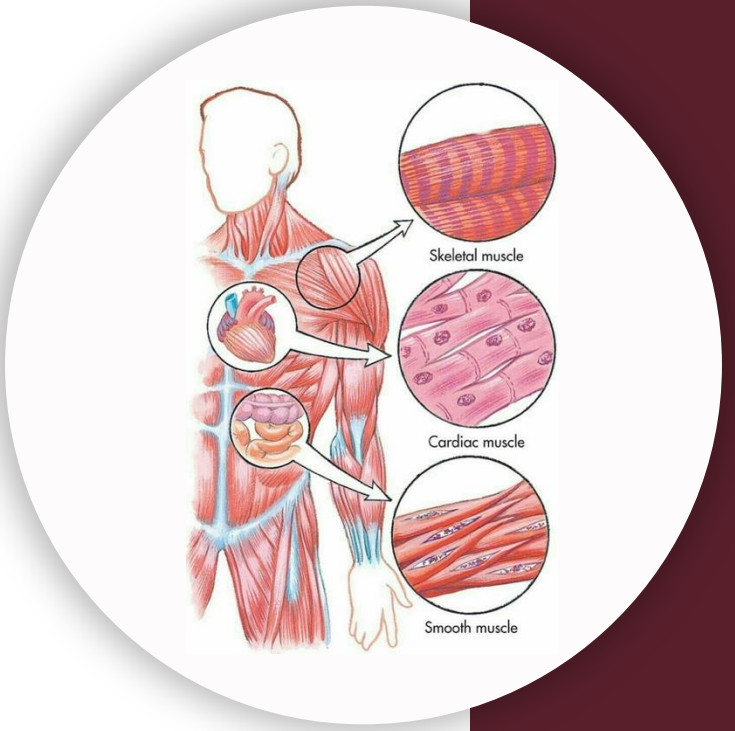
بسم الله الرحمن الرحيم

Histology - Final 3

Bone Tissue pt.1



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BONE TISSUE

Bones come from mesenchyme, which is a type of connective tissue. This tissue consists of cells surrounded by matrix, and this structure is what makes it special. The matrix is usually made of ground substance and fibers, and the cells are embedded within it.

In bone, we add calcium and phosphate to the inorganic part of the matrix. This is what makes bone different from cartilage ~> the presence of these inorganic compounds.

Cartilage does not usually contain inorganic material, but with aging, it may have inorganic compounds through a process called calcification. This calcification mainly happens in hyaline cartilage, especially in areas like the costal cartilage or the xiphoid.

Bones are formed by cells and fibers, which are mainly the strongest type ~> collagen type I, along with other types but in less number. The ground substance is composed of proteoglycans and glycoproteins, which help build the matrix.

Components

- **Bone matrix**

- Organic
  - Collagen++
  - Proteoglycans
  - Glycoproteins

- Inorganic
  - Calcium hydroxyapatite +++

Cells ⟶ **might be young and active , or semi-retired**

- **Osteoblast~>** •Is located at the inner layer of the periosteum
- **Osteocytes~>** •the innermost cell
- **Osteoclasts~>**

To get and maintain the inorganic part, there are special cells called osteoclasts, which come from monocytes ~>big cells found in the blood, with a kidney-shaped nucleus, and a size around 10 to 30 micrometers.
This description is for the monocyte before the career shift. After the career shift, when these monocytes leave the bloodstream and move to the bone surface, a number of them will fuse together.
The result is one large multinucleated cell, called an osteoclast, which is able to liberate inorganic calcium and phosphate by breaking down bone matrix.
These cells are always found at the surface of the bone, where resorption happens.

The inorganic part gives bone the hardness, not the strength, as the strength comes from all matrix, primarily collagen type 1 and also the inorganic compound.
To understand, buildings are supported by columns made by iron, which makes the building stand between different elements. Cement and stone are the inorganic, and iron in buildings has the same function as collagen in bones.

Collagen makes bone not susceptible to be broken easily, and I can't easily break it also because of the inorganic part.

Functions

- Main constituent of the adult skeleton ~> makes the shape of a human ~>your length, your form, all of these come from the bones.
- Provides solid support for the body, protects vital organs such as those in the cranial (houses the most important and delicate structure which is the brain) and thoracic cavities, also the vertebral canal, which protects the spinal cord
- Encloses internal (medullary) cavities containing bone marrow → By the medullary spaces, bone houses the blood-forming cells. Blood cells come from the bone marrow, which is the main site of blood formation in the body.
- Bone tissue also serves as a reservoir of calcium, phosphate, and other ions.

Usually, we keep the calcium level normal, and if it is shifted or decreased from its desired level, even in small numbers, the body corrects this by increasing absorption and decreasing secretion immediately.
If calcium is still low, it must be corrected immediately, as it is so important in muscle contraction, especially in the heart, which takes calcium from the blood.
If your diet is deficient in calcium, the body will trap it from the bones, and this can result in osteoporosis.
While calcium exists in many types of food, it does not exist in every food we eat, so a balanced diet is important.

Periosteum ,as the concept of the cartilage, is a connective tissue wrap. The outer surface layer is fibrous, rich with collagen type 1 and fibroblasts. The inner surface has the progenitor cells, which are called osteogenic cells.

Nutrient arteries, arteries that come from major blood vessels and then are orientated to the bones, so they will reach the periosteum, and in it they advance within the inner structure of the bone.
If you remember, in the cartilage, they stop at the perichondrium, and by diffusion, they reach to the cells. But as you see, the bone is highly vascular.

There are also canals: central canal and perforating canal. These canals within the bone tissue allow the passage of the neurovascular bundle: artery, vein, and nerve.

If you compare between the inner and outer parts of the bone, you will notice that **the outer part is the most organized and strictly structural, as it has much more matrix and much less spaces.**
This part gives the strength to the bone.
The inner part has much more spaces, and this part follows what we call the spongy bone model, with the spaces being called medullary spaces.
Inside these spaces, we can see the difference between the yellowish element, which is the organized matrix, and the darkish element, which is the cells ~> **osteocytes**.
In the bone lamellae, the matrix and the osteocytes appear in different shapes, and as you see, because of this, we give them different names.

The external circumferential lamellae is at the outside, as it covers the bone from the outside.
We also have **the inner circumferential lamellae**, located at the inner surface, and it faces the inner aspect of the bone.

Between the external circumferential lamellae and the inner circumferential lamellae, there are osteons, which are the functional building blocks of the bone.

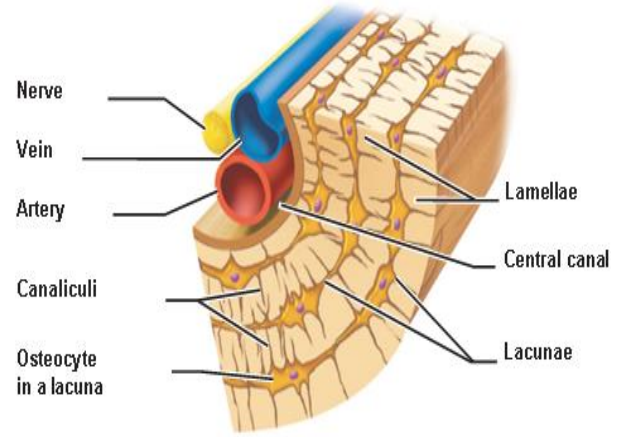
Each osteon contains lamellae, and these are called **concentric lamellae.**
In between the osteons, we also find **interstitial lamellae.**

Osteon is made from concentric lamellae. As you note, there is something unique about them, as they are striped.

These lamellae are lined with collagen, and with each second lamella, the collagen orientation changes, **usually by 90 degrees** , and this is very important, as it gives the strength to the bone matrix in multiple directions.
The striation between one lamellae and its neighbouring appears as roughly 90 degrees, and this striation comes from the collagen arrangement.

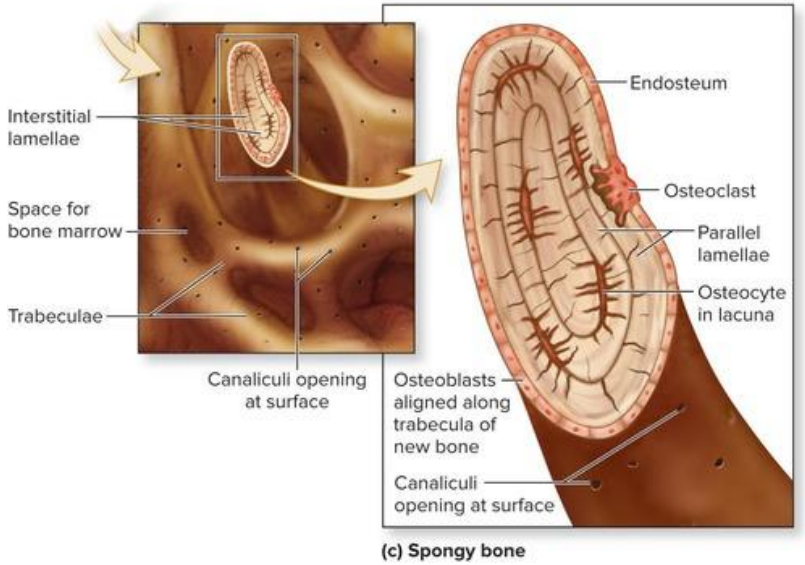
The final form of the lamellae appears during the maturation of bone.
So, when the bone is fractured, the osteoblasts exist, they jump to the site and fill the gaps, forming bone, but this bone is not organized ~> it does not have lamellae.
Once the bone is healed, the tissue is remodeled: the unorganized bone is replaced with organized bone that has lamellae and collagen fibers arranged at 90 degrees.
This organized structure gives the bone its final strength, and marks the maturation of the bone.

Bone is vascular, meaning it has blood vessels that supply it, including those that go to the periosteum. These vessels pass through the center of the osteon, forming the central canal. Running along the long axis of the bone, there are vessels that connect the central canals and travel transversely. These are called perforating canals.



Lacuna is the space where chondrocytes and osteocytes are found. However, there is something special about the lacunae in bone, as they have extensions, small spaces within the matrix, called canaliculi. The process of adjacent lacunae of cells meeting at the canaliculi allows them to communicate. Here, between them, you will find gap junctions. This is very important because, within the matrix, there are no capillaries to directly supply nutrients. So, while diffusion occurs, the presence of the canaliculi facilitates it, allowing cells to exchange gases and nutrients more efficiently.

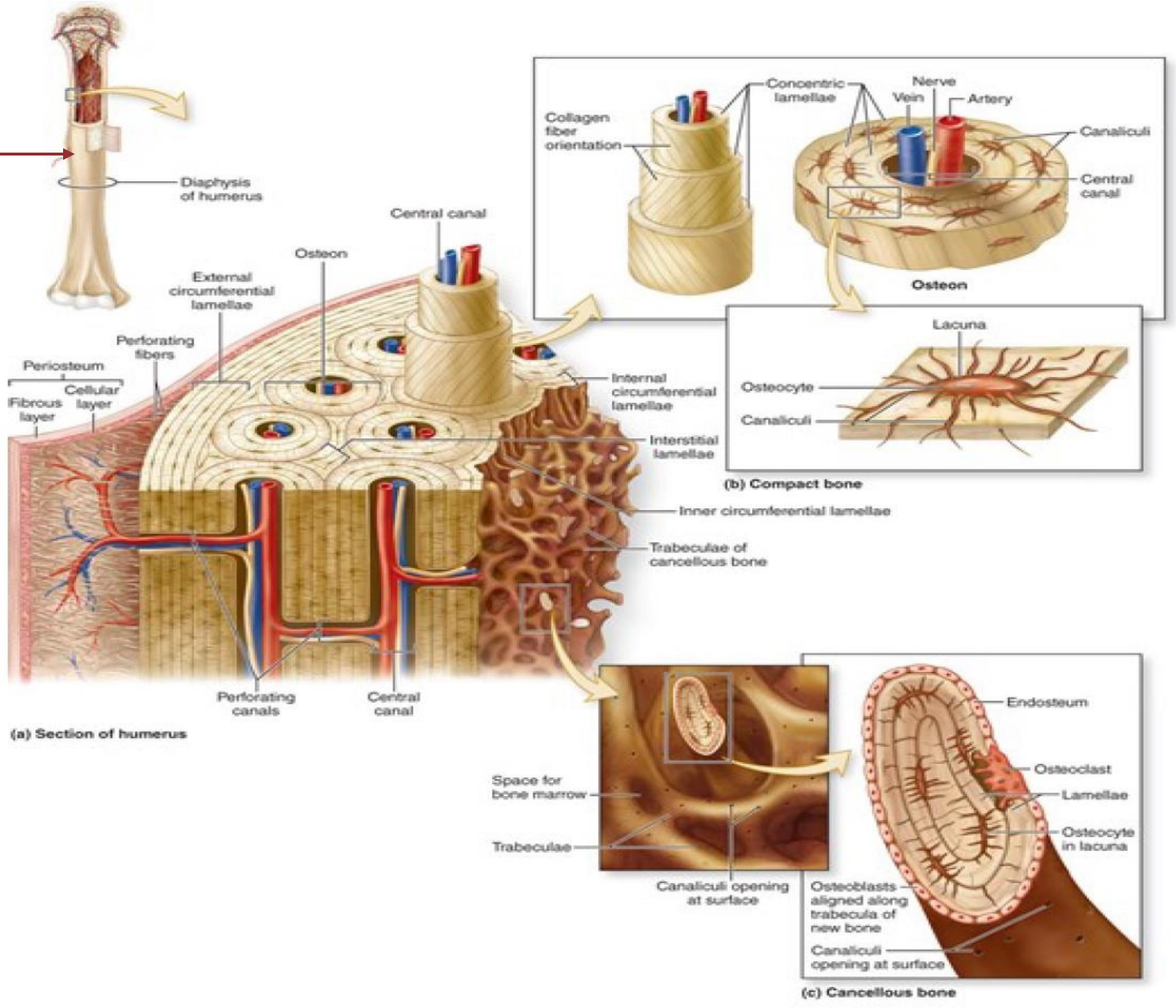
Osteocytes can't divide, but their main function is to maintain the matrix. The number of osteogenic cells in bone is higher than in cartilage, and the blood supply is also more abundant. This is why bone has a much higher regenerative capacity than cartilage.



Cancellous bone, also known as spongy bone, lacks the strict organization found in compact bone. Instead, the bone lamellae and osteocytes form a network, all interconnected. The trabeculae are interconnected lamellae in spongy bone, while in compact bone, each lamella is individually named. The endosteum, a layer of bone-lined cells, has a structure somewhat similar to the periosteum.

a bone in which the length is the greatest dimension.

Bone



Mesenchymal stem cells differentiate into various types of cells, including osteoblasts, which are always located on the surface and line the osteoid. The osteoid is the first form of bone, mostly organic. Over time, it matures through mineralization. Not all osteoblasts become osteocytes. Some osteoblasts will remain as osteoblasts, while others will transform into osteocytes. Once osteoblasts complete their function, they undergo apoptosis, a form of programmed cell death. This makes sense because having too many osteocytes would be inefficient. The physical properties of bone primarily come from the matrix, so a greater amount of matrix is required compared to cells. However, we still need some osteocytes to maintain the matrix and act as mechanostats.
The term “mechanostat” can be broken down into two parts: “mechan-” refers to mechanical forces, such as the attachment of muscles and the impact of weight, while “-stat” refers to sensing and regulating these forces. Osteocytes, acting as mechanostats, are responsible for sensing mechanical forces and regulating bone remodeling accordingly.

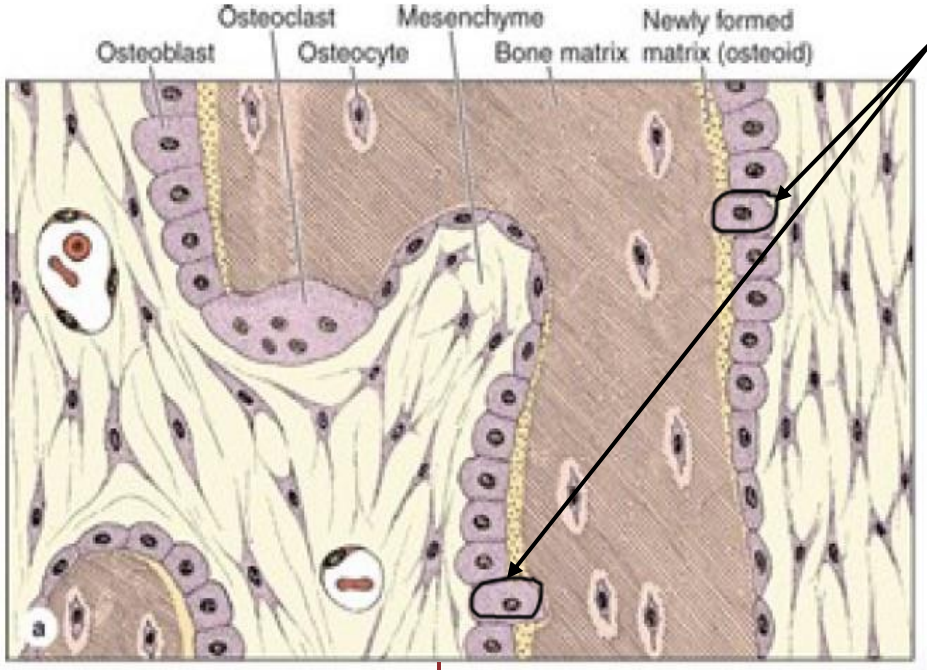
The health and strength of the bone matrix come from its constituent structure. We need to eat properly and stay physically active so that our bones remain in their best health. This is because there are cells that sense mechanical activity. These cells ensure that the matrix is maximally saturated with inorganic minerals.

When physical activity is reduced, such as in certain diseases or prolonged bed rest (for example, staying in bed for a month), these sensing cells cannot detect mechanical forces. As a result, the density of the matrix decreases. If this condition continues, it can lead to osteoporosis. It is more common in females, but bedridden individuals may also develop bone weakness, especially in the thoracic region.

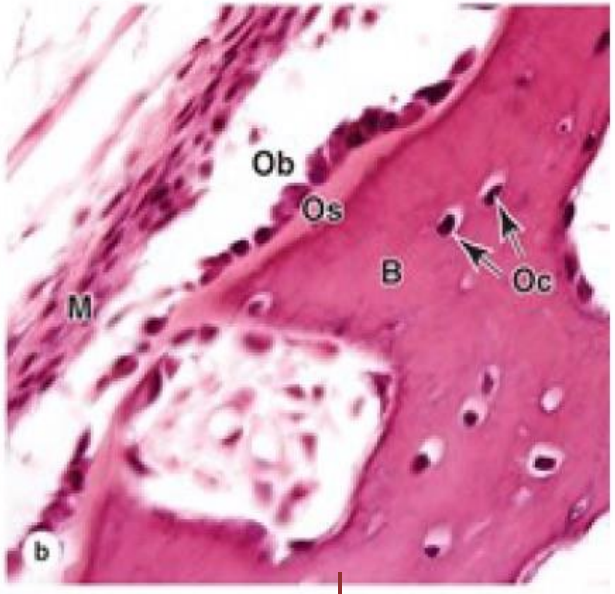
In conclusion, most of the bone cells will undergo apoptosis, but some remain to become osteocytes, while others become bone-lining cells.

Bone cells

1. Osteoblast
2. Osteocytes
3. Osteoclasts



Future osteocytes



Bone is intensely eosinophilic because it is saturated with collagen.

Active osteoblasts (Ob) and osteocytes (Oc). Rounded osteoblasts, derived from progenitor cells in the adjacent mesenchyme (M), cover a thin layer of lightly stained osteoid (Os) on the surface of the more heavily stained bony matrix (B).

This picture shows intramembranous bone formation, where bone forms directly from mesenchyme. It is considered the most direct and simplest way of forming bone. By the way, there is another type of bone formation called endochondral ossification, in which mesenchyme first differentiates into cartilage, and then the cartilage is replaced by bone.

This picture shows the actual events that occur. The letter “B” refers to bone, specifically trabecular bone. Since it has not reached the level of lamellae formation in the embryo, it is not yet organized. Most of the cells in this image are derived from animals, with fewer cells from humans. However, the events observed in both animals and humans are not significantly different and are not easily distinguishable. This picture mainly shows organic tissue from bone, as bone is rich in collagen, which gives it its structure and strength. The image, however, is missing the calcium, which is typically present in mature bone, making it less mineralized and more similar to early developmental bone tissue.

Cells

- Osteocytes are found in cavities (lacunae) between bone matrix layers (lamellae), with cytoplasmic processes in small canaliculi that extend into the matrix.
- Osteoblasts growing cells which synthesize and secrete the organic components of the matrix
- Osteoclasts which are giant, multinucleated cells involved in removing calcified bone matrix and remodeling bone tissue

Remodeling **happens because bone keeps developing itself without stopping. We have osteon old and new. The bone removes the old and puts another one, depending on the physical properties. The more we move, the more bone receives mechanical forces. These forces give the bone an indication to change the direction of existing osteons. So, it removes the present osteon and places a new one. The new one will grow and enlarge in the area of the old osteon that was removed.**

For any feedback, scan the code or click on it.

Corrections from previous versions:

Versions	Slide # and Place of Error	Before Correction	After Correction
V0 → V1	Slide 10 A wrong word	Polymerization	Mineralization
V1 → V2			

رسالة من الفريق العلمي:

{فَأَمَّا مَنْ خَافَ مَقَامَ رَبِّهِ وَنَهَى النَّفْسَ عَنِ الْهَوَىٰ ﴿٤٠﴾ فَإِنَّ الْجَنَّةَ هِيَ الْمَأْوَىٰ ﴿٤١﴾}
سورة النازعات، الآيتان(40–41)

في هذه الآية الكريمة، يبيّن الله تعالى أن من خاف مقامه، أي استشعر عظمته وراقب أفعاله، وكبح جماح نفسه ومنعها من اتباع الأهواء والشهوات، فإن مصيره سيكون الجنة، وهي المأوى الأبدي والراحة الأزلية.

وهذا هو الفوز المقصود هنا، وهو فوزٌ مزدوج:
فوز في الدنيا: بالراحة النفسية، والسكينة، والرضا عن الذات، وطمأنينة القلب.
وفوز في الآخرة: بدخول الجنة، والنجاة من العذاب، والفوز برضا الله.

إنه وعد من الله لعباده المتقين، بأن جهاد النفس في الدنيا لا يضيع، بل يقود إلى أعظم النهايات.