WJEC (England) Biology A Level

Topic 3B: Human Musculoskeletal Anatomy

Notes

Skeletal Tissues

Cartilage - smooth, elastic connective tissue which provides structural support to the body. Cartilage consists of cells called chondrocytes, which produce and are surrounded by extracellular matrix. The spaces between cells are called lacunae.

There are three main types of cartilage. They differ primarily because of the differences in the ratio of chondrocytes to extracellular matrix/the density of chondrocytes in the extracellular matrix:

- **Yellow/elastic cartilage** (highest density of chondrocytes)
- **Hyaline cartilage** (middle density of chondrocytes)
- **White/fibrous cartilage** (lowest density of chondrocytes)

Compact bone - dense bone which forms the hard external layer of all bones to provide protection and strength to bones.

Compact bone is made up of a bony matrix containing 30% **organic** and 70% **inorganic** tissues. The organic component of compact bone is mostly the protein collagen, and the inorganic component is mostly hydroxy-apatite, containing calcium and phosphate. Collagen provides **tensile strength** (resistance to being pulled apart) to the bone, and hydroxy-apatite provides **compressive strength** (resistance to being compressed).

- **Osteoblasts** - cells, embedded in the matrix of the bone, which form, repair and reform the inorganic component of the bone.

- **Osteoclasts** - cells which break down the inorganic component of the bone when the bone is broken down and reformed.

Haversian System - a unit/osteon of compact bone. Haversian systems consist of a central canal containing the bone's blood vessels and nerve fibres, called the Haversian canal, surrounded by lamellae, which are layers of compact matrix containing organic and inorganic tissues. The function of Haversian systems is to help the bone resist bending and fracturing.

The bones can be subject to various disorders:

- **Rickets** - a disorder, only found in children, caused by a deficiency of calcium, Vitamin D or phosphorus. Causes weak or soft bones, stunted growth and skeletal deformities.
- **Osteomalacia** - the same disorder, except when found in adults. Also causes weak or softened bones. Also caused by a deficiency of Vitamin D, calcium or phosphate.
- **Osteoporosis**/brittle bone disease -

- Caused by loss of bone density due to a fall in oestrogen levels due to menopause, or fall in testosterone levels due to alcohol consumption, hypogonadism or use of certain medications.
- Symptoms include back pain, loss of height and stooped posture, and bone fractures which occur much more easily than might be expected.
- Treated by use of bisphosphonates (medications to increase bone density), selective oestrogen receptor modulators (medications which maintain bone density by acting like synthetic oestrogen), parathyroid hormones (medications to regulate the amount of calcium in bones), supplements of calcium or Vitamin D and HRT/testosterone treatment. Fractures would also be treated using plaster etc.

Skeletal muscle - muscle, which is connected to the skeleton, which moves the limbs and other parts of the body.

Skeletal muscle is made up of muscle fibres bundled together and separated into compartments. Each muscle is wrapped in a connective tissue sheath called the epimysium. Connective tissues called fascia separate the muscles. Bundles of muscle fibres are surrounded by a layer of protective tissue called the perimysium. Each individual muscle fibre is surrounded by connective tissue called the endomysium.

Muscle fibres are made up of smaller fibres called myofibrils, which are in turn made up of two major filaments - **actin** (a thin filament) and **myosin** (a thick filament). Actin also has two accessory proteins called tropomyosin and troponin (which regulate muscle contraction) . The smallest units of muscle fibres which can contract independently are called sarcomeres. Muscle contraction occurs via the following steps:

1. An impulse stimulates the release of the neurotransmitter acetylcholine.
2. Acetylcholine stimulates the release of **calcium ions**.
3. Calcium ions bind to the accessory protein **troponin**. This causes tropomyosin (another accessory protein) to move away from the active site of actin.
4. ATP is hydrolysed, which releases energy.
5. The head of the **myosin filament attaches to actin**. This is called a cross-bridge.
6. **Myosin pulls the actin** filament into the middle of the sarcomere. This **shortens the muscle** slightly.
7. ATP attaches to the head of the myosin filament. Myosin detaches from the actin. The **cross-bridge is broken**.
8. This repeats until either calcium ions or ATP run out.

This mechanism is called the **sliding filament theory**, because the proteins of muscles slide past/over one another, and this results in movement.

Muscle fibres can be fast-twitch or slow-twitch:

- **Slow-twitch** muscle fibres are responsible for **endurance** activities. They contract more slowly, and release large amounts of energy more slowly. They respire mostly aerobically, and therefore have high capillary density and a high concentration of mitochondria. They have a high concentration of myoglobin, and therefore can store more oxygen.

- **Fast-twitch** fibres are used for **rapid movements**. They release small amounts of energy and contract very quickly. They respire mostly anaerobically and therefore have a lower density of mitochondria. They have a low concentration of myoglobin. They have large glycogen stores which are used for glycolysis (the first stage in aerobic or anaerobic respiration which produces pyruvate).

Anaerobic respiration occurs when there is insufficient oxygen for aerobic respiration. After glycolysis, the pyruvate is reduced to **lactic acid** using reduced coenzymes. The buildup of lactic acid in muscles decreases pH of muscles, which affects the Central Nervous System. Reduced stimulation from the CNS reduces muscle contraction. Anaerobic respiration is also much less efficient than aerobic respiration and produces many fewer molecules of ATP per molecule of glucose that enters into glycolysis.

- **Creatine phosphate** donates a phosphate group to ADP molecules to regenerate ATP during a short burst of activity.

Glycogen and protein are the main stores of energy during muscle contraction.

Structure and Function of the Human Skeleton

Appendicular Skeleton - the bones of the limbs/that support the limbs:

- **Pectoral girdle** - clavicle (collarbone) and scapula (shoulder blades)
- **Forelimb** (arm) - humerus (shoulder to elbow), radius and ulna (elbow to wrist)
- Hand - carpals (wrist), metacarpals (wrist to first knuckle), proximal phalanges (first to second knuckle), intermediate phalanges (second to third knuckle, not present on the thumb), and distal phalanges (after the third knuckle)
- **Pelvic girdle** - hip bone
- **Hindlimb** (leg) - femur (hip to knee), patella (kneecap), tibia and fibula (knee to ankle)
- Foot - tarsals (ankle), metatarsals (ankle to toe), proximal phalanges (first to second knuckle), intermediate phalanges (second to third knuckle, not present on the biggest toe) and distal phalanges (after the third knuckle)

Axial Skeleton - bones of the head and torso:

- **Skull** - cranium (protects the brain) and facial bones
- Middle ear ossicles (bones in the middle ear)

- Hyoid bone (neck)
- Rib cage - ribs, sternum (breastbone)
- Vertebral column - vertebrae

Types of Fractures:

- Closed/simple (bone doesn't break the skin)
- Open/compound (bone breaks the skin)
- Stress (hairline crack)
- Transverse (horizontal fracture)
- Oblique (angled)
- Segmental (two locations, same bone)
- Comminuted (three or more locations, same bone)
- Compression (bone is crushed)

Causes:

- Trauma
- Osteoporosis/some types of cancer (weakens bones)
- Repeated stress

The vertebral structure if a series of 33 vertebrae, separated by intervertebral discs. There are also ligaments spanning the length of spine and in-between the vertebrae. The function of the vertebral column is protection of the spinal cord, support of the weight of the body above the pelvis, posture, and movement.

Each vertebrae is made up of:

- Vertebral body (towards the back of the body, supports the weight of the body, lined with hyaline cartilage)
- Vertebral arch (towards the sides and front of the body, muscles and ligaments are attached)
- Vertebral foramen (all vertebral foramen together forms vertebral canal for the spinal cord)

Vertebrae can be:

- Cervical - the vertebrae in the neck
  - Smaller vertebral body, as it bears less weight
  - Much wider vertebral canal, as the spinal cord is thickest nearest where it meets the brain
  - Transverse foramen for vertebral arteries and veins
- Thoracic - the vertebrae of the upper back
  - Attached to the ribs, have more limited motility
- Lumbar - the vertebrae of the lower back
  - Larger vertebral body, as it bears more weight

Postural deformities:

- Kyphosis
  - Convex curvature of the spine
  - Caused by bad posture, weakness of back muscles, rickets, injury of the spine, arthritis
  - Treated by a brace, physical therapy or surgery
- Lordosis
  - Concave curvature of the spine
  - Caused by imbalances muscle strength and length
  - Treated by a brace, medications or physical therapy
- Scoliosis
  - Sideways curvature of the spine
  - Most causes largely unknown, can be caused by neuromuscular conditions, or by injury/infection of the spin
  - Treated by a brace, surgery, or medication

The function of the skeleton:

- Support
- Muscle attachment
- Protection
- Production of red blood cells
- Storage of calcium

Joints

Joints can be movable (e.g. knee), slightly moveable (e.g. in joints between vertebrae) or fused/fixed/immovable (e.g. joints in the skull).

Moveable joints can be:
- Hinge
- Ball and socket
- Pivot
- Gliding
- Saddle
- Planar

Osteoarthritis - a joint disease resulting from the breakdown of joint cartilage. Causes stiff and painful joints. Caused by joint injury, secondary arthritis, age, and obesity. Treated by lifestyle changes (weight loss, regular exercise, suitable footwear), medication, physiotherapy, and surgery.

Rheumatoid arthritis - an autoimmune disorder. Causes stiff, swollen and painful joints. The causes of the triggering of the immune system unclear, although women, smokers and people with a family history of rheumatoid arthritis are at an

increased risk. Treated by medication, physiotherapy/occupational therapy, and surgery.

Joints act as **levers**. Levers can be:

1. **First Order** (axis between the weight and the force) e.g. joint between the head and the first vertebrae
2. **Second Order** (weight between the axis and the force) e.g. lower leg on tiptoes
3. **Third Order** (force between the axis and the weight) e.g. elbow joint

Synovial joints - freely movable joints.

A synovial joint is made up of the bones surrounded by a synovial capsule. The inside of the capsule is lined by the synovial membrane - the inner membrane, which secretes synovial fluid, and the outer membrane, which contains ligaments. The ends of the bone are covered with hyaline cartilage. The gap between the bones is referred to as the synovial cavity.

- **Articular cartilage** - absorbs shock and reduces friction.
- **Synovial membrane** - secretes synovial fluid.
- **Synovial fluid** - acts as a lubricant and reduces friction.
- **Ligaments** - connect the bone to bone.

Antagonistic pairs of muscles work via one contracting while the other relaxes to create movement. The **biceps and triceps** are an example of an antagonistic pair of muscles.

Tendons connect **muscle to bone** and are also required for movement. When a muscle contracts, the tendon pulls on the bone to move it.