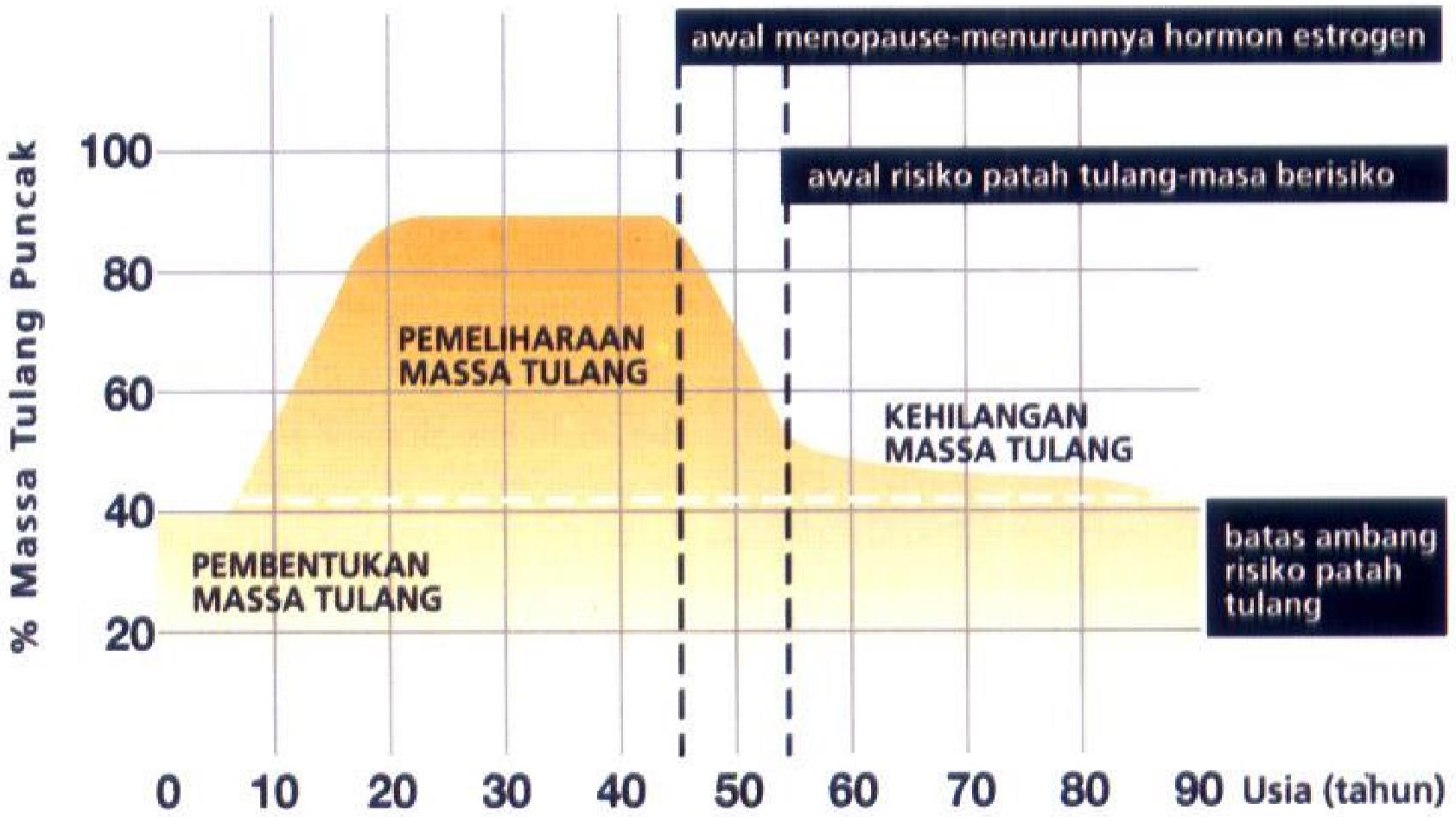
Klasifikasi Osteoporosis

(Riggs and Melton, 1983)

- **Osteoporosis Primer**
  - **Tipe 1 ➔ Osteoporosis pd wanita pasca menopause**
  - **Tipe 2 ➔ Osteoporosis senil /penuaan**

- **Osteoporosis Sekunder**
  - **➔Osteoporosis oleh penyakit, efek samping obat, kondisi yg mengakibatkan kelainan tlg**

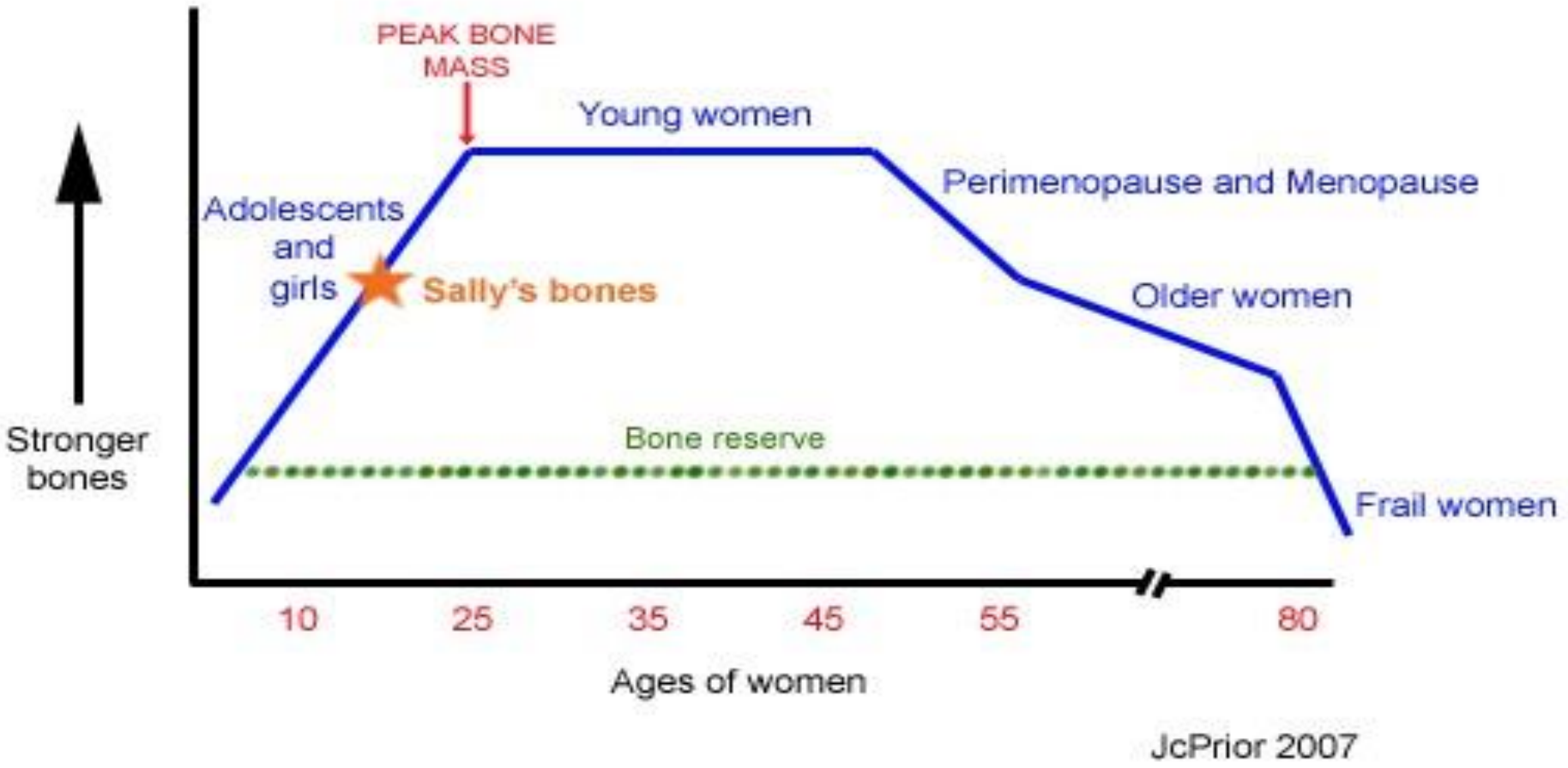
Tabel Massa Tulang Puncak



Puncak Massa Tulang yang Tinggi Dipengaruhi :

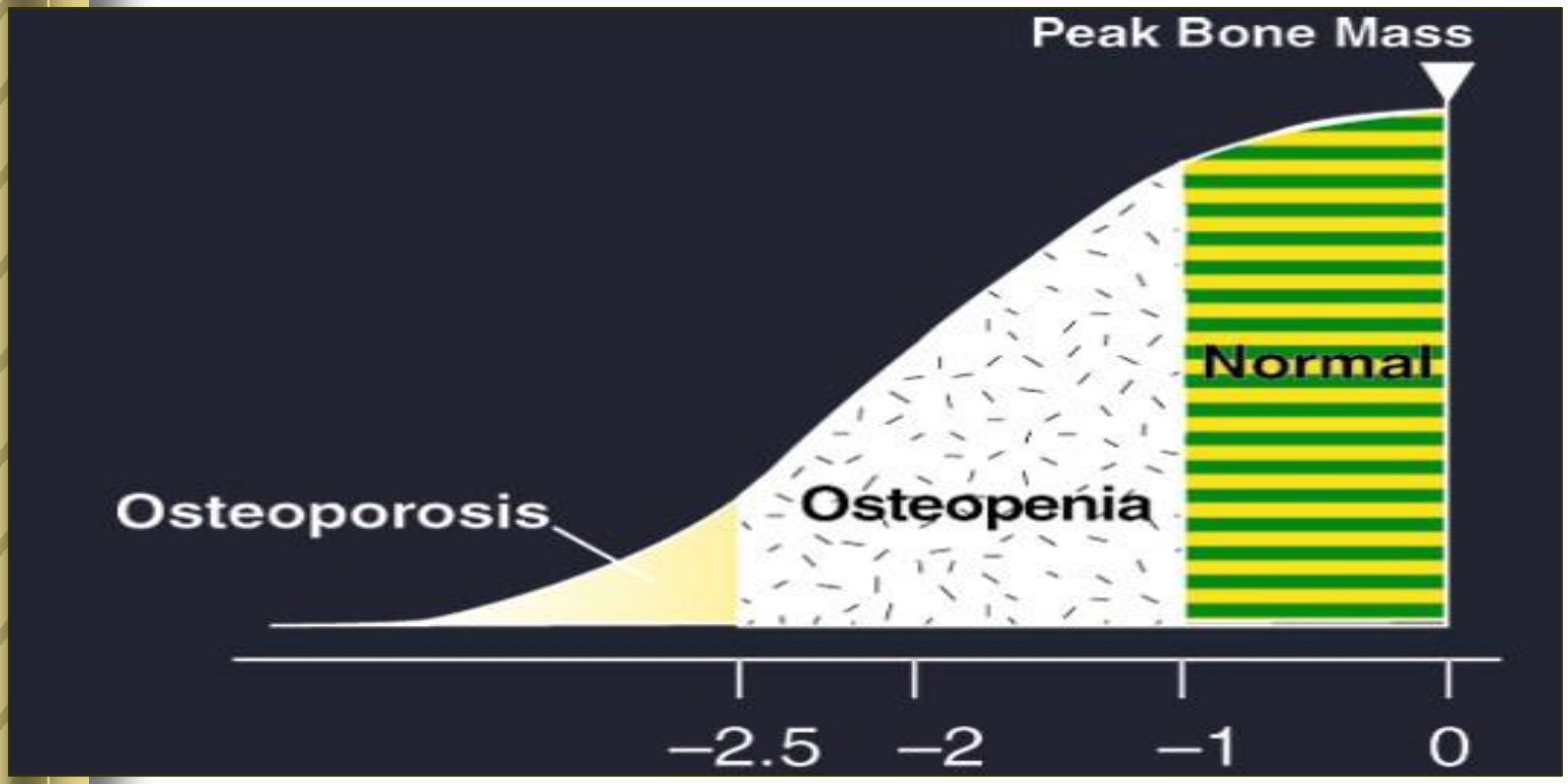
- Latihan fisik yang baik, benar, terukur dan teratur (BBTT)
- Diet seimbang, kaya akan kalsium, cukup vitamin D dan zat-zat lain utk tulang
- Hindari gaya hidup tak sehat : merokok, alkohol, kafein dll.

Life Cycle of Bone - Women



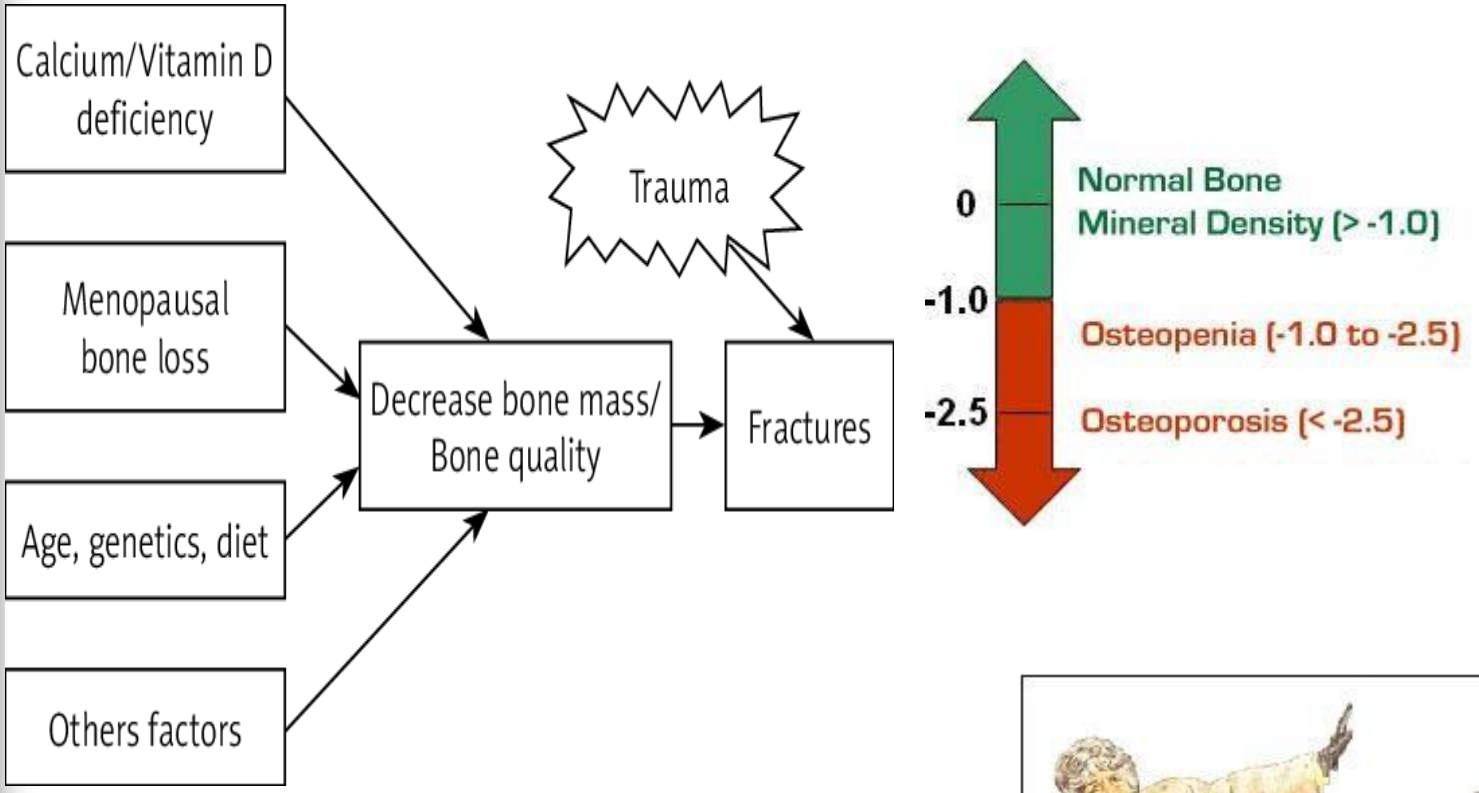
JcPrior 2007

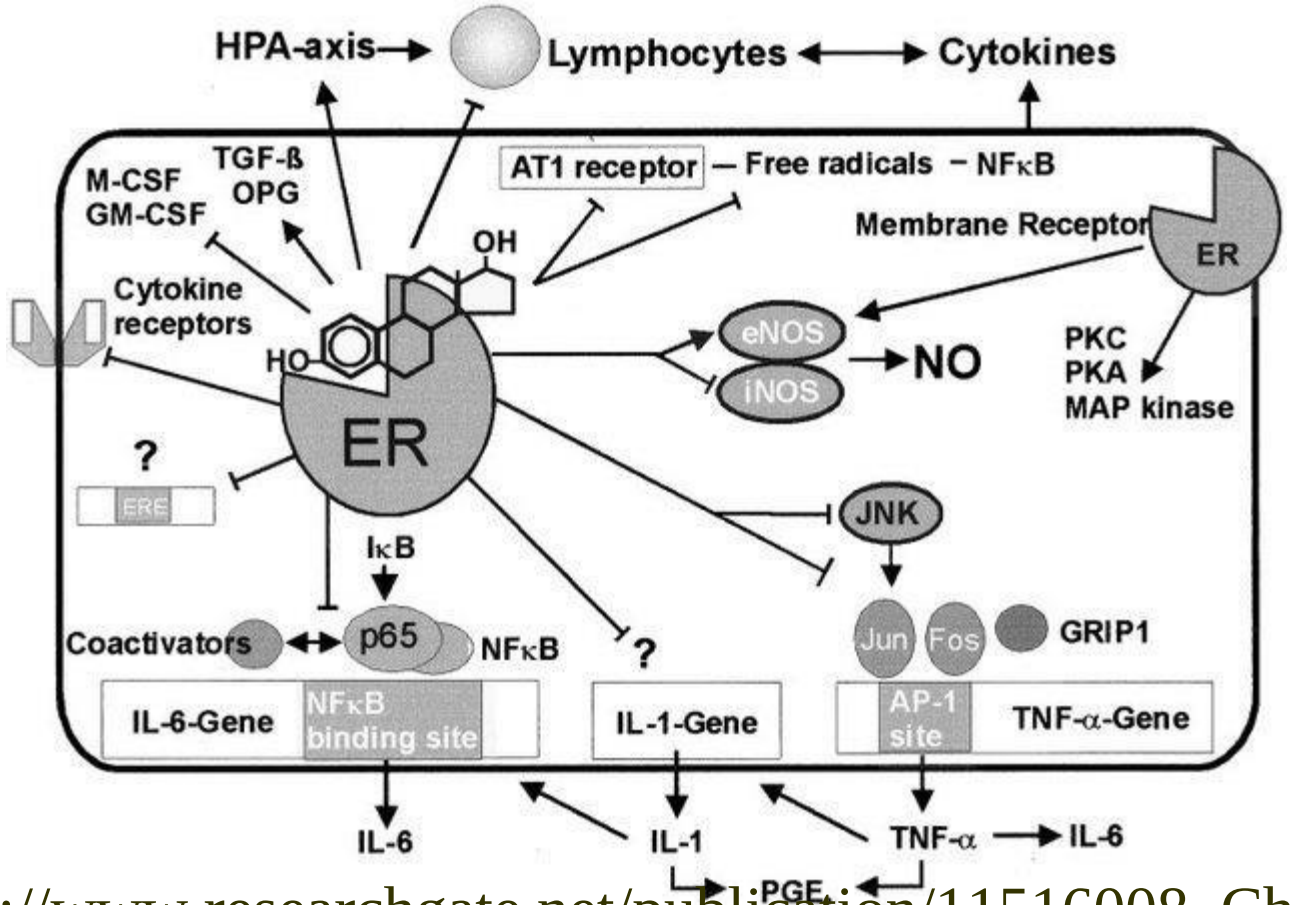
WHO Osteoporosis Guidelines
(Berdasarkan hasil pemeriksaan kepadatan mineral tulang dgn alat Bone Densitometer)



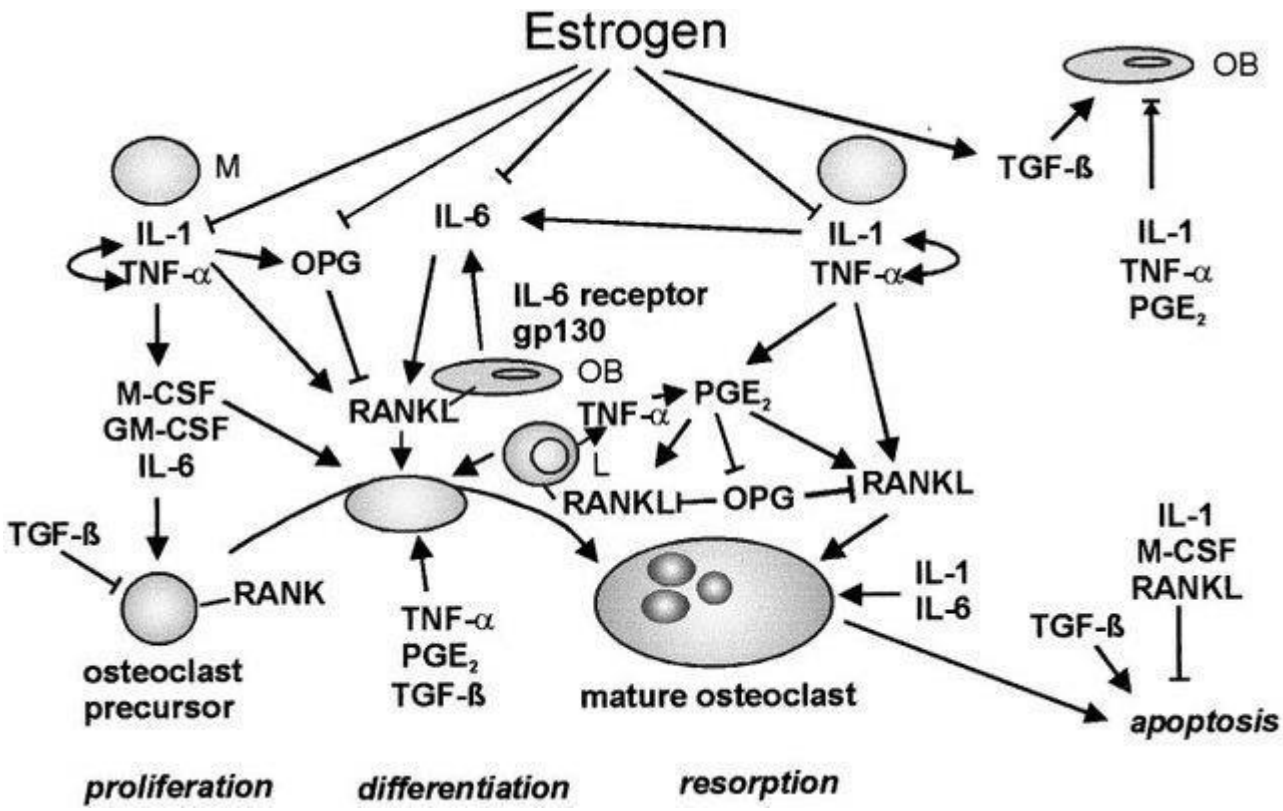
WHO, *Guideli*

Osteoporosis & Fraktur



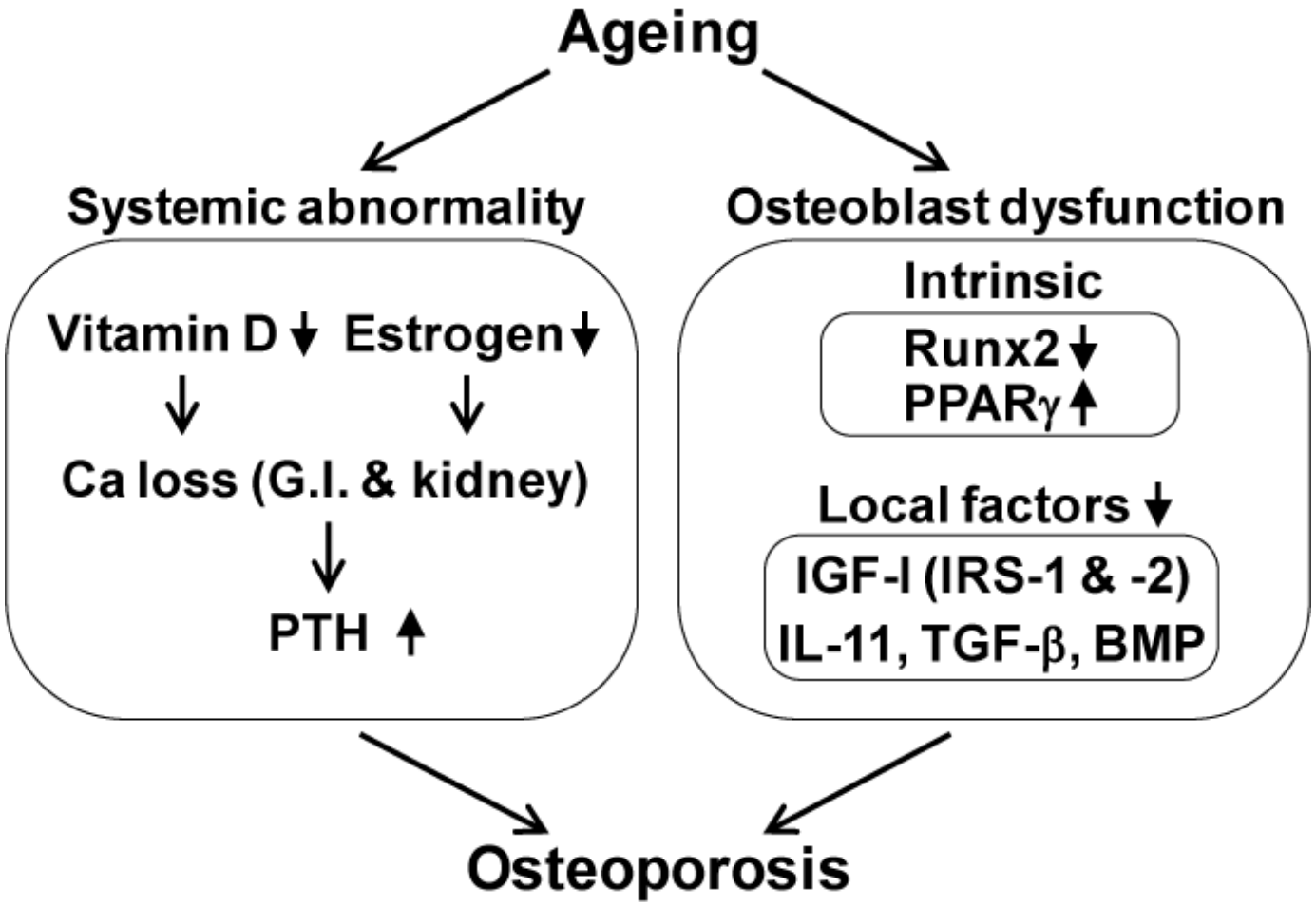


https://www.researchgate.net/publication/11516008_Changes_in_Proinflammatory_Cytokine_Activity_after_Menopause/figures

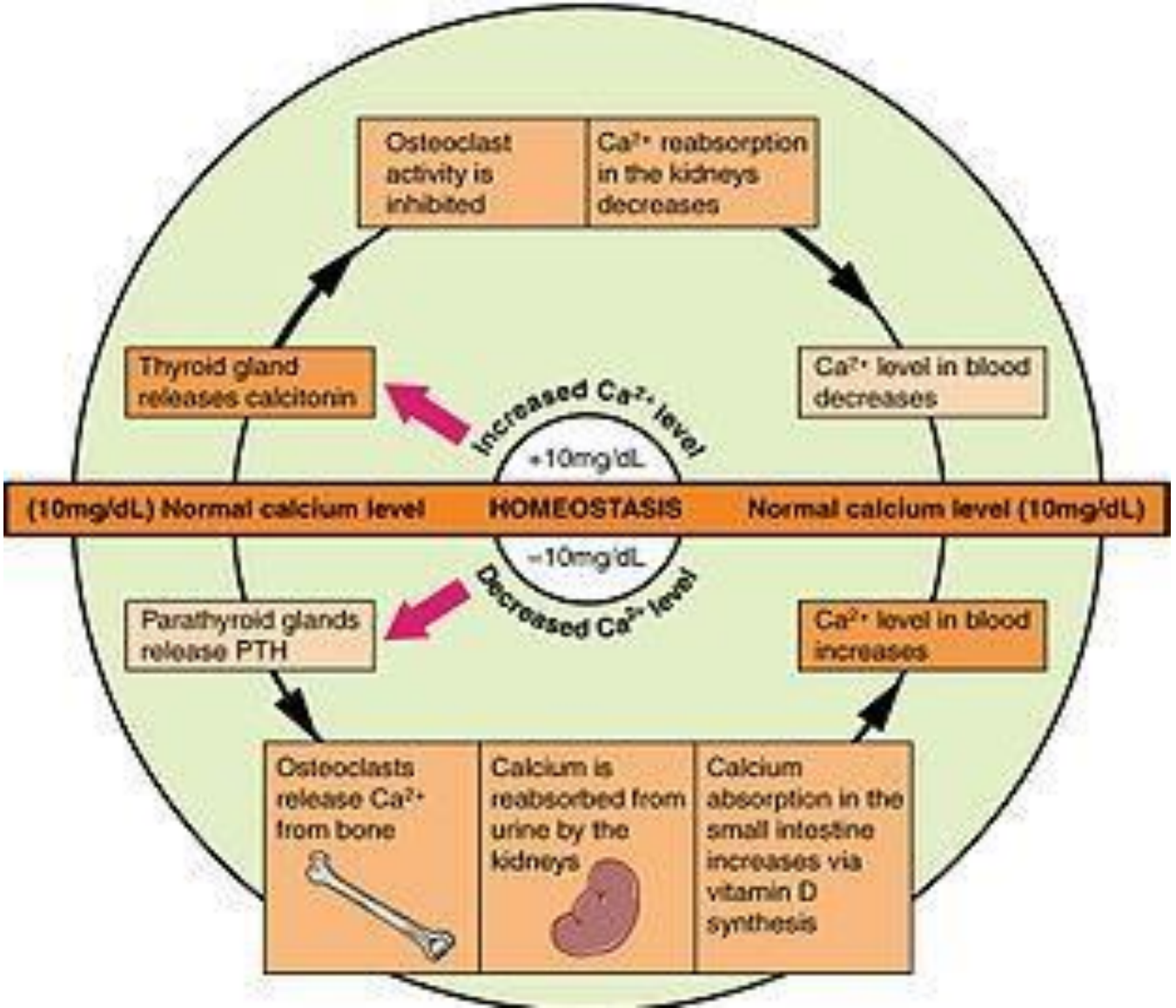


https://www.researchgate.net/publication/11516008_Changes_in_Proinflammatory_Cytokine_Activity_after_Menopause/figures

Osteoporosis and Aging

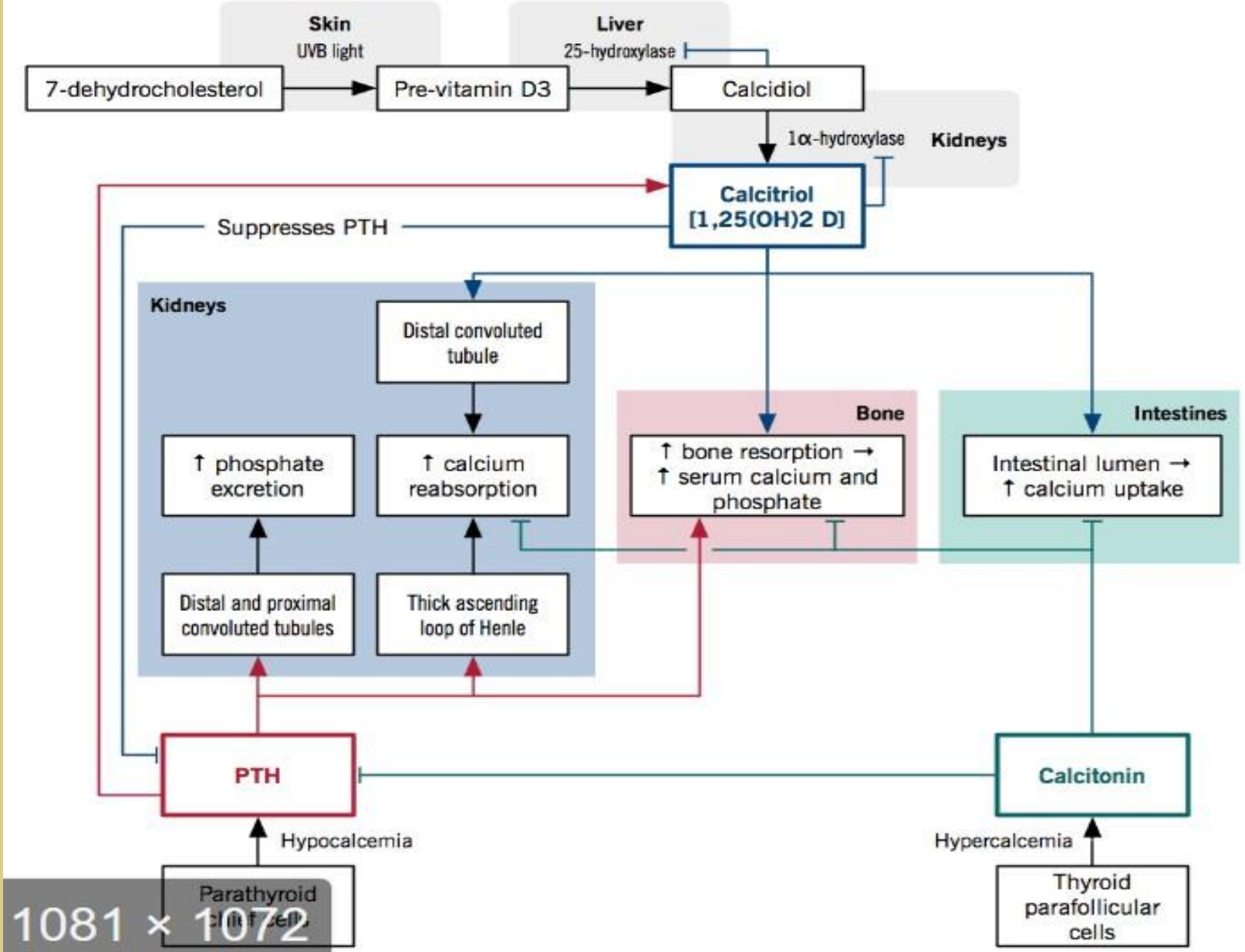


Homeostasis Ca2+



Why is less calcium absorbed

- **Lower intake vitamin D rich foods**. Vitamin D maintains plasma calcium concentrations by increasing its intestinal absorption and mobilising calcium from bones
- **Conversion of vitamin D to its active form decreases in the elderly**. This is due to an age related decrease in the production off 7-dehydrocholestrol,the immediate precursor of vitamin D during adulthood
- Cholecalciferol (vitamin D3) formed in the skin by exposure to ultraviolet light also prevents osteoporotic fractures
- Calcium absorption also impaired in chronic renal and liver disease


Skin
UVB light
Liver
25-hydroxylase
7-dehydrocholesterol
Pre-vitamin D3
Calcidiol
1α-hydroxylase
Kidneys
Calcitriol
[1,25(OH)2 D]
Suppresses PTH
Kidneys
Distal convoluted tubule
↑ phosphate excretion
↑ calcium reabsorption
Distal and proximal convoluted tubules
Thick ascending loop of Henle
Bone
↑ bone resorption →
↑ serum calcium and phosphate
Intestines
Intestinal lumen →
↑ calcium uptake
PTH
Calcitonin
Hypocalcemia
Hypercalcemia
Parathyroid
Thyroid parafollicular cells

Risk factors

Primary

- **genetics (up to 80%)**
- Female –post menopausal
- Increasing age
- Low BMI
- Caucasian ethnicity
- Poor nutrition, poor dietary intake Ca and Vit D
- Smoking
- Sedentary lifestye
- Untreated premature menopause
- inadequate physical activity
- low weight/BMI

Secondary

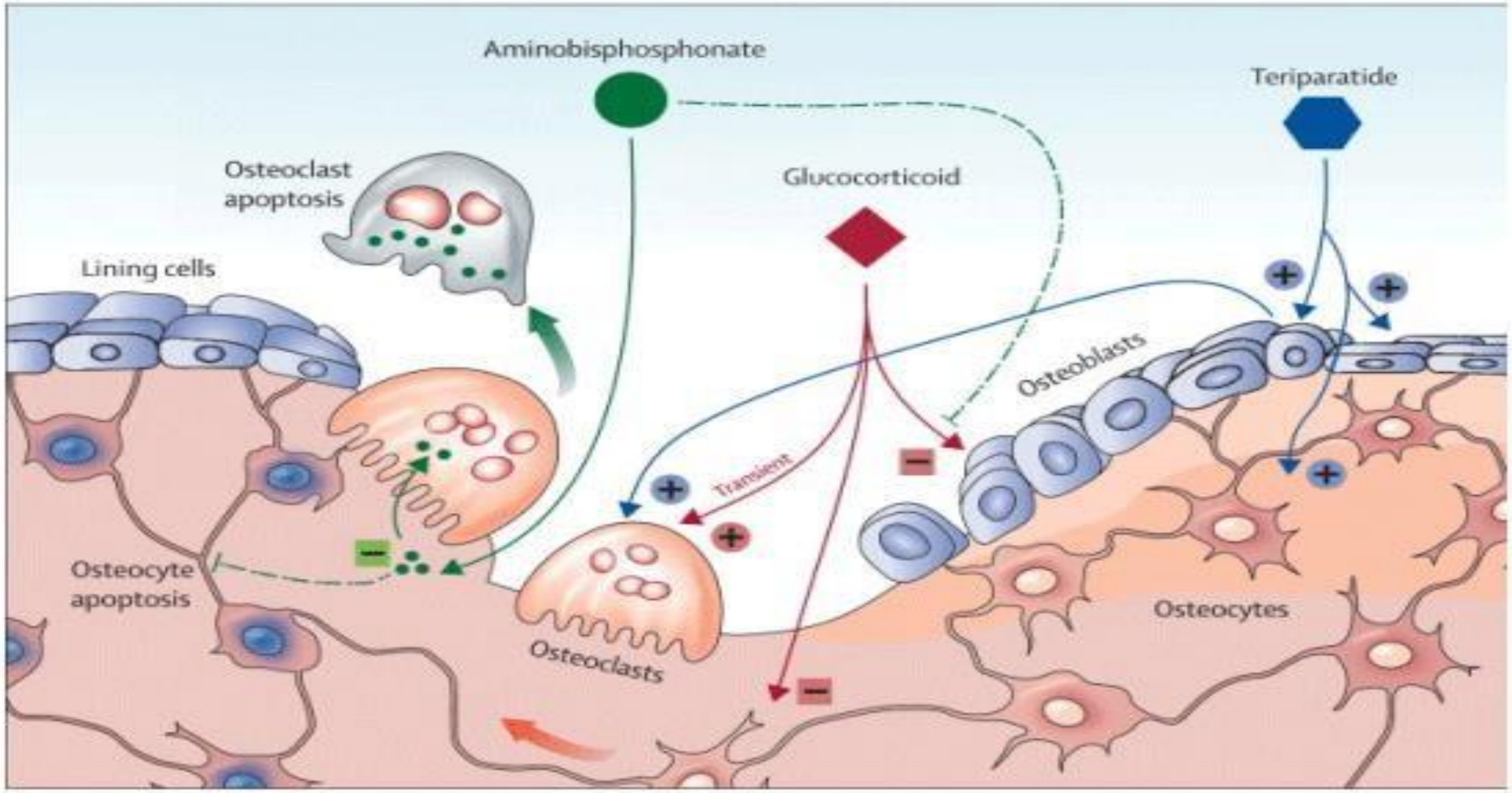
- Renal impairment
- Chronic liver disease
- Rheumatoid arthritis
- Long term corticosteroid use
- hyperthyroidism

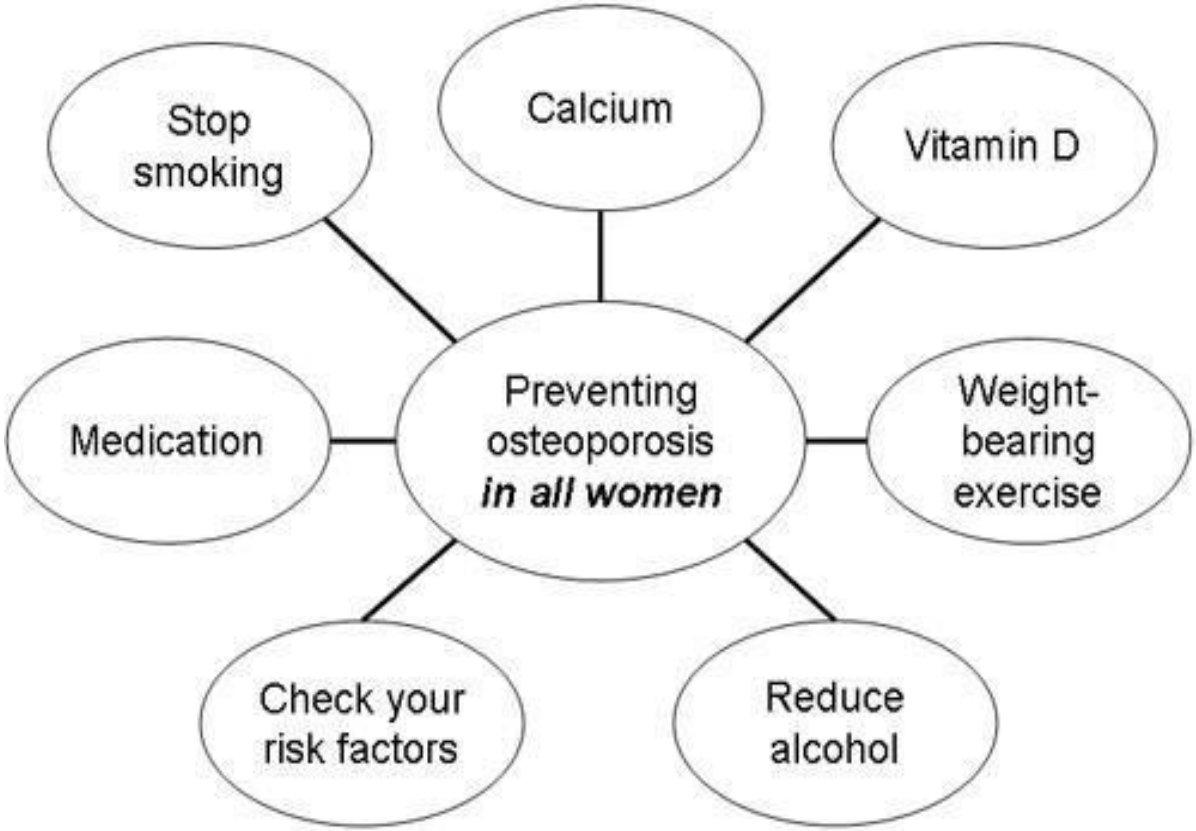
Medical conditions associated with o'porosis

- AIDS/HIV
- Amyloidosis
- Ankylosing spondylitis
- COPD
- Congenital porphyoria
- Cushing's
- Eating disorders
- Gastrectomy
- Gaucher's
- Hemochromatosis
- Hemophilia
- Hyperparathyroidism
- Hypogonadism
- Hypophosphatasia
- Idiopathic scoliosis
- Inflammatory bowel disease
- IDDM
- Lymphoma/leukemia
- Malabsorption syndromes
- Mastocytosis
- Multiple myeloma
- Multiple sclerosis
- Pernicious anemia
- Rheumatoid arthritis
- Liver dz (esp PBC)
- Spinal cord transection
- Sprue
- Stroke
- Thalessemia
- Thyrotoxicosis
- PTH secretion due to malignancy
- Weight loss

Drugs associated with increased o'porosis risk

- Aluminum
- Anticonvulsants (phenobarb/phenytoin)
- Cytotoxic drugs
- Glucocorticosteroids and adrenocorticotropin (up to 10% bone loss in first year of tx with high doses)
- GNRH agonists
- Immunosuppressants
- Lithium
- Long term use of heparin (bone loss in 1/3 of women)
- Long acting parenteral progesterone
- Supraphysiologic thyroxine doses
- Premenopausal use of tamoxofen


Aminobisphosphonate
Teriparatide
Osteoclast apoptosis
Glucocorticoid
Lining cells
Osteoblasts
Transient
Osteocyte apoptosis
Osteocytes
Osteoclasts


Stop smoking
Calcium
Vitamin D
Medication
Preventing osteoporosis *in all women*
Weight-bearing exercise
Check your risk factors
Reduce alcohol

Kebutuhan kalsium berdasarkan usia

Usia	Kebutuhan kalsium perhari (mg)
0 to 6 bulan	210
7 to 12 bulan	270
1 to 3 tahun	500
4 to 8 tahun	800
9 to 18 tahun	1,300
19 to 50 tahun	1,000
⩾ 50 tahun	1,200

Tumbuh cepat

Anjuran Pemberian Vitamin D berdasarkan kelompok umur

Kelompok Umur	(IU/hari)	RNI (µg/har)
Usia 0-9 tahun	200	5
Usia 10-18 tahun	200	5
Usia 19-50 tahun	200	5
Usia 51-65 tahun	400	10
Usia 65+ tahun	600	15
Masa kehamilan	200	5
Masa menyusui	200	5

Sumber: FAO/WHO: Human Vitamin and Mineral Requirements, 2002

The truth about exercise

- **Weight bearing exercise has positive effect on skeleton**
- **Insufficient to prevent bone loss in early menopause, but will slow the rate**
- **Impact loading (ie weight lifting) best osteogenic stimulus**
- **Exercise reduces risk of falls, +/- reduces fracture risk in falls that do occur**

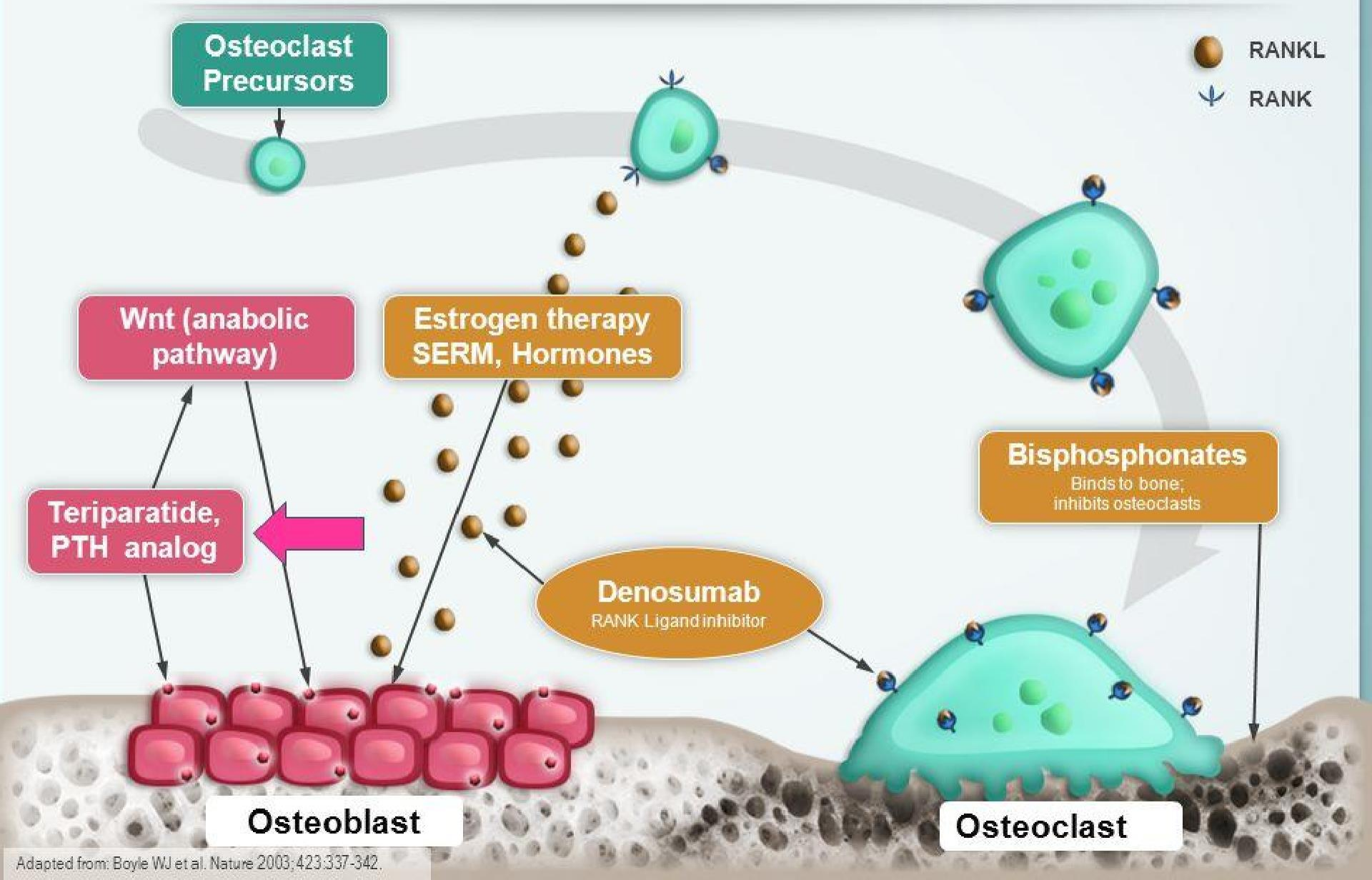
Latihan Fisik

- Latihan pembebanan
- Gerakan dinamis dan ritmis
- Daya tahan (endurans) dlm bent *aerobic low impact*

When to treat

- **First – lifestyle changes (details to follow)**
- **Next – follow guidelines as stated by National Osteoporosis Foundation (NOF); recommend pharmacologic therapy to postmenopausal women with T-scores** *<-2.0* **as measured by central DEXA regardless of risk factors, and** *<-1.5* **if risk factors present**

Mechanism of Action of Available Osteoporosis Therapies



Adapted from: Boyle WJ et al. Nature 2003;423:337-342.

Drug Treatments for Osteoporosis

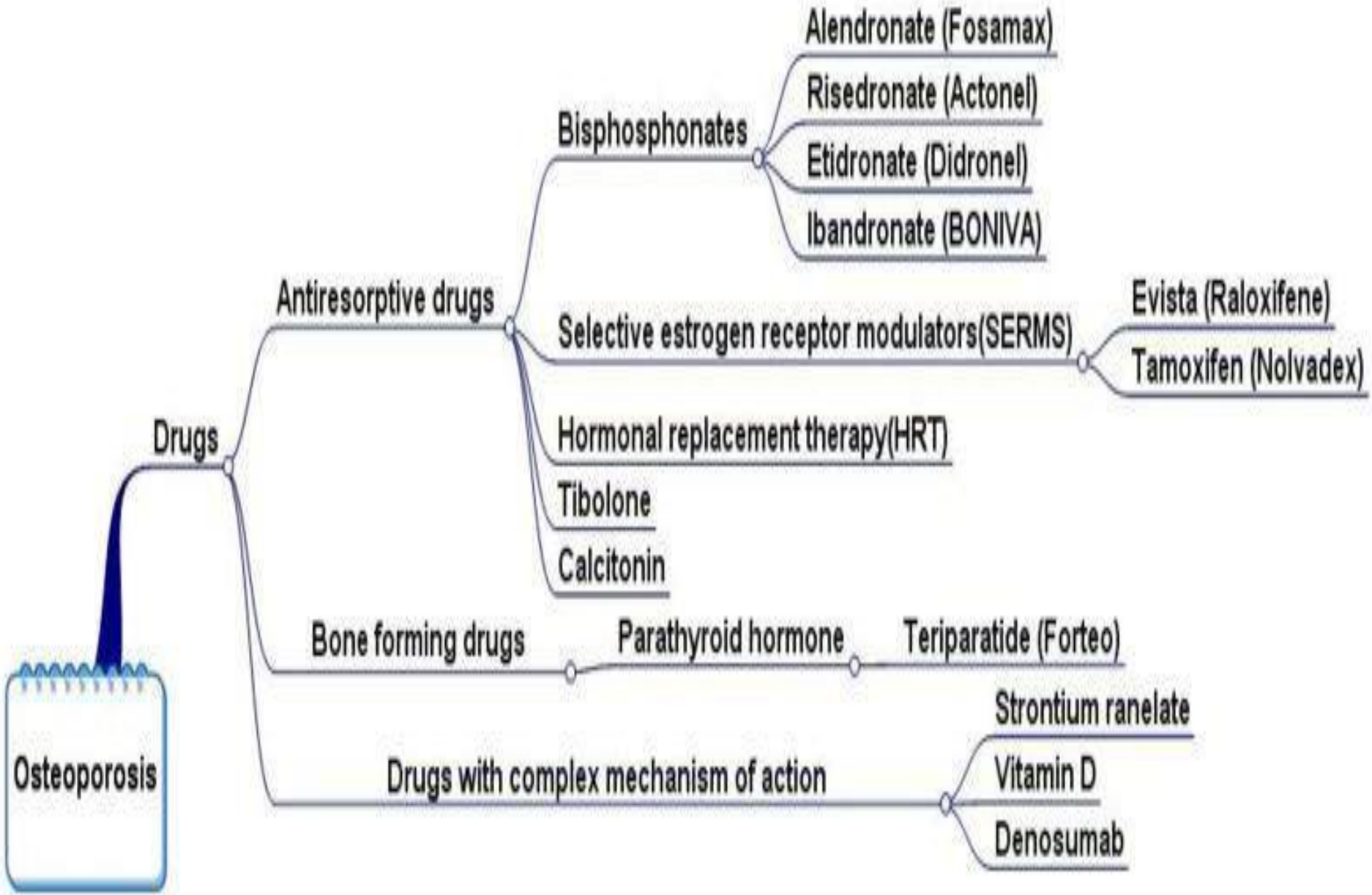
Antiresorptive

- Bisphosphonates

  alendronate, risedronate, ibandronate, etidronate
- SERMs (Selective estrogen receptor modulators)- raloxifene
- Calcitonin
- Estrogen

Anabolic

- PTH -Teriparatide


Osteoporosis
Drugs
Antiresorptive drugs
Bisphosphonates
Alendronate (Fosamax)
Risedronate (Actonel)
Etidronate (Didronel)
Ibandronate (BONIVA)
Selective estrogen receptor modulators(SERMS)
Evista (Raloxifene)
Tamoxifen (Nolvadex)
Hormonal replacement therapy(HRT)
Tibolone
Calcitonin
Bone forming drugs
Parathyroid hormone
Teriparatide (Forteo)
Drugs with complex mechanism of action
Strontium ranelate
Vitamin D
Denosumab

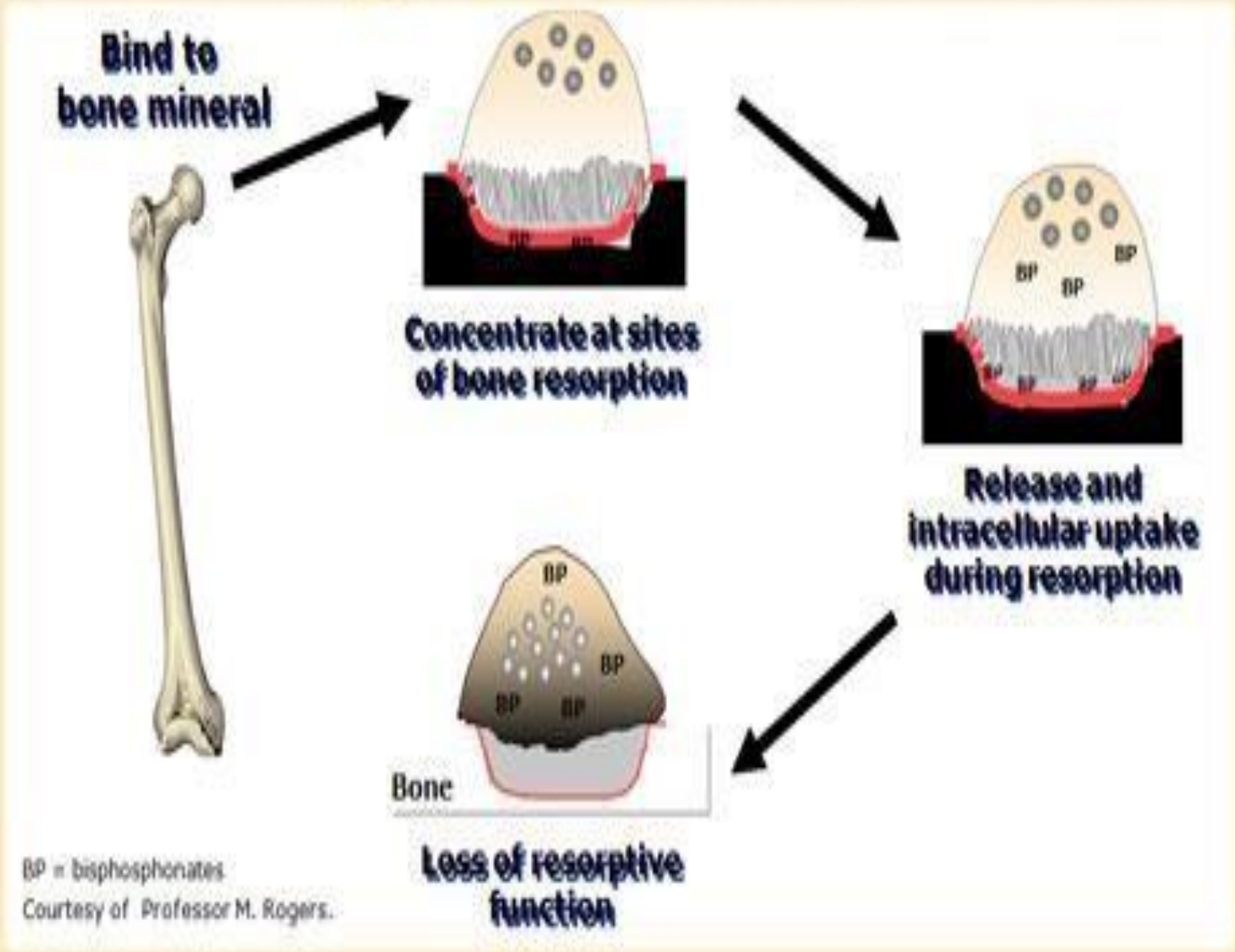
Treatment of Postmenopausal Osteoporosis
FDA Approved Indications

	Prevention	Treatment
Alendronate (Fosamax)	Yes	Yes
Risedronate (Actonel)	Yes	Yes
Calcitonin (Miacalcin)	No	Yes
HT	Yes	No
Raloxifene (Evista)	Yes	Yes
PTH (Forteo)	No	Yes

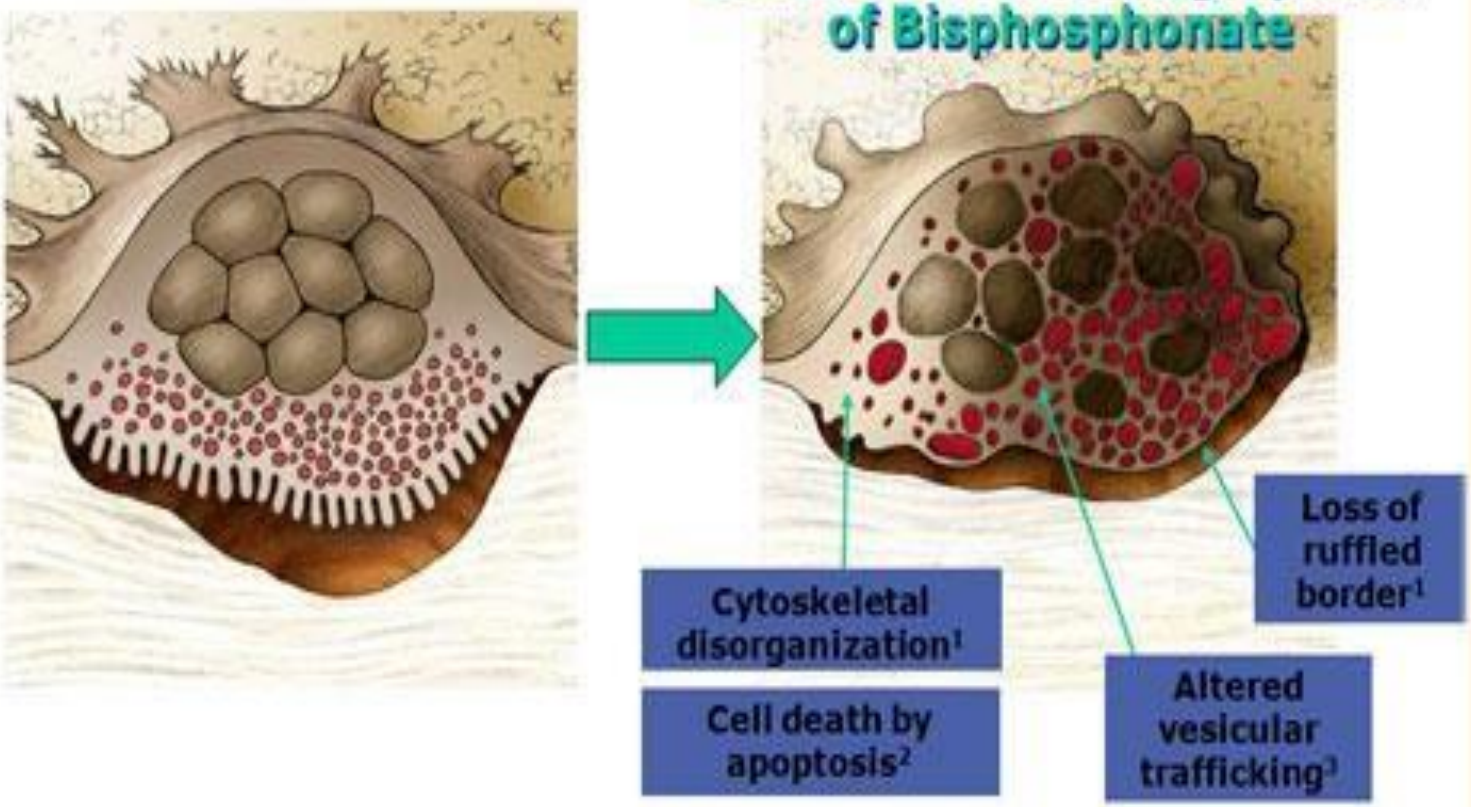
Bisphosphonates

- Ada 2 kelas :
  - Non-nitrogenous bisphosphonates (clodronate, etidronate, tiludronate)
    - Pro-drug, dimetab di dlm sel osteoclast menghasilkan metabolit aktif yg sitotoksik dan menyebabkan kematian sel osteoklast
  - Nitrogenous bisphosphonates (pamidronate, Alendronate, risendronate, ibandronate)
    - Menghamb farnesyl diphosphate synthase (FDPS) pd jalur mavalonate, shg menghilangkan fungsi GTPase small→regulasi fungsi osteoklast terganggu
- Effective for tx and prevention of osteoporosis
- Low oral bioavaibility, highly polar, high molecular weight, paracellular route absorbtion
- Precautions – avoidance of pill induced esophagitis (CI with reflux, GERD, other esophageal abnormalities); must take on empty stomach, with 1 glass water and remain upright for 30 min

Action of Bisphosphonates Depends on Mineral Binding and Effects on Osteoclasts



Effects of Bisphosphonates on Osteoclast Function



1. Sato, M, et al. *J Clin Invest.* 1991;88:2095-2105.
2. Hughes DE, et al. *J Bone Miner Res.* 1995;10:1478-1487.
3. Rogers M. *Curr Pharm Des.* 2003;9:2643-2658.

Generasi Biphosphonate

Bisphosphonate	Relative potency
First generation BPNs	
Etidronate	1
*Tiludronate	10
Second generation BPNs	
Pamidronate	100
Alendronate	100–500
*Ibandronate	500–1000
Third generation BPNs	
Risedronate	1000
Zoledronate	5000

Bisphosphonates	*Points to consider*
Alendronate (oral) & Risedronate (oral)	• Post-menopausal women: prevents vertebral, non-vertebral, and hip fractures[31,32] • Men: Some evidence of decreased risk of vertebral fractures;[27,28] some evidence of increased hip bone density, but no significant hip fracture reduction • Glucocorticoid induced osteoporosis (GIO): Some evidence of decreased vertebral fracture risk
Etidronate (oral)	• Post-menopausal women: prevents vertebral fractures[33] • GIO: maintains BMD in GIO although data is limited; Health Canada approved indication is for GIO prevention only (not treatment)[29]
Zoledronic acid (intravenous)	• Post-menopausal women: prevents vertebral, non-vertebral, and hip fractures[34] • Men: Data is limited; Some evidence of decreased risk of vertebral and non-vertebral fractures (study included those with prior hip fracture and only 24% men);[31] • GIO: maintains BMD • Cost effectiveness may limit use • Consider for high-risk patients who are unable to tolerate oral therapy or have poor adherence

SERMs

- Mixed estrogenic and antiestrogen properties depending on tissue
- Raloxifene
  - Besides increasing BMD, also lowers risk of breast Ca without stimulating endometrial hyperplasia. However can increase risk of vasomotor symptoms (hot flashes, etc). Decreases LDL without noticeable effect on CVD.
- Tamoxifen
  - Not typically rx for osteoporosis alone, but if already being used for breast cancer can provide effective bone protection

Drug	Points to consider
Raloxifene (oral)	• Post-menopausal women: reduces the incidence of vertebral fractures • May be considered in post-menopausal women who are unable to tolerate bisphosphonates and have no history of thromboembolic disease • Caution: Significantly increases the risk of venous thromboembolic disease and stroke

RANK Ligand Inhibitor:

Denosumab

Denosumab =injeksi monoklonal Ab thd R/activator dari nuklei faktor - kB ligan (RANK-L).Mek kerja : menghambat resorpsi tulang oleh osteoclast dg cara memblok interaksi antara RANKL dg R/ RANK yg tdp di perm osteoclast

ab

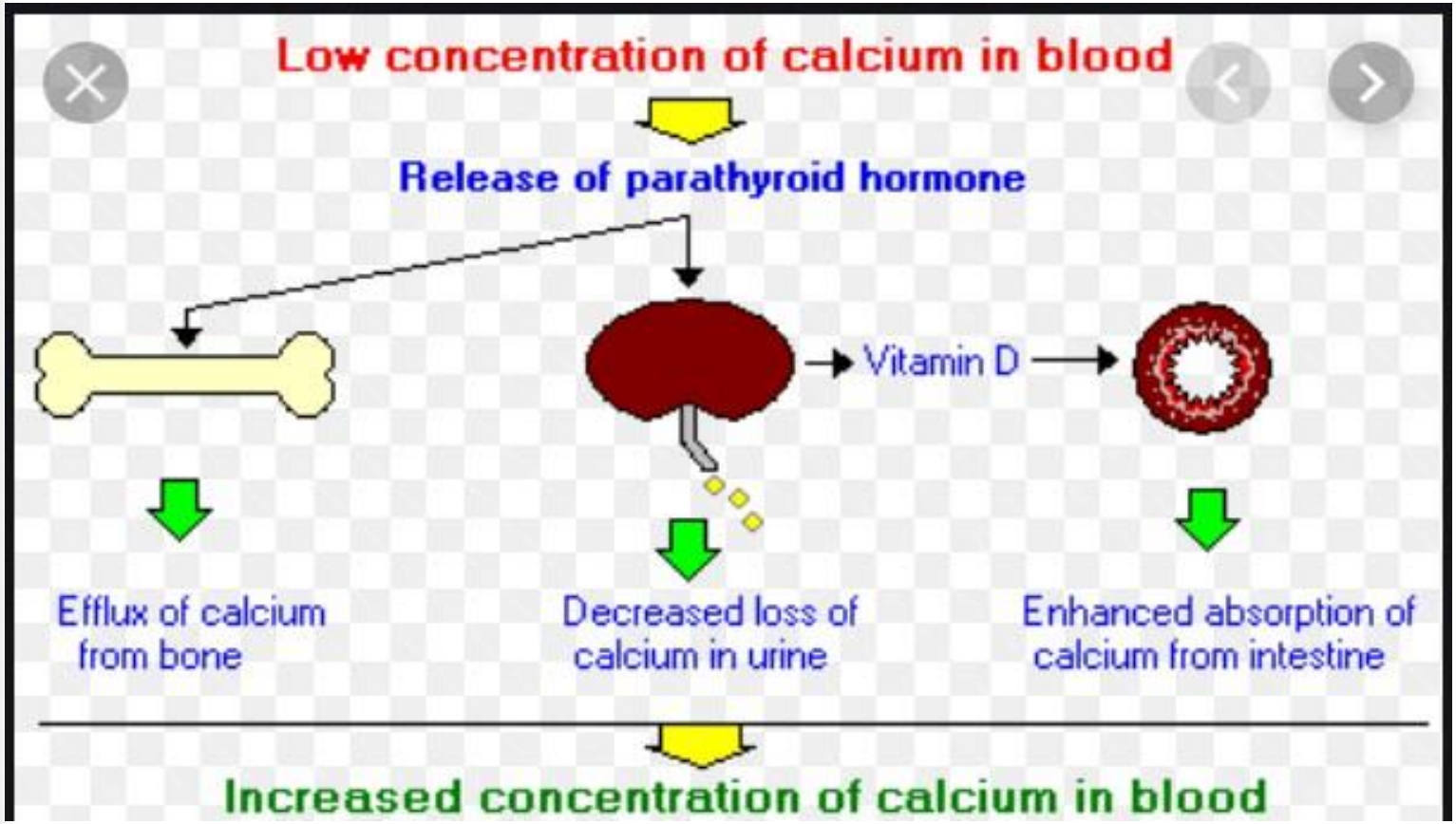
Drug	Points to consider
Denosumab (subcutaneous)	• Postmenopausal women: prevents vertebral, non-vertebral, and hip fractures • Cost and lack of long term safety data may limit use

Calcium/Vitamin D

- **Should be considered adjuvant therapy for all individuals (esp >65 y/o)**
- WHI study **– modest benefit in bone health. Statistically significant only with FULL doses and in older population. Otherwise – small increase in BMD with small decrease in hip fractures.**
- **NIH recs:**
  - **Premenopausal: 1000 mg**
  - **Postmenopausal <65 y/o using estrogen: 1000 mg**
  - **Postmenopausal not using estrogen: 1500 mg**
  - **All women >65: 1500 mg**

4.2.4 Synthetic Parathyroid Hormone: Teriparatide is an anabolic agent that improves bone quality, quantity, and increases bone strength. [22-24,30,36]

Drug	*Points to consider*
Teriparatide (subcutaneous)	• Post-menopausal women: prevents vertebral and non-vertebral fractures in postmenopausal women with severe OP • Men: increases BMD; currently no fracture data available • GIO: Some evidence of benefit in the treatment of GIO • Cost and need for daily subcutaneous injection may limit use • Consider for patients at increased risk of fracture or lack of response to other therapies • Maximum lifetime exposure is 24 months • Bisphosphonates must be discontinued prior to treatment • Gains in BMD decline once treatment with teriparatide is discontinued; consider anti-resorptive therapy after completing treatment course


Low concentration of calcium in blood
Release of parathyroid hormone
Vitamin D
Efflux of calcium from bone
Decreased loss of calcium in urine
Enhanced absorption of calcium from intestine
Increased concentration of calcium in blood

4.2.5 Calcitonin Peptides: Calcitonin Salmon is an inhibitor of bone resorption; available in parenteral and nasal spray formulations. Although calcitonin does not build bone, in women > 5 years beyond menopause, it appears to slow bone loss and increase spinal bone density. [26,37,38]

Drug	*Points to consider*
Calcitonin (nasal)	• Post-menopausal women: Reduces incidence of vertebral fractures however evidence for benefit is limited • Consider as an alternative when other more effective drugs cannot be used • Effective in decreasing acute pain associated with vertebral osteoporotic fractures • Calcitonin injection is currently not approved for the treatment of OP; it is sometimes prescribed for patients who have pain due to acute vertebral fractures (See *Appendix D - Prescription Medication Table for Osteoporosis*) • Nasal route of administration has the most data for use in OP and is more commonly used due to convenience and tolerability

4.2.6 Hormone Replacement Therapy [HRT] (estrogen with or without progesterone): HRT is primarily indicated for the management of moderate to severe menopausal symptoms in women. [22,24-26,35] A beneficial effect has been seen on BMD and fracture risk due to the significant anti-resorptive activity of estrogen.

Drug	*Points to consider*
HRT (oral or transdermal)	• Post-menopausal women: Shown to prevent vertebral, hip and non-vertebral fractures • Is not recommended for the sole indication of OP prevention and for long term use for this indication; consider benefits versus risks (See *Appendix D - Prescription Medication Table for Osteoporosis*) • May be appropriate for OP prevention when it is already being used for the management of menopausal symptoms

The Guidelines and Protocols Advisory Committee on

Hormones

- Estrogen + medroxyprogesterone reduced risk of hip and clinical vertebral fractures by 34%, and overall fractures by 24%
- Another study showed positive bone changes after unopposed estrogen for 24 months – without induction of endometrial hyperplasia
- Initial recommendations – start hormone therapy within 5-10 years after menopause

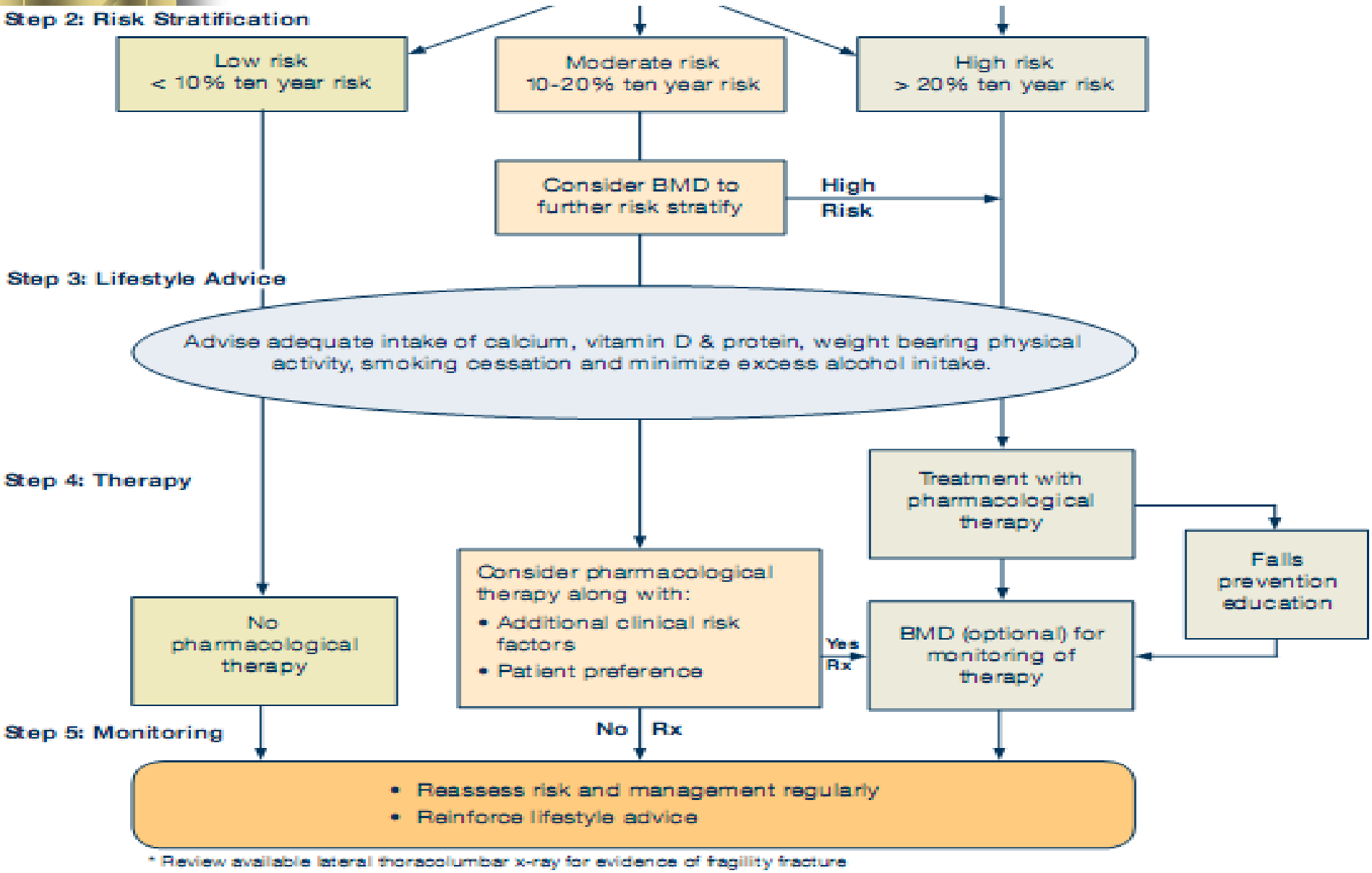
Hormones – cont'd

- **However, as of recent WHI study, estrogen-progesterone therapy** *no longer* **first-line approach for osteoporosis treatment in postmenopausal women due to increased risk of breast cancer, stroke**
- **Indications: persistent menopausal symptoms, inability to tolerate other options, failure to respond to other options.**

Why not try…

- PTH – daily subcutaneous injections can favor bone formation over resorption. Use should be limited to high risk/refractory patients. Should not be combined with bisphosphonates.
- Calcitonin – nasal formulation, concern over tachyphylasis, less effective; use suggested in pts with painful osteoporotic fractures for analgesic action
- Calcitrol – must monitor for hypercalcemia, hypercalciuria, renal insufficiency. Lack of consistent benefit.
- Vitamin K – required for carboxylation of osteocalcin (needed in mineralization). Perhaps only beneficial when Vit K deficiency present.
- Sodium fluoride – not recommended – “hardens” teeth but increased bone brittleness.

Guideline Tx Oseoporosis



Related Research and Community Services

Nurdiana, H. 2024. Peningkatan pengetahuan tentang Faktor Risiko dan Pencegahan Osteoporosis pada Anggota Aisyiyah.

Sekian……