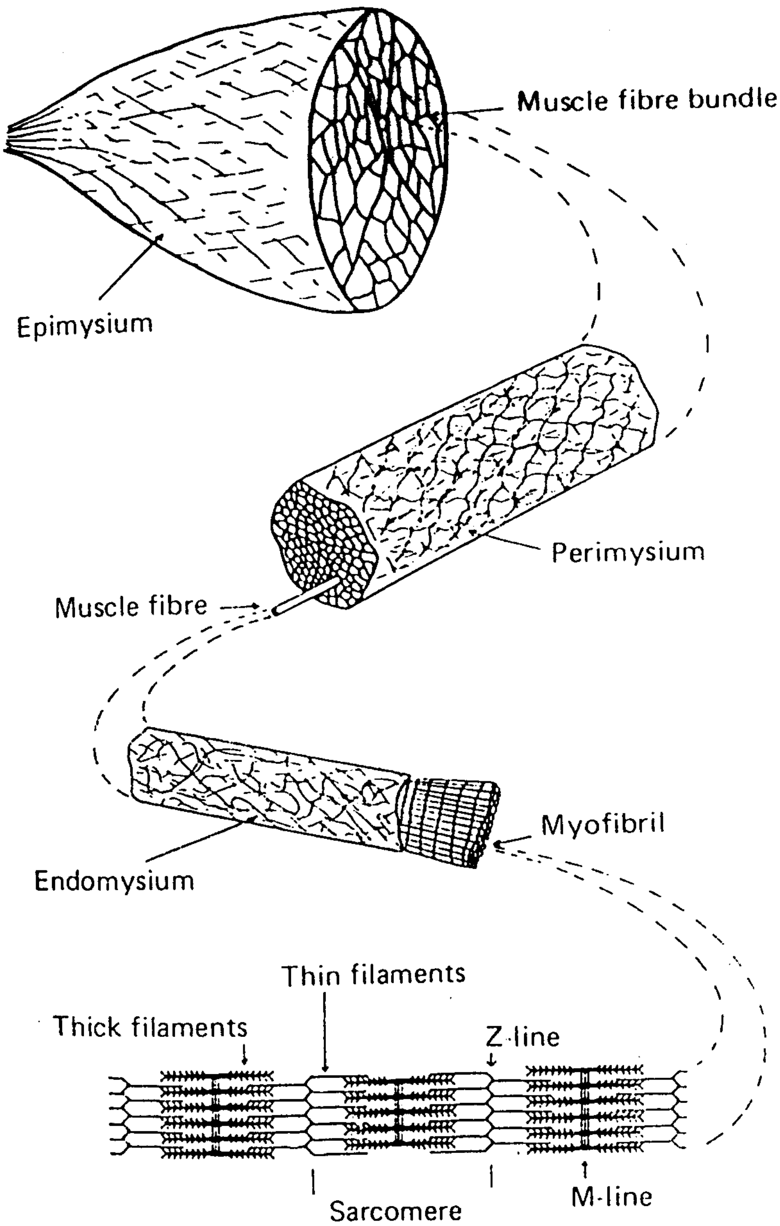
Muscle

- **Another hierarchical structure – rather like the cellulose in cell walls.**



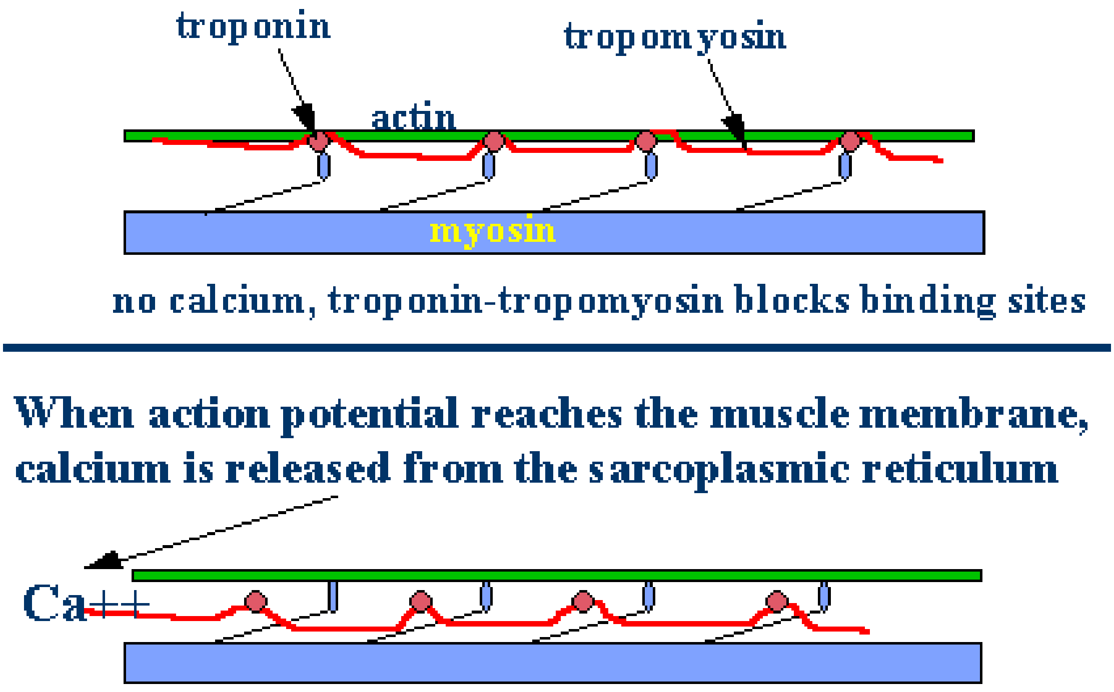
- **And also have highly extended chain structures.**

The role of the muscle is to do work, rather than simply support stress.

The rate of working is determined ultimately by mechanical variables, but this has to be matched by the rate of supply of energy.

Muscle consists of thin filaments of actin, and thick filaments of myosin.

Troponin and tropomyosin sit in between these two, and can either block or favour binding between them depending on Ca^{2+} concentration.

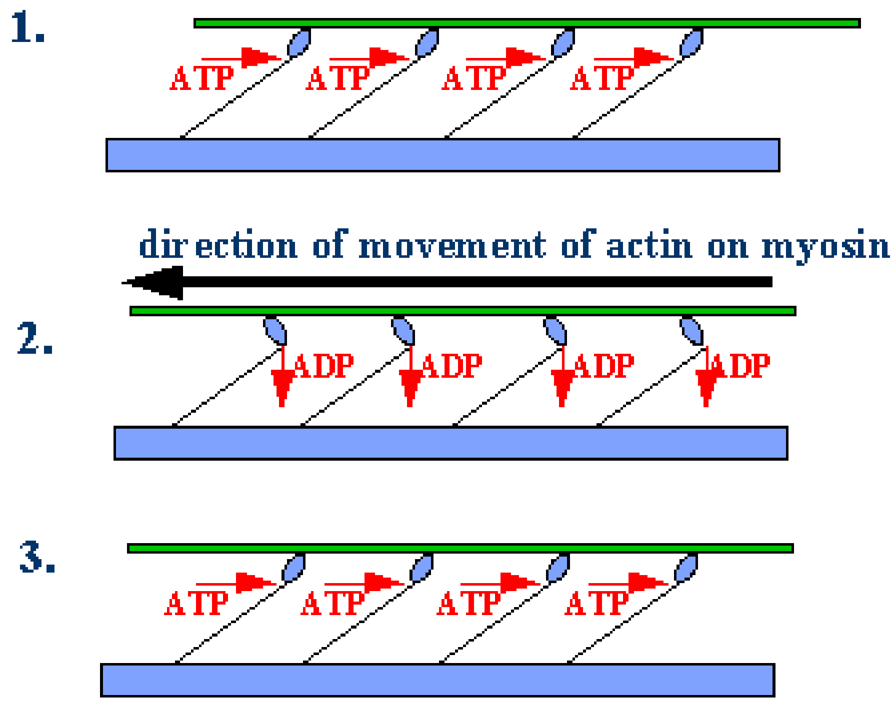


- The shape of the myosin molecule is very complex. with a globular head which attaches to a long stalk on the major portion of the myosin molecule; numerous heads exist on a single myosin molecule.

- The head is flexible and attaches to the actin molecule, with an energy cost.

- It can be considered a ratchet because it detaches from the binding site on actin after the power stroke, goes back to its original orientation, and attaches to another binding site on actin, further down the molecule.

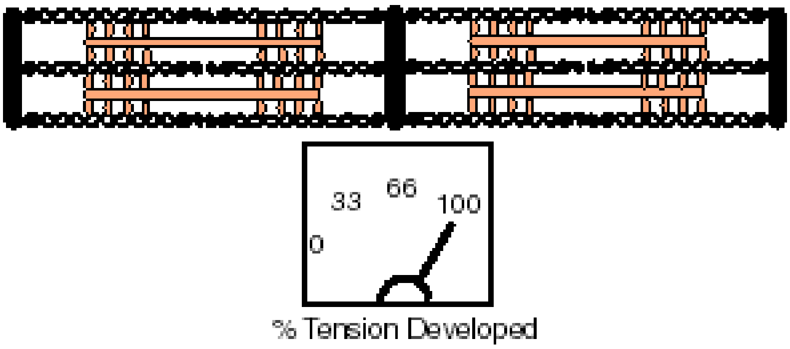
- This process slides the actin filament along the myosin filament and is known as the sliding filament theory of muscle contraction.

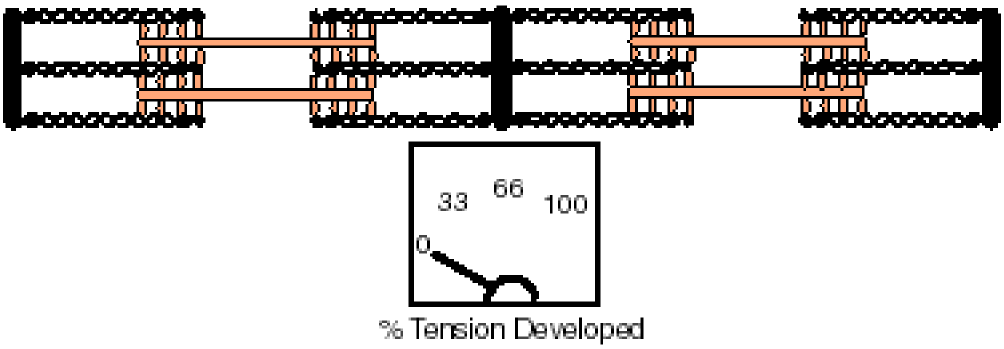


Mechanical Situation

Each thin filament is coupled to neighbouring thick filament by cross bridges.

Each cross bridge can exert a maximum force of ~5.3pN.
Muscle contracted
Muscle relaxed





Typically ~100 cross bridges pulling in same direction

This implies ~530pN at the centre of the filament.

This tension must be balanced by an equal number of cross bridges pulling in th eother direction at the other end of the filament.

Total force depends on number of attachment points, and this in principle can vary during contraction.

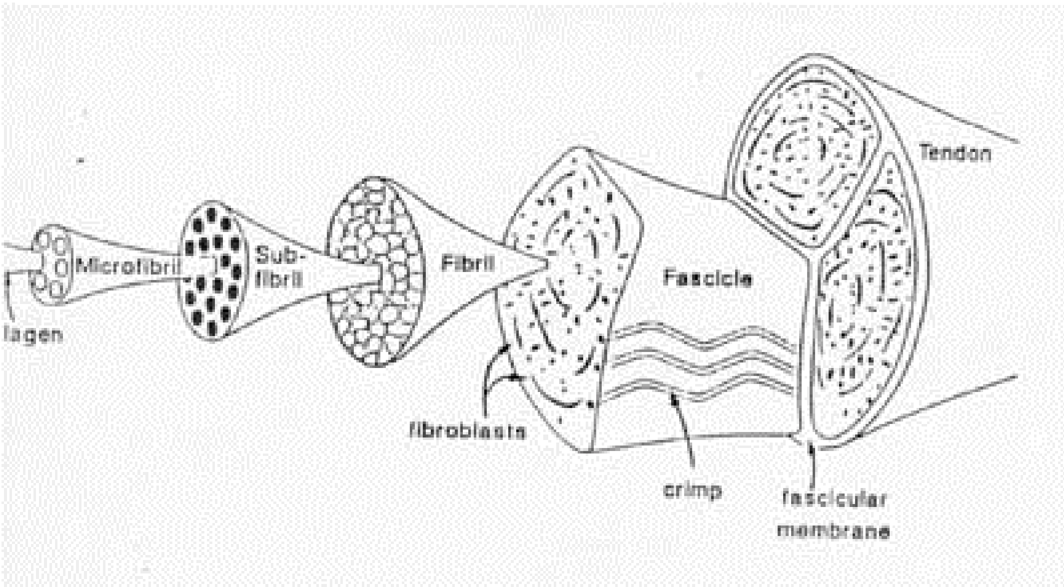
With a density of ~ 5.7 x 10^{14} m^{-2} for the filaments have a (maximum) stress of ~300kPa.

Typical strain at maximum exertion ~0.25 (less if the animal is 'cruising').

In practice different muscles work best at different rates, and efficiency of energy conversion may also vary and be dependent on fitness, temperature etc.

Tendon

This is another ordered and oriented structure (ligaments are rather similar).



In this case the tendons consist of crimped collagen fibrils embedded in a proteoglycan matrix.

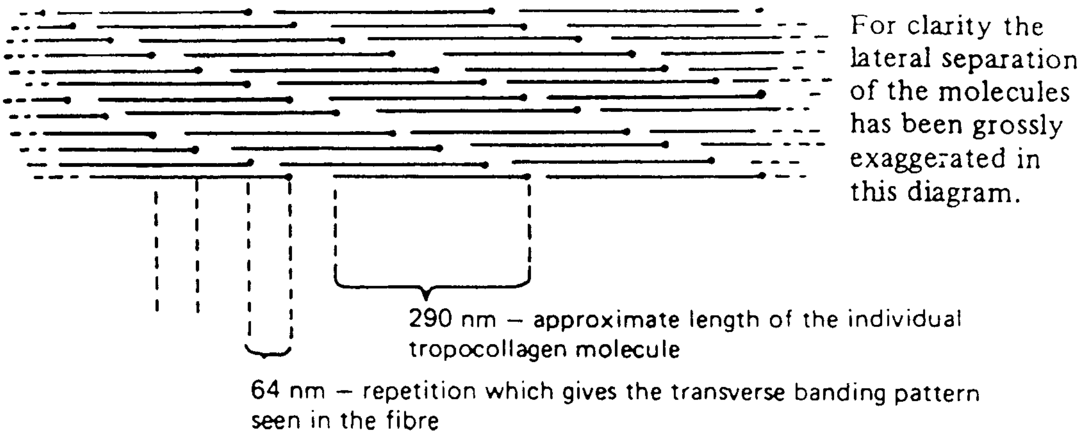
The collagen is a protein with a sequence of gly-X-pro along the chain, where X is variable.
Typical sequence......

—Ser—Gly—Pro—Arg—Gly—Leu—Hyp—Gly—Pro—Hyp—Gly—Ala—Hyp—Gly—

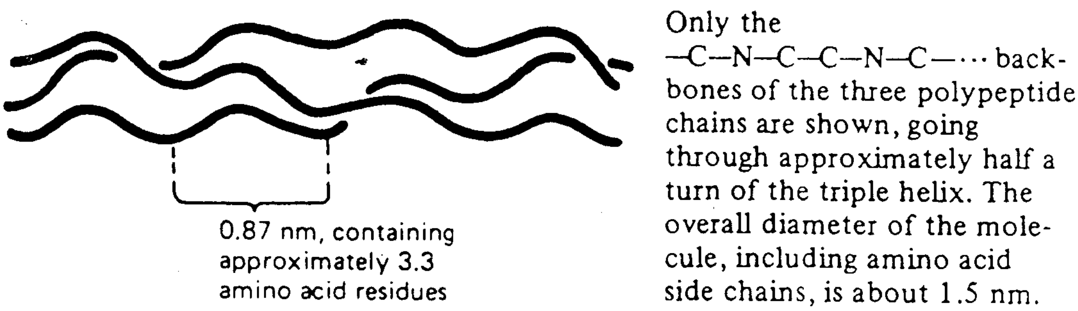
Collagen exists as tropocollagen, in which 3 of the molecules wrap around one another.

The tropocollagen molecules line up with a stagger, to give a highly oriented structure with a characteristic repeat.

The role of the proteoglycan (a polysaccharide with



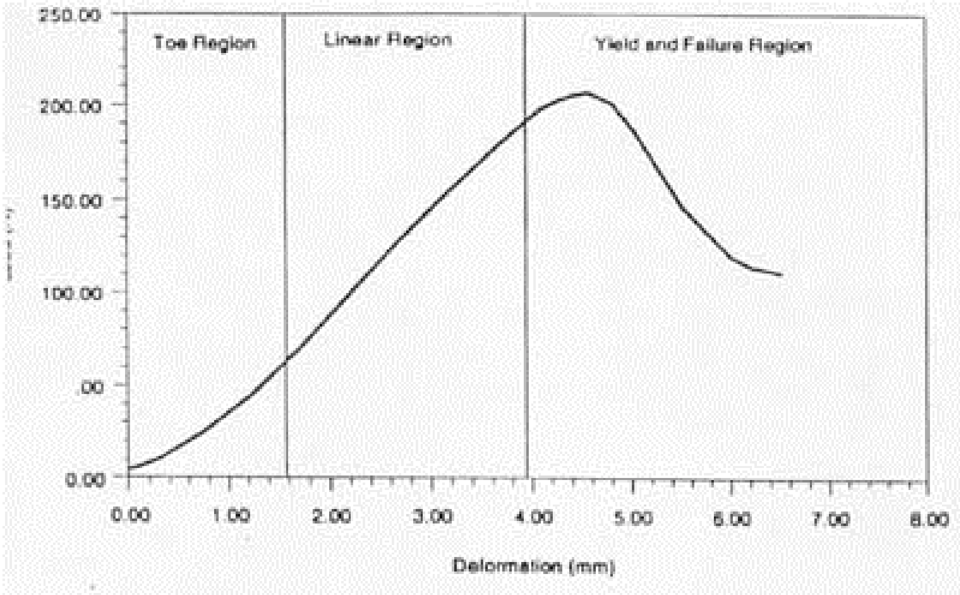
(ii) *The three polypeptide chains of tropocollagen:*



short chains of protein hanging off) matrix is to improve mechanical properties, particularly in compression or shear.

(Note the fibroblasts are cells which produce more collagen).

The crimping in the collagen structure is important in giving non-linear mechanical properties.



In the toe-region, the crimping is being straightened out.

The material also exhibits viscoelasticity, and consequently hysteresis.

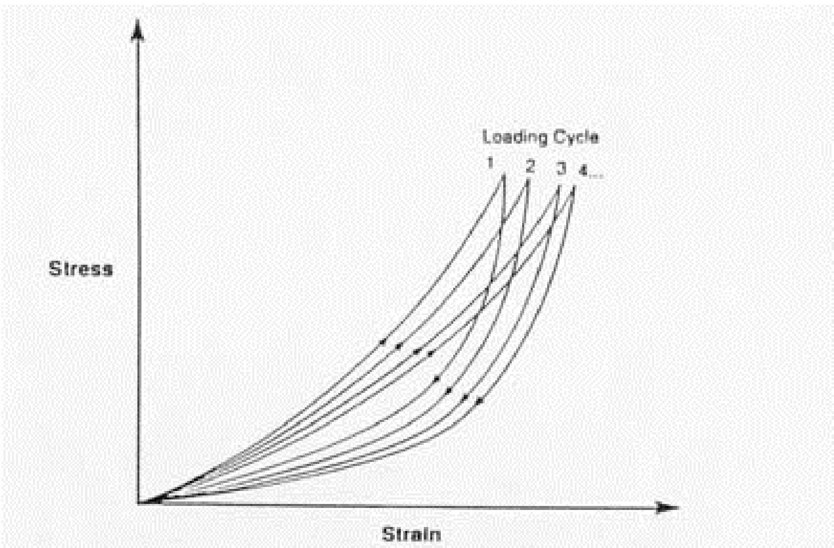


Figure 14
During cyclic loading of tendon, the stress-strain curve gradually shifts to the right. Usually, after 10 cycles, the curves become quite repeatable and steady.