Lecture 13, Mar 9, 2023

Cross-Bridge Cycle

1. Binding
   - Calcium from the SR (released when muscles are excited via ACh) allows the attachment of myosin heads to binding sites on the actin
   - This forms cross-bridges that attach the myosin to the actin
   - Without calcium binding cannot start
   - ATP is used to push calcium back into the reservoirs using SERCA pumps
2. Bending
   - Once the binding happens, the head of the myosin rotates
   - Each head is about 5 piconewtons of force
   - ADP is used here to power this
3. Detachment
   - ATP attaches to the myosin head, which breaks the cross-bridge
   - Without ATP, the myosin heads are stuck and cannot be detached, so no further muscle movement can occur
   - This is the reason for rigor mortis – without ATP muscles are stuck
4. Energization
   - As soon as ATP is attached, it becomes ADP, and the head becomes energized
   - If there's more calcium available, the cycle repeats again

What Affects Tension of a Single Fibre?

1. Action potential frequency
   - Each action potential causes a muscle twitch
   - For a single action potential, after a few ms to allow the calcium being pumped, tension increases during the contraction phase; then tension decreases during the relaxation phase
     - The latent period is the time between the stimulation and contraction
     - Contraction and relaxation time together is about 100 ms
   - Multiple action potentials cause twitch summations like spatial summations of action potentials
   - As the frequency of action potentials increase, the tension increases up to an upper limit (*tetanus*) and the muscle stays contracted instead of twitching
     - This happens at around 60 Hz for some muscles
2. Fibre length
   - Muscles can be much longer or shorter than resting length
   - At resting muscle length, there is optimal overlap, when the most tension could be produced; if the muscle gets longer or shorter the force decreases
     - At 70% (contracted muscle) there is more overlap, and force drops sharply
     - At 130% (stretched muscle) there is less overlap, force also drops but less sharply
   - Between 70% and 130% is usually what happens within the body; under experimental conditions it's possible to stretch the muscle so much that there is no more binding so no tension can be produced
   - There is also some passive tension produced by the muscle as it gets stretched, like a spring
     - The passive tension is added onto the active tension
3. Fibre diameter
   - If each myofibril gets bigger, it can develop more tension (fibre hypertrophy)
   - If more myofibril gets packed into a single fibre, it can also develop more tension (fibre splitting/hyperplasia)
     - Bigger filaments will exert more tension on z-disc connections when fibres contract, which can cause it to snap
     - When z-discs snap, they become separate myofibrils which is how hyperplasia happens
4. Fatigue
   - Different types of fibre types have their tension fall off in different ways

- Slow-oxidative fibres have nearly constant tension, up to an hour
- Fast-oxidative glycolytic fibres exert good tension up to 10 minutes but decrease after that; after an hour they exert nearly no tension
- Fast-glycolytic fibres get fatigued much faster, with tension dropping rapidly at around 2 seconds
  * e.g. chicken breast because chickens can fly for a very short duration

5. Fibre Type

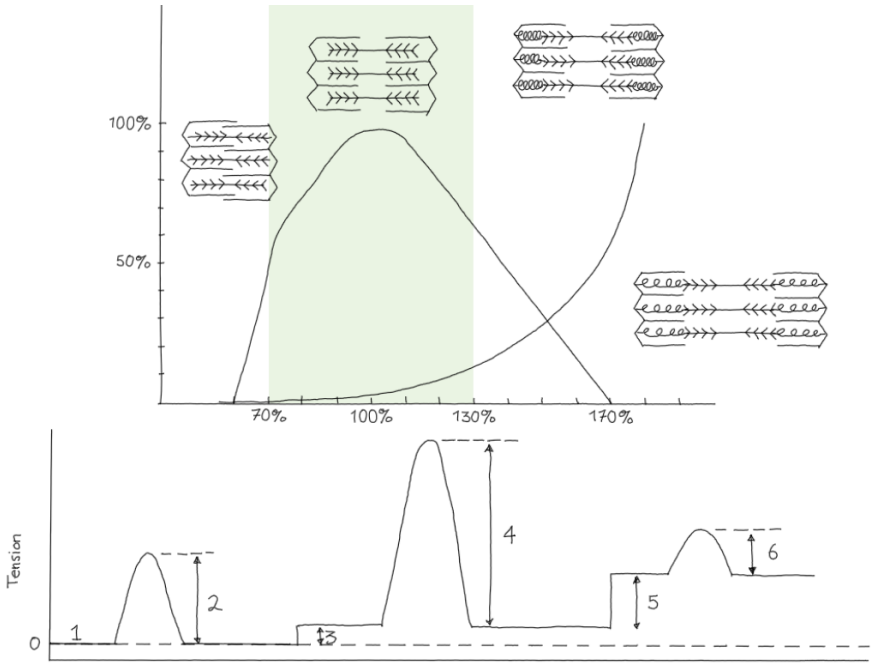

Figure 1: Combination of the effects of active (stimulated) and passive tension

	Slow-Oxidative Fibers (Type 1)	Fast-Oxidative-Glycolytic Fibers (Type 2A)	Fast-Glycolytic Fibers (Type 2X)
Fiber diameter	Small	Largest	Large
Rate of fatigue	Slow	Intermediate	Fast
Size of motor neuron innervating fiber	Small	Intermediate	Large

Figure 2: Comparison of fibre types

What Affects Tension of Multiple Fibres?

1. Number of fibres per motor unit
   - Motor units are stimulated together by nerves

- More fibres in a single motor unit means more power
- Motor units can consist of multiple muscle cells in a single fascicle, but they don't have to consist of the whole fascicle
  - This can account for fatigue as different motor units are switched around
- Different types of fibres can be stimulated to produce tension that is a sum of the different types

2. Number of active motor units
   - Different neurons excite different motor units
   - More neurons stimulate more motor units which creates more power
   - All these motor units would be within the same fascicle

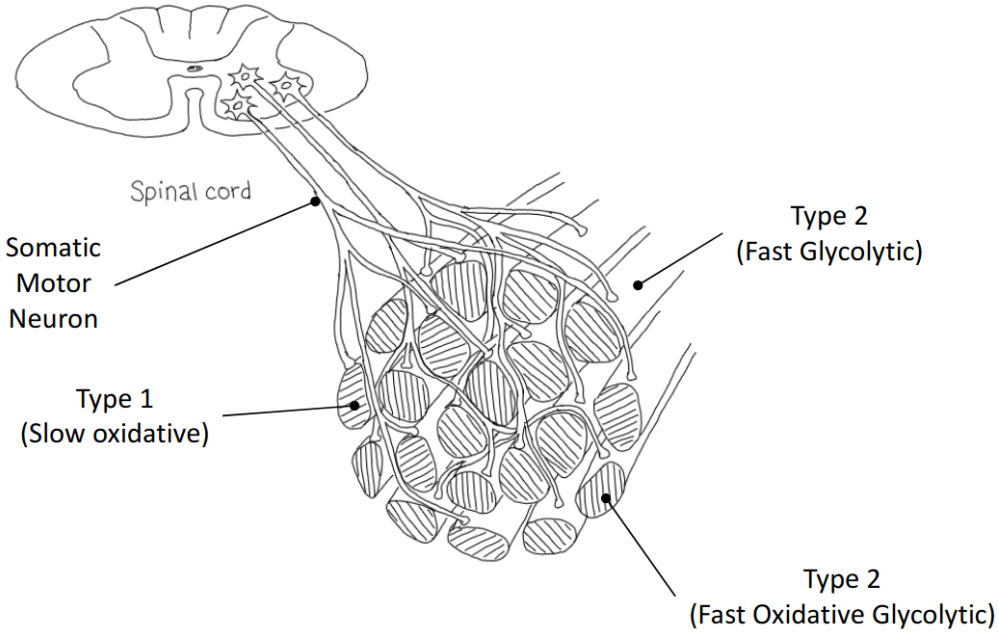

Figure 3: Structure of somatic neurons to muscle fibres