Answers
2.4 Cartilage and Bone

106. a – b – c – d – e –

107. a + b + c – d + e +

108. a – b + c + d + e +
Perichondrium contains collagen fibers and undifferentiated connective tissue cells resembling fibroblasts (chondroprogenitor cells). Perichondrium covers all hyaline cartilage (except for articular cartilage of synovial joints. It is not found on intervertebral disks or fibrocartilage. Perichondrium is a source of chondroblasts and is essential for appositional growth of hyaline and elastic cartilage. The blood supply of the perichondrium is the source of nutrients and metabolites for cartilage, which lacks an intrinsic blood supply. These nutrients must diffuse through the salvation water of the matrix to reach the cartilage cells. Damaged cartilage in adults has a very limited capacity for regeneration. In case of injury to the cartilage, connective tissue cells from the perichondrium can invade the damaged area if it is not too large and generate new cartilage. More commonly connective tissue cells from the
perichondrium form a scar of dense connective tissue at the site of injury.

109. a – b – c + d + e +

110. a + b + c + d + e +
The interstitial matrix of hyaline cartilage contains collagen fibers, which show a 64nm cross-striation periodicity at the electron microscope level. The matrix is basophilic and also stains metachromatically with aniline dyes such as toluidine blue. The matrix contains PAS-positive sulfated proteoglycans such as: chrondroitin-4-sulfate or keratin sulfate. Cartilage lacks an intrinsic blood supply and receives all its nutrients by diffusion from the perichondrial blood vessels or in the case of articular carilage from the synovial fluid.

111. a + b + c + d + e +
Cartilage serves many functions especially in fetuses, where it provides basic skeletal support for the developing tissues and limbs. It plays an important role in endochondral ossification. The cartilage of the epiphyseal growth plate permits the elongation of developing long bones. In the respiratory tract suchas in the trachea or bronchi, cartilage helps maintain the tubular shape and prevent the collapse of these vital airways. Articular cartilage provides a smooth surface for the movement of synovial joints.

112. a + b – c + d + e +
The interstitial growth of cartilage arises from the division of existing chondroblasts deep in the matrix and results in the formation of groups of isogenous or nest cells. These then secrete new matrix and contribute to the formation of the so-called territorial or capsular matrix surrounding the group of isogenous cells.

113. a – b – c – d – e –
Articular cartilage, which lacks perichondrium, is found on the epiphyses of long bones in synovial joints. Its cells are not arranged in orderly columns. Unlike other cartilage, articular cartilage receives its nutrients by diffusion from the synovial fluid. Articular cartilage has no real ability to regenerate if damaged.

114. a – b + c + d + e –

115. a + b + c + d – e –
Elastic cartilage has a fairly restricted distribution which includes the epiglottis, walls of the Eustachian tubes and walls of the external auditory canals. It has a yellowish color when fresh because of the large amount of elastin in the matrix. The elastin can be stained with specific stains such as orcein. Like hyaline cartilage, the matrix of elastic cartilage contains collagen fibers and chondroitin sulfate.

116. a – b – c + d + e +
Capsular or territorial matrix surrounds the lacunae of chondrocytes including isogenous or nest cells. This capsular matrix has relatively few collagenous fibrils, but is rich in amorphous material that shows intense basophilia, matachromasia and PAS- positive reactivity owing to its high proteoglycan content.

117. a + b + c + d + e +
Chondroitin-4-sulfate is found in the matrix of hyaline and elastric cartilageas well as in bone. It belongs to the proteoglycans.

118. a – b + c + d + e +

119. a + b – c – d – e –
Fibrocartilage is found in the intervertebral disks, public symphysis, temporomandibular joints and in the attachment of some ligaments to joints, such as the ligamentum teres femoris. Fibrocartilage has a very large quantity of collagen fibers in its intercellular matrix and this results in its marked acidophilia. Fibrocartilage is associated with dense connective tissue, from which it develops. The border between dense connective tissue and firocartilage that adjoints it is not clear cut. Fibrocartilage lacks a surrounding perichondrium.

120. a – b + c – d + e +
The intervertebral cartilaginous disks possess fibrocartilage. In histological preparations of young intervertebral disks one usually finds a central nucleous pulposus, which is the remnant of the embryonic notochord. This is surrounded by fibrocartilage, which forms the 'annulus fibrosus'.

121. a + b – c + d – e –
Secondary cartilage is cartilage that develops in association with specific bones formed by intramembranous ossification and which develops later than the bone with which it is associated. It can form the aricular cartilage of bones that develop by intramembranous ossification. A good example of secondary cartilage is found in the temporomandibular joint. The distribution of secondary cartilage is very limited.

122. a – b – c + d – e –
Woven bone is primary or immature bone in which bundles of collagen fibers of the matrix run in various directions and the lacunae of osteocytes show no special order. Woven bone is primitive bone found predominantly in embryonic life and is replaced by mature bone (also called secondary or lamellar bone_. In post-natal life woven bone is very restricted in distribution and can be found in tooth sockets or temporarily during the repair of bone fractures.

123. a + b + c + d + e –
Because bone is a hard mineralized tissue, special techniques must be used to obtain thin enough sections than can be observed by light microscopy. Bone can be cut into small pieces with a saw and these can ground mechanically on a stone until they are thin enough to transmit light. These ground sections lack cellular detail, but the lacunae and canaliculi are well demonstrated. Ground sections can also be viewed by polarizing microscopy. It is nowadays possible to cut non-decalcified bone using specially hardened microtome knives, usually made from tungsten carbide. More commonly bone is decalcified using either nitric acid or chelating agents such as EDTA. Decalcification makes the tissue soft and it can be processed (embedded and sectioned) like other soft biological material. For electron microscopy undecalcified bone can be cut into ultrathin sections using diamond knives.

124. a – b + c + d – e +

125. a – b + c – d + e –
Flat or 'membrane' bones, such as those found in the skull, develop by intramembranous ossification. They have an outer layer of compact bone (the outer table), a middle layer of spongy bone called the deploë, and an inner layer of compact bone (the inner table).

126. a + b – c – d + e –

127. a – b + c – d – e +
The osteon or Haversian system is the morpho-functional unit of compact bone. The osteon is composed of a series of concentric lamellae surrounding a central vascular canal, the Haversian canal. Osteons are constantly subject to structural change and remodeling. Surrounding each osteon is the so-called cement line. Osteons are present in all mature or secondary bone including the compact bone of the flat bones.

128. a – b + c + d + e –
In each osteon the collagen fibers have an orderly arrangement within each individual lamella. In adjacent lamella the direction of the collagen fibers alternates. This orderly arrangement is well seen when compact bone is examined by polarizing microscopy.

129. a + b + c + d – e +

130. a – b – c – d + e +
The lamellae of bone are composed primarily of intercellular matrix containing collagen fibers and amorphous ground substances, which becomes calcified. This mineralization prevents the diffusion of nutrients through the matrix. The system of canaliculi that penetrate the lamellae permits the transport of nutrients to the osteocytes and the removal of waste metabolites. Lamellar bone is found only in mature or secondary bone.

131. a – b + c + d + e +
Bone remodeling continues throughout life even into old age. All the time new osteons are being formed or remodeled in response to the physical and metabolic needs of the body. The lamellae of the osteons are the main store of calcium in the body and this is released to the body fluids as needed.

132. a + b – c – d – e –

133. a – b – c + d + e –
Osteogenic tissue is the source of bone cells and bone tissue. Osteogeic tissue includes the periosteum and endosteum, which contain the osteo-progenitor cells.

134. a – b + c – d + e +

135. a – b – c – d + e –

136. a – b – c – d + e +
Osteoclasts are large cells, which have a large number of nuclei. They function in the resorption of bone and the release of its minerals to the body fluids. The osteoclasts are often situated in depressions of bone tissue undergoing resorption (Howship's lacunae). Osteoclasts stain strongly acidophilic. At the electron micsrope level they are seen to have a 'ruffled border' composed of multiple invaginations of the plasma membrane adjacent to the bone that is being resorbed. It is now widely believed that the origin of osteoclasts is from monocytes.

137. a – b + c + d + e –

138. a – b – c + d + e –
Hydroxyaptite is a stable form of calcium salts present in bone tissue as needle-like crystals. The formula of hydroxyapatite is usually represented as $[Ca_3 (PO_4)_2]_3$. Ca $(OH)_2$. The hydroxyapatite is formed in the extracellular matrix of hypertrophic chondrocytes during endochondral ossification. It serves as a body reservoir for calcium and phosphate, which can be released to the blood according to the physiological requirements of the body (following osteoclastic activity). Hydroxyapatite is not found in the cement line.

139. a – b – c + d – e +
Volkman's canals are found in secondary compact bone. They contain blood vessels and run in a predominantly transverse direction in osteons of long bones. Unlike Haversian canals, they are not surrounded by concentric bone lamellae. Volkmann canals bring nutrients from the blood vessels of the periosteum to the Haversian canals of the osteons.

140. a + b + c + d + e +
Sharpey's fibers, also called 'perforating fibers', are mainly composed of collagen. They are the means of attachment of the periosteum to the outer circumferential lamellae of long bones and act as a sort of anchoring mechanism. Sharpey's fibers are especially numerous and prominent in areas of tendon attachment.

141. a – b + c + d + e –

142. a – b + c – d – e +
Endochondral ossification is a process of bone formation in which a cartilage model precedes the formation of bone. Endochondrial ossification is well seen in the area of the epiphyseal growth plate of developing long bones and is the main means of bone lengthening. After the closure of the epiphyses and the loss of the growth plate, no further bone lengthening is possible. Endochondral ossification is also found in the secondary centers of ossification in the epiphyses of lone bones.

143. a – b + c – d + e +
Long bones grow in length due to the endochondral ossification process that occurs in the epiphyseal growth plate. This is accompanied by the enlargement of the bone marrow cavity. Growth hormone from the adenohypophysis has an important role in long bone elongation. The epiphyseal growth plates are target organs for this hormone.

144. a – b + c – d + e +
Long bones grow in diameter when bone is laid down in the periosteal collar of diaphyses by intramembranous ossification. At the same time as the appositional external deposition of new bone, there is a complementary resorption of bone on the inner surface and enalargement of the marrow cavity.

145. a – b – c + d + e –

146. a – b – c + d – e –
Primary centers of ossification in long bones are in the diaphyses and develop in hyaline cartilage models. Secondary centers of ossification are found in the epiphyses.

147. a + b – c – d + e –
Bone resorption is performed by the osteoclasts. The process of bone resorption and bone remodeling continues throughout life. Parathyroid hormone is effective when blood calcium levels are low and causes enhanced bone resorption which helps in the homeostasis of blood calcium levels.

148. a – b – c + d + e +
Osteoblasts have a single nucleus. They have basophilic cytoplasm and marked alkaline phosphatase activity. They develop from osteoprogenitor cells of the periosteum or endosteum and are found on the surface of developing bone tissue.

149. a – b + c + d + e +
The closure of the epiphyses of long bones involves the union of the bone marrow cavity of the diaphysis with that of the epiphysis and the disappearance of the epiphyseal growth plate. This closure of the epiphyses occurs at different times in different bones and can be used in estimating the age of growing individuals. With the loss of the epiphyseal growth plate, bones are unable to elongate any further. The process is influenced by hormones, especially growth hormone. Damage to the epiphyseal plate area can result in retardation of bone elongation.

150. a – b + c + d + e +
Calcification of cartilage involves the secretion of matrix vesicles by chondrocytes and the formation of hydroxyapatite on the collagen fibrils of the extracellular matrix. In endochondral ossification this calcification of the matrix occurs in the zone of hypertrophic chondrocytes. As a result of the calcification of the matrix, nutrients are unable to diffuse through the matrix and this results in the death of the chondrocytes.

151. a – b + c – d – e –
Resorption cavities are found in osteons of secondary bone. Certain fixative, such as Bouin's fixative, can result in the formation of artifacts in the colloid of thyroid follicles. These artifacts are called 'resorption vacuoles'.

152. a – b + c – d + e +
Rickets is a disease caused as a result of faulty calcification of bone and occurs in children in particular that have a diet that is deficient in vitamin D. Rickets is a condition in which growth continues in long bones without proper calcification of the osteoid. The weight of the body causes curvature of the bones of the legs.

153. a + b + c + d – e +
Epiphyseal plate dysfunction may result from deficiencies in diet, disturbances in the secretion of growth hormone, parathyroid hormone, estrogen or metabolism of vitamin D.

154. a + b + c + d + e +
During endochondral ossification the hypertrophic chondrocye secrete at least two different sort of matrix vesicles into the extracellular matrix. These matrix vesicles are membrane-bound. One variety of matrix vesicle contains lysosomal enzymes, though the function of this type of matrix vesicle shows alkaline phosphatase activity and is believed to be involved in the initial calcification of the matrix.

155. a + b + c – d + e –

156. a – b + c + d – e +
Synovial joints are lined laterally by a synovial membrane, which has cells similar to macrophages and cells similar to fibroblasts. The macrophage-like cells are phagocytic and remove debris from the synovial fluid. The synovial fluid, which is secreted by the fibroblast-like cells, is rich in hyaluronic acid. Synovial fluid has a lubricating function in the joint and is also a source of nutrients for the articular cartilage of the epiphyses.

157. a + b + c – d – e +
Hyaluronic acid is a non-sulfated glycosaminogly-can found in amorphous intercellular substance of most connective tissue. It is present in large amounts in the cavities of synovial joints. Hyaluronic acid is found in the skin, where it helps maintain the softness and pliability of the skin. It is also found in fairly large amounts in the Wharton's Jelly of the umbilical cord.