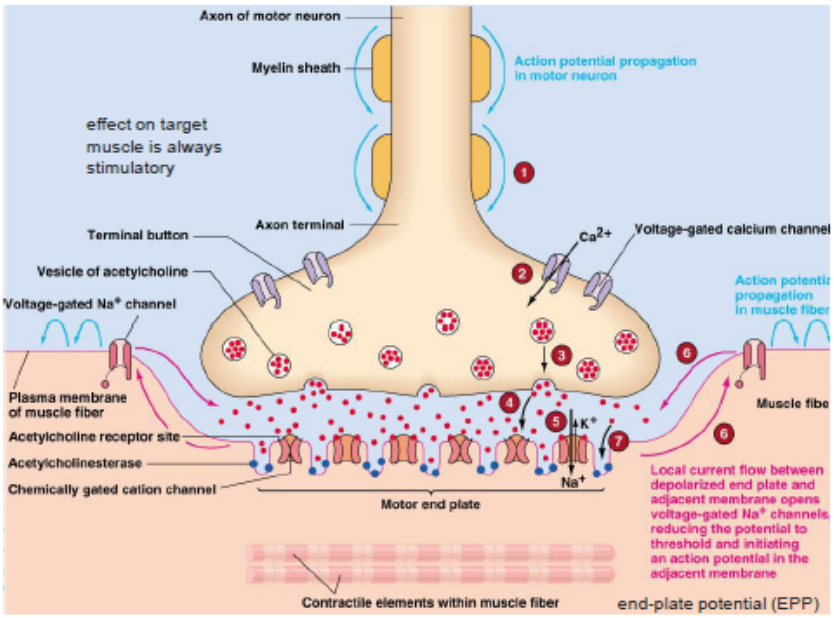
LECTURE 1: Functional Properties of Skeletal Muscle I

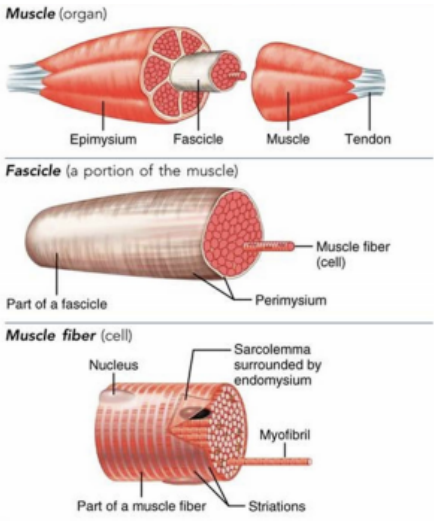
Neuromuscular Junction

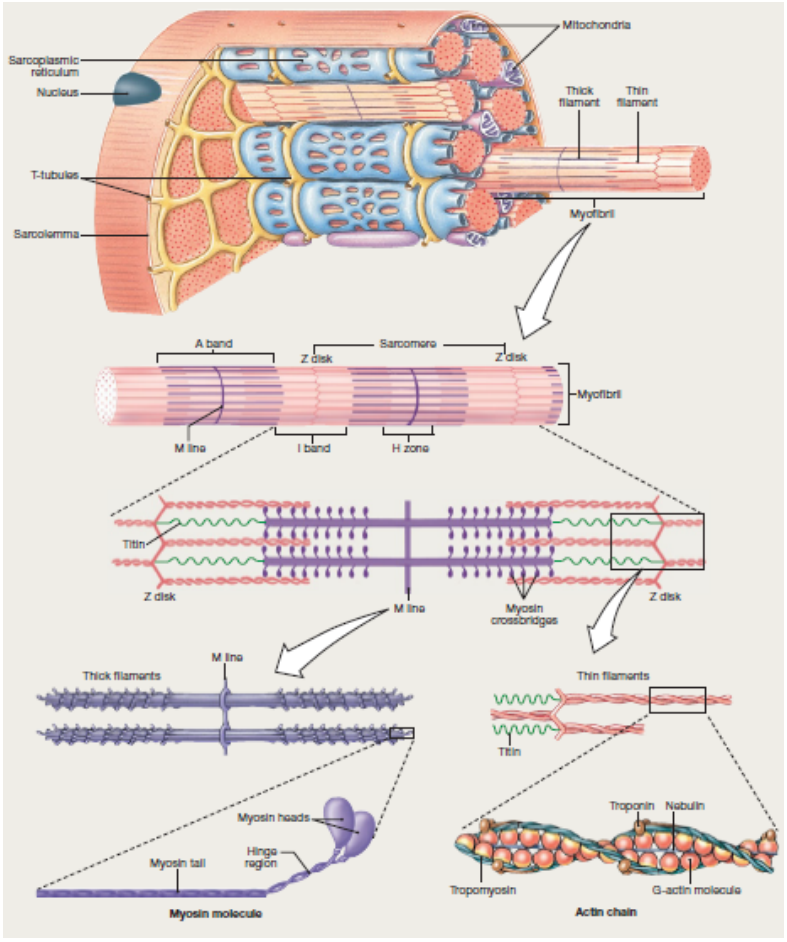
- Action potential travels from the pre-synaptic neuron, through the synaptic cleft then to the post-synaptic channel
- Voltage-gated calcium channels open when membrane reaches threshold and releases calcium into the pre-synaptic neuron
- Acetylcholine (ACh) diffuse across the cleft and binds with receptors on the motor end plate
- Cation channels on the motor end plate opens allowing sodium (Na^+) in and potassium (K^+) out
- Neurotransmitters diffuse across the synapse and bind to specific receptors which elicit a specific response



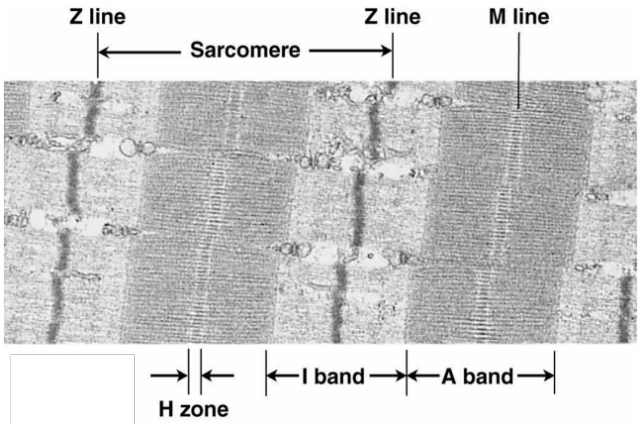
Muscle Structure

- Muscles have an origin (proximal) and an insertion (distal) ends with with tendons on both sides
- Muscle is made up of fascicles of fibres with each fibre made up of many myofibrils
- The myofibrils appear striated due to the dark (A) and light (I) bands in register
- Myofibrils (~1-2 µm) occupy 80% of the fibre volume with 100s to 1000s of myofibrils that exist in each fibre
- Maintained in transverse register across the cell giving rise to the striation pattern



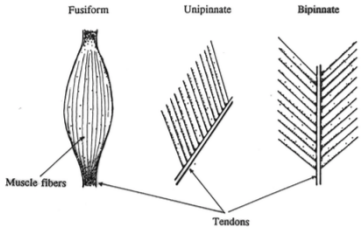


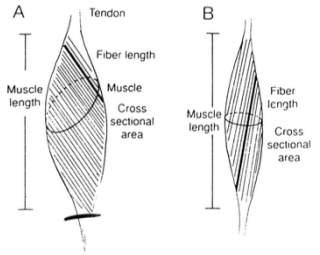
- Sarcoplasmic reticulum is the internal storage of Ca^{2+}
- Action potential from the neuromuscular junction travels down the t-tubular network and causes a change in electrical potentials
- This releases Ca^{2+} from the internal storage site and allows contraction to occur
- Sarcomeres are the basic contractile unit of the muscle
- Filaments side within one another during contraction where the length of the filaments does not change



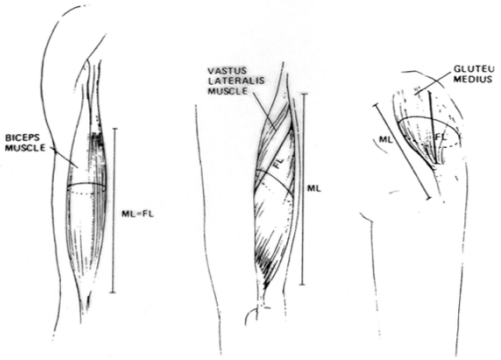
- The Z line will come towards the midline; muscle always have the desire to shorten
- Nebulin helps align actin
- Titin, body's largest protein, provides elasticity and stabilises myosin
- Muscle fibres are held together by a network of cytoskeleton protein that tethers the myofibril into position
- The two headed myosin molecule has two binding sites; one for action, the other for ATP
- The hinge region gives a level of flexibility when a myosin head attaches to an actin filament it can pull sarcomeres towards the midline
- Myosin head cannot bind to the binding sites on the actin molecules at rest due to the presence of troponin binding to tropomyosin
- When Ca^{2+} is released it binds to troponin to causes tropomyosin to pull away and allow the myosin head to attach

Arrangement of Fibres



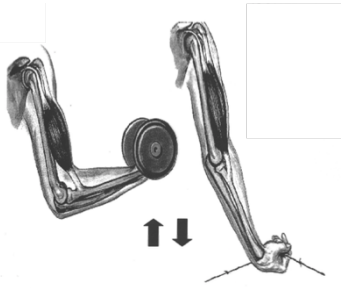


- The arrangement of fibres relative to the axis of force generation
- Fibre length (FL) is rarely the same as muscle length (ML)
- Most fibres insert obliquely into the tendon which represent a feather arrangement are called either pinnation or pennation
- Allows more fibres to be packed in which increases the effective muscle cross-sectional area (CSA)
- Fusiform: Fibres run the length of the muscle (from one tendon to the other)
- Unipennate: A central tendon with fibres running into the midline
- Muscle A is fatter compared to to Muscle B and this more fibres can be packed into that area to produce a greater contraction force
- Force production in proportional the muscle CSA
- Different muscles are required for different tasks; some for dexterity others for force and power



- Biceps: Fusiform; fibre length is almost the size of the muscle length
- Vastus laterallis: Overall muscle length is overall much shorter than the actual muscle length

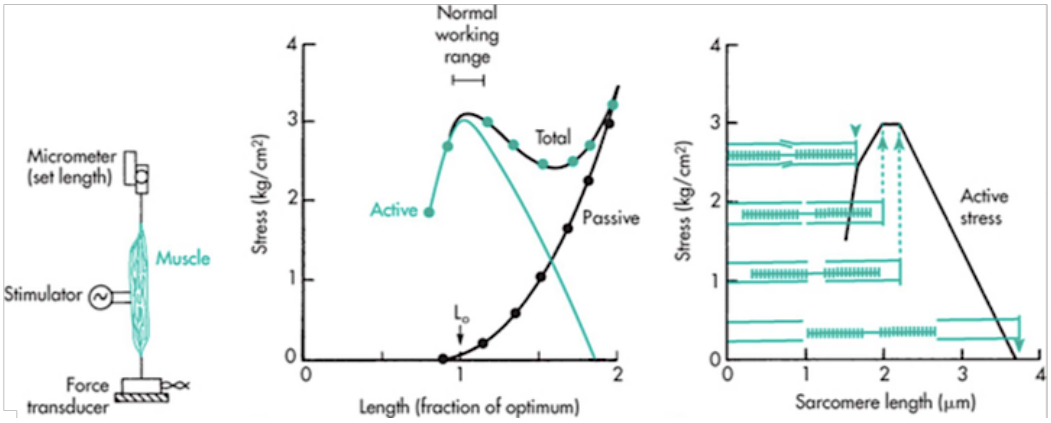
Muscle Action



- Isometric Contraction: Any contraction that creates force without moving a load (immovable object)
- Isotonic (concentric) Contraction: Any contraction that creates force and moves a load
  - Every isotonic contraction begins with an isometric phase
  - The force exceeds the weight and overcomes the load, muscle shortens and moves to an isotonic contraction
- Eccentric contraction: Exerting force, muscle still lengthening – load greater than the force exerted by the muscle
- If the force developed by the muscle is greater than the load on the muscle, a shortening or (miometric, concentric) action occurs
- When the force developed by the muscle and the load are equivalent, or the load is immovable, a fixed-end or isometric action occurs
- When the load on the muscle is greater than the force developed by the muscle the muscle is stretched, producing a lengthening (plyometric or eccentric) action

Length-Tension Relationship

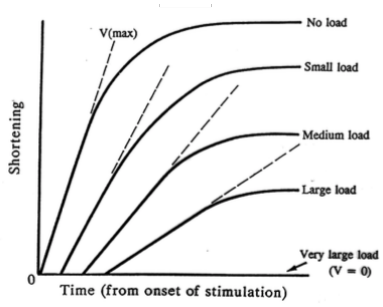
- Relationship between actin and myosin filament overlap and isometric force
- Maximally stimulate muscle at a number of discrete lengths (sarcomere lengths) and the record P_o

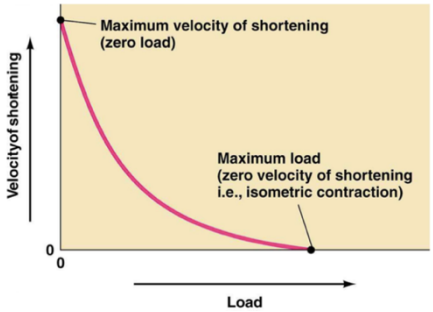


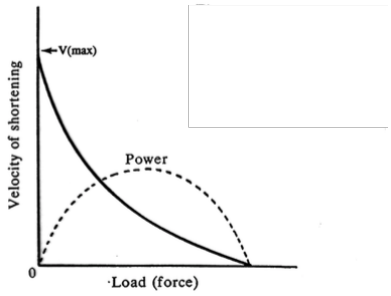
- Total: Addition of active and passive
- Ascending limb: Sarcomere length short; overlap not optimal between actin and myosin; maximum active force compromised
- Plateau region: Sarcomere length optimal; overlap optimal between actin and myosin; ideal for maximum force
- Descending limb: Sarcomere length long or stretched; little or no overlap between actin and myosin; maximum force compromised

Force-Velocity Relationship

- Muscle allowed to shorten against a constant load and its velocity is plotted against resistive force
  - Heavier the load, slower the lift
- There is a latent period where muscle is contracting isometrically until sufficient tension has been produced to equal the load
- Not only is the rate of shortening reduced for heavy loads, the amount of shortening is decreased

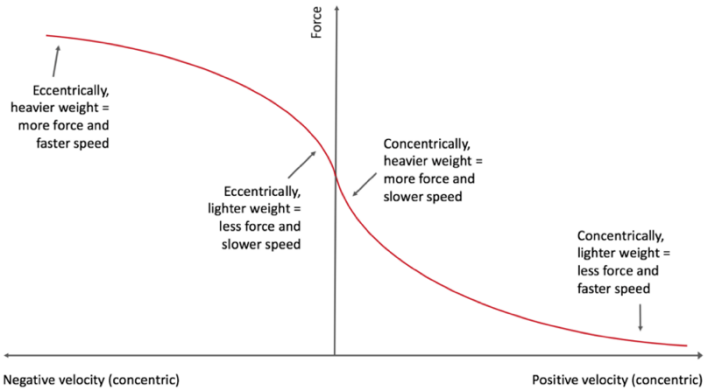


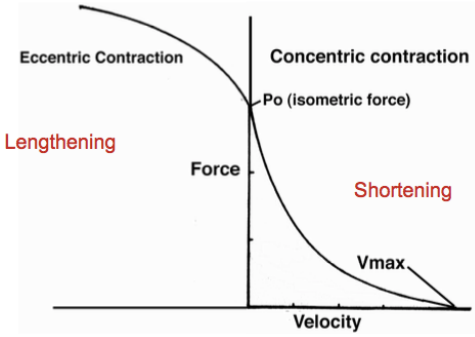




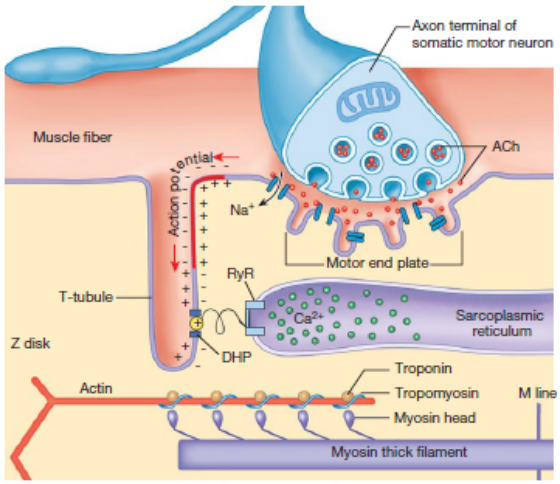
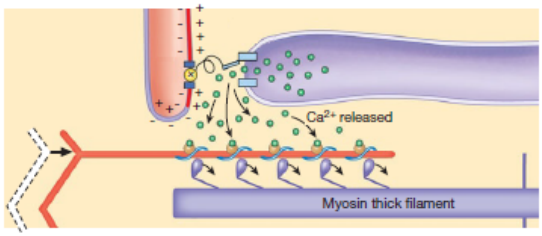
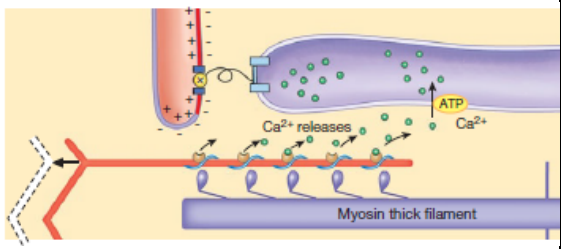
- V_{max}: The maximum velocity of shortening
- Related to muscle fibre type distribution and muscle architecture
- Power = Load x Velocity
- Power will be zero when there is no load on the muscle and when the load is so heavy it cannot be moved at all

- Success in many sports is dependent upon maximal power output





Muscle Contraction

Muscle Fibre Activation	
	- Somatic motor neuron releases ACh at neuromuscular junction - Initiates an action potential along cell membrane - T-tubule are extensions into the surface membrane of muscle fibre - Couples with the T-tubule is the sarcoplasmic reticulum loaded with calcium - Allow both sodium and potassium ions to the cross the membrane, however sodium influx exceeds potassium efflux as the electrochemical driving force is greater for sodium
	- Action potential propagates down the T-tubule - Ryanodine receptors open releasing calcium into the cytoplasm - Calcium binds to troponin allowing actin-myosin binding
	- Sarcoplasmic Ca^{2+}-ATPase pumps Ca^{2+} back into sarcoplasmic reticulum - Decrease in calcium concentration causes calcium to unbind from troponin - Tropomyosin re-covers binding site - Myosin heads return back to relaxed position