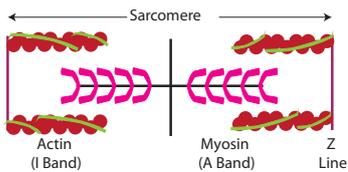


MUSCULOSKELETAL PHYSIOLOGY

	Skeletal Muscle	Cardiac Muscle	Smooth Muscle
Anatomy	Like cardiac muscle skeletal muscle has a striated pattern due to regular interdigitating thick myosin and thin actin fibres. In contrast it is multinucleated. Motor end plates and muscle spindles are present, more developed sarcoplasmic reticulum (SR)	Generally similar to skeletal with several important differences; it is in series more than parallel. Usually smaller and mostly mononuclear. Has a greater number of mitochondria, and there are intercalated discs which bind the cells together and improve conduction speeds.	Smooth muscle lacks cross-striations and can be further subdivided into two broad types: unitary (or visceral) smooth muscle which is functionally syncytial, mononuclear, and contains pacemakers and multiunit smooth muscle which resembles skeletal muscle and is found in places such as the eye.
Innervation	Innervated by voluntary α motor fibres, with separate γ fibres. Each motor neuron innervates a number of fibres, comprising a motor unit.	Autorrhhythmic but modified by the autonomic nervous system. PNS is supplied by the vagal nerve. SNS originate from the upper thoracic spinal cord and synapse in the middle of stellate ganglia then form a complex plexus (incl. parasympathetic fibres) to innervate the heart.	Generally under the control of autonomic nervous systems. Some resemble skeletal muscle and are innervated by motor neurons, other smooth muscles are autorrhhythmic and are only modified by nerve activity.
AP Duration	~ 1 msec	150 msec (SA Node) 250-300 msec (ventricles)	~10 msec
Excitation-Contraction Coupling	Nerves trigger ACh release at the motor end plate, this binds to nicotinic receptors, which open allowing K^+ and Na^+ flux which generates an action potential, T tubules trigger release of Ca^{++} from the SR. The Ca^{++} binds to troponin C uncovering myosin, allowing cross-linkages with actin allowing contraction.	Pacemakers trigger an action potential (AP) which propagates. Following Na^+ influx, Ca^{++} influx triggers T-tubules to release Ca^{++} from the SR (unlike skeletal which is triggered depolarisation alone). Nb without Ca^{++} in the ECF there is no contraction. Same mechanism as skeletal but prolonged due to the length of the AP.	Smooth muscle does not contain troponin but instead have calmodulin. In smooth muscle E-C coupling is achieved by Ca^+ combining with calmodulin which then activates myosin via phosphorylation. This enables contraction. Phosphatase breaks the myosin-actin contraction. Sustained stimulation 'latches' the muscle.



Length-tension relationship of skeletal muscle is confirmed by the observation that developed tension during an isometric contraction depends on the initial muscle length. The overlap of actin and myosin filaments in the sarcomere determines the number of cross bridges developing tension, and this is reduced by excessive shortening or stretching. If a muscle is stretched too much or not enough it becomes inefficient. In life, muscle fibres are arranged at or near their optimal length, and this is usually called the resting length.

Single twitch is a single stimulus-contraction-relaxation sequence in a muscle fibre. The duration of the twitch varies with the type of muscle being tested. "Fast" muscle fibers, primarily those concerned with fine, rapid, precise movement, have twitch durations as short as 7.5 ms. "Slow" muscle fibers, principally those involved in strong, gross, sustained movements, have twitch durations up to 100 ms. The twitch has a latent period where the action potential sweeps across the sarcolemma and the SR releases Ca^{++} ions. In the contraction phase the tension rises to a peak, calcium ions bind to troponin C, the active sites on the thin (actin) filaments are exposed, and cross bridging with the myosin occurs. Finally the relaxation phase is characterised by a decrease in Ca ions which are pumped back into the SR, cross bridges dissociate, and the active sites are again covered by tropomyosin.

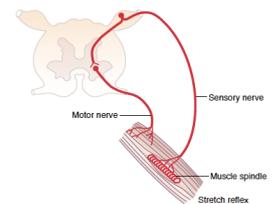
Treppe effect if a skeletal muscle is stimulated a second time immediately after the relaxation phase has ended, the contraction that occurs will develop a slightly higher maximum tension than the previous contraction. This may continue over roughly 30-50 stimulations before plateau. Because it rises in steps it is called the treppe effect (treppe = stairs in German). The cause is believed to be a gradual increase in Ca^{++} in the sarcoplasm as the ion pumps in the SR are unable to recapture the Ca^{++} in between stimulations.

Tetanus if the muscle is re-stimulated before the end of the relaxation phase a second more powerful contraction occurs. This is the summation of twitches or wave summation. If the stimulation continues at a frequency which does not allow complete relaxation tension will rise to a peak and remain at this level, this is called incomplete tetanus. If the frequency of stimulation increases further the relaxation phase will be completely abolished, this is called complete tetanus.

Motor unit all of the muscle fibres controlled by a single motor neuron constitute a motor unit. The size of the motor unit is an indication about how fine the control of movement can be. In the eye a motor neuron may control 4-6 fibres. In a leg muscle a single motor neuron may control 1000-2000 muscle fibres.

Excitation-contraction coupling is a term used to collectively refer to the sequential series of events from the action potential through to the contraction of the muscle.

Monosynaptic stretch reflex When a skeletal muscle with an intact nerve supply is stretched, it contracts. This response is called the stretch reflex. The stimulus that initiates the reflex is stretch of the muscle, and the response is contraction of the muscle being stretched. The sense organ is a small encapsulated spindle-like or fusiform shaped structure called the muscle spindle, located within the fleshy part of the muscle. The impulses originating from the spindle are transmitted to the CNS by fast sensory fibers that pass directly to the motor neurons which supply the same muscle. The neurotransmitter at the central synapse is glutamate.



Muscle Fatigue An increasing difficulty to sustain a given level of exercise initiates a sensation called fatigue. Fatigue occurring during the first few seconds of very intense exercise is due to depletion of ATP and creatine phosphate stores in active muscles. When fatigue occurs with less intense exercise it is associated with the accumulation of lactic acid in the muscles. There are several types of muscles which are adapted for different types of activity. Type I or slow oxidative fibres have a slow contraction speed and low myosin ATPase activity. These cells are specialised for steady continuous activity and are highly resistant to fatigue. Type I cells have a high surface to volume ratio, a good capillary supply and are rich in mitochondria and myoglobin and are therefore red. They typically utilise fat as a substrate for oxidative phosphorylation. Type IIA are fast oxidative-glycolytic and high myosin ATPase activity, their appearance is similar to Type 1 and they are also generally resistant to fatigue. Type IIB are fast glycolytic fibres with high myosin ATPase activity and are distinct in appearance from the previous muscle types. They have limited capillary supply, few mitochondria and little myoglobin. As a result they are pale, and generate ATP from anaerobic metabolism leading to rapid fatigue.

