Universität Stuttgart

Human Motion Research

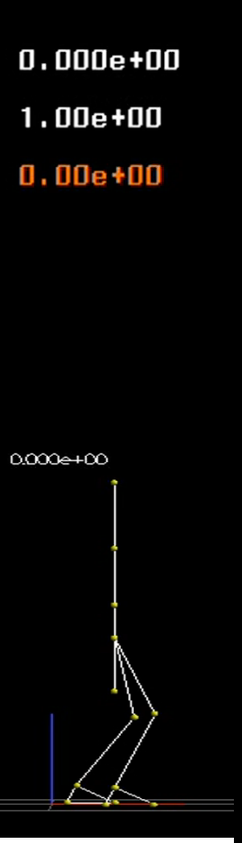
Department of Social and Economic Science
Department of Mechanical Engineering
Stuttgart Research Centre for Simulation Technology

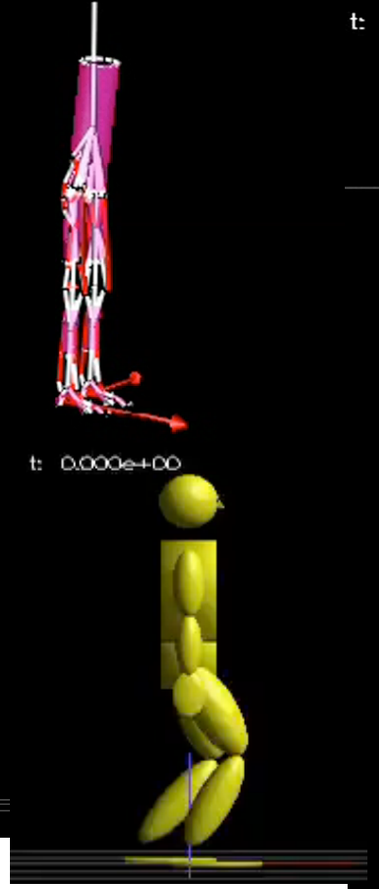
The Human Movement Simulation Lab

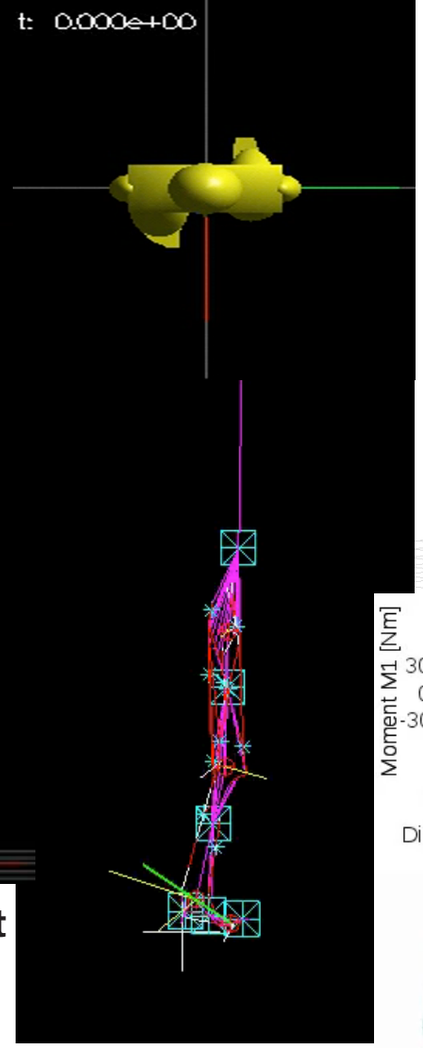
SimTech Cluster of Excellence

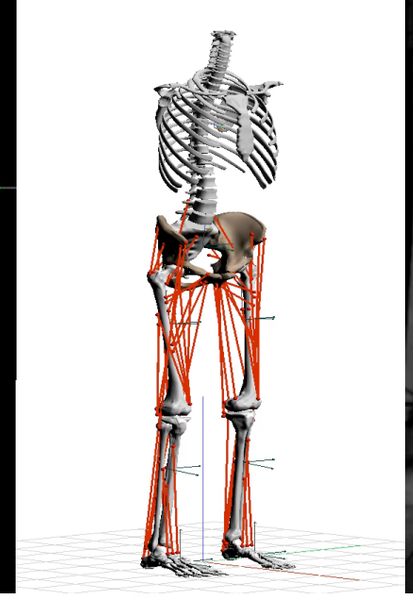
Technologie Transfer Initiative

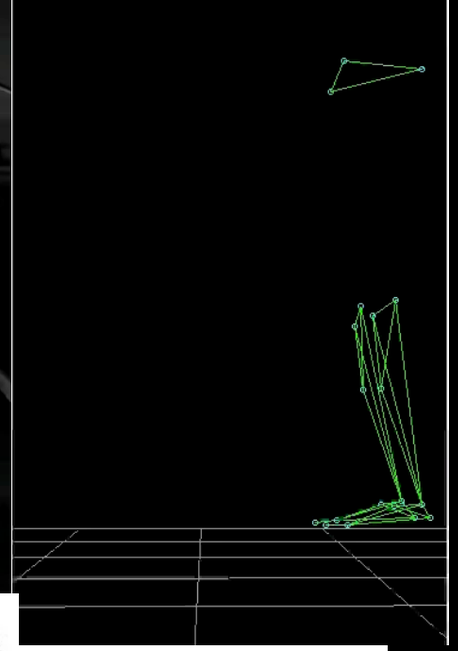
Jun.-Prof. Dr. Syn Schmitt

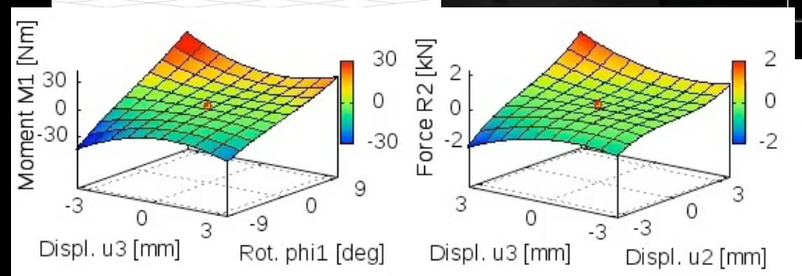


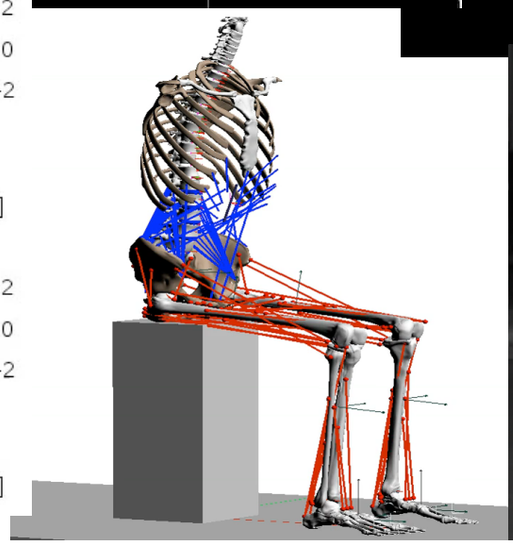


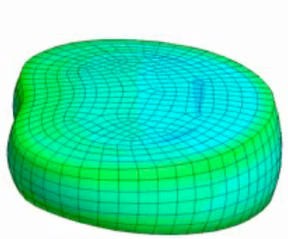


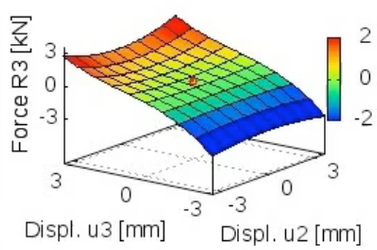


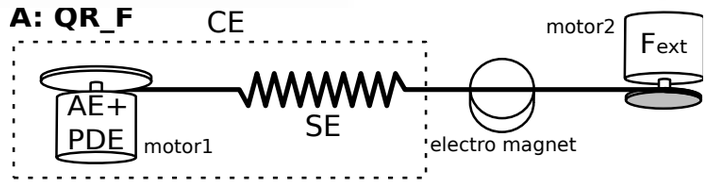


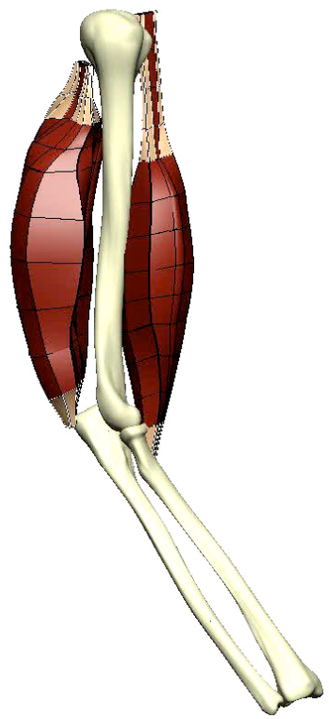


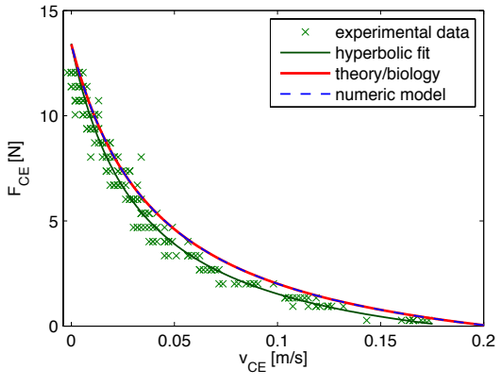


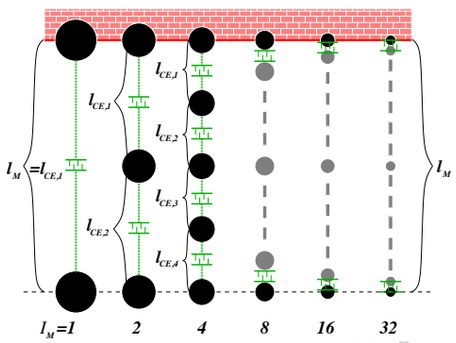


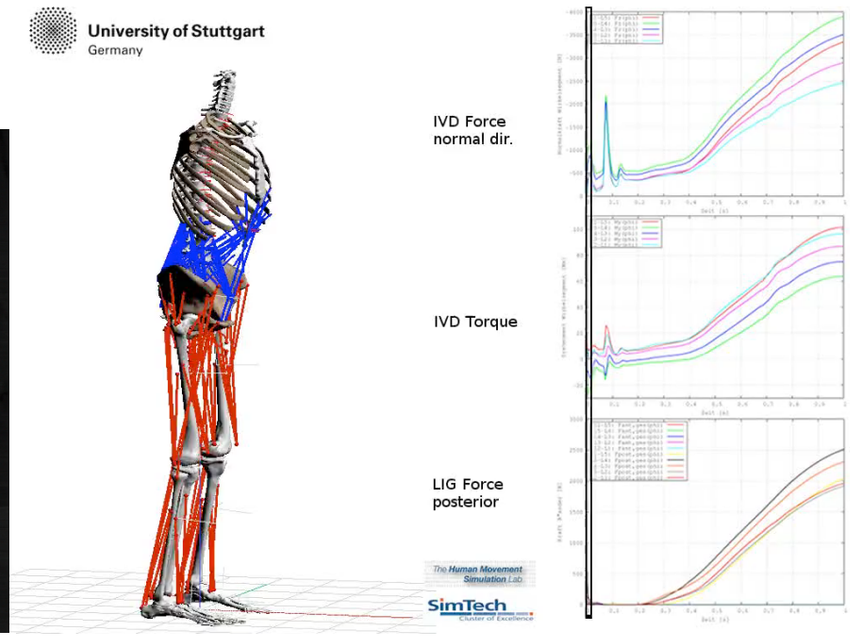












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Fraunhofer IPA

BGN Berufsgenossenschaft Nahrungsmittel und Gastgewerbe

DAIMLER

DFG Deutsche Forschungsgemeinschaft

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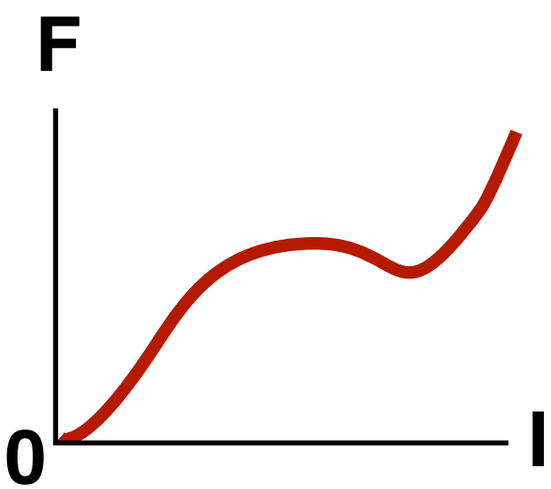
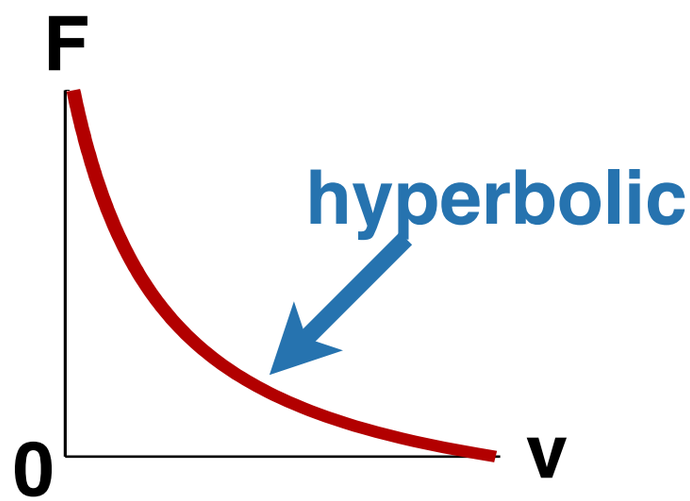
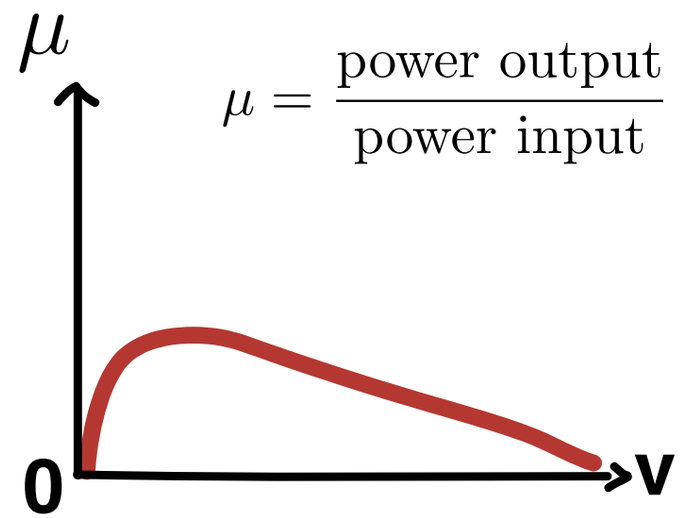
Skeletal muscle's contraction dynamics



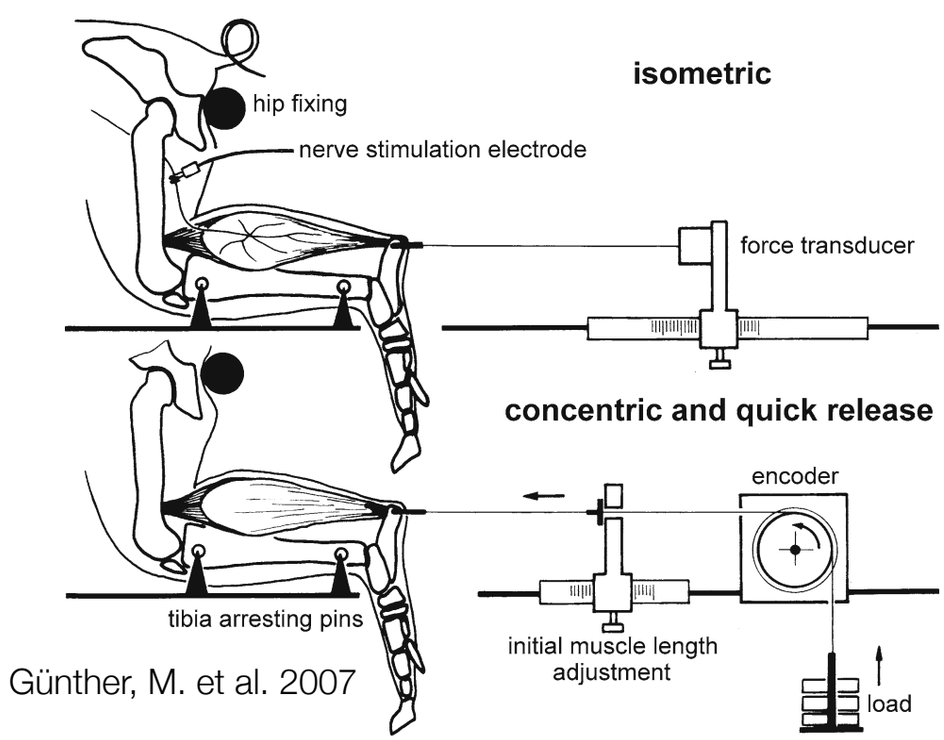
Force-length relationship



Force-velocity relation

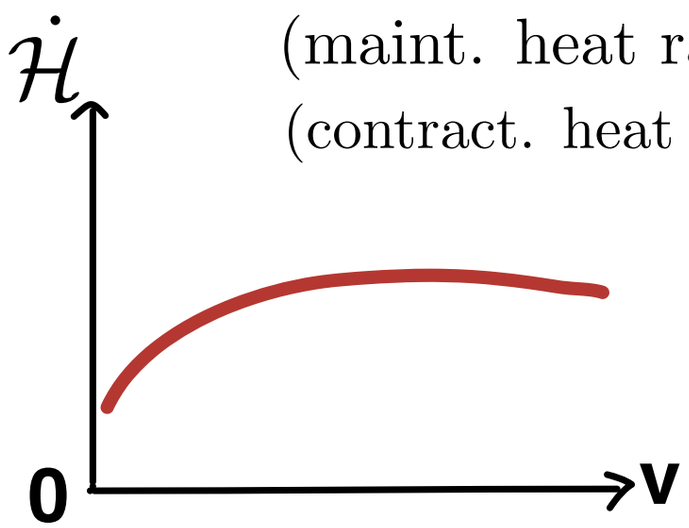


Mechanical efficiency



Günther, M. et al. 2007

$$\dot{\mathcal{H}} = (\text{mech. power output}) + (\text{maint. heat rate}) + (\text{contract. heat rate})$$



Enthalpy rate

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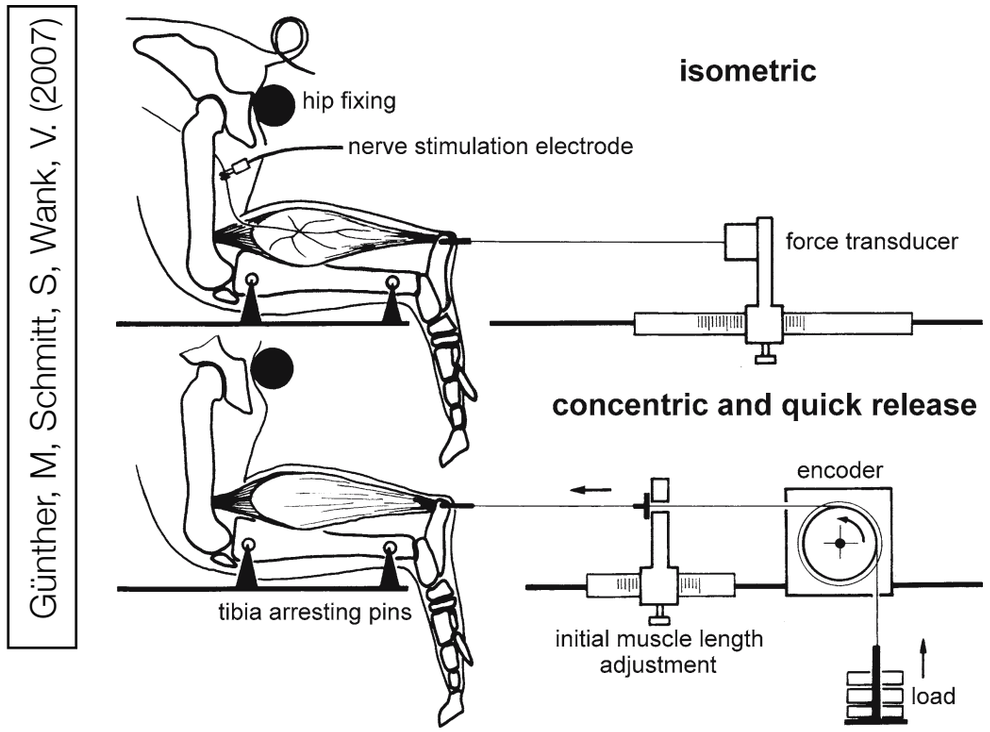
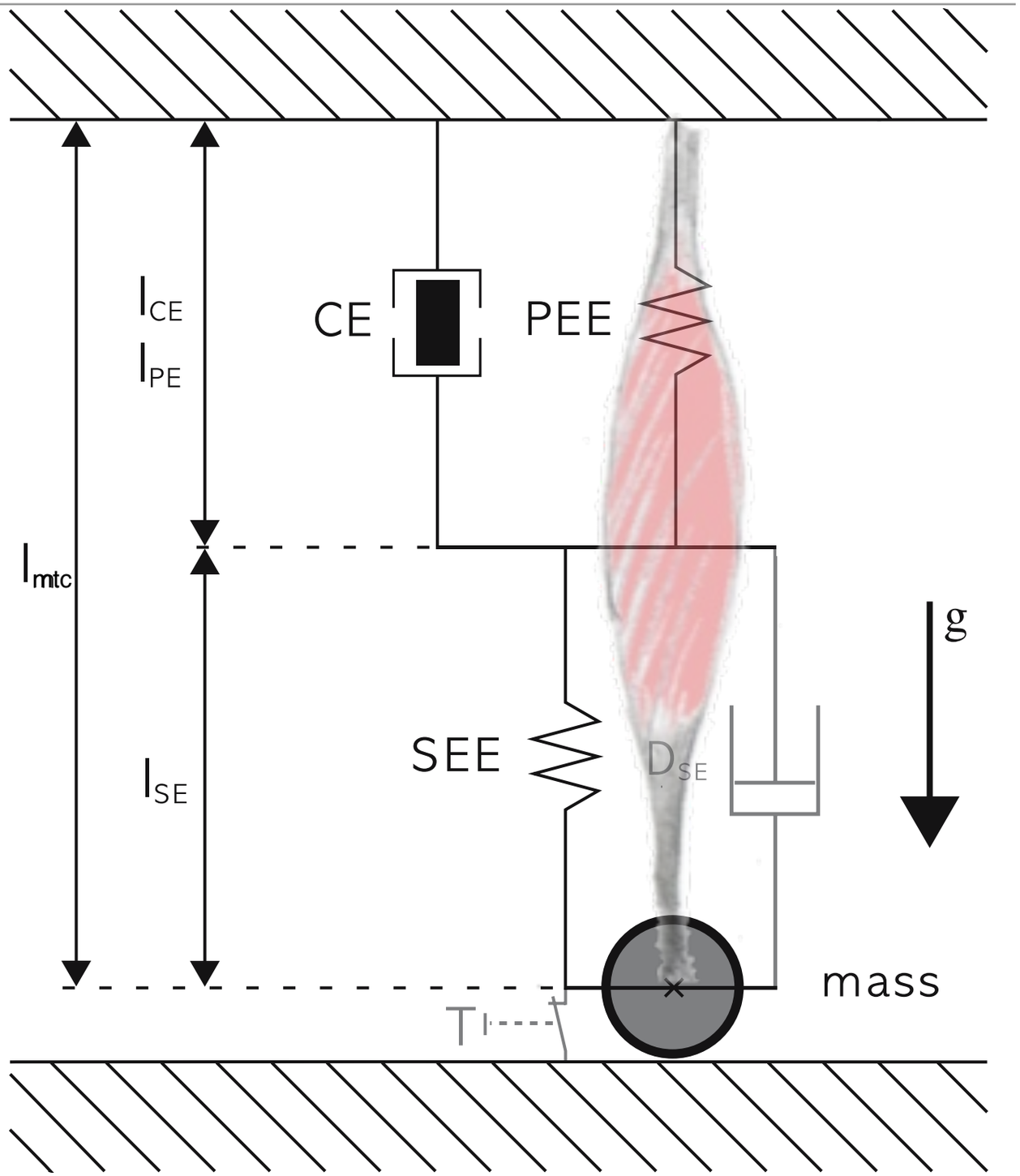
Macroscopic model of the skeletal muscle



mass: 100, ….., 1800 g
g: earth's gravitation field



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Formulate contraction dynamics ...

cf. Hill (1938)

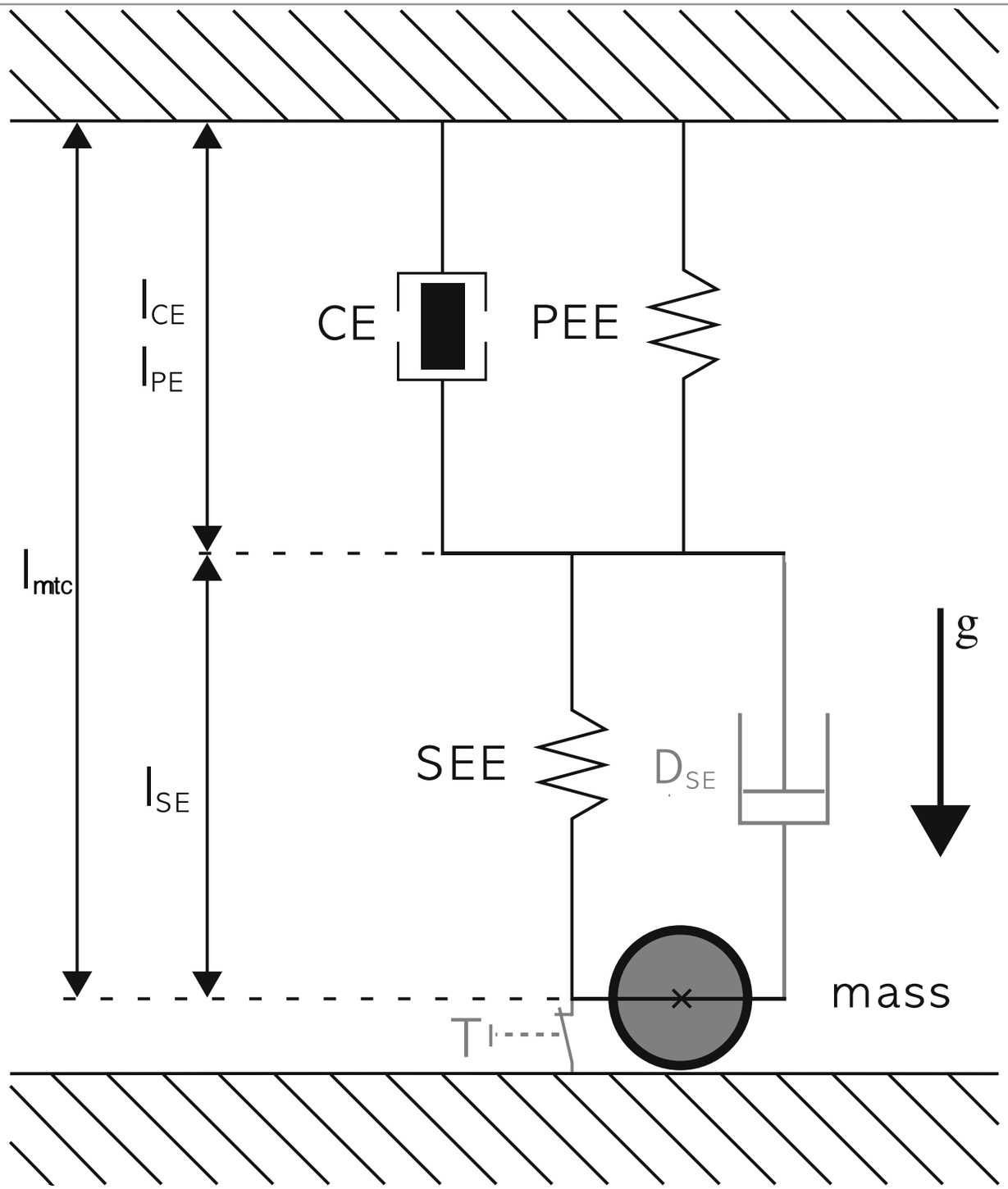
$$F_{mtc} = F_{mtc}(\dot{l}_{mtc})$$

take force equilibrium into account

$$F_{SDE}(l_{mtc}, l_{CE}) + F_{SEE}(l_{mtc}, l_{CE}) = F_{PEE}(l_{CE}) + F_{CE}(l_{CE}, \dot{l}_{CE}, q)$$

writes

$$\boxed{\dot{l}_{CE} = \dot{l}_{CE}(l_{mtc}, l_{CE}, q)}$$



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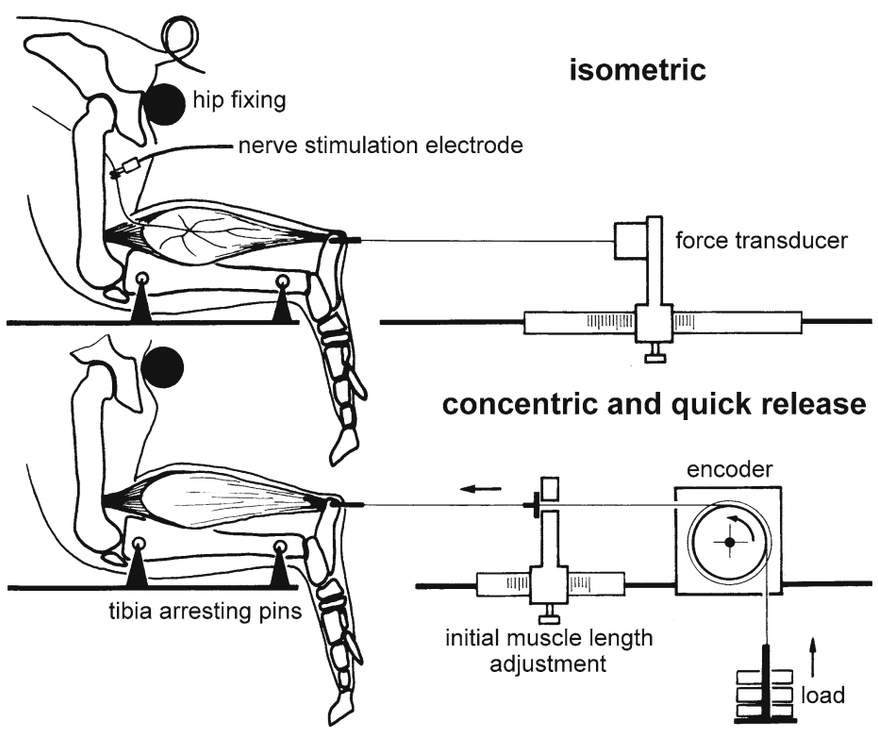
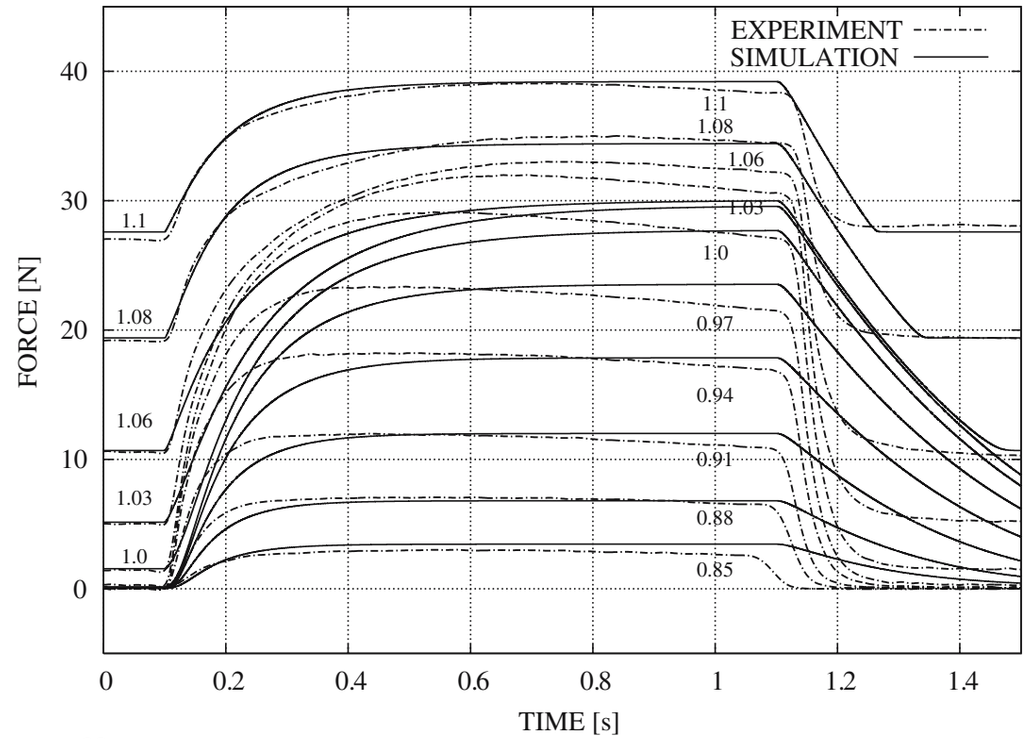
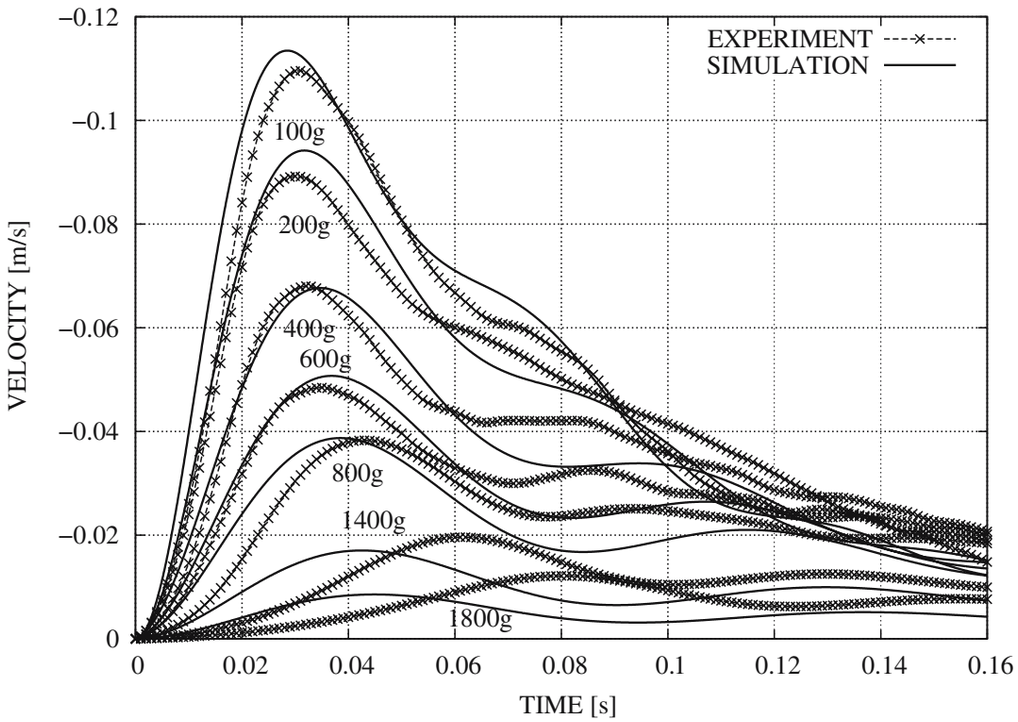
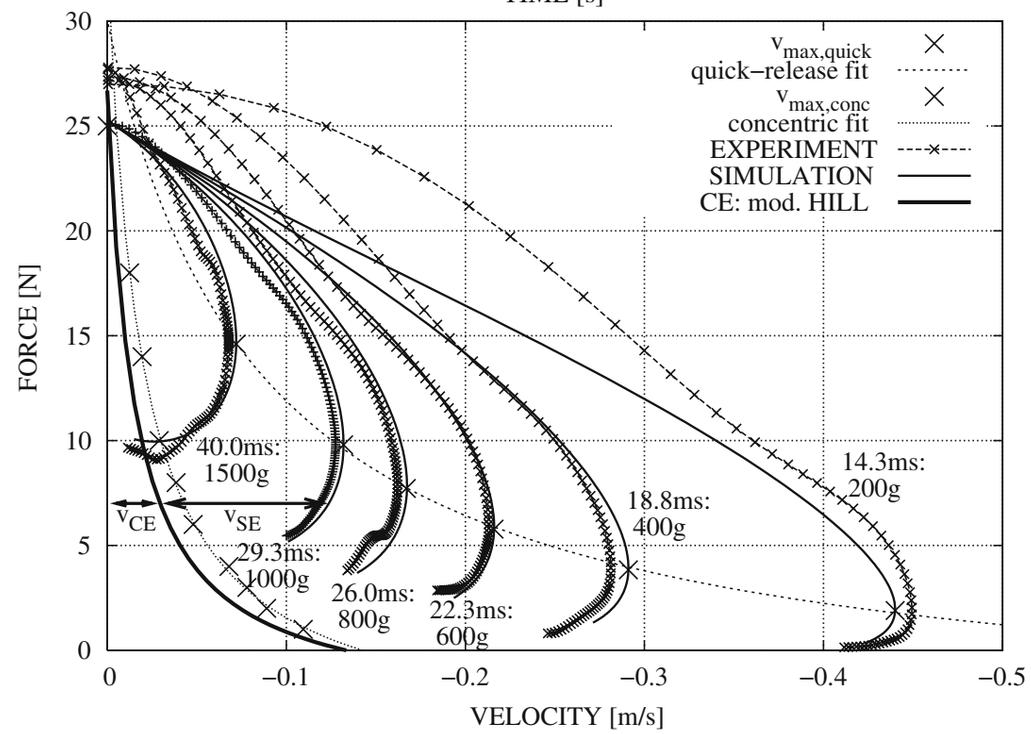
Compare simulation and experiment ...

Günther, M, Schmitt, S, Wank, V. (2007)









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A model perspective on the biological drive

Muscle

Hill type muscle model:

$$v_j^{CE} = \dot{l}_j^{CE} = f_v(l_j^{mtc}, l_j^{CE}, q_j)$$

$$\dot{q}_j = f_q(q_j, \mathrm{STIM}_j^i)$$

$$f_j^{mtc} = f_f(l_j^{mtc}, v_j^{mtc}, l_j^{CE}, q_j)$$

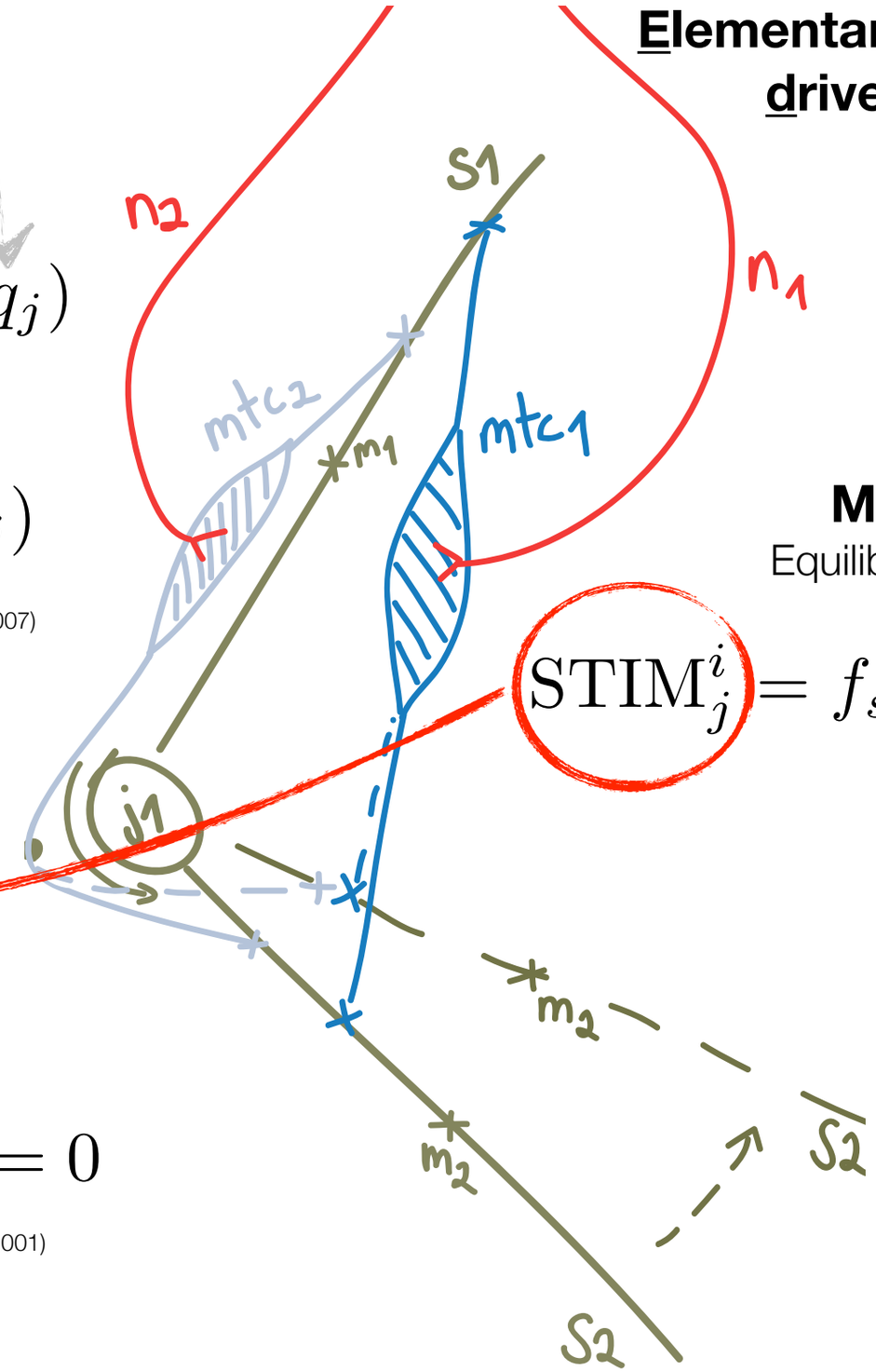
Günther, Schmitt, Wank (2007)

Skeleton

Model of the mechanical system:

$$M(r)\ddot{r} + C(r)\dot{r}^2 + g(r) + \\ + R(r)f^{mtc} + e(r, \dot{r}) = 0$$

Pandy (2001)



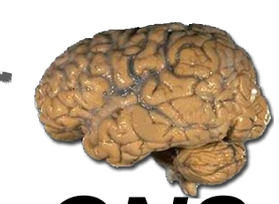
Elementary biological drive (EBD)

Motor Control

Equilibrium-Point-Control:

$$\mathrm{STIM}_j^i = f_s(\lambda_j^i, l_j^{CE}, v_j^{CE})$$

Günther and Ruder (2003)



CNS

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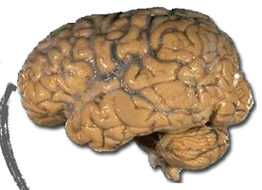
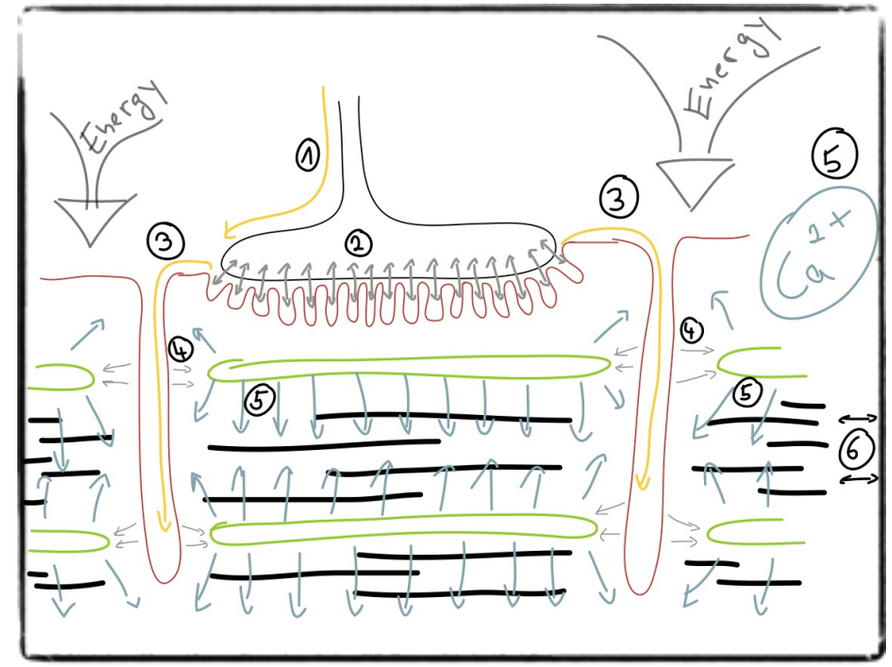
Macroscopic (Hill type) muscle model



CNS + mot. control



Activation dynamics

↓

Contraction dynamics

↓↑

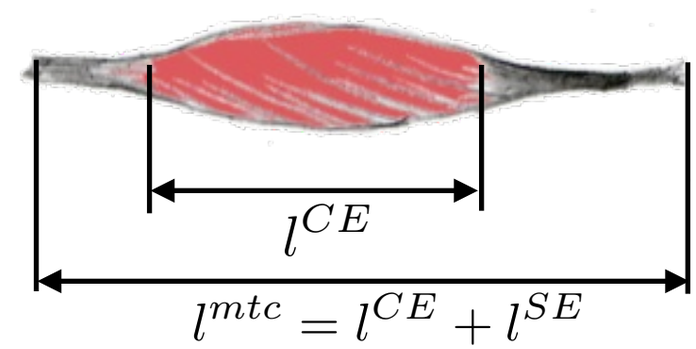
Musculo-skeletal system

Activation rate

$$\dot{q}_j = f_q(q_j, \mathrm{STIM}_j^i)$$

Contraction velocity

$$v_j^{CE} = \dot{l}_j^{CE} = f_v(l_j^{mtc}, l_j^{CE}, q_j)$$



Muscle force

$$f_j^{mtc} = f_f(l_j^{mtc}, v_j^{mtc}, l_j^{CE}, q_j)$$