

VORLESUNG 6

Vorlesung
Humboldt-Universität zu Berlin
Institut für Physik

Biologische Physik

Die Dynamik biologischer Prozesse im menschlichen Körper

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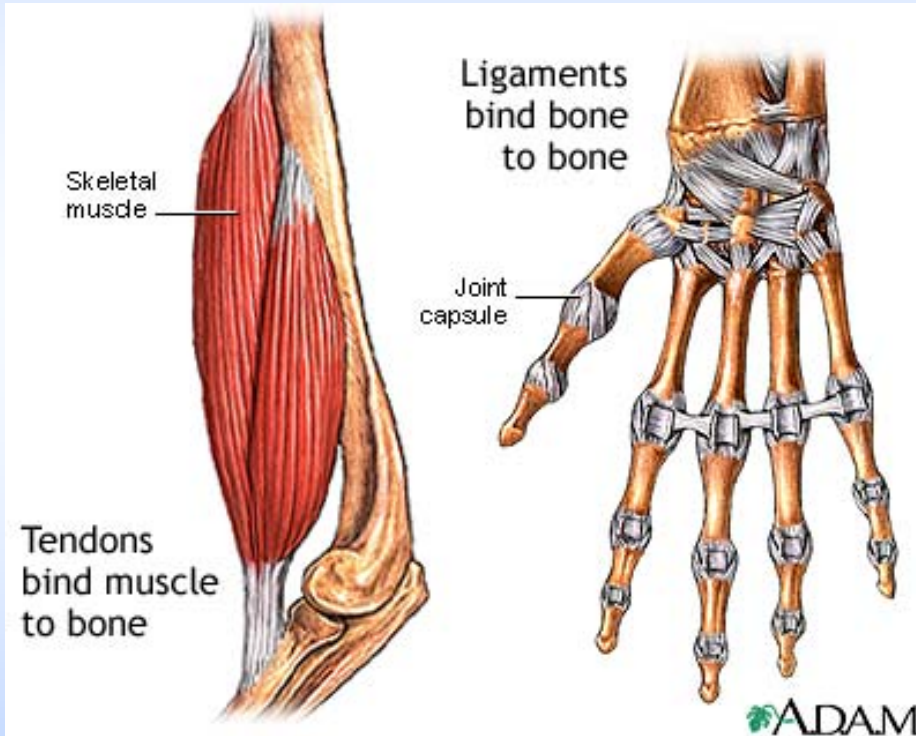
**Max Planck Institute
of Colloids and Interfaces**



4 Muscle

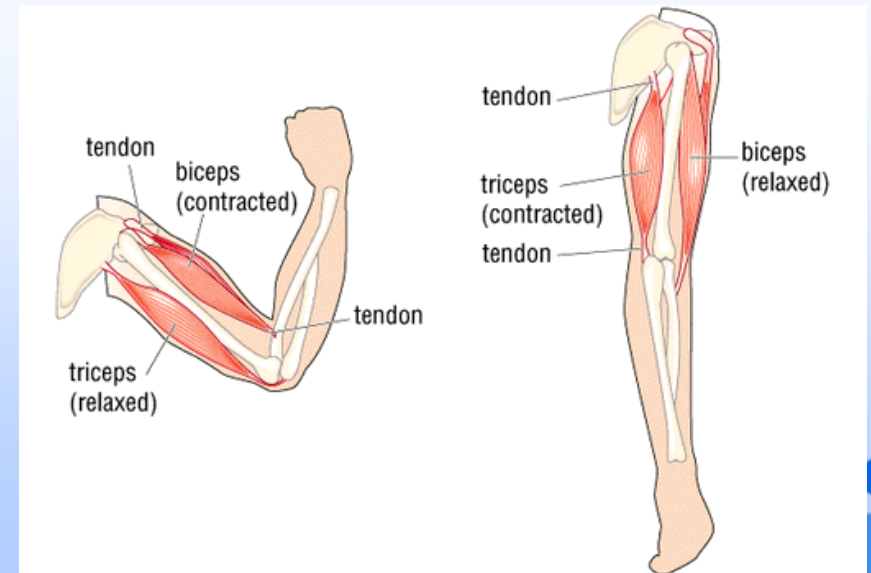
function:

to produce force and cause motion due to contraction



antagonist muscles:

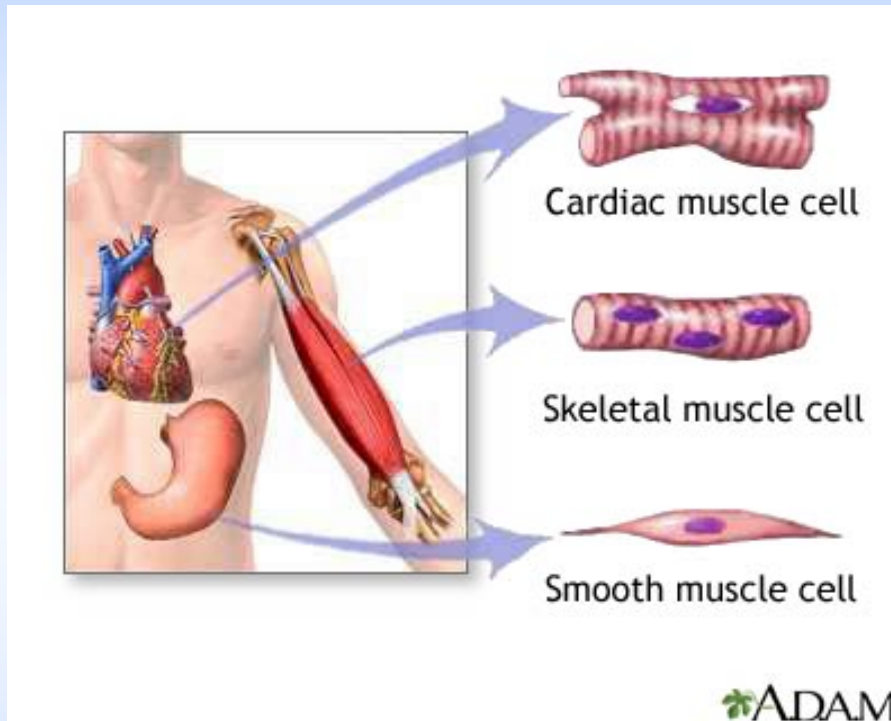
- flexion: contraction of the biceps brachii
- extension: contraction of the triceps brachii





4.1 Muscle - macroscopically

different muscle cells:



involuntary

voluntary

involuntary

striated

no striation

three types of skeletal muscle fibers
(= muscle cells):

- type I (slow twitch red fibers) – resistant to fatigue
- type IIA (fast twitch red intermediate fibers) – “intermediate”
- type IIB (fast twitch white fibers) – fatigue quickly

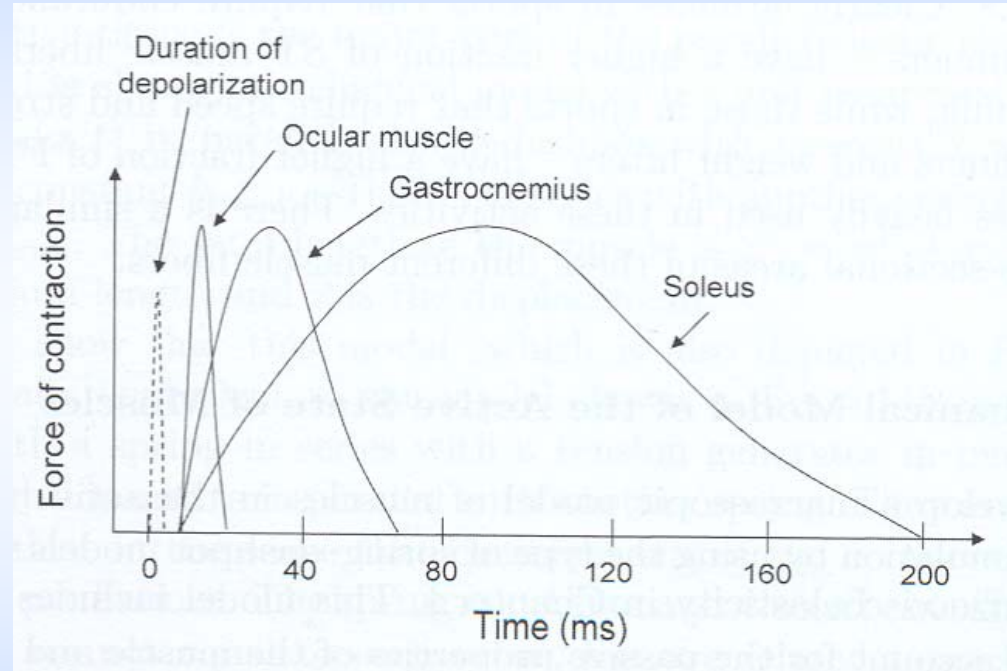
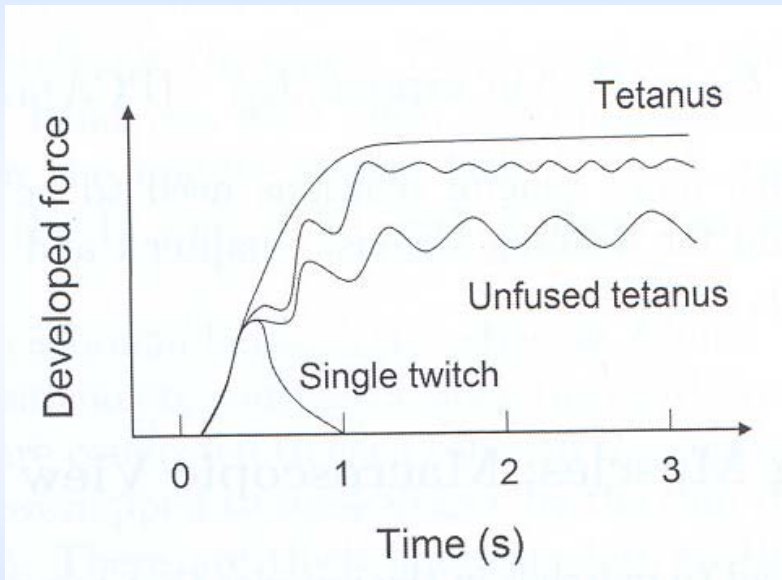




4.1 Muscle - macroscopically

maximum muscle force: $F_{\max} = k PCA$

PCA ... physiological cross-sectional area



effect of exercise:

- hypertrophy (increase in the cross-sectional area of individual muscle fibers)
- hyperplasia (formation of new fibers)





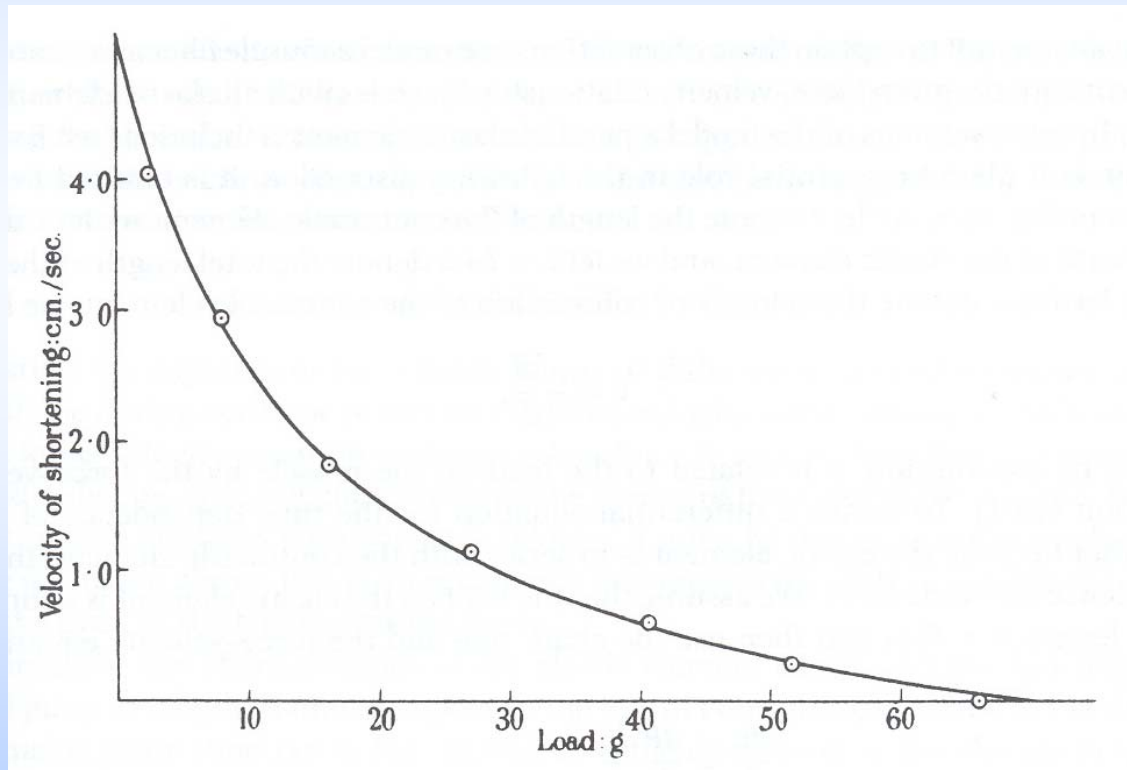
4.2 The Hill Model

force-velocity equation:

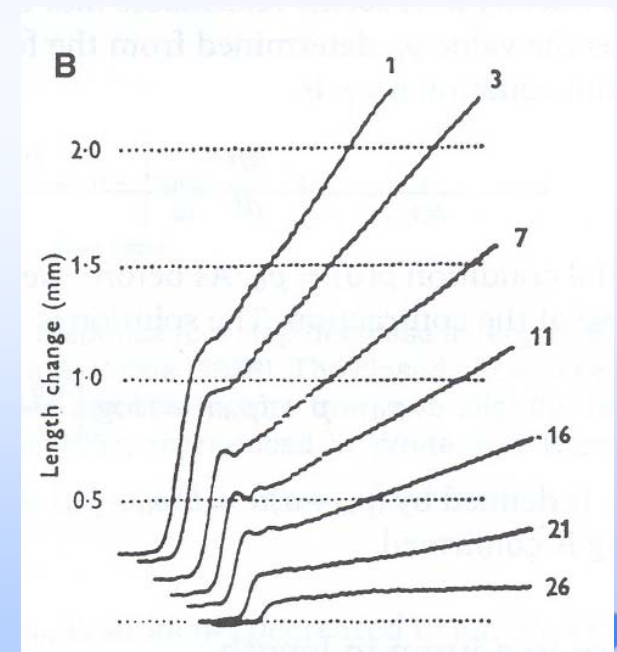
$$(p + a)v = b(p_0 - p)$$

$$(p + a)(v + b) = (p_0 + a)b$$

experimental data points:



length change after a step decrease in tension:





4.2 The Hill Model

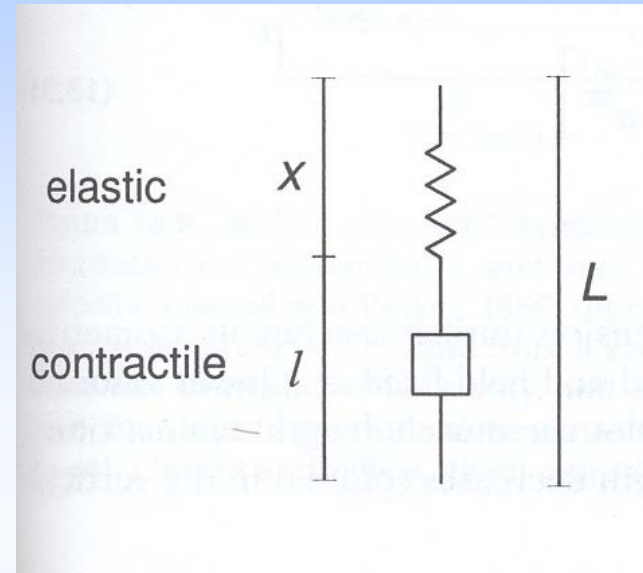
$$\frac{dp}{dt} = \alpha \left[\frac{dL}{dt} + \frac{b(p_0 - p)}{p + a} \right]$$

solutions of the Hill model:

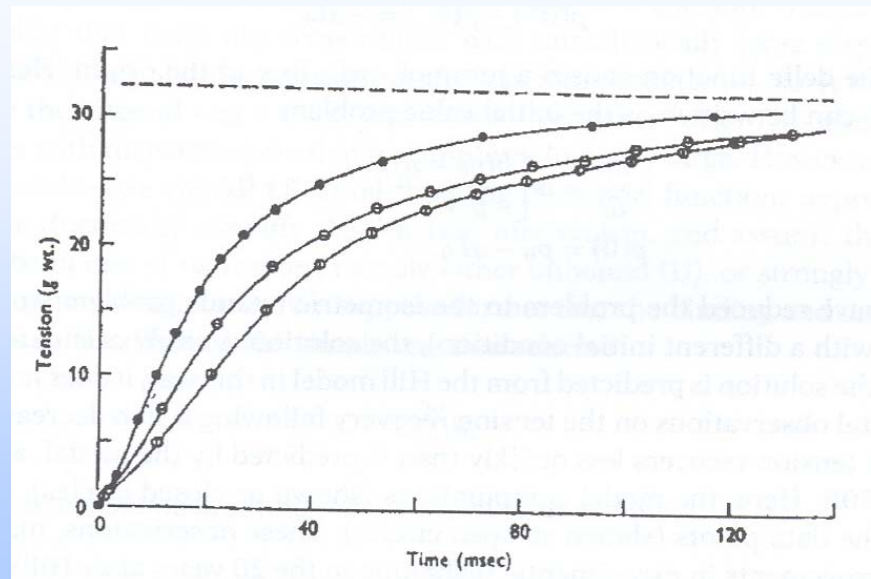
isometric tetanus:

$$-p - (p_0 + a) \ln \left(\frac{p_0 - p}{p_0} \right) = \alpha b t$$

Hill's two-element model
for skeletal muscle:



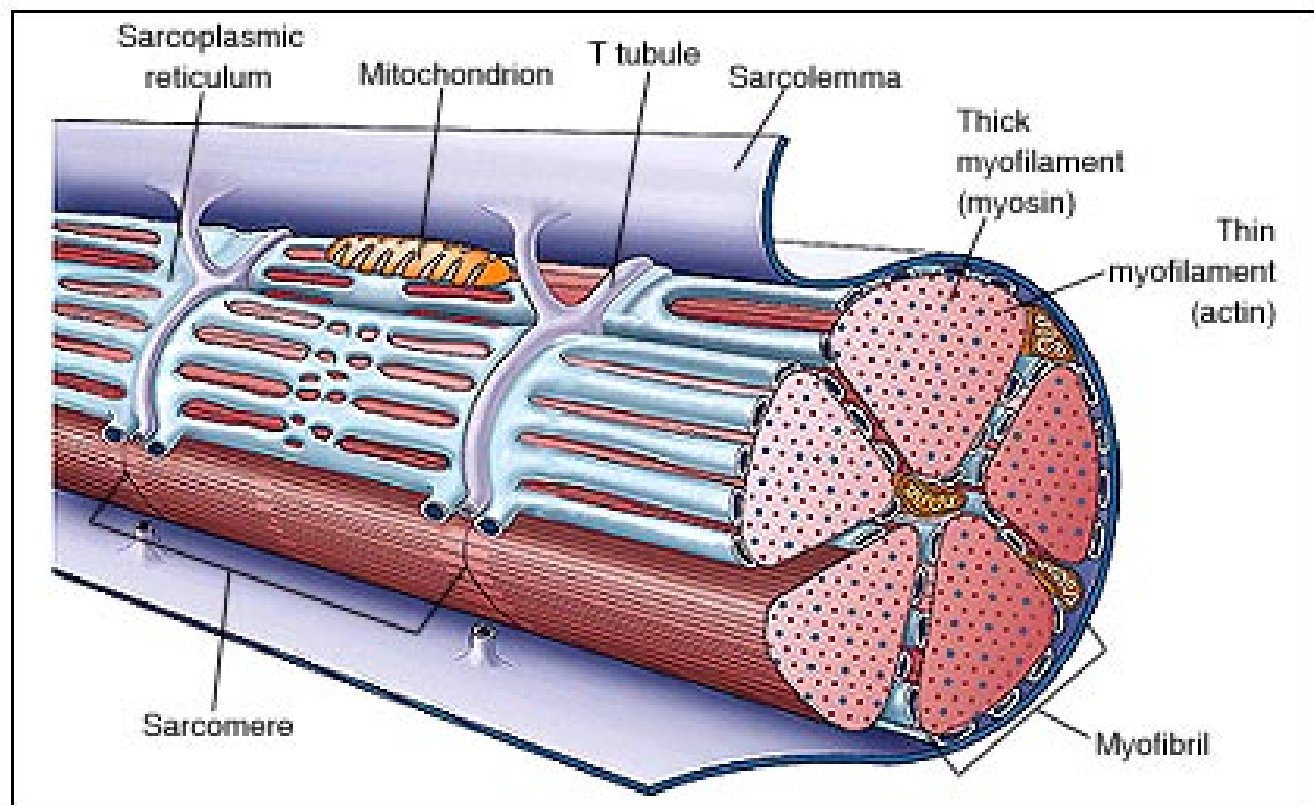
response to
a jump in length:





4.3 Muscle - microscopically

the muscle fiber (= muscle cell):

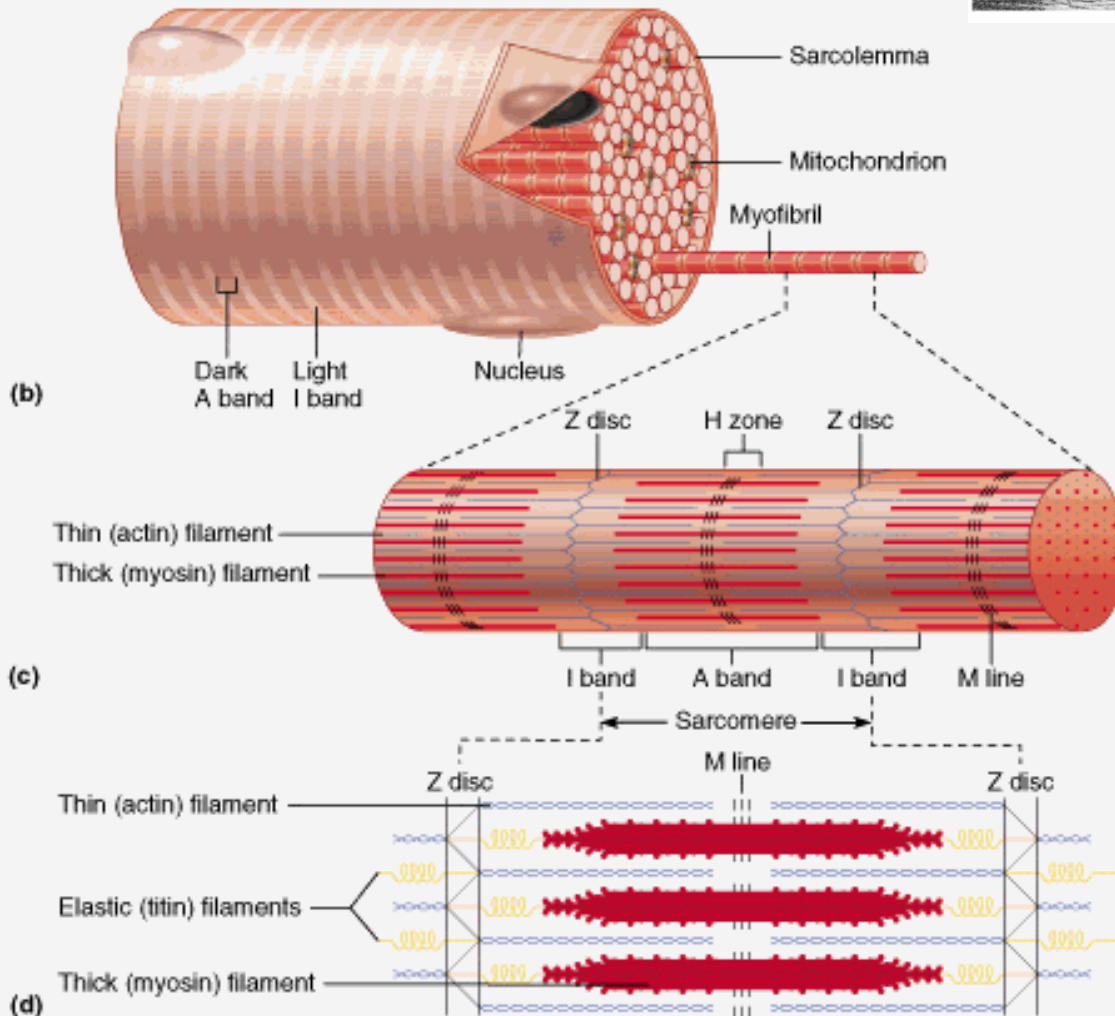
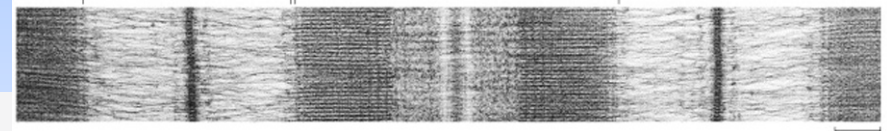


- action potential spreads across sarcolemma and T-tubules
- voltage-gated Ca^{2+} channels are opened, release of further Ca^{2+} from the sarcoplasmic reticulum
- high intracellular Ca^{2+} concentration causes a change in the myofilament structure



4.3 Muscle - microscopically

sarcomere structure:

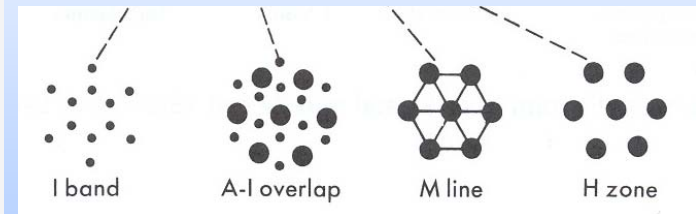


overlap regions: A band (dark)
no overlap: I band (light)

two types of parallel filaments:

- thin filaments (actin)
- thick filaments (myosin)

viewed end on:



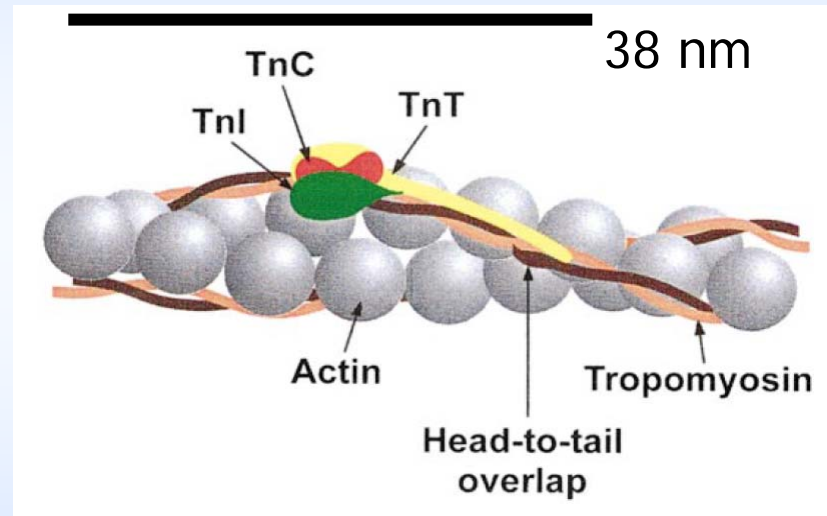
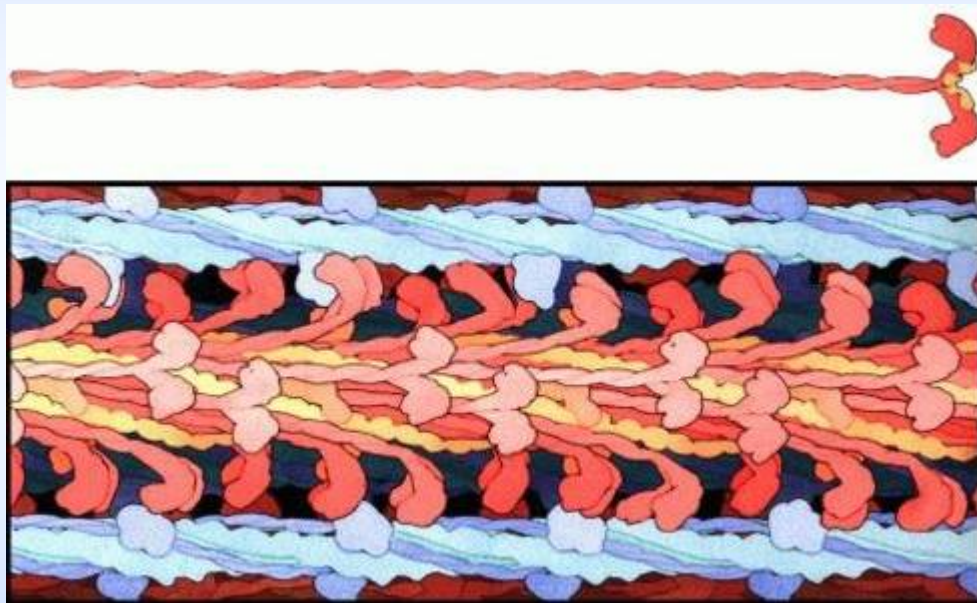


4.4 Muscle - nanoscopically

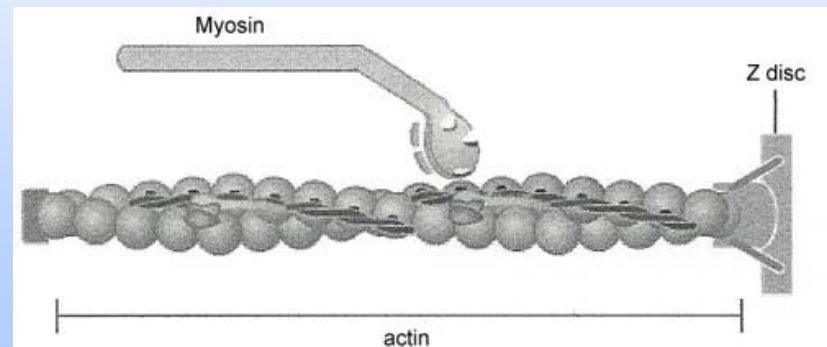
filament structure – crossbridge theory:

thick filaments contain protein myosin
globular heads constitute the crossbridges

thick filaments contain actin,
tropomyosin, and troponin (Tn)



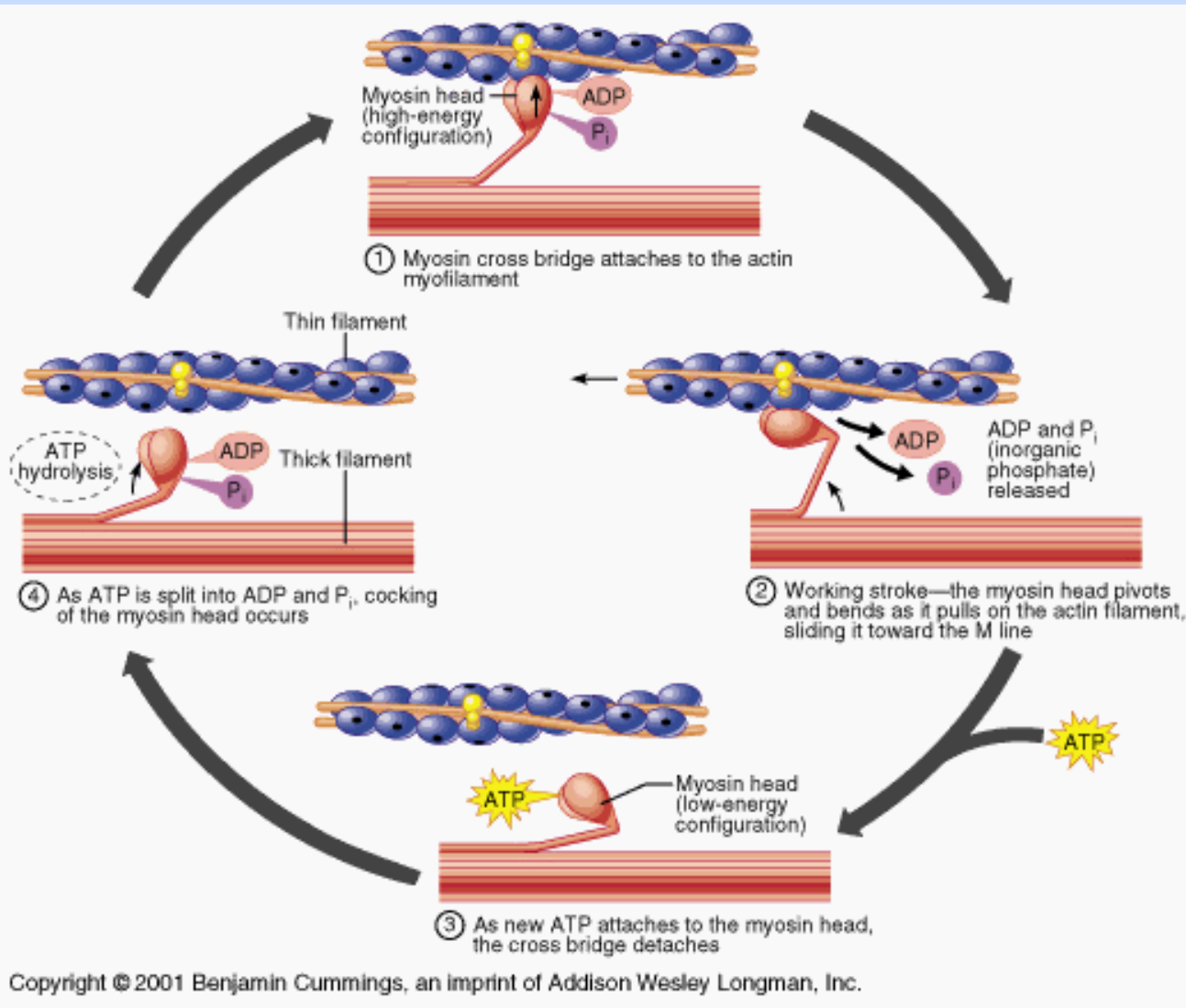
crossbridge between
myosin and actin filament:



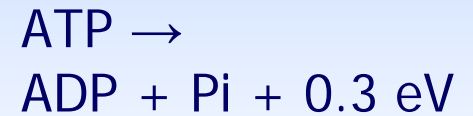


4.4 Muscle - nanoscopically

the crossbridge cycle – power stroke:



reaction:



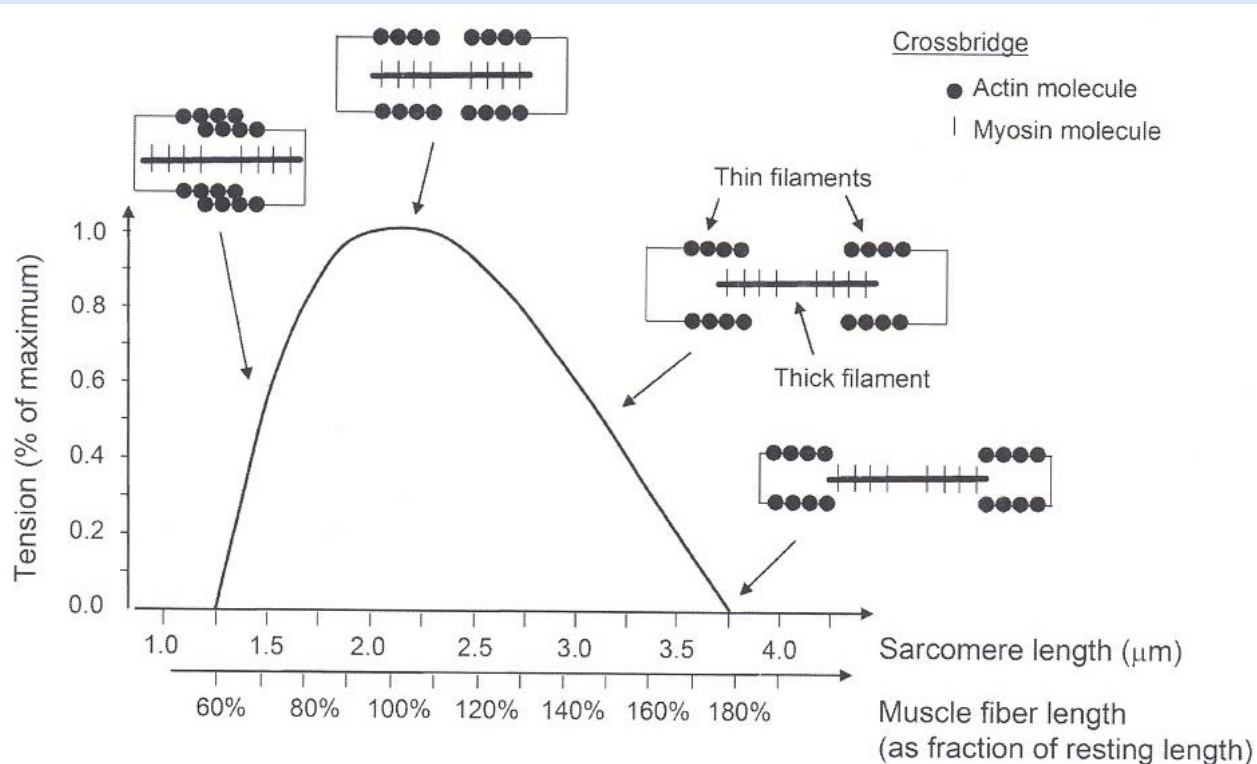
configurational change of the crossbridge:
from nearly perpendicular to a bent position



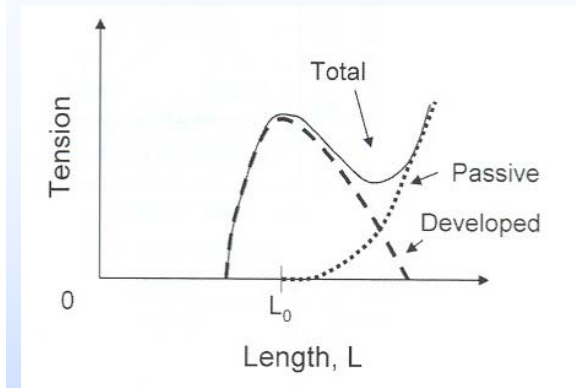


4.3 Muscle - microscopically

force vs. sarcomere length:



active, passive,
and total tension
vs. length:



example: clenching your fist with a strongly flexed wrist

