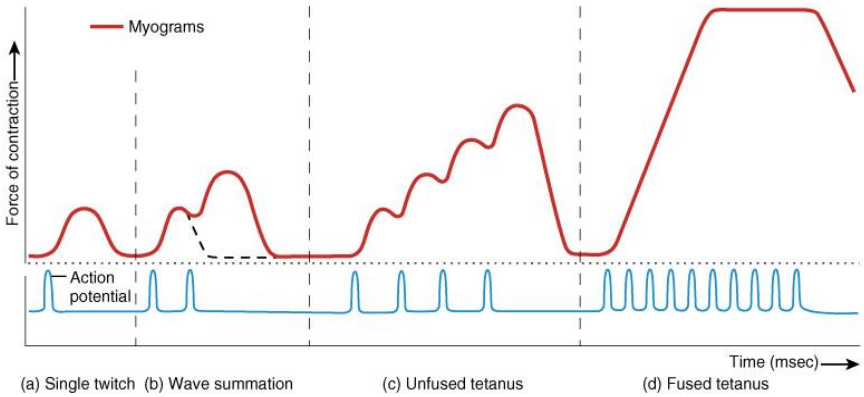
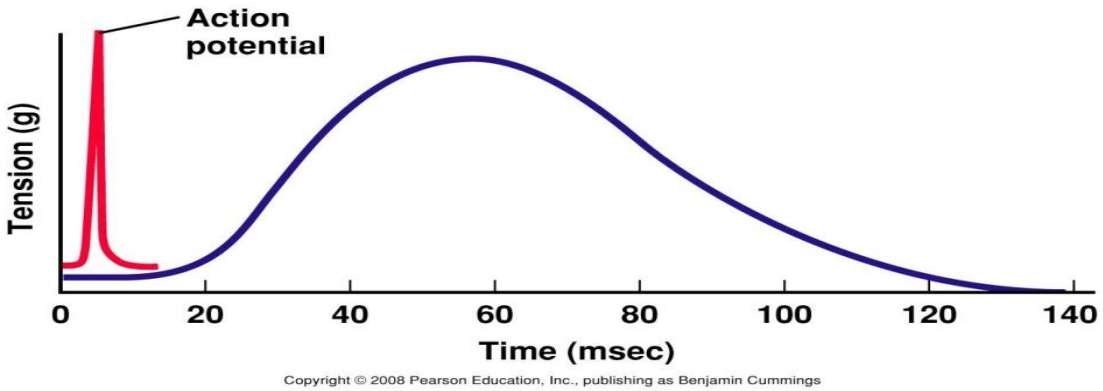
Unit VII – Problem 1 – Physiology: Muscle Contraction

- **Physiological anatomy of muscles:**
  - A muscle is composed of fasciculi (which is covered by perimysium) → myofibers (covered by endomysium) → myofibrils → myofilaments (actin & myosin).
- **40% of our body mass is composed of skeletal muscles** and another 10% is composed of smooth + cardiac muscles.
- Skeletal muscles are attached to bones and hence their name.
- **The t-tubules** in sarcolemma (muscle membrane) start to appear in myofibrils. They conduct action potentials coming from motor neurons to muscle fibers causing the sarcoplasmic reticulum to release its storage of calcium ions which will aid in the process of contraction. Each t-tubule meets two sarcoplasmic reticulum cisternae and mediates the release of calcium ions from them which will bind to troponin C and expose the active sites on actin filaments so they can interact with myosin heavy heads and cause contraction.
- **The functional unit of a muscle is the sarcomere** (it is the distant between two Z lines: note that the ends of actin filaments attach to these Z lines). Skeletal muscles are striated and characterized by light and dark bands. Light bands are formed by (I bands) which only contain actin filaments while dark bands are formed by (A bands) which contain myosin and some actin filaments).
- **A myosin filament contains:**
  - **A hinge region** which is highly movable (45 degrees).
  - **A head** with ATPase activity to provide energy used for contraction.
- The number of fibers innervated by a single motor neuron varies (from a few to thousand). The fewer the number of fibers per neuron → the finer the movement
- **The sliding filament model of muscle contraction**: actin filaments are pulled centrally by myosin heads →sarcomere shorten → muscle fiber shortens → muscle shortens and contraction occurs.
- **Process of contraction:**
  - An action potential will travel along a motor neuron until it reaches the neural end where it is going to cause the opening of voltage-gated calcium channel leading to influx of calcium ions into the axonal bulb.
  - These calcium ions will cause the release of stored ACh in vesicles via exocytosis.
  - 2 Ach molecules will bind to Ach-gated receptors leading to influx of sodium ions and local depolarization of a muscle fiber.
  - An action potential will be generated and travel along t-tubules to reach the sarcoplasmic reticulum where they are going to cause the release of stored calcium ions from sarcoplasmic reticulum cisternae.
  - Calcium ions will bind to troponin C to cause conformational changes in troponin-tropomyosin complex and exposing the active sites of actin filaments to which myosin heads will bind and release their ADP+P
  - Actin filament will be pulled centrally by myosin heads and the whole process will repeat again.
- **Length tension-curve**: 100% overlap between myosin & actin filaments → maximal force is developed.
- **Mechanical characteristics of body muscles differ:**
  - **Ocular muscles**: fast contraction to acquire and fixate visual targets.
  - **Gastrocnemius**: contracts moderately rapid to cause limb movements for running and jumping.
  - **Soleus muscle**: slow contraction for long-term support of the body against gravity
- **Unfused and fused tetanus (see the image in next page):**
  - **Unfused**: if a muscle is stimulated 20-30 times/sec before it enters its refractory period, there will be only partial relaxation between stimuli.
  - **Fused**: if a muscle is stimulated 80-100 times/sec, a sustained contraction with no relaxation between stimuli will result.



- **Production of ATP in muscle fibers (read biochemistry notes for more details):**
  - **Phosphocreatine & creatine kinase**: fastest – only for 5-10 seconds (100 m race)
  - **Breakdown of glycogen and anaerobic glycolysis**: fast – only for 1-3 min – leading to accumulation of lactic acid causing muscle fatigue (200 m race).
  - **Oxidative metabolism**: long-term, most energy comes from fat if contraction lasts many hours (2-4 hours).
- **Events during twitch:**



Latent phase	Contraction phase	Relaxation phase
Stimulus to beginning contraction: action potential causing myosin to bind to actin active sites	Beginning to end of muscle tension: myosin heads slide along the actin filaments	Peak tension to no tension: calcium ions moved back to sarcoplasmic reticulum, tropomysin moves back over actin, myosin head release actin and the filaments move back to resting position

- **Muscle fibers come in two forms:**

- **Isotonic contraction (same tone)** = a load is moved.
- **Isometric contraction (same length)** = no movement occurs (maintaining posture & supports objects in a fixed position).