Muscle - How it works.

Chapter 10 in Eckert.
Muscles produce two to five-fold more force when they are stretched than when they shorten.

Muscle function 2: concentric versus eccentric contractions
Muscle function 2: concentric versus eccentric contractions

Hindlimbs dominate during acceleration.

Ground forces in an accelerating dog
Muscle function 2: concentric versus eccentric contractions

Forelimbs dominate during deceleration.

Ground forces in a decelerating dog

[Graph showing force versus time for forelimb and hindlimb, with labels for vertical and fore-aft force]
Muscle function 2: concentric versus eccentric contractions
Muscle function 2: concentric versus eccentric contractions

Strength of the Extensor Muscles of the Elbow and Knee

Cursorial adaptation - relatively weak forelimbs!

![Graph showing cross-sectional area comparison between Grey Hound and Pit Bull for elbow and knee muscles.](image-url)

Cursorial adaptation - relatively weak forelimbs!
Muscle function 3: gearing

Do animals have transmissions?
Gear ratio = $R/r$
Gearing for muscle power

Gearing for elastic storage
Muscle function 5: Muscle structure

- Plasma membrane
- Intercalated disk
- Myofibril
- Mitochondrion
- Sarcoplasmic reticulum
- SR contacts T tubule
Muscle function 5: Muscle structure

www2.nau.edu/~sll/energetics.htm, www4.nau.edu/electron/TEM_img.htm
Muscle function 4: Muscle fiber types
## Muscle function 4: Muscle fiber types

<table>
<thead>
<tr>
<th>Property</th>
<th>Slow oxidative (type I)</th>
<th>Fast oxidative (type IIa)</th>
<th>Fast glycolytic (type IIb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber diameter</td>
<td>↓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Force per cross-sectional area</td>
<td>↓</td>
<td>↔</td>
<td>↑</td>
</tr>
<tr>
<td>Rate of contraction ($V_{max}$)</td>
<td>↓</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Myosin ATPase activity</td>
<td>↓</td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Resistance to fatigue</td>
<td>↑</td>
<td>↔</td>
<td>↓</td>
</tr>
<tr>
<td>Number of mitochondria</td>
<td>↑</td>
<td>↑</td>
<td>↓</td>
</tr>
<tr>
<td>Capacity for oxidative phosphorylation</td>
<td>↑</td>
<td>↑</td>
<td>↓</td>
</tr>
<tr>
<td>Enzymes for anaerobic glycolysis</td>
<td>↓</td>
<td>↔</td>
<td>↑</td>
</tr>
</tbody>
</table>

*Table 10-1 Properties of twitch (phasic) fibers in mammalian skeletal muscles*

*Source: Adapted from Sherwood, 2001.*

Key: $\downarrow$ Low, $\leftrightarrow$ Intermediate, $\uparrow$ High
Muscle function 4: Muscle fiber types

(a) Force/cross-section vs. Velocity of shortening

(b) Mechanical power/cross-section vs. Velocity of shortening

(c) Rate of energy utilization/cross-section vs. Velocity of shortening

(d) Efficiency vs. Velocity of shortening
Terrestrial locomotion
Walking is a transfer of kinetic and potential energy. With each step we fall forward and then catch ourselves.

\[ E_{kf} = \frac{1}{2}mV^2 \]
\[ E_p = mgh \]

Mechanics of a pendulum.
Running is a bounce, a mass and a spring.

$E_{es} = $ elastic strain energy
We all walk and run the same way.
Locomotor energetics

![Graph A: Relationship between speed and rate of burning energy for mammals.](image)
- Anaerobic
- Aerobic
- Cost of basal metabolism and posture

![Graph B: Relationship between speed and rate of burning energy for horses.](image)
- Least economical speeds are avoided
- Gallop
- Trot
- Walk

![Graph C: Energy used per unit distance vs. speed.](image)
Two types of work in locomotion: “external” and “internal”.

In humans, $W_{\text{int}}$ increases as the square of locomotor speed.
In cursorial birds and mammals, $W_{\text{int}}$ increases as the 1.5 power of locomotor speed.

These data are from humans Willems et al., (1995) JEB 198, 379-393.
Tyrannosaurian
Oviraptor
Ornithomimid
Bird
Crocodilomorph
Cursorial Archosaurs

Oviraptor
Tyrannosaurian
Cursorial Archosaurs
Crocodilomorph
Ornithomimid
Bird
Cursorial lizards

Zebra-tailed

Basiliscus
Cursorial mammals
Cursorial lagomorphs