

# 第四章 软骨和骨

## (Cartilage & Bone)



# 本章主要内容

- 软骨-透明软骨
- 骨基质和骨细胞
- 长骨的结构
- 骨发生
- 骨折



# 一、软骨 (*cartilage*)

较硬，略有弹性，能承受压力，耐磨擦

## 结构:

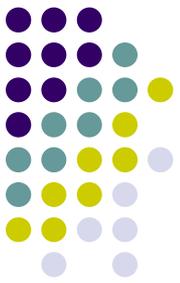
软骨组织: { 软骨细胞: 代谢能力很弱  
基质: 蛋白多糖和蛋白—软骨粘蛋白  
纤维: 胶原纤维和弹性纤维  
软骨膜

无血管，无神经，无淋巴管；由软骨膜和关节滑液获得营养。



# 功能

- 承受机械力而不会永久变形；
- 支撑柔软组织，如鼻、耳、气管；
- 缓冲震荡，利于骨骼运动；
- 对长骨的发育和生长是必不可少的。

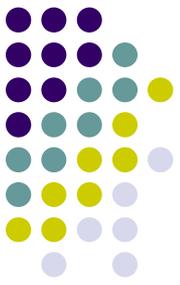


## 分类:

透明软骨 (**hyaline cartilage**): II 型胶原蛋白

弹性软骨: (**elastic cartilage**): II 型胶原蛋白

纤维软骨: (**fibrous cartilage**): I 型胶原蛋白



## (一)、透明软骨 *hyaline cartilage*

新鲜时淡蓝色半透明。较脆易折断。

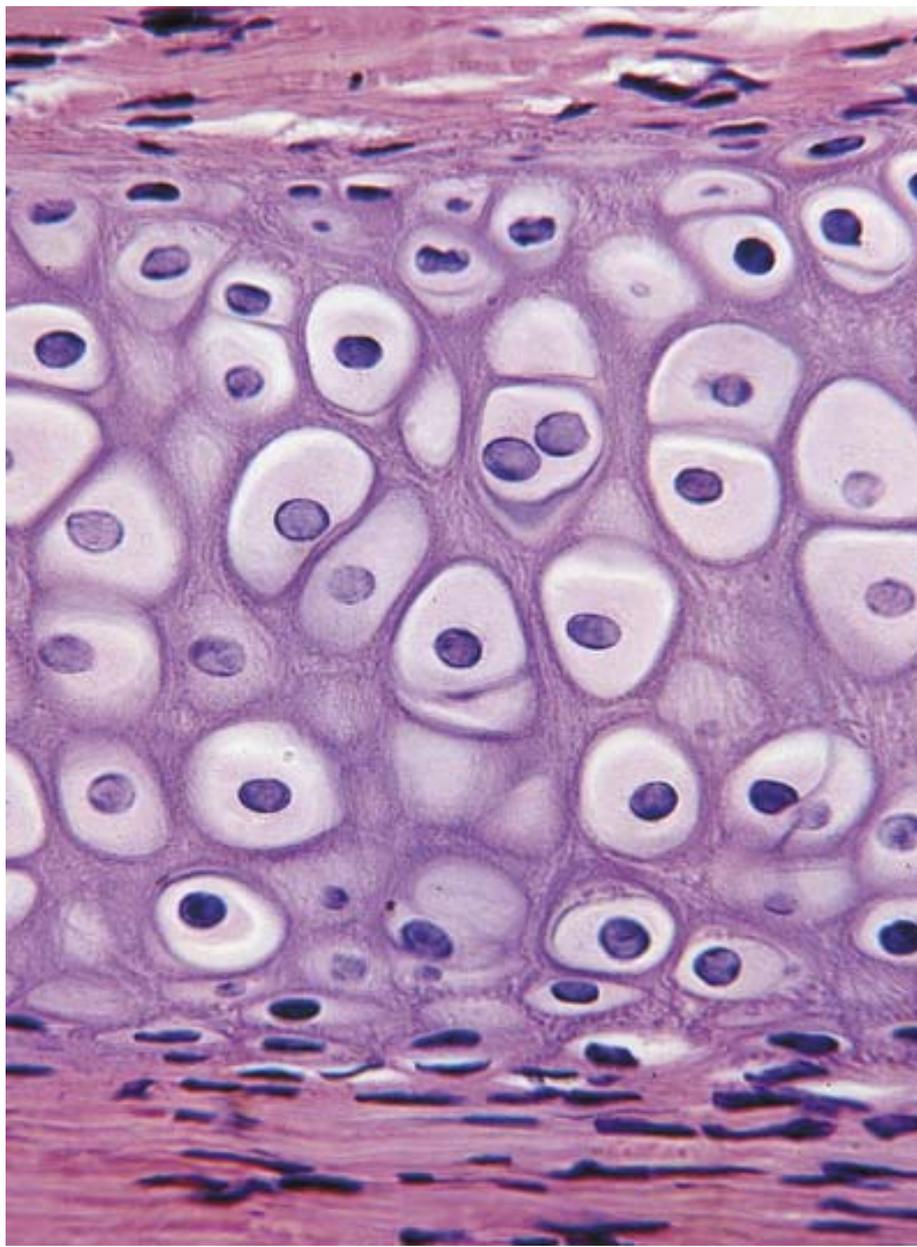
**分布：**胚胎早期：暂时骨架

成体：鼻、喉、气管的软骨、肋软骨、

关节软骨长骨的骺板

结构:

基质  
纤维  
软骨细胞  
软骨膜



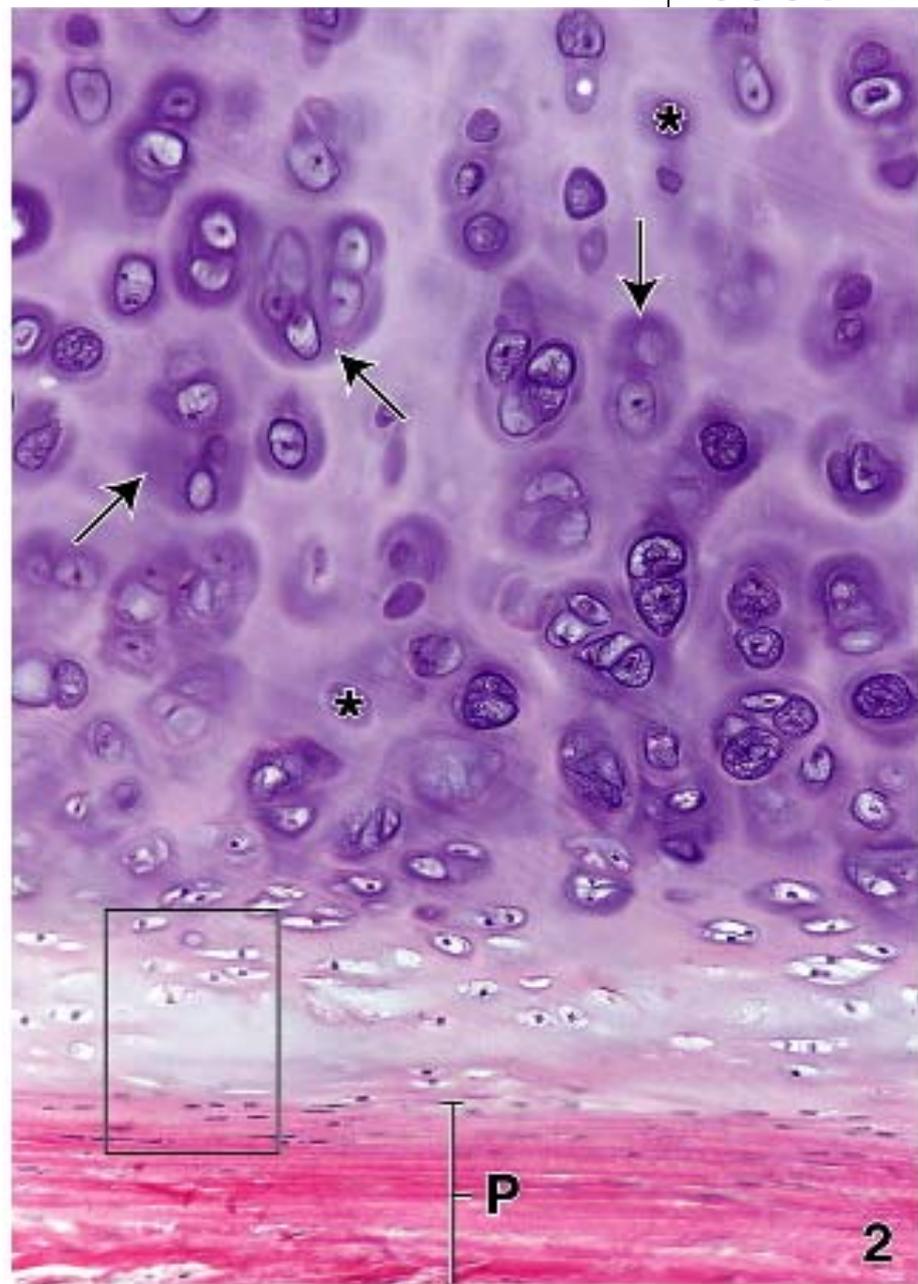


# 1. 软骨细胞 Chondrocyte

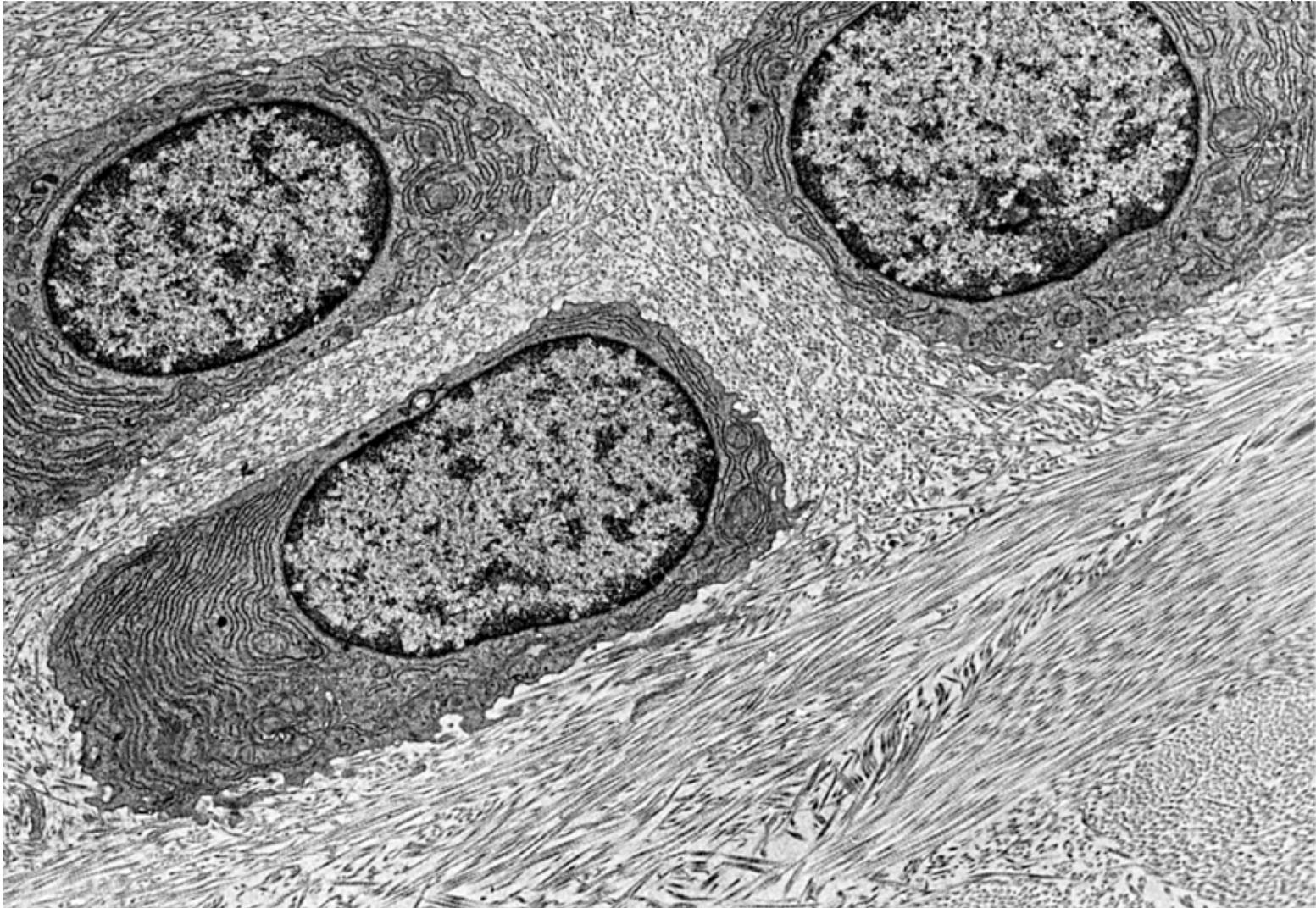
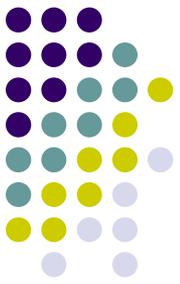
同源细胞群 (*isogenous group*)

软骨陷窝 (*cartilage lacuna*)

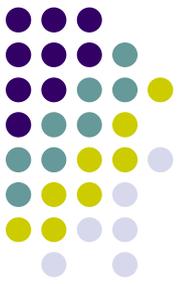
软骨囊 (*cartilage capsule*)



粗面内质网多，Golgi体发达。合成和分泌基质与纤维



**Chondroma; chondrosarcoma**



## 2. 基质 (Matrix)

蛋白多糖+水 (约占 75%)

(硫酸软骨素含量高 → 嗜碱性、异染性)

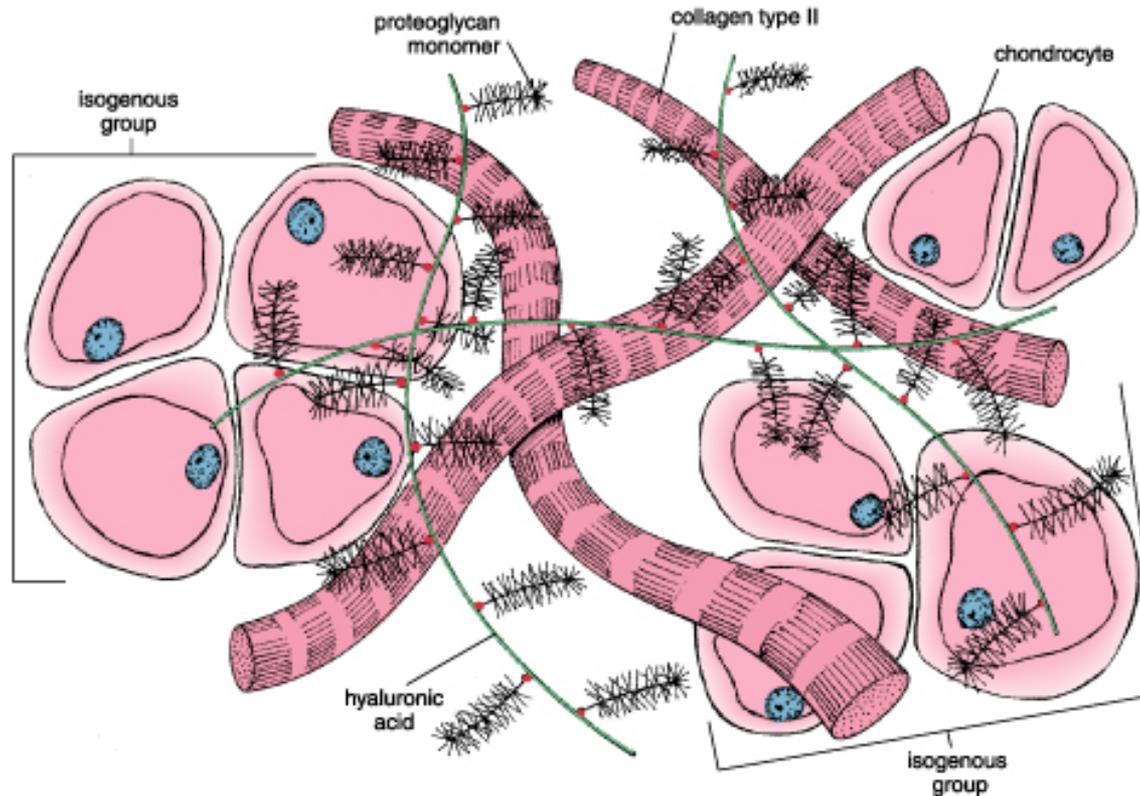


Figure 7.1. Molecular structure of the ground substance of hyaline cartilage.

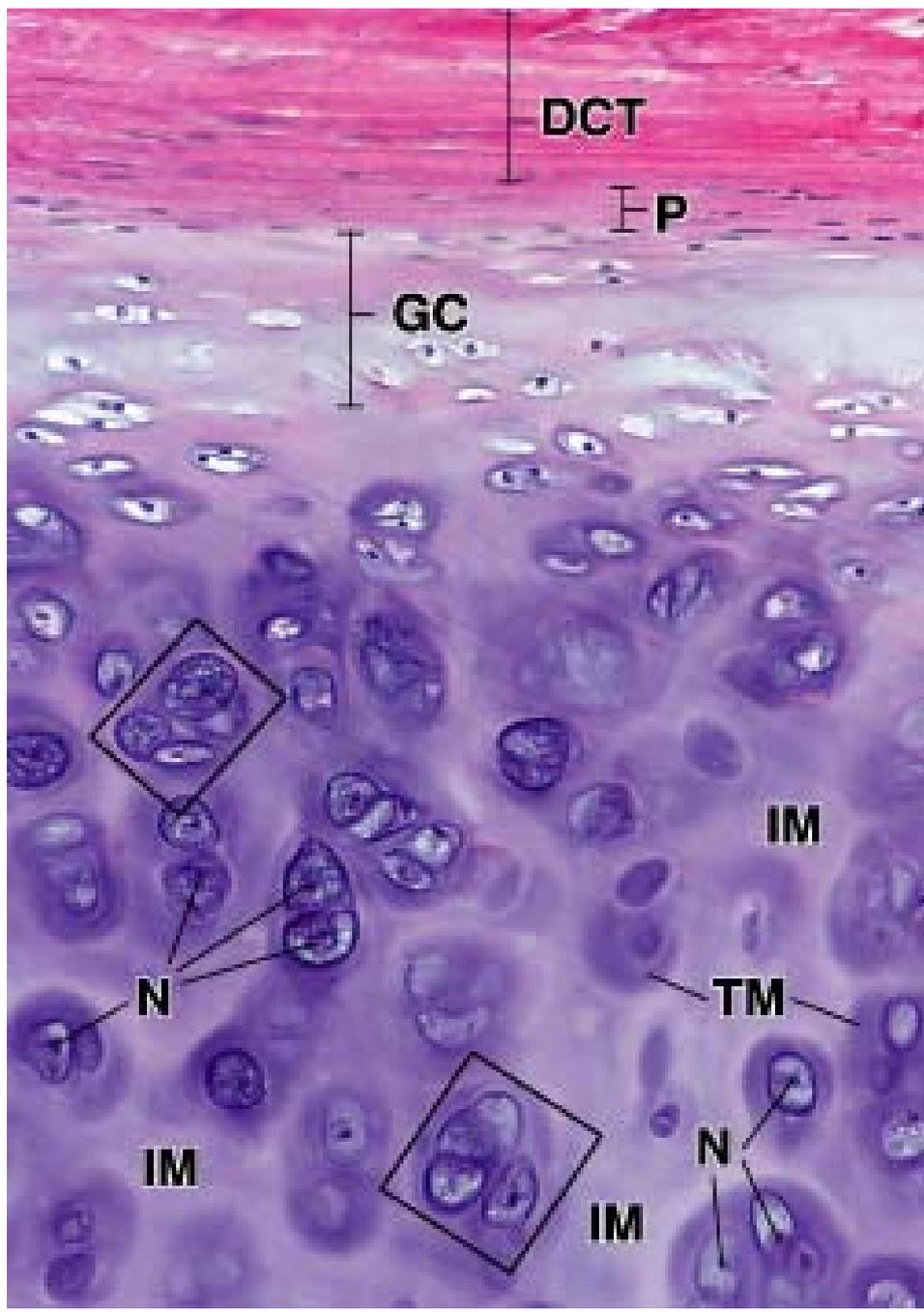


### 3. 软骨膜 (*perichondrium*)

致密结缔组织  
(关节软骨表面无)

- 外层: 致密; 纤维多, 细胞和血管少; 保护
- 内层: 疏松; 纤维少, 血管和细胞多
- 骨原细胞 (干细胞)

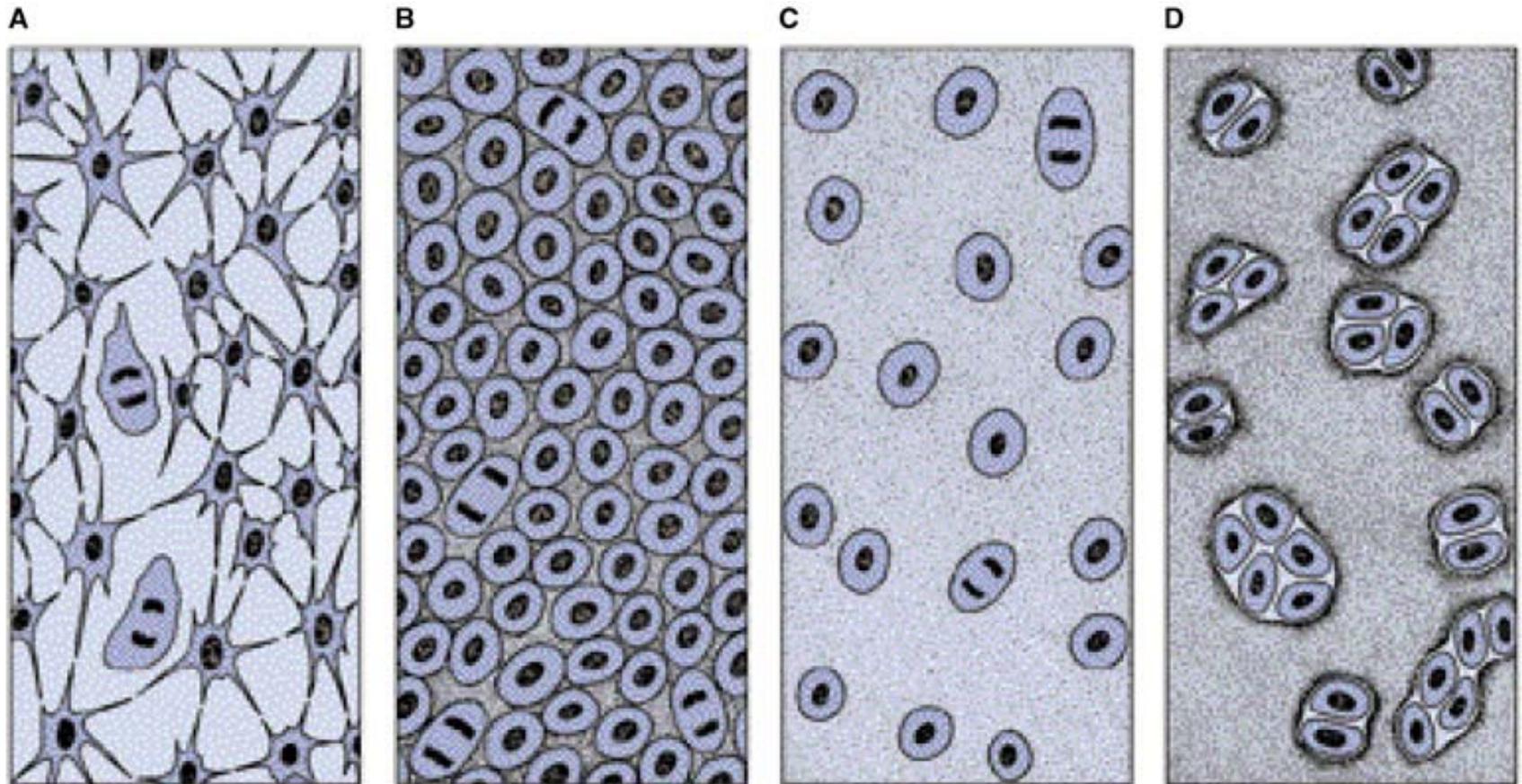
软骨组织内无血管, 软骨细胞通过基质与软骨膜内血管进行物质交换。

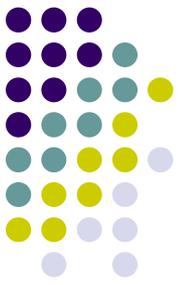




# 软骨的组织发生和生长

软骨来源于间充质





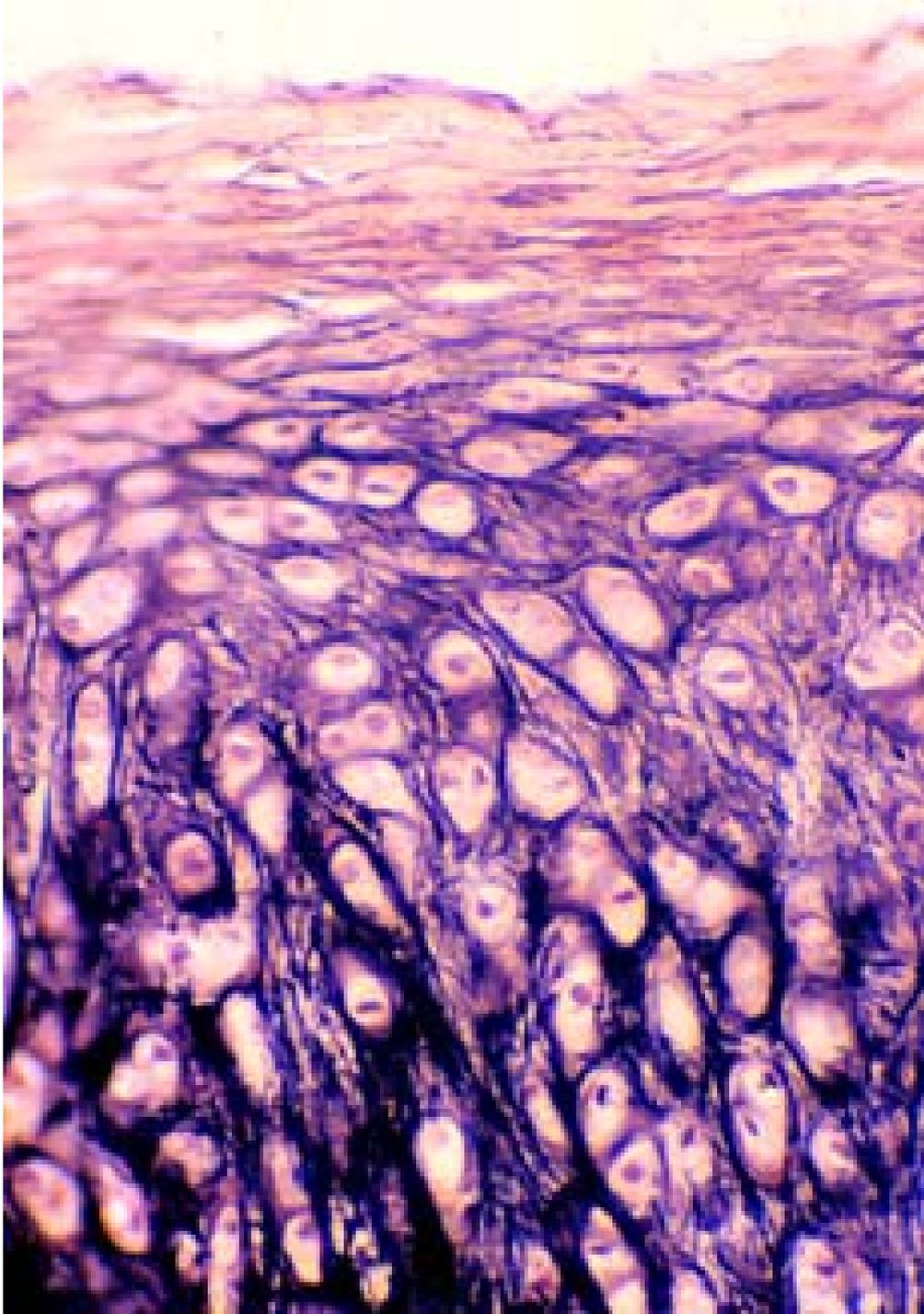
# 生长

## 附加生长 Appositional growth

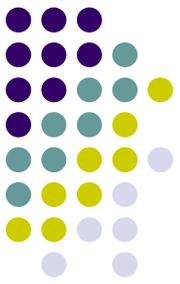
软骨膜内层骨原细胞 → 成软骨细胞 (附加在软骨组织表面分泌基质和纤维, 将自身埋于其中) → 软骨细胞

## 间质生长 Interstitial growth

软骨内部细胞分裂增殖 → 新的软骨细胞 → 新的基质和纤维



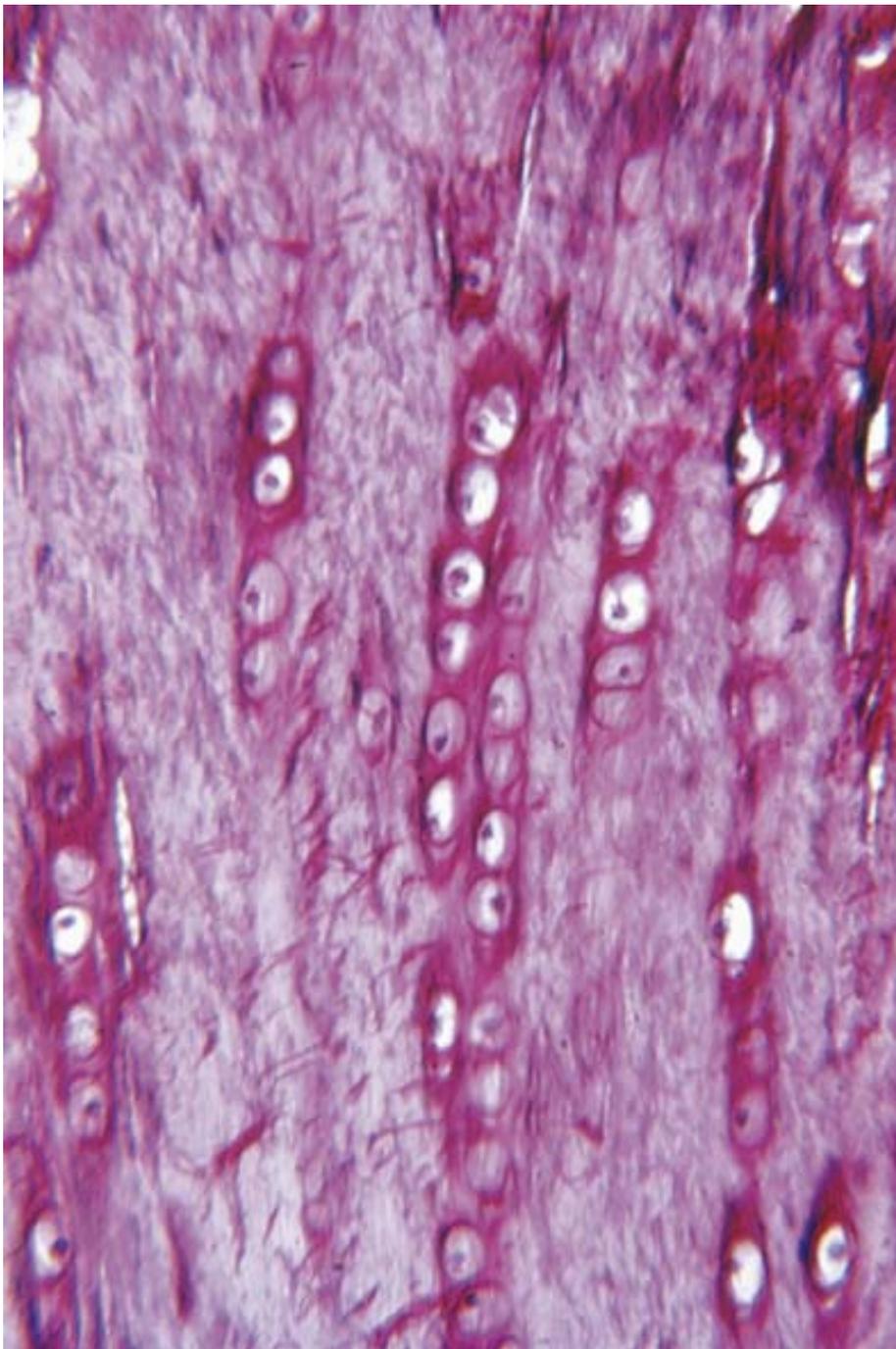
## (二)、弹性软骨 (*elastic cartilage*)



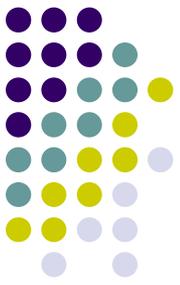
新鲜时呈黄色

分布：耳廓、咽鼓管、  
会厌

结构：间质含大量**弹性纤维**，互相交织成网，具有很大弹性。有软骨膜。



### (三)、纤维软骨 (*fibrous cartilage*)



**分布：**椎间盘、耻骨联合、  
关节盘

**结构：**间质多，细胞少。间质内含大量胶原纤维，纤维与基质的分布不均。细胞较小，散在分布。

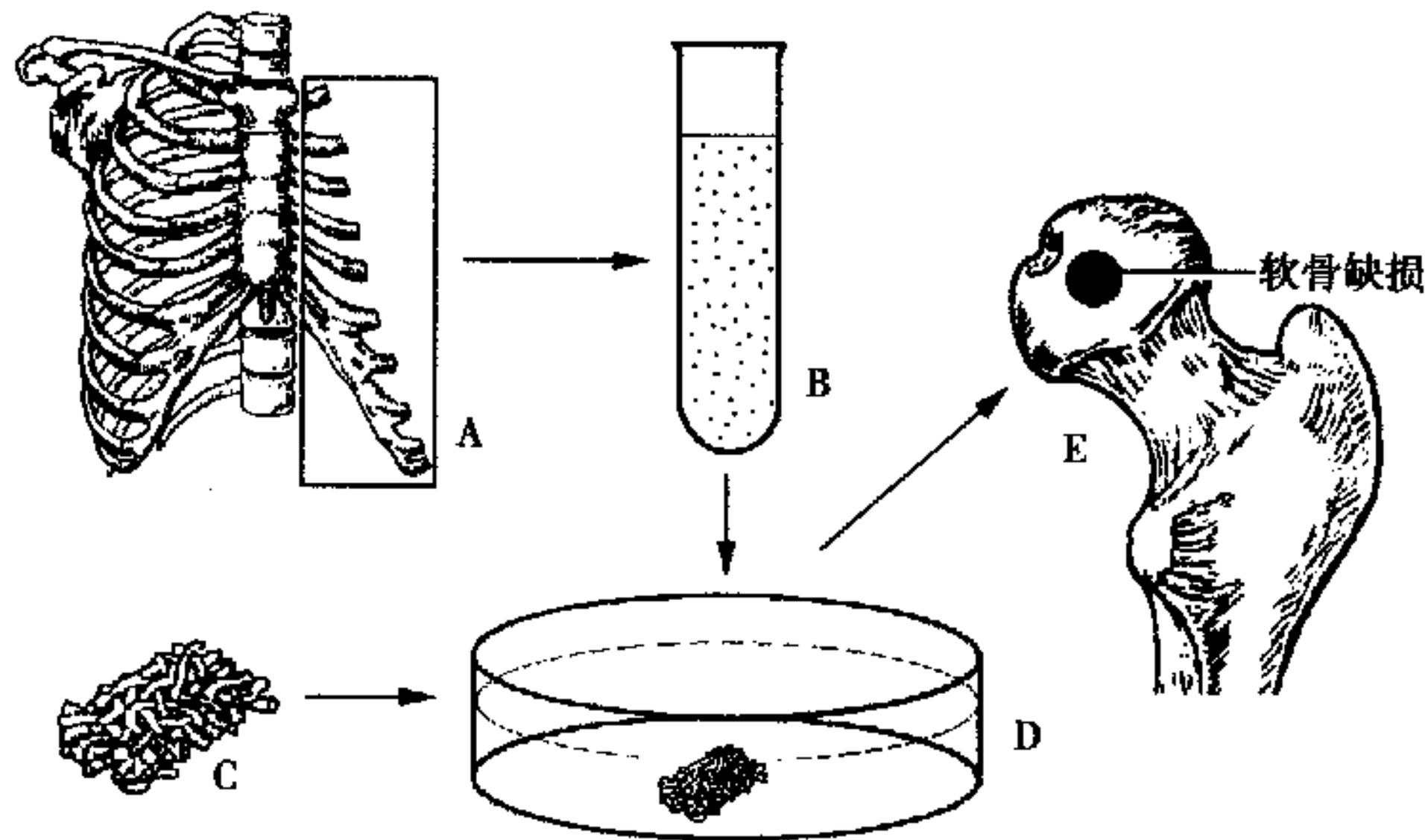


图 4-16 软骨组织工程的基本方法

A. 获取软骨 B. 分离、培养软骨细胞 C. 制备三维支架 D. 将软骨细胞种植于支架 E. 将细胞-支架复合物植入软骨缺损



## 二、骨 (*bone*)

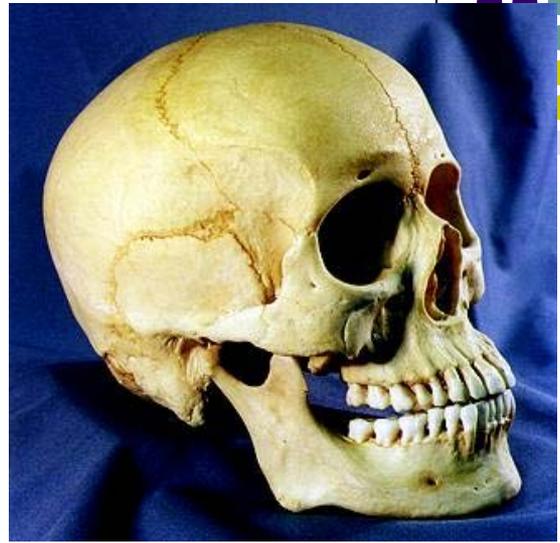
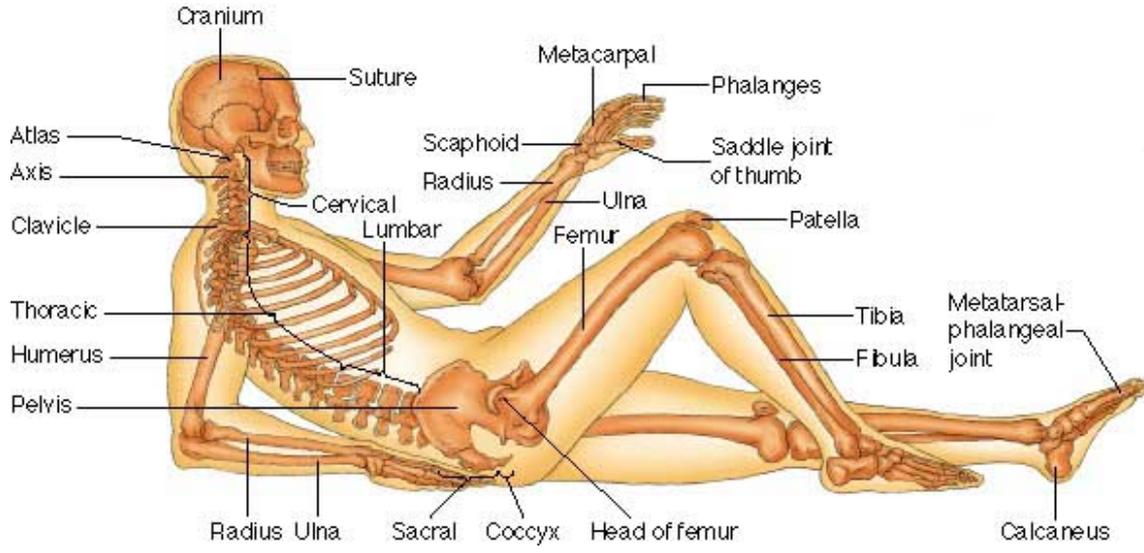
由骨组织、骨膜、骨髓、关节软骨构成

(一) 骨组织 (*osseous tissue*)

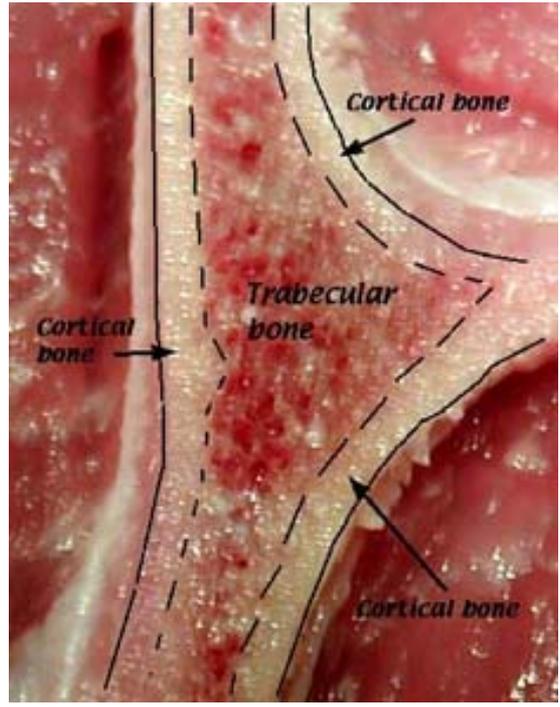
(二) 长骨的结构

(三) 骨的发生

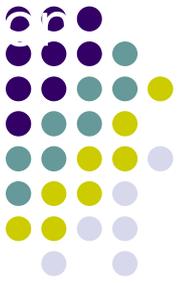
(四) 影响骨的生长因素



功能 { 支持  
保护  
储存

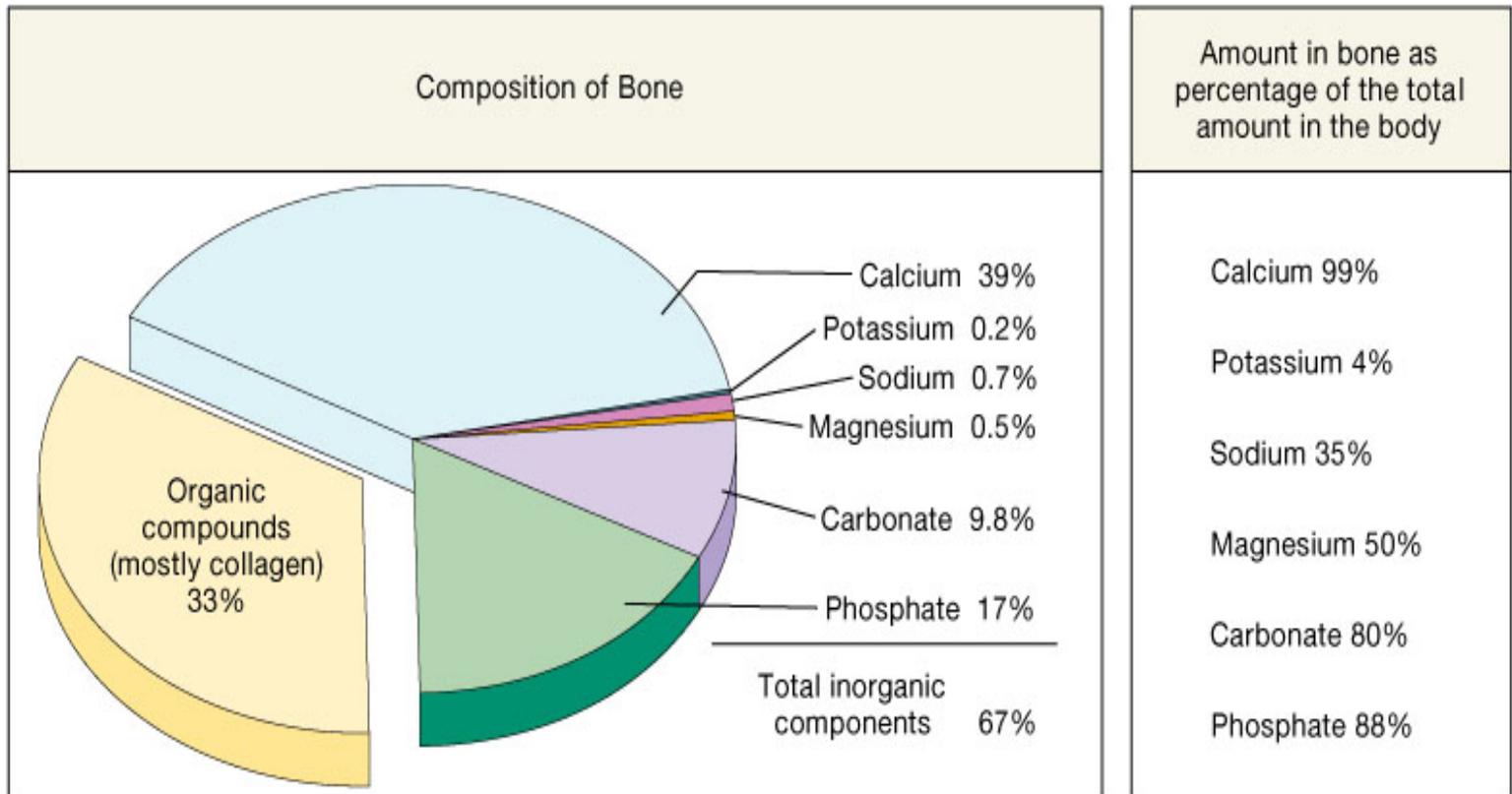


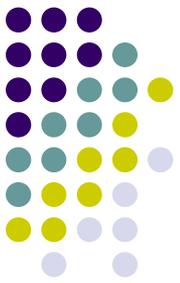
# (一)、骨组织 (*osseous tissue*)



1. 骨基质 (*bone matrix*): 钙化的细胞间质

2. 细胞: 骨细胞、骨原细胞、成骨细胞、破骨细胞





# 1. 基质

- 有机物 35%

{ I型胶原蛋白构成的胶原纤维: 95%  
无定型基质: 5%

- 无机物 65%

羟基磷灰石结晶 *hydroxyapatite crystal*,  
[Ca10(PO4)6(OH)2]

骨板 (bone lamella)

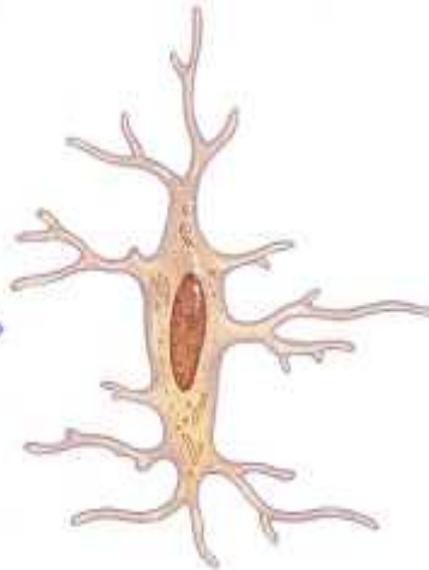
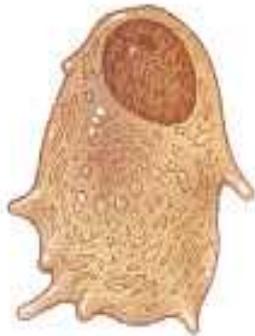


# 2. 细胞

骨源细胞 成骨细胞

骨细胞

破骨细胞

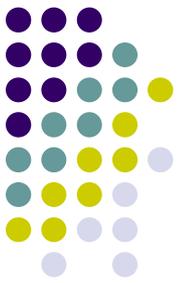


Osteogenic cell  
(develops into an  
osteoblast)

Osteoblast  
(forms bone  
tissue)

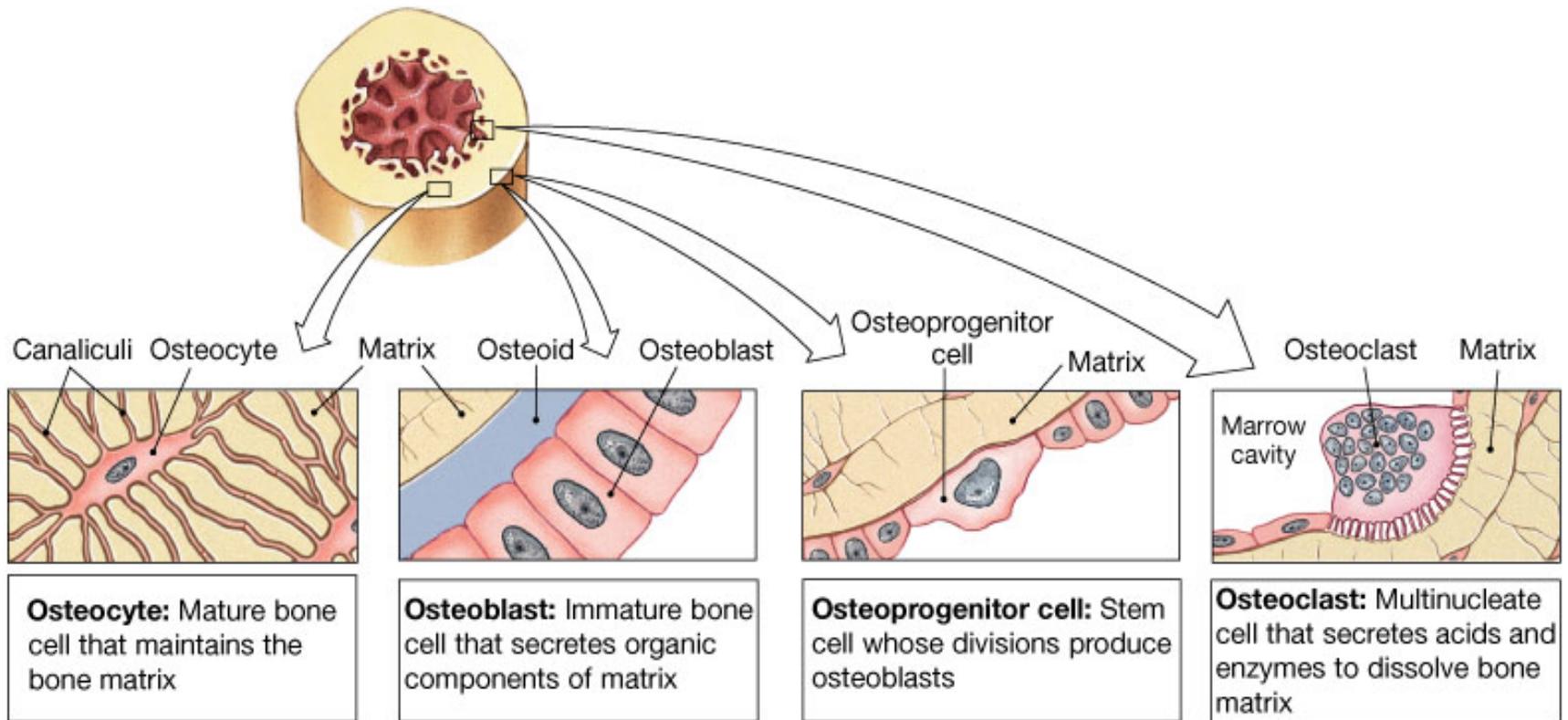
Osteocyte  
(maintains  
bone tissue)

Osteoclast  
(functions in resorption, the  
destruction of bone matrix)



# (1) 骨源细胞 osteoprogenitor cell

- 存在于骨的内外表面
- 可分裂形成成骨细胞



(a) Cells of bone



## (2)成骨细胞 osteoblast

位于骨组织边缘，分泌有机物合成类骨质，  
释放基质小泡钙化类骨质。

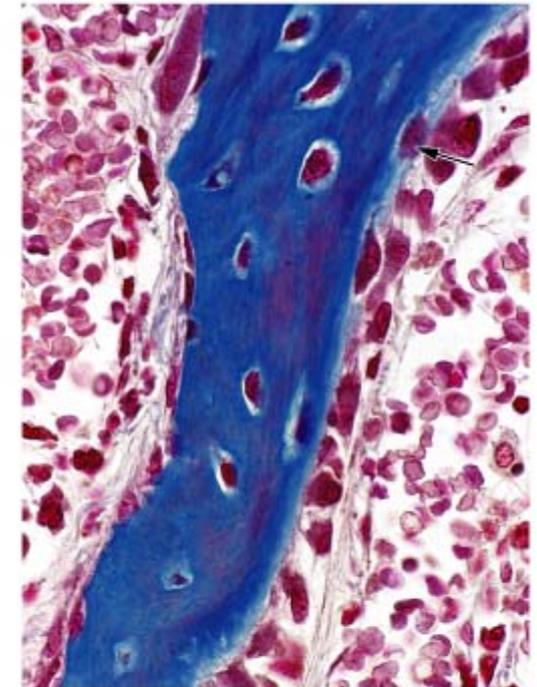
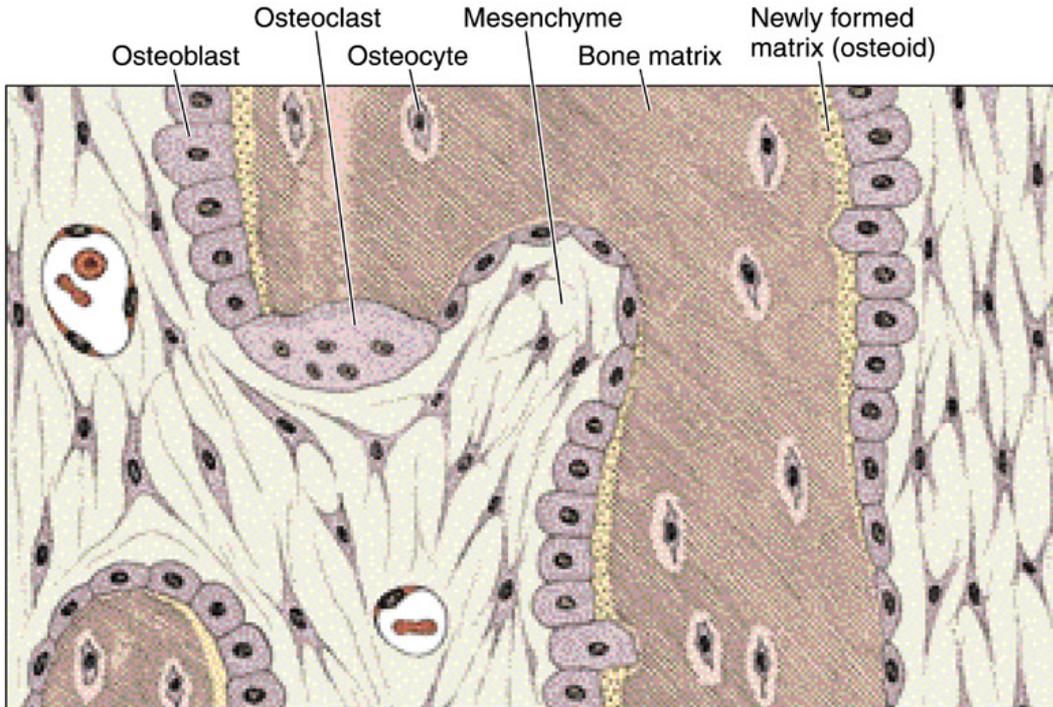
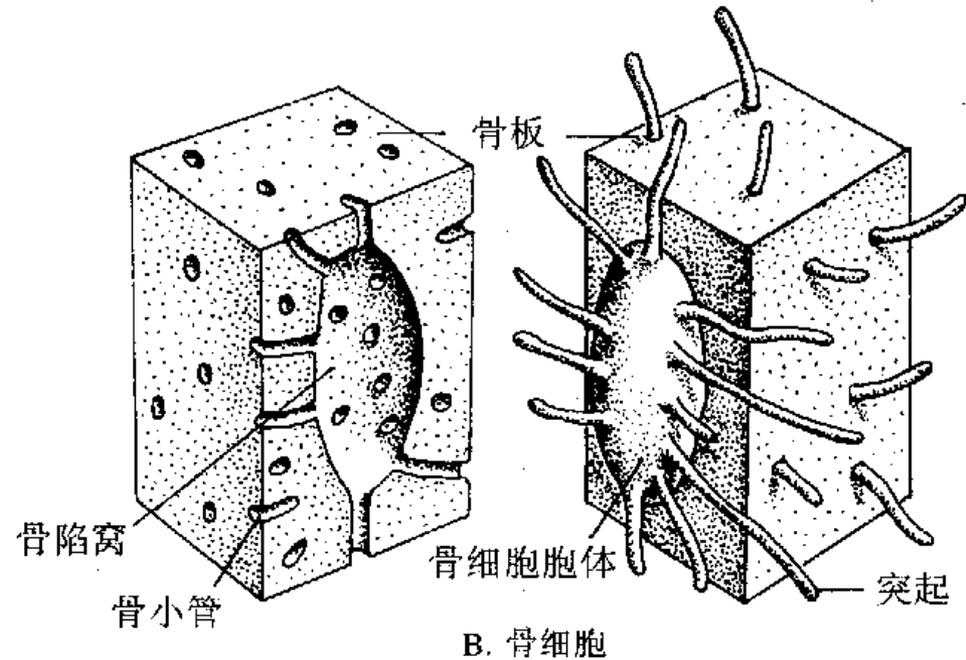
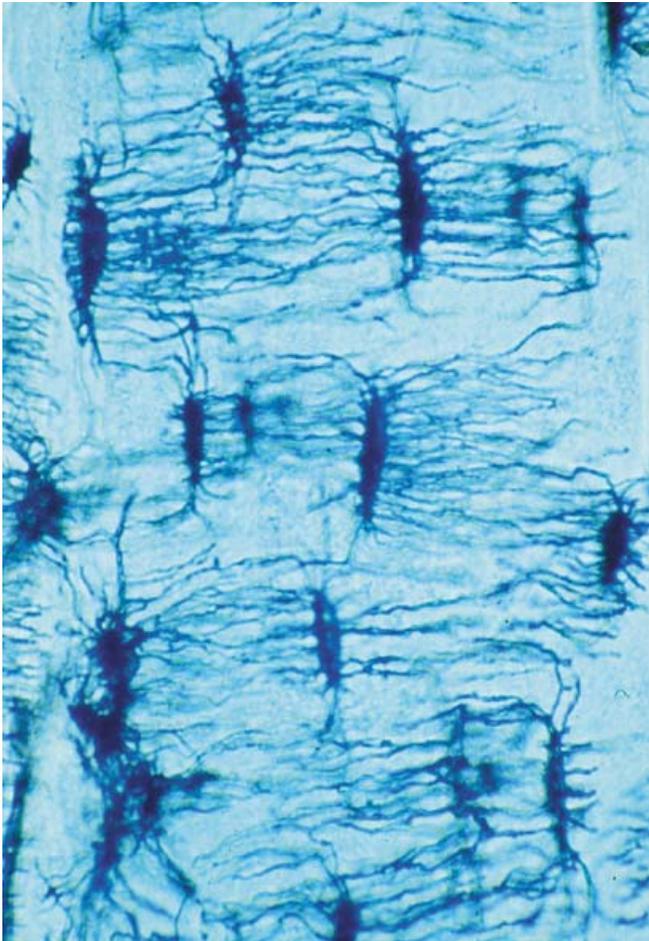


Figure 8.8. Photomicrograph of growing bone spicules stained with Mallory-Azan. X550.

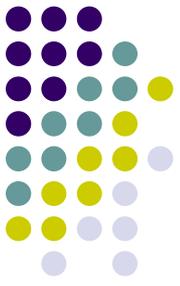
### (3)骨细胞 osteocyte



夹在相邻两层骨板间或分散排列于骨板内。  
扁椭圆形，突起细长，核扁圆、胞质弱嗜碱性。相邻骨细胞突起之间有缝隙连接。



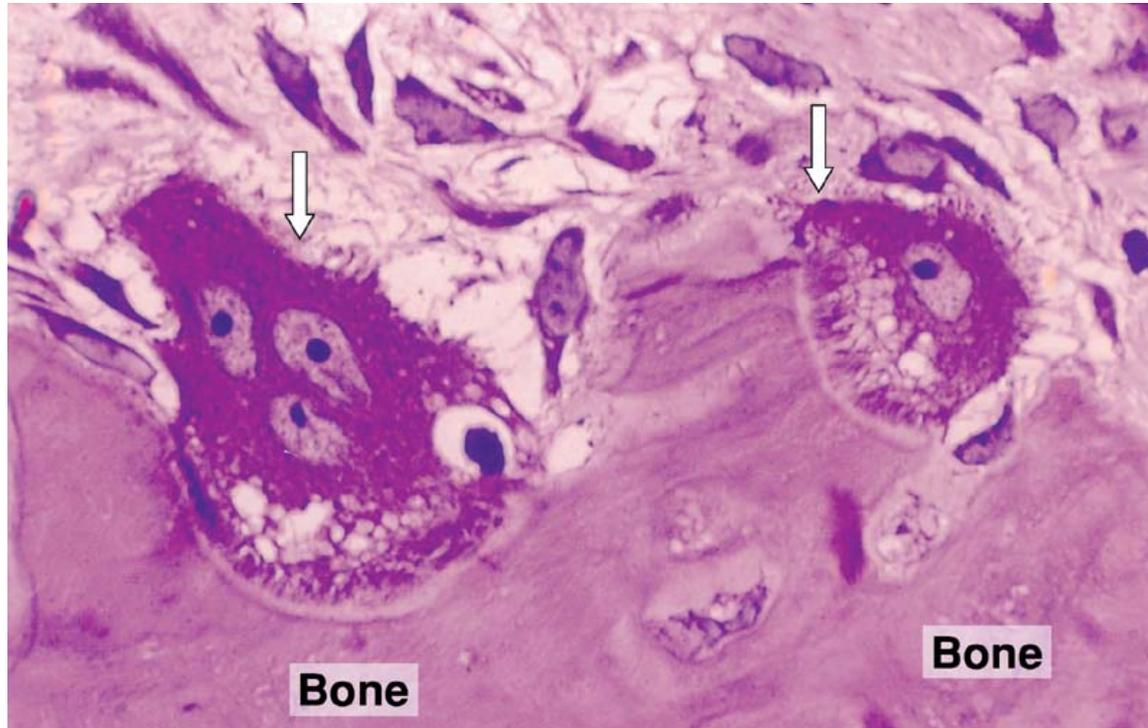
{ 骨陷窝 bone Lacuna  
骨小管 bone Canaliculi

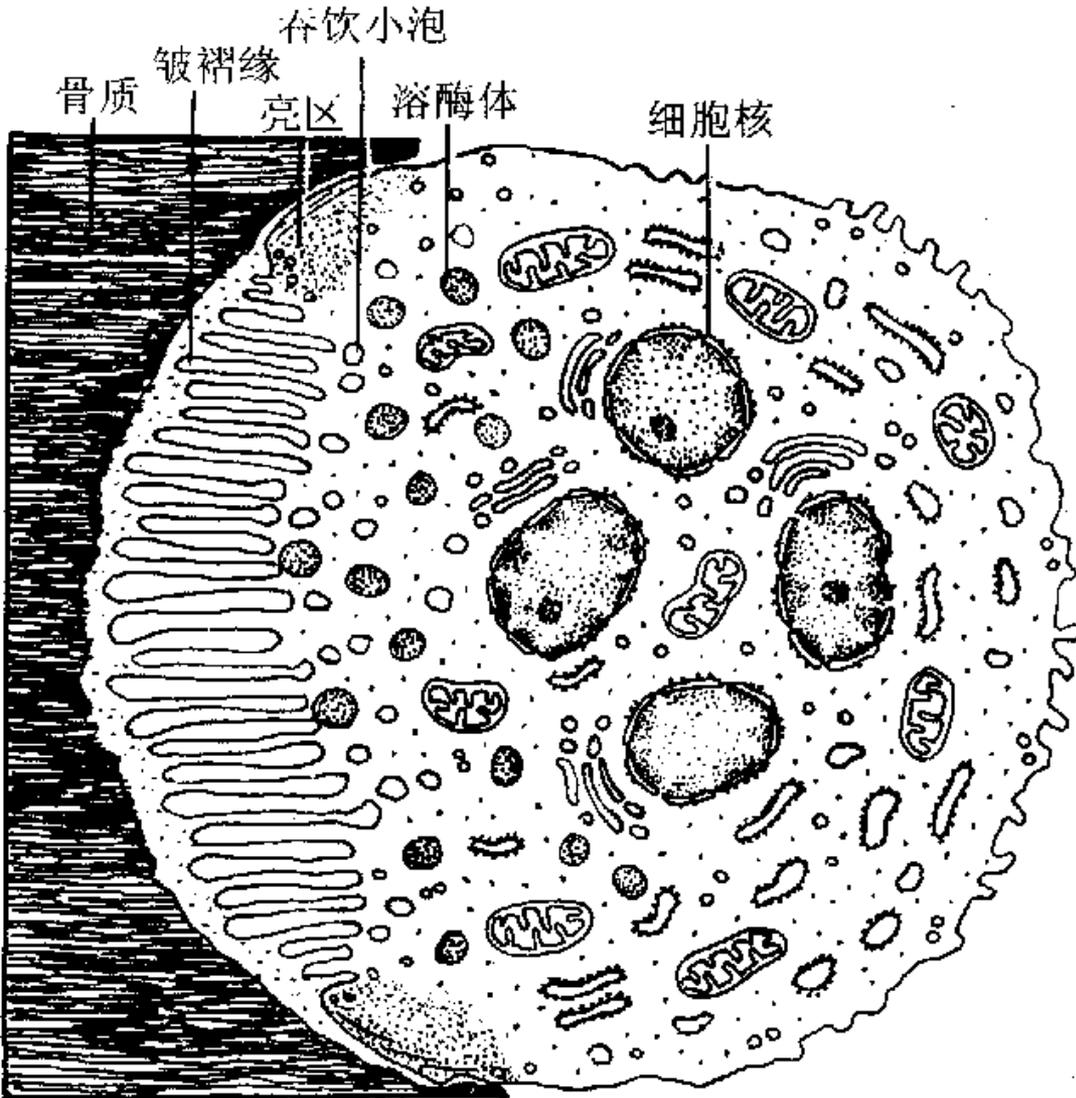


## (4) 破骨细胞 osteoclast

多核巨细胞（由多个单核细胞融合而成）

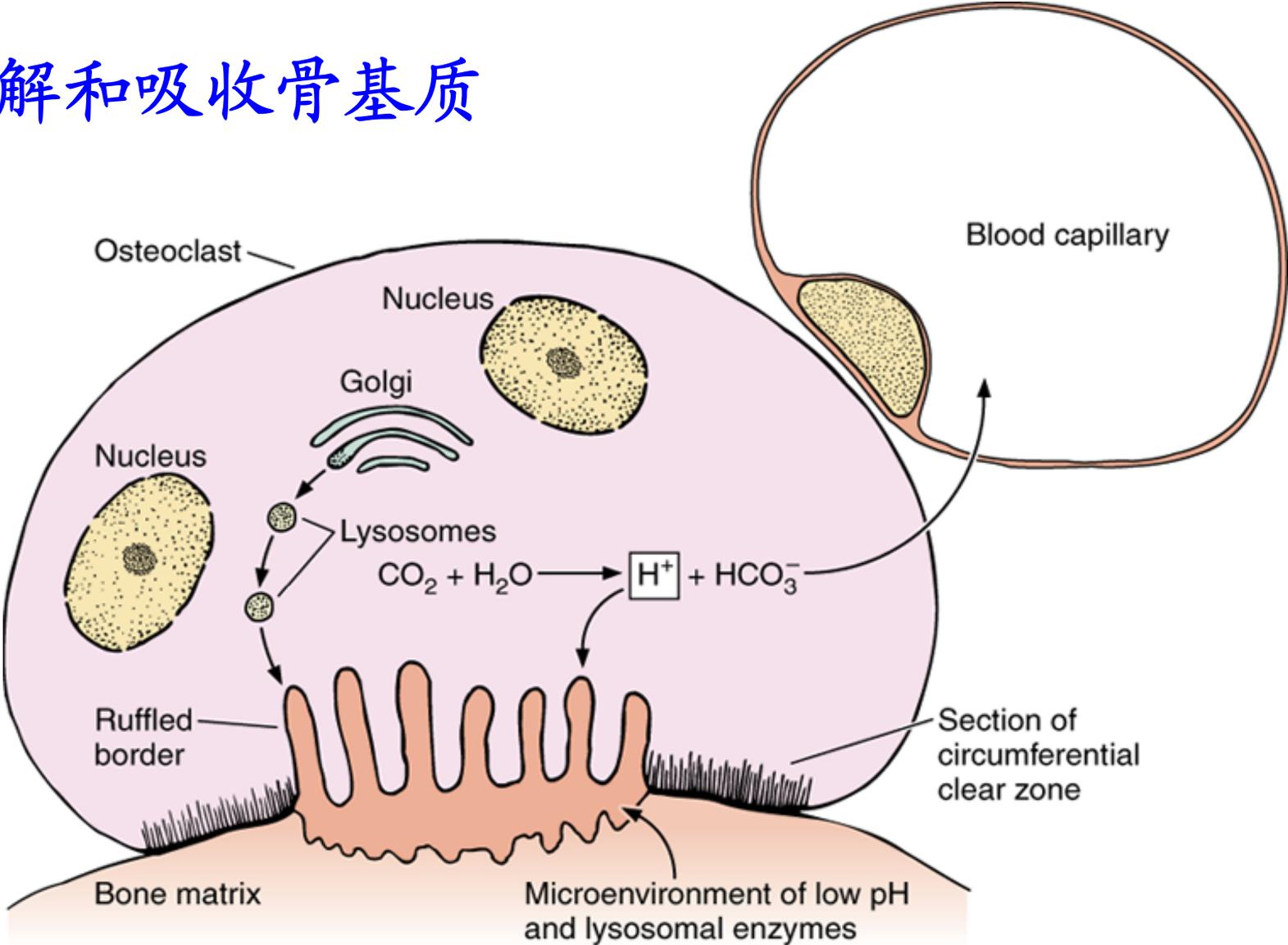
光镜：位于骨组织被吸收部位的陷窝内，多核，胞质嗜酸性，贴近骨基质的一侧有**纹状缘**



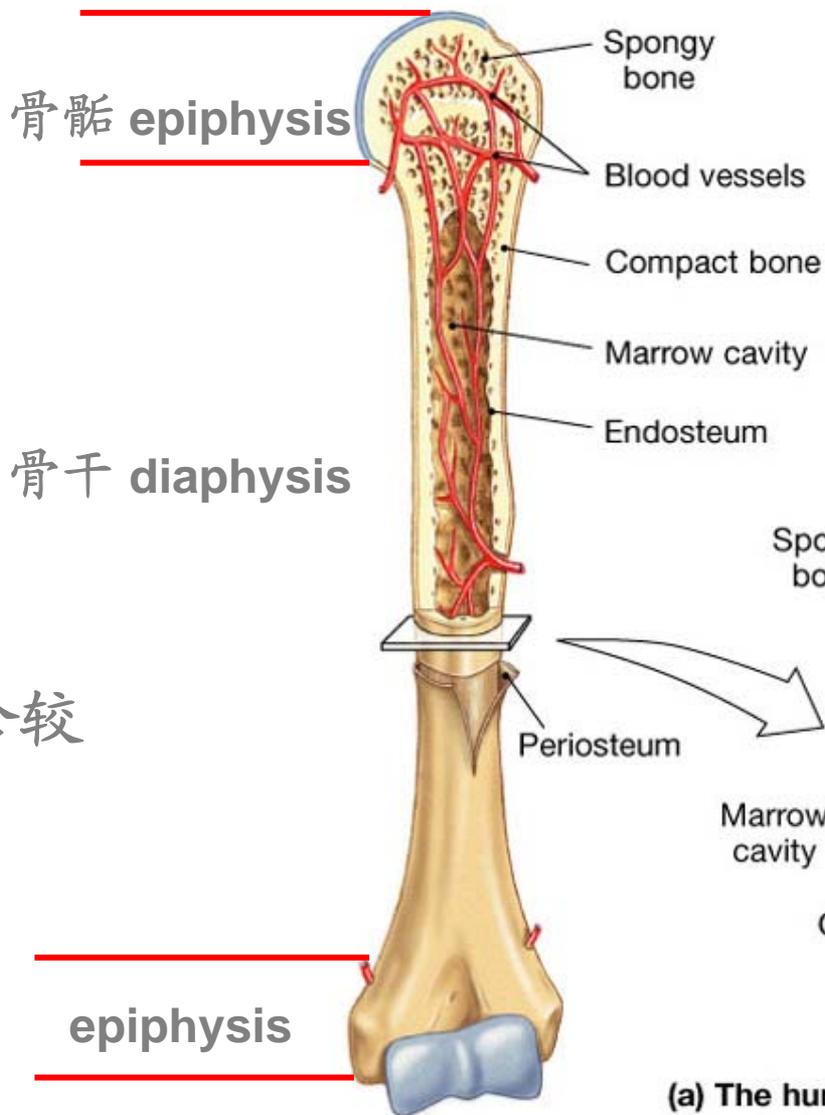


电镜:  
**皱褶缘 (ruffled border)**: 高而密集的微绒毛。  
**亮区 (clear zone)**: 皱褶缘周围的环形胞质区。

# 溶解和吸收骨基质



## (二)、长骨的结构



骨骺 epiphysis

Spongy bone

Blood vessels

Compact bone

Marrow cavity

Endosteum

骨干 diaphysis

骨松质

Spongy bone

Periosteum

Marrow cavity

Compact bone

骨密质

epiphysis

(a) The humerus

(1) 骨外膜

(*periosteum*):

外层

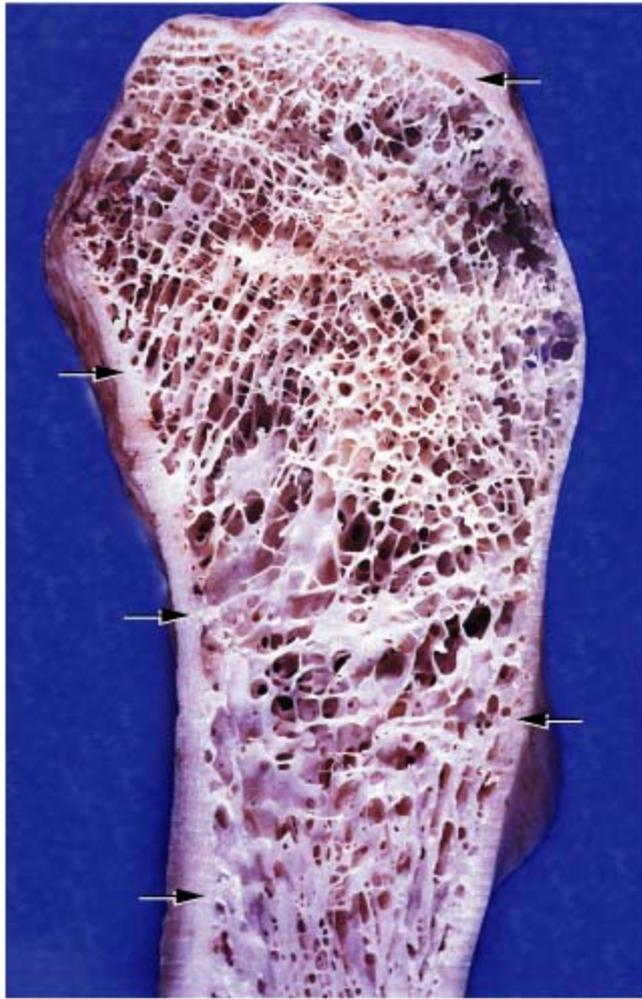
内层

(2) 骨内膜

(*endosteum*):

含较多的骨原细胞

含较

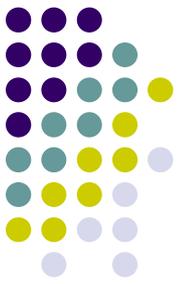
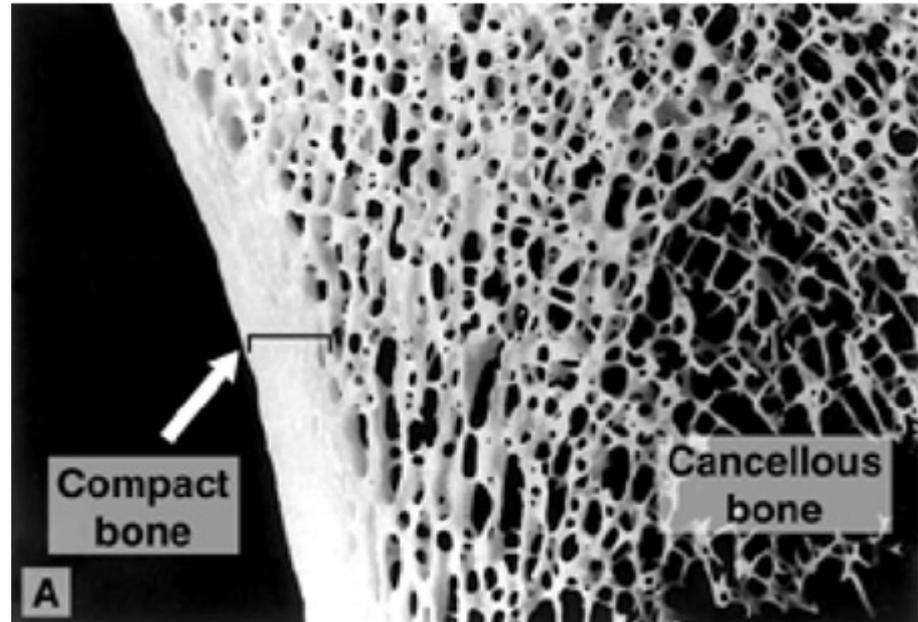


## 骨密质 Compact bone

- 骨干和骨骺的外侧
- 分为环骨板、骨单位和间骨板。

## 骨松质 Spongy bone

- 骨干和骨骺的内侧面
- 骨小梁相互连接成多孔网架。



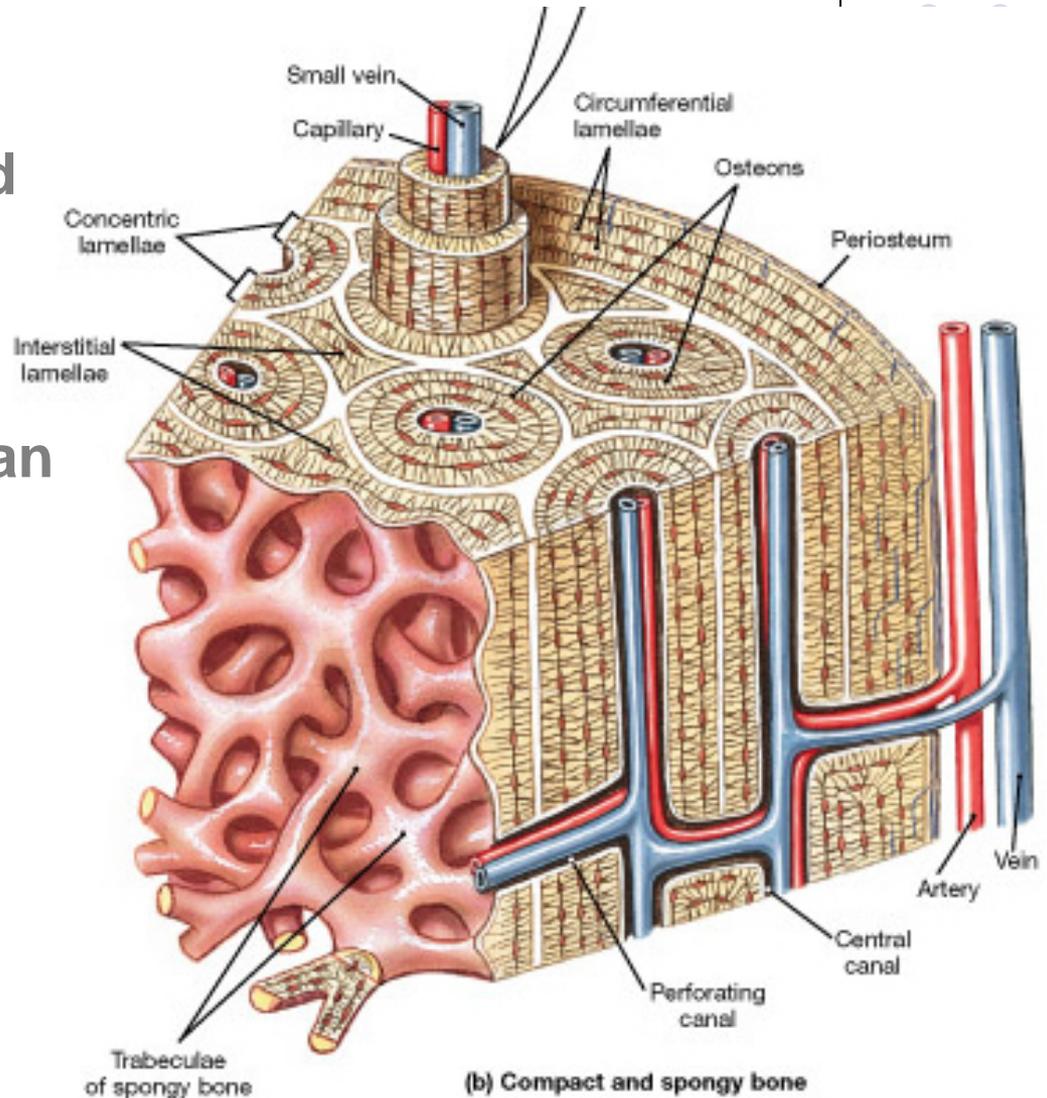
# 骨密质

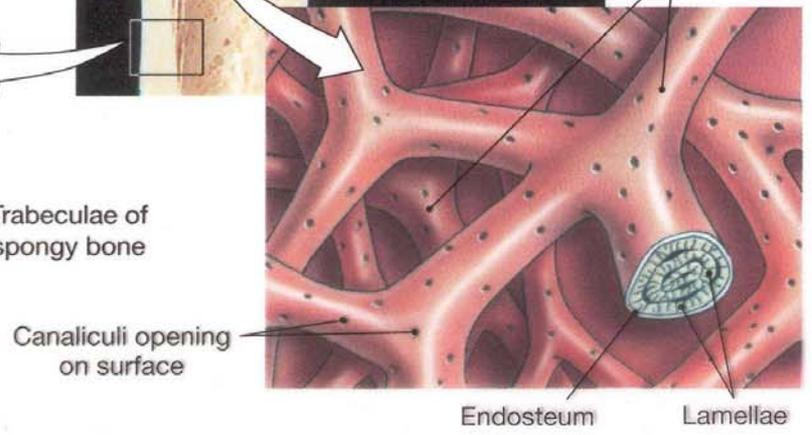
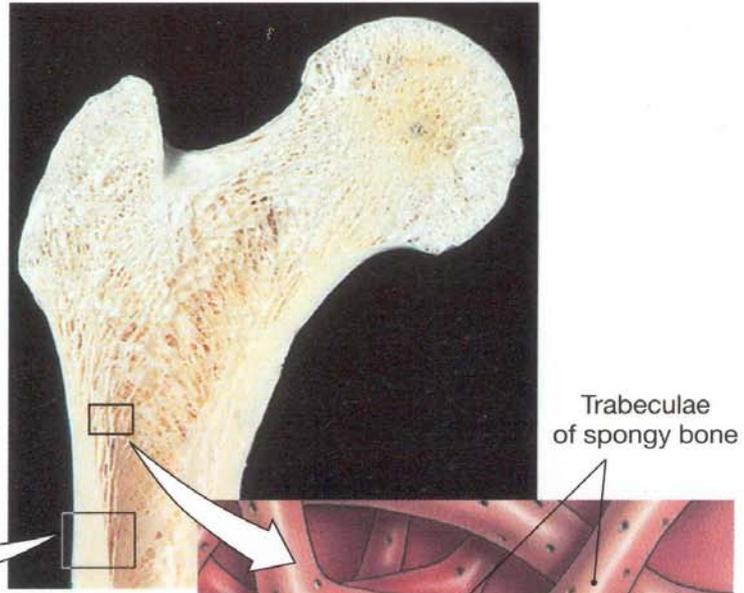
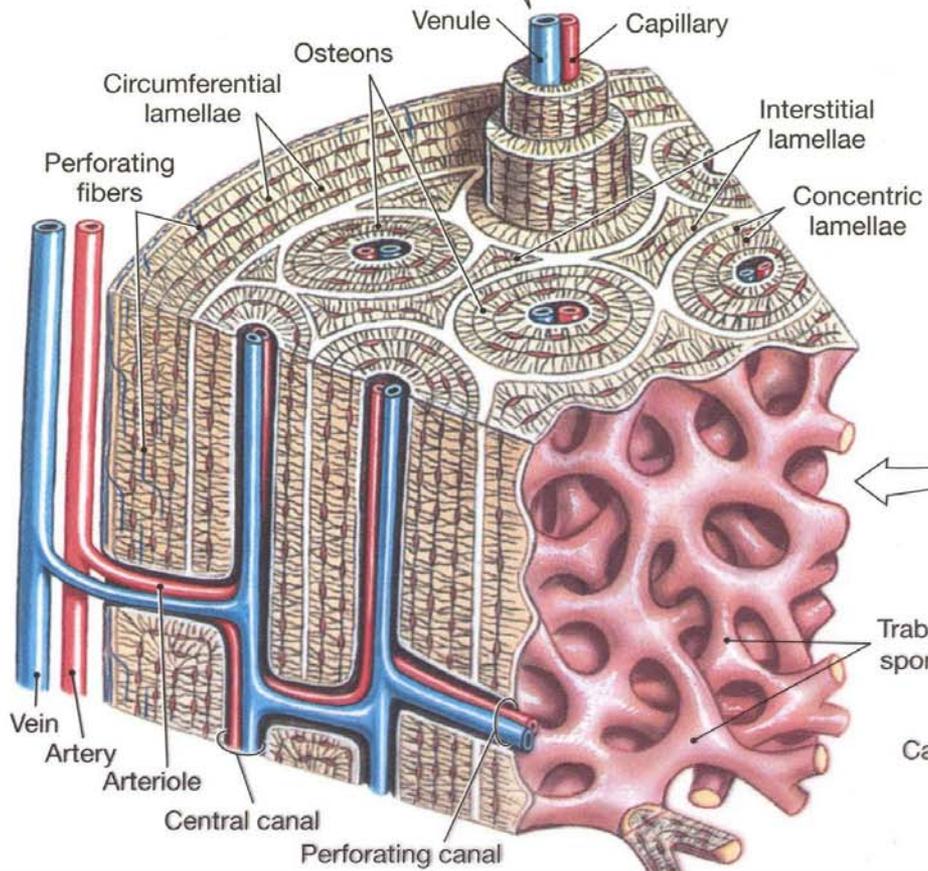
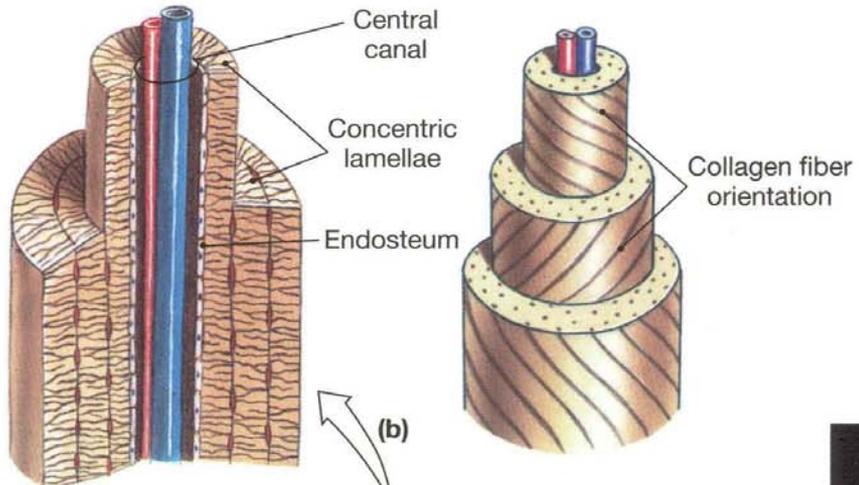


(1) 内、外环骨板(inner and outer circumferential lamella)

(2) 骨单位(osteon; Haversian system)

(3) 间骨板 ( interstitial lamella )

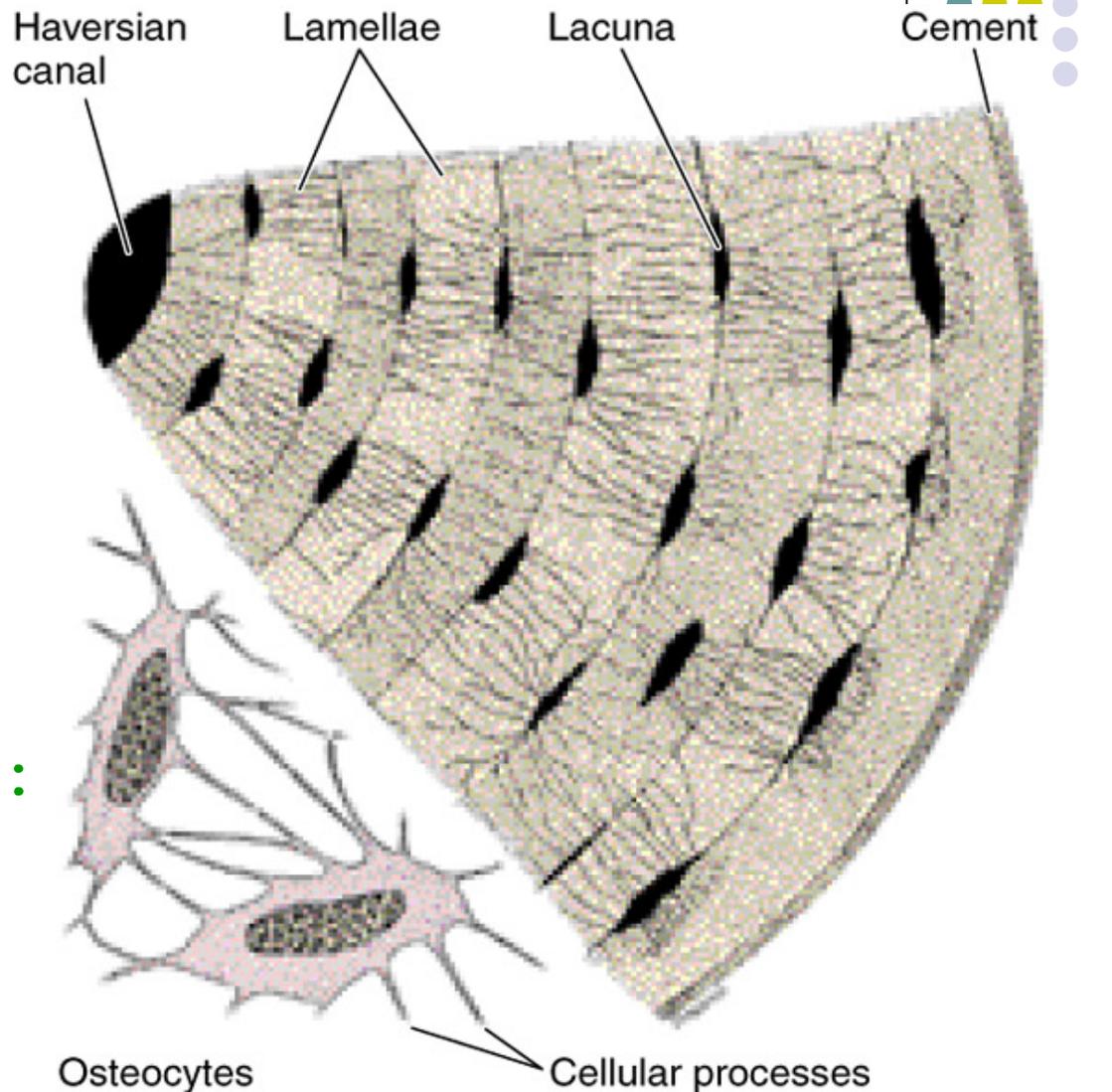


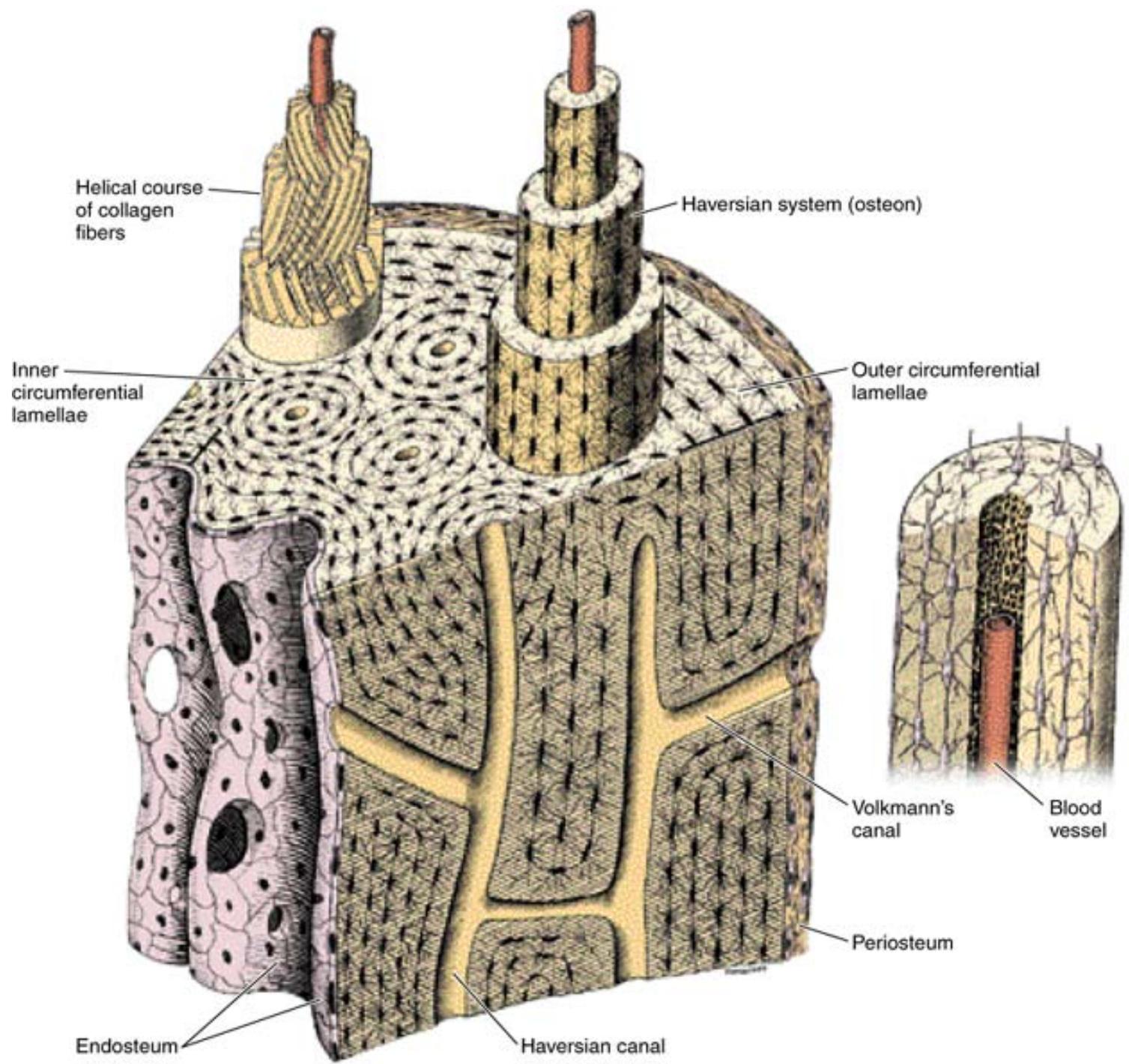


# 骨单位 osteon

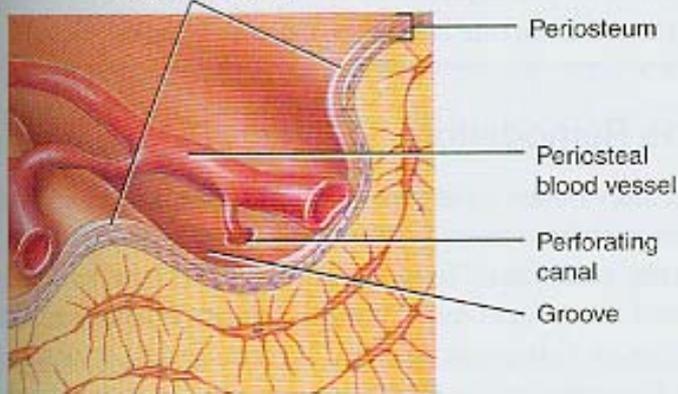
位于内、外环骨板之间，  
构成长骨干的结构单位。

**中央管 (central canal;  
Haversian 管):** 纵行  
**骨单位骨板 (osteon  
lamella; Haversian 骨板):**  
同心圆排列

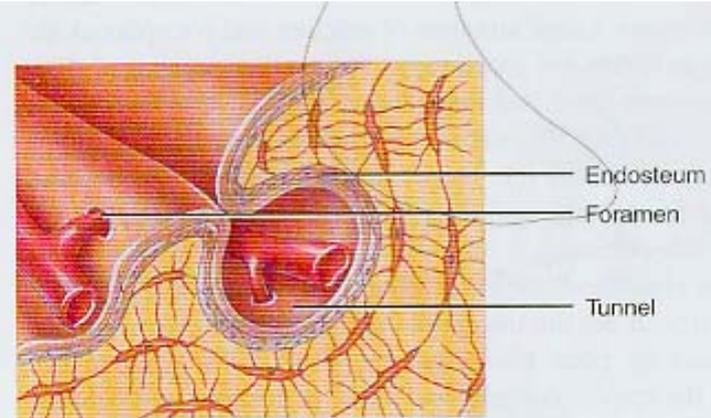




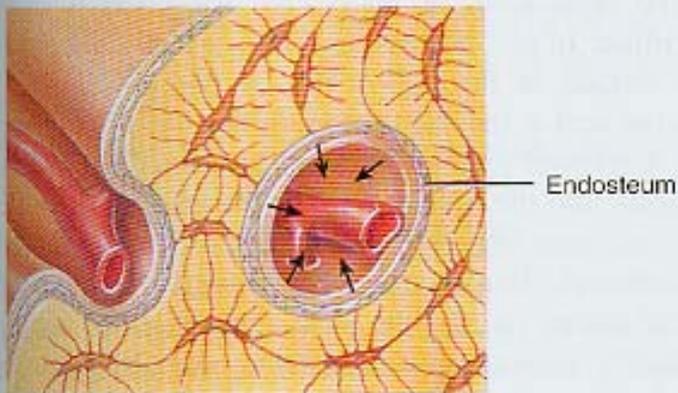
# 骨单位的形成



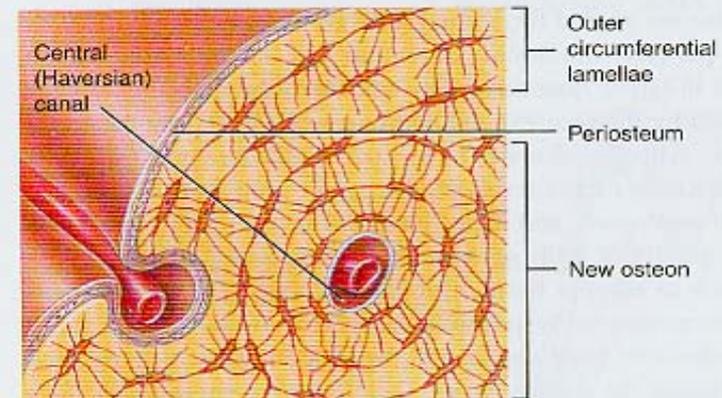
- 1 Ridges in periosteum create groove for periosteal blood vessel.



- 2 Periosteal ridges fuse, forming an endosteum-lined tunnel.



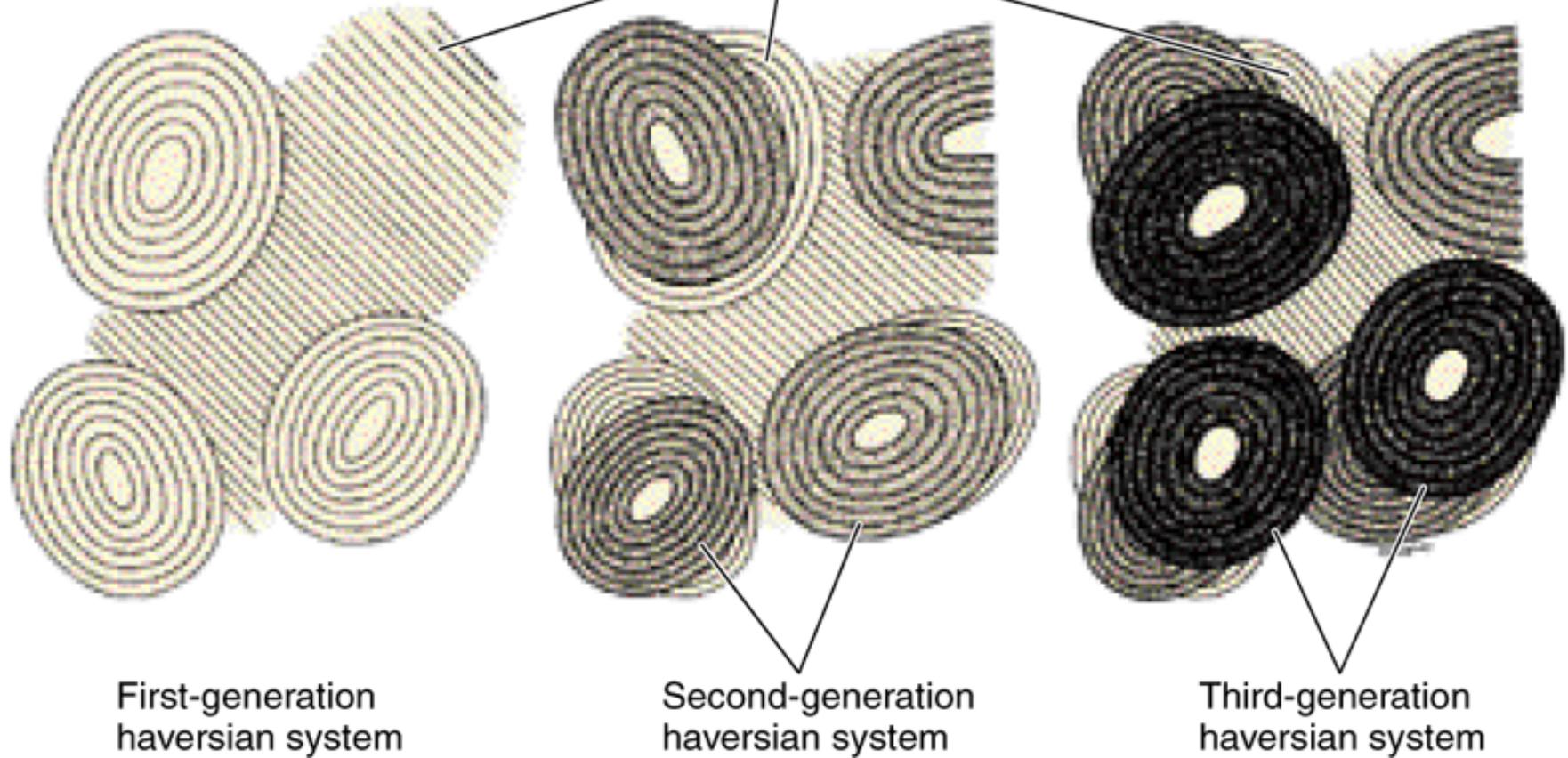
- 3 Osteoblasts in endosteum build new concentric lamellae inward toward center of tunnel, forming a new osteon.



- 4 Bone grows outward as osteoblasts in periosteum build new outer circumferential lamellae. Osteon formation repeats as new periosteal ridges fold over blood vessels.



Intermediate, or  
interstitial, lamellae



First-generation  
haversian system

Second-generation  
haversian system

Third-generation  
haversian system

**Figure 8–12.** Schematic view of diaphyseal bone remodeling. Three generations of Haversian systems are shown. At right, the contribution of first and second generation Haversian systems to the formation of intermediate or interstitial systems can be seen.

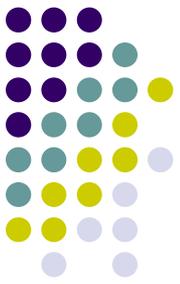
## (三)、骨发生 (*osteogenesis*)

由胚胎时期的间充质发生

- 1. 膜内成骨 (*intramembranous osteogenesis*)  
顶骨、额骨、锁骨
- 2. 软骨内成骨 (*cartilagenous osteogenesis*)

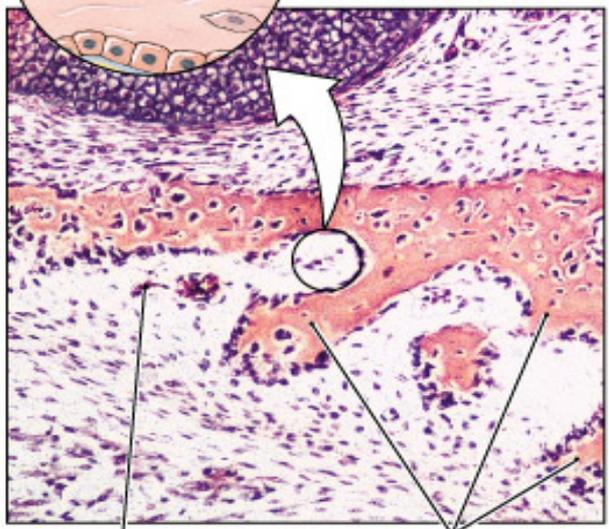
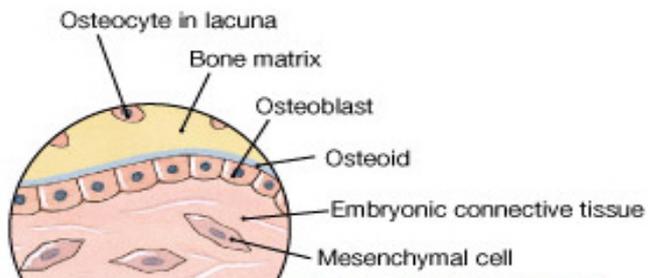
四肢骨、躯干骨、部分颅底骨

- (1) 软骨雏形的建立
- (2) 软骨周骨化
- (3) 软骨内骨化
- (4) 次级骨化中心的出现和骺板形成
- (5) 骨的生长和改建





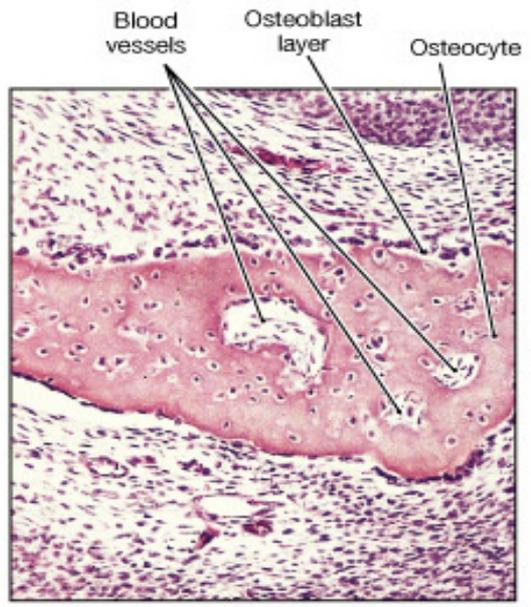
# 1. 膜内成骨



Blood vessel      Spicules

**Step 1:** Mesenchymal cells aggregate, differentiate into osteoblasts, and begin the ossification process. The bone expands as a series of spicules that spread into surrounding tissues. (LM × 32)

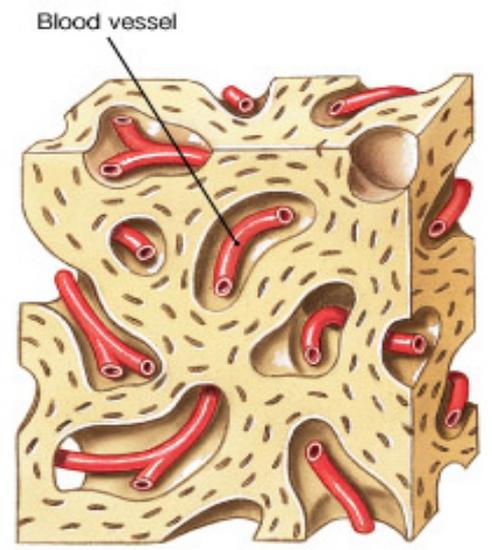
骨化中心



Blood vessels      Osteoblast layer      Osteocyte

**Step 2:** As the spicules interconnect, they trap blood vessels within the bone. (LM × 32)

骨小梁包入血管

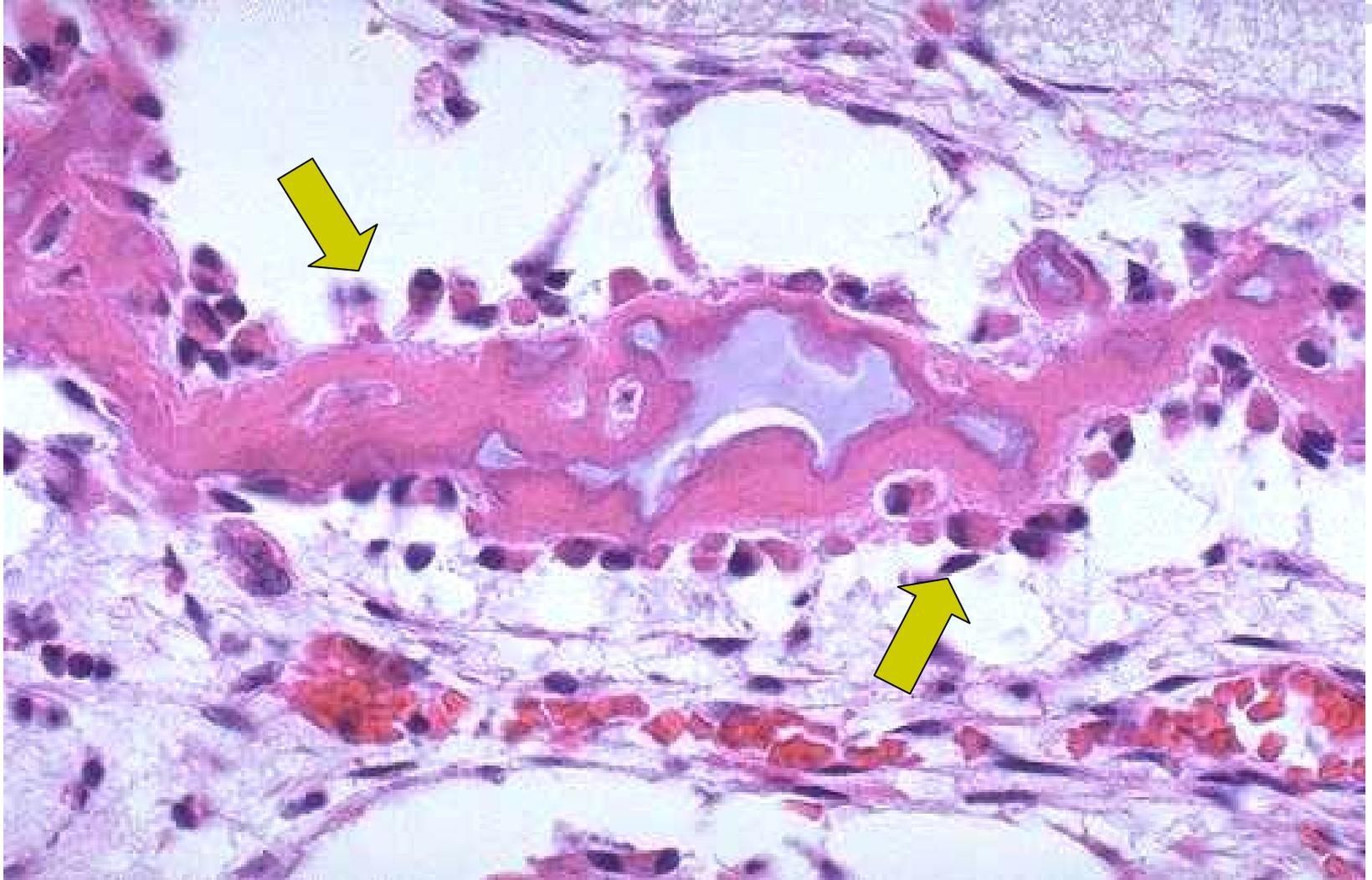
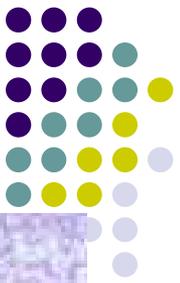


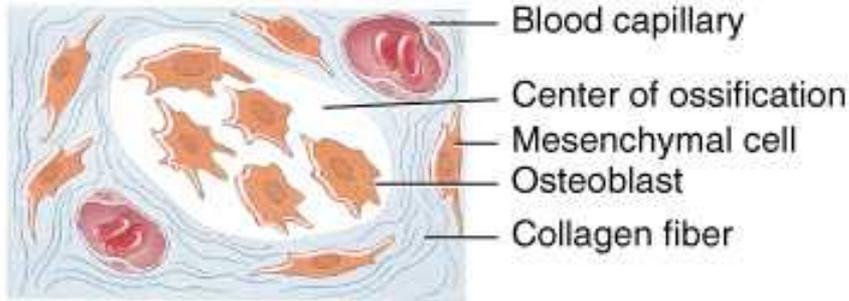
Blood vessel

**Step 3:** Over time, the bone assumes the structure of spongy bone. Areas of spongy bone may later be removed, creating marrow cavities. Through remodeling, spongy bone formed in this way can be converted to compact bone.

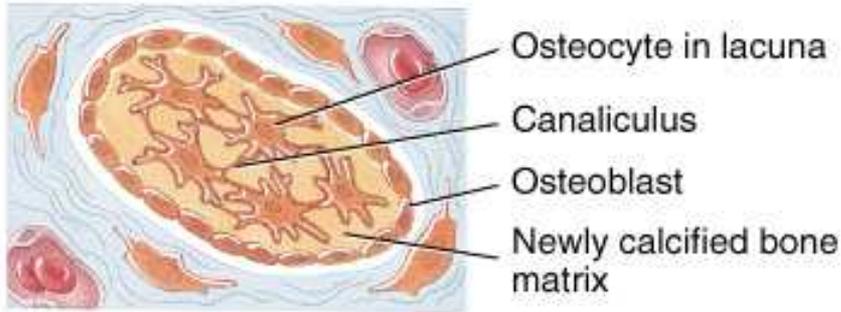
骨松质 → 骨密质

# Osteoblasts:

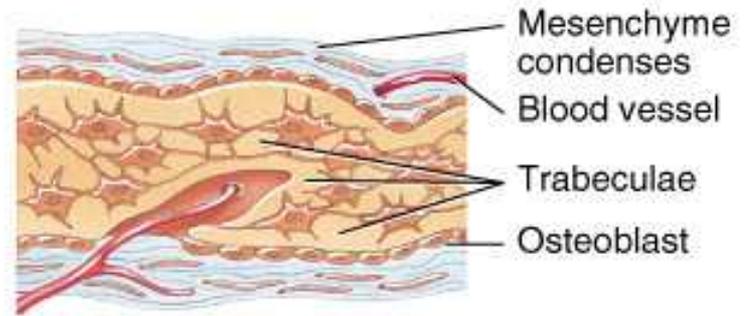




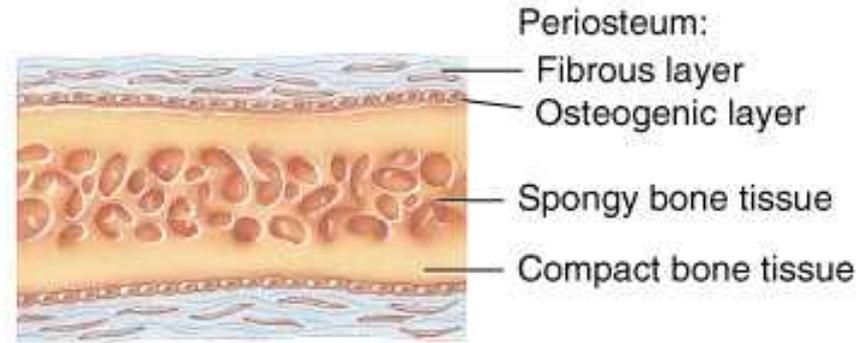
1 Development of center of ossification



2 Osteocytes deposit mineral salts (calcification)



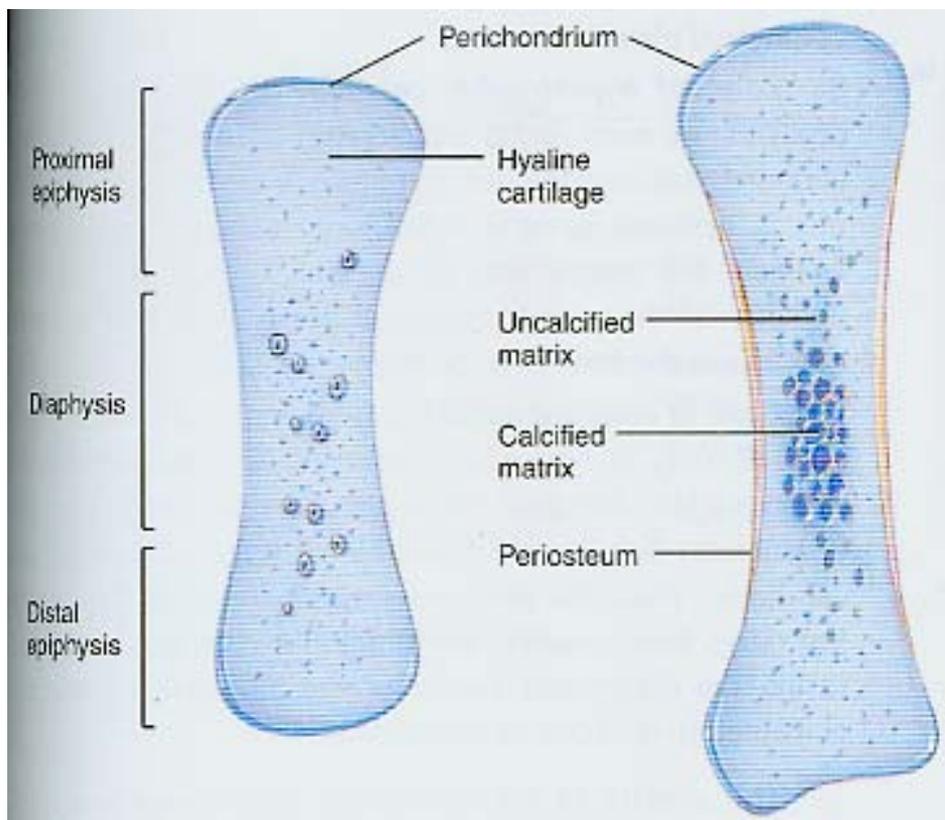
3 Formation of trabeculae



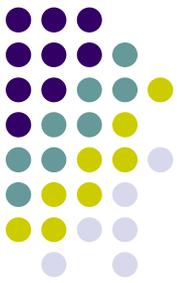
4 Development of periosteum, spongy bone, and compact bone tissue



## 2、软骨内成骨



(1)软骨雏形的建立：在将形成长骨的部位，间充质细胞密集并分化为骨原细胞。部分骨原细胞分化为软骨细胞，软骨细胞向周围分泌基质并将其包埋其中，成为透明软骨组织。



## (2) 软骨周骨化(*perichondral ossification*)

软骨膜内层的骨原细胞增生分化为成骨细胞，贴在软骨组织表面形成类骨质，继而钙化为骨组织，骨领(*bone collar*)。骨领逐渐改建成骨干的骨密质。

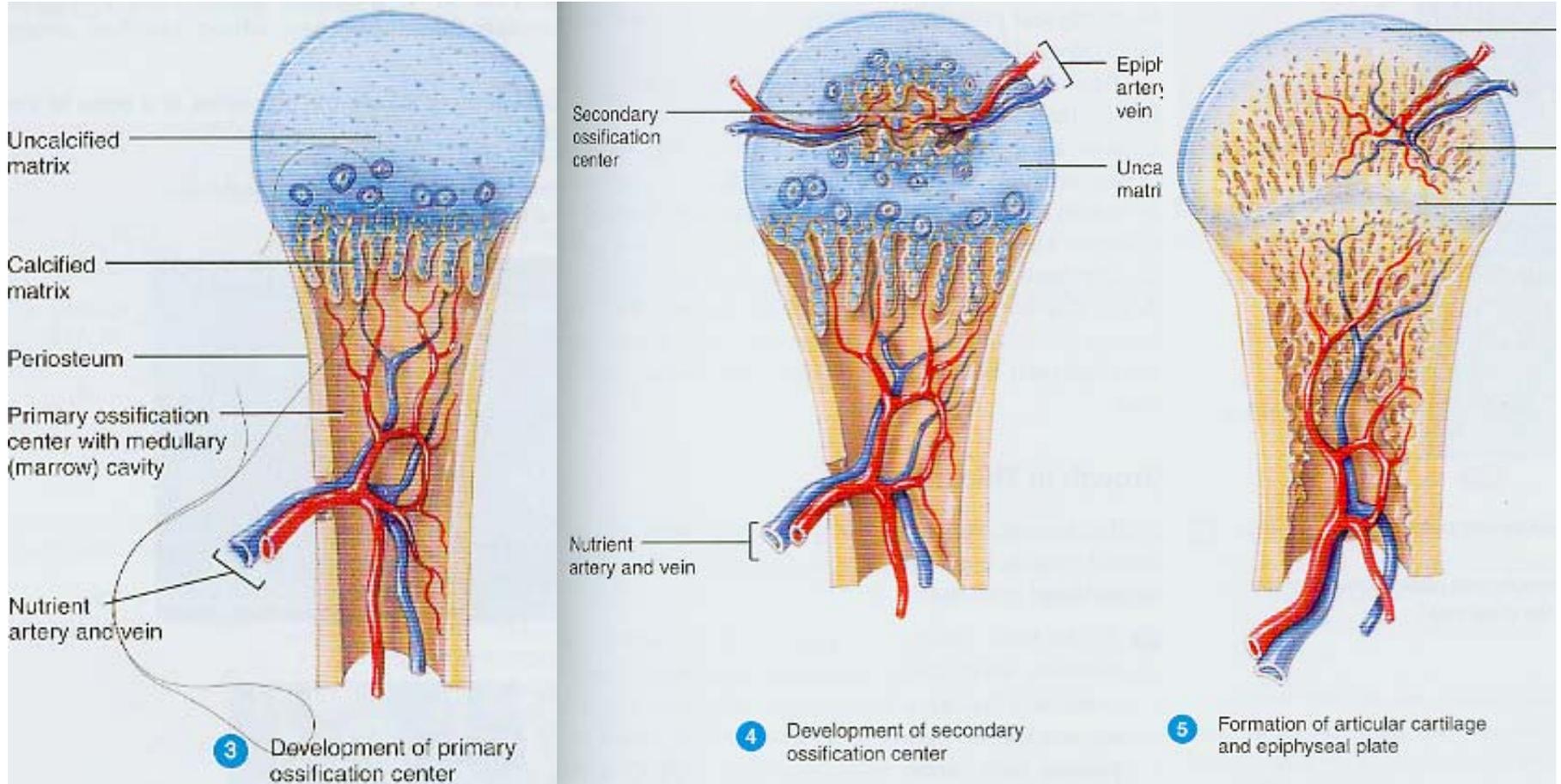
### (3) 软骨内骨化

a. 初级骨化中心的出现:

b. 骨髓腔的形成:

(4) 次级骨化中心的出现和骺板形成

(5) 骨的生长和改建



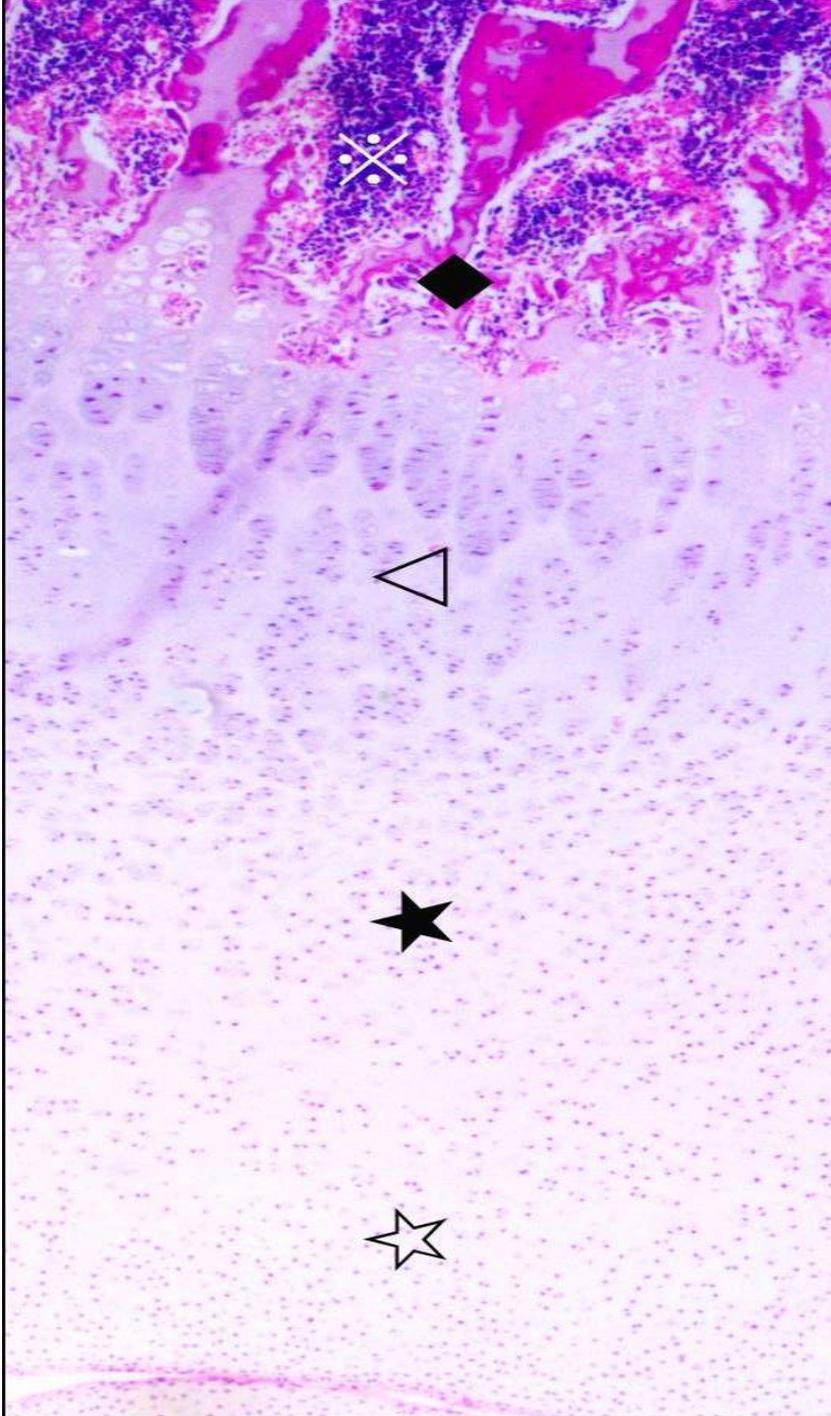


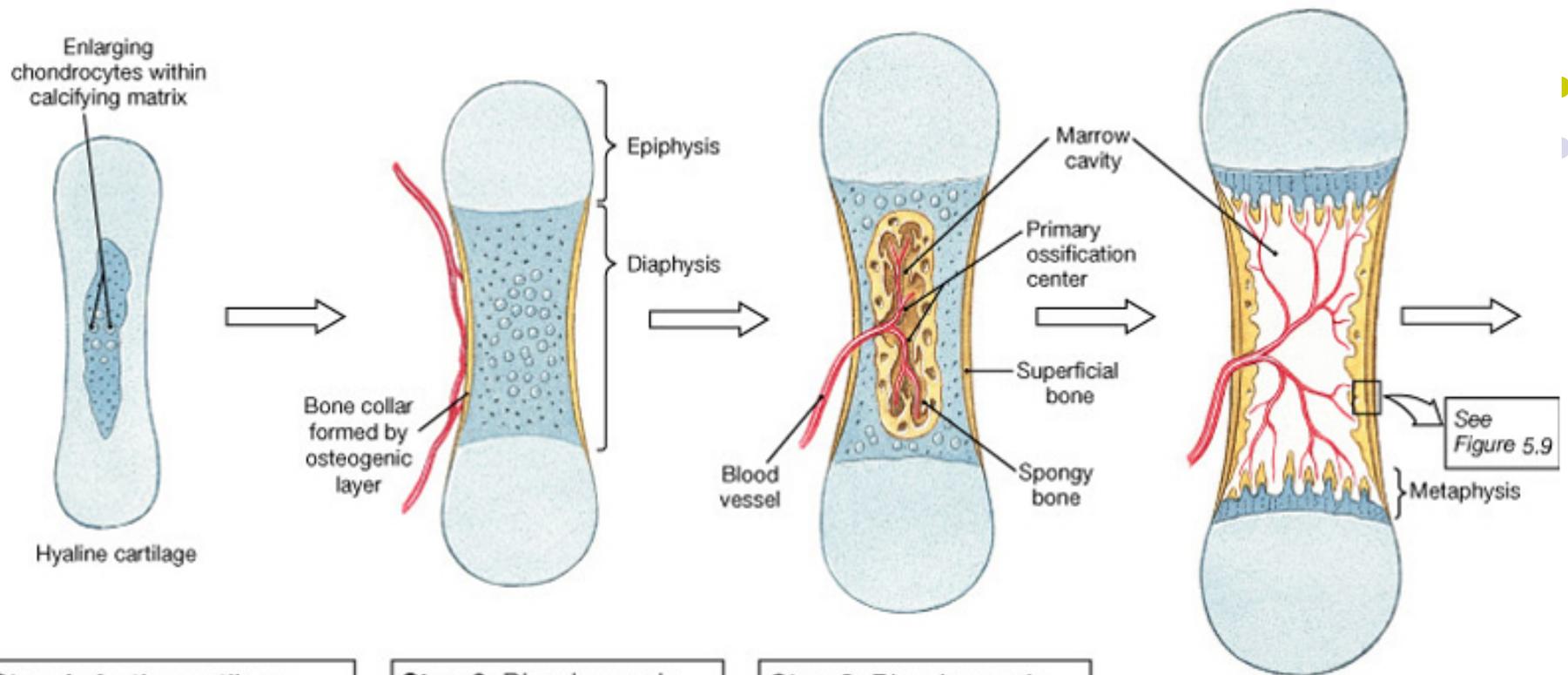
①软骨储备区 (**zone of reserve cartilage**)

②软骨增生区 (**zone of proliferating cartilage**): 软骨细胞变大, 分裂形成的同源细胞群纵向排列成行。

③软骨钙化区 (**zone of calcifying cartilage**): 软骨细胞肥大, 软骨基质钙化。

④成骨区 (**zone of ossification**): 骨细胞整齐地排列在残留的软骨基质表面, 产生类骨质, 继而钙化为骨组织, 形成骨小梁。





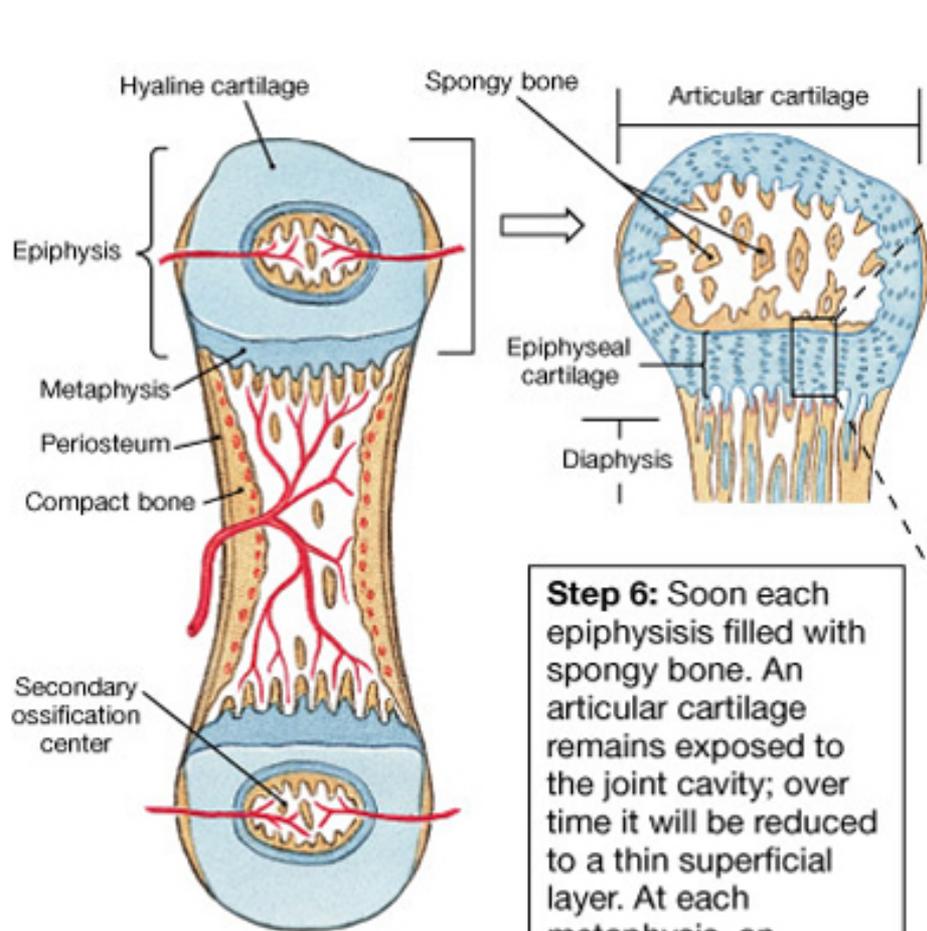
**Step 1:** As the cartilage enlarges through appositional and interstitial growth, chondrocytes near the center of the shaft increase greatly in size. The matrix is reduced to a series of small struts that soon begin to calcify. The enlarged chondrocytes then die and disintegrate, leaving cavities within the cartilage.

**Step 2:** Blood vessels grow around the edges of the cartilage, and the cells of the perichondrium convert to osteoblasts. The shaft of the cartilage then becomes ensheathed in a superficial layer of bone.

**Step 3:** Blood vessels penetrate the cartilage and invade the central region. Fibroblasts migrating with the blood vessels differentiate into osteoblasts and begin producing spongy bone at a primary ossification center. Bone formation then spreads along the shaft toward both ends.

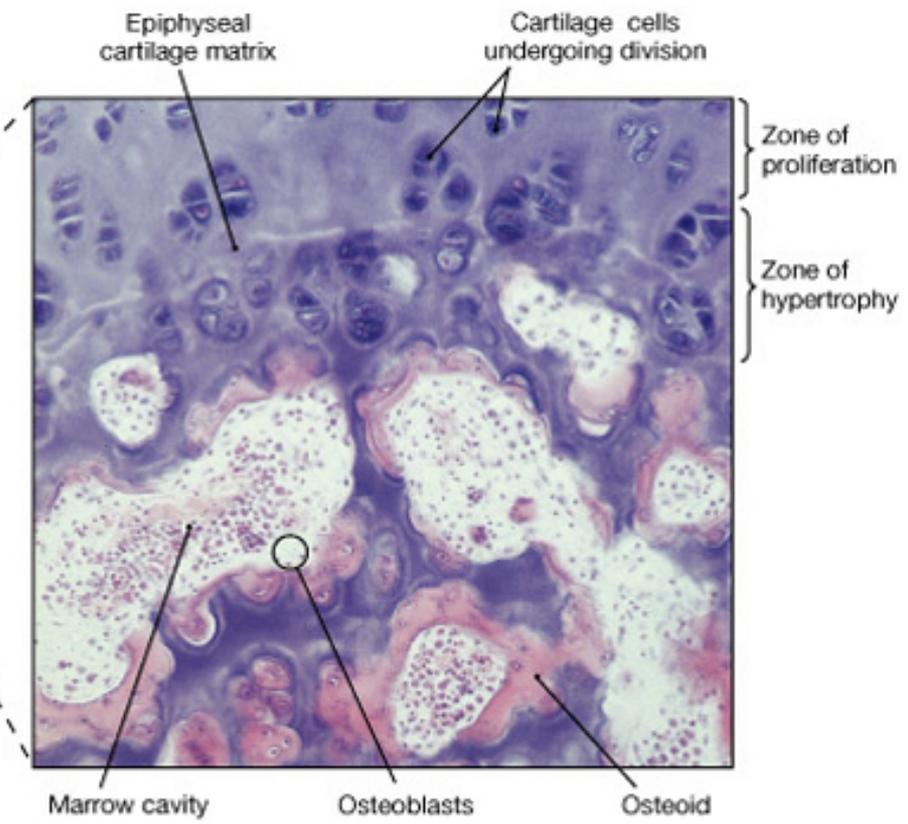
**Step 4:** Remodeling occurs as growth continues, creating a marrow cavity. The bone of the shaft becomes thicker, and the cartilage near each epiphysis is replaced by shafts of bone. Further growth involves increases in both length (Steps 5-6) and diameter (Fig.5.9).

(a) Steps in endochondral ossification

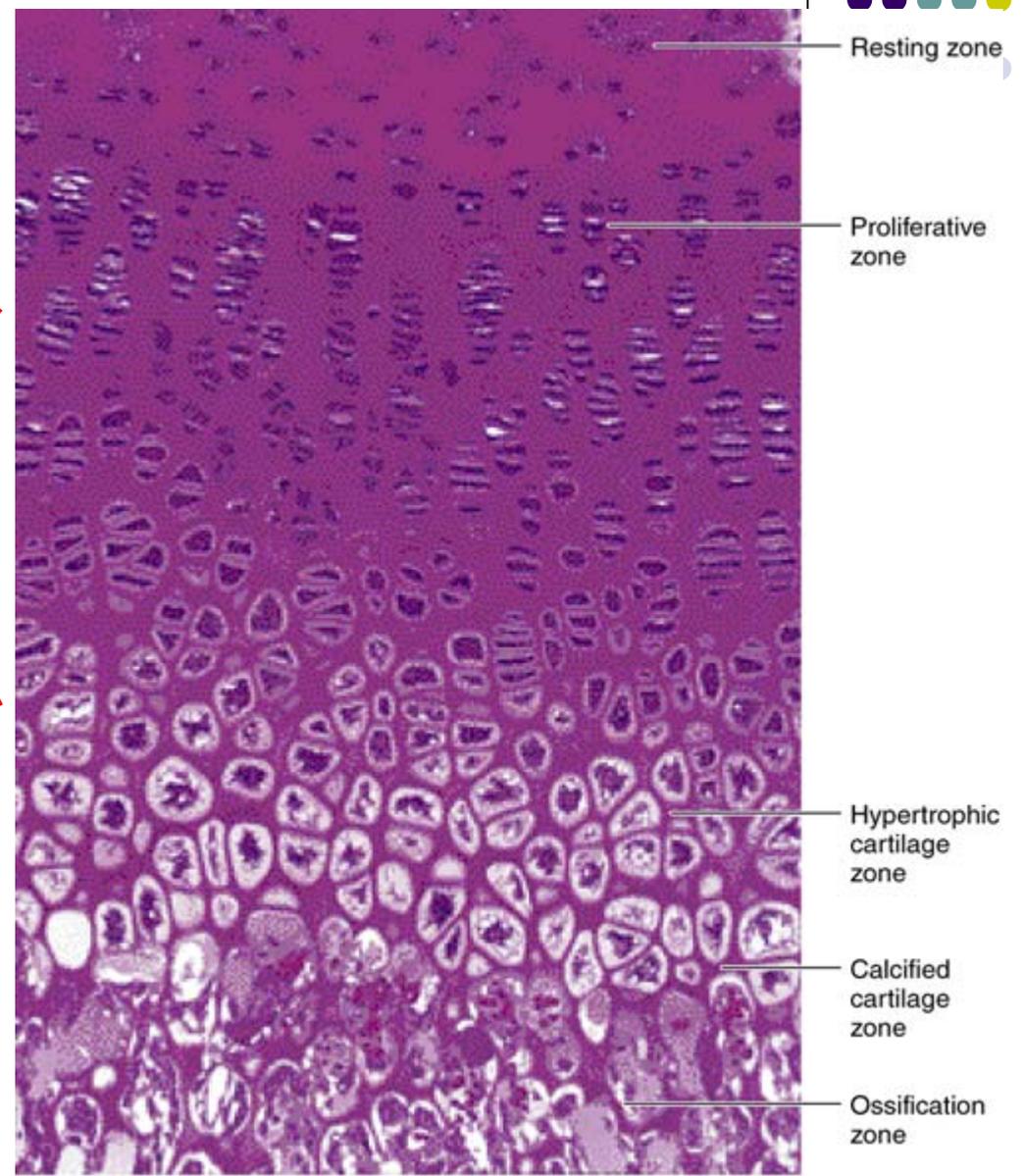
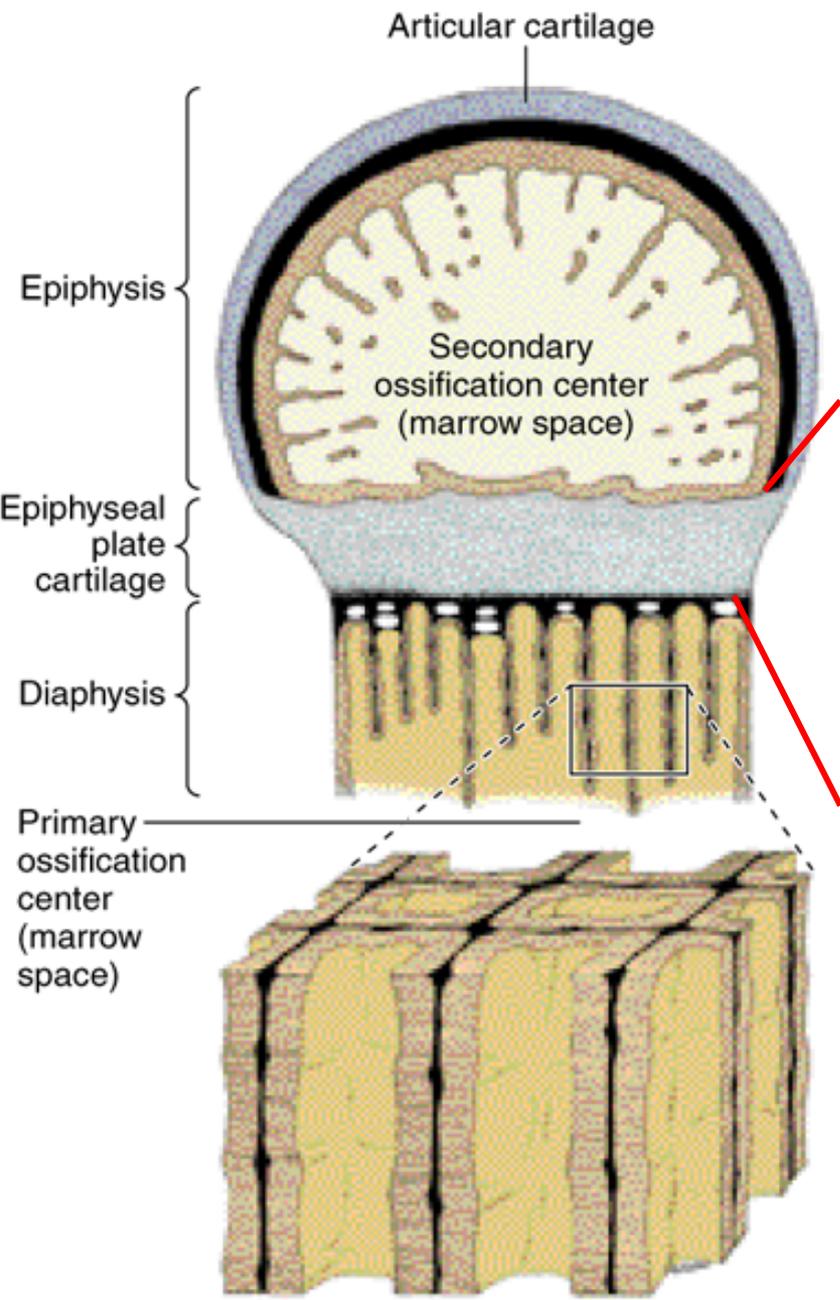


**Step 5:** Capillaries and osteoblasts migrate into the epiphyses to create secondary ossification centers.

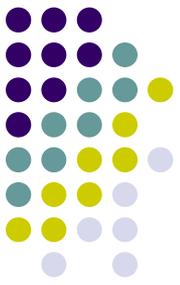
**Step 6:** Soon each epiphysis is filled with spongy bone. An articular cartilage remains exposed to the joint cavity; over time it will be reduced to a thin superficial layer. At each metaphysis, an epiphyseal cartilage separates the epiphysis from the diaphysis.



**(b) Light micrograph of an epiphyseal cartilage**



## 影响骨的生长因素



1. 遗传因素的控制

2. 激素：  
生长激素-甲状腺激素（骺板软骨）  
甲状腺旁腺激素-降钙素（血钙）  
雌激素-雄激素  
糖皮质激素

3. 维生素：A；C；D

4. 其他生物活性物质：转化生长因子- $\beta$  (TGF- $\beta$ )、前列腺素 (E1、E1a、E2)、白细胞介素1和6、表皮生长因子、巨噬细胞释放的肽刺激因子