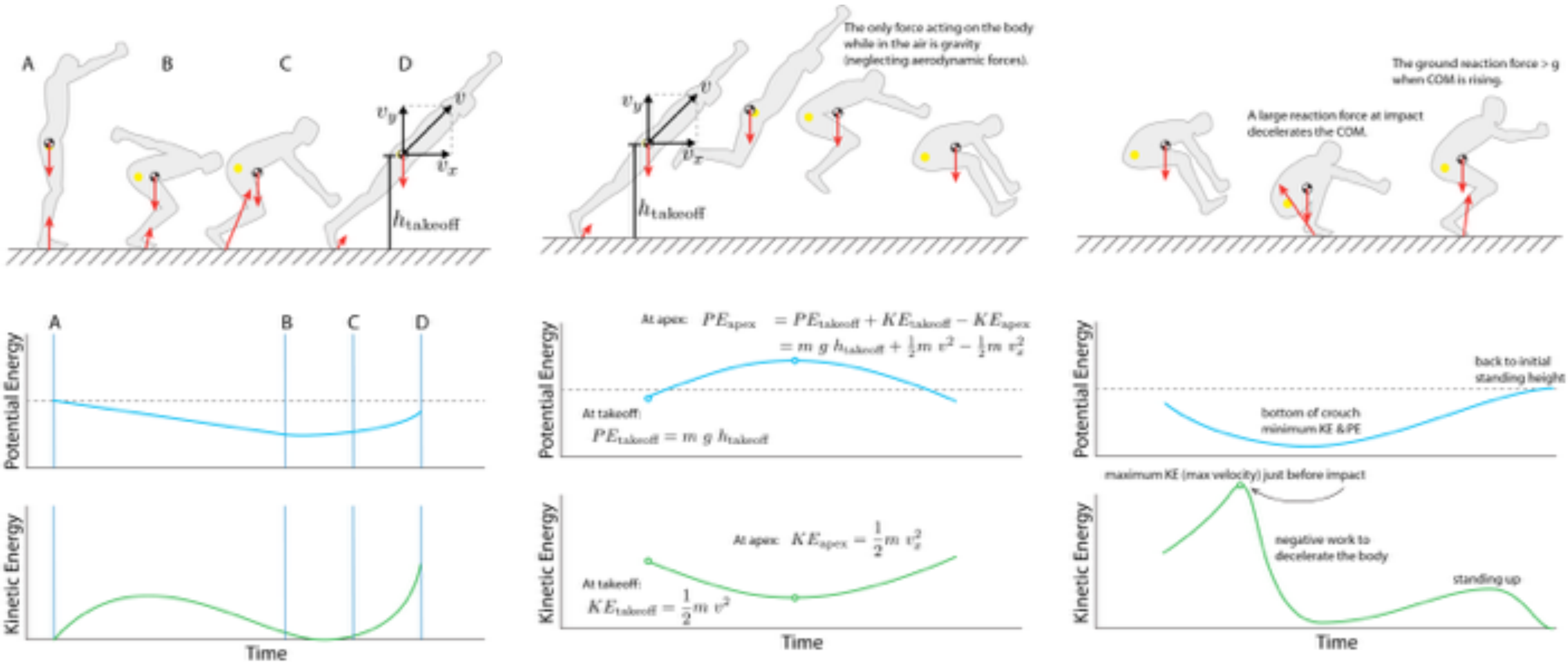
Lecture 4. Terrestrial locomotion III: mechanical analysis of gaits and jumpiness.

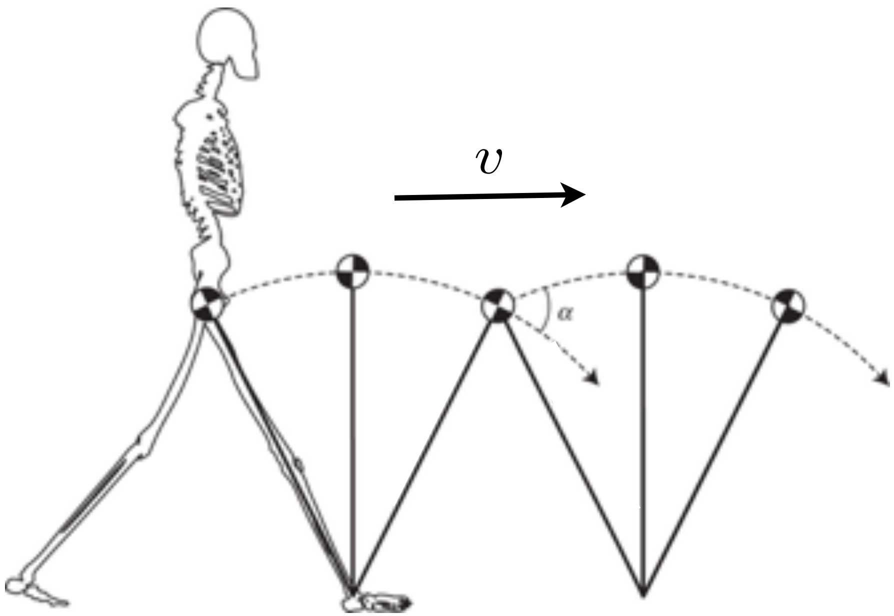
- Recap: gaits and ballistic walking
- When the Froude Number ($V^2/g\ L$) is greater than 1, simple ballistic walking is no longer possible.
- More aspects of jumping (energy and force)
- The jumper model accounts for an airborne phase of movement.
- Calculating optimal gaits for energy expenditure

Lecture 4. Terrestrial locomotion III: mechanical analysis of gaits and jumpiness.



A
B
C
D
v_y
v
v_x
h_{takeoff}
Potential Energy
Kinetic Energy
Time
The only force acting on the body while in the air is gravity (neglecting aerodynamic forces).
At apex: $PE_{\text{apex}} = PE_{\text{takeoff}} + KE_{\text{takeoff}} - KE_{\text{apex}}$
$= m\ g\ h_{\text{takeoff}} + \frac{1}{2} m\ v^2 - \frac{1}{2} m\ v_x^2$
At takeoff: $PE_{\text{takeoff}} = m\ g\ h_{\text{takeoff}}$
At apex: $KE_{\text{apex}} = \frac{1}{2} m\ v_x^2$
At takeoff: $KE_{\text{takeoff}} = \frac{1}{2} m\ v^2$
The ground reaction force > g when COM is rising.
A large reaction force at impact decelerates the COM.
back to initial standing height
bottom of crouch minimum KE & PE
maximum KE (max velocity) just before impact
negative work to decelerate the body
standing up

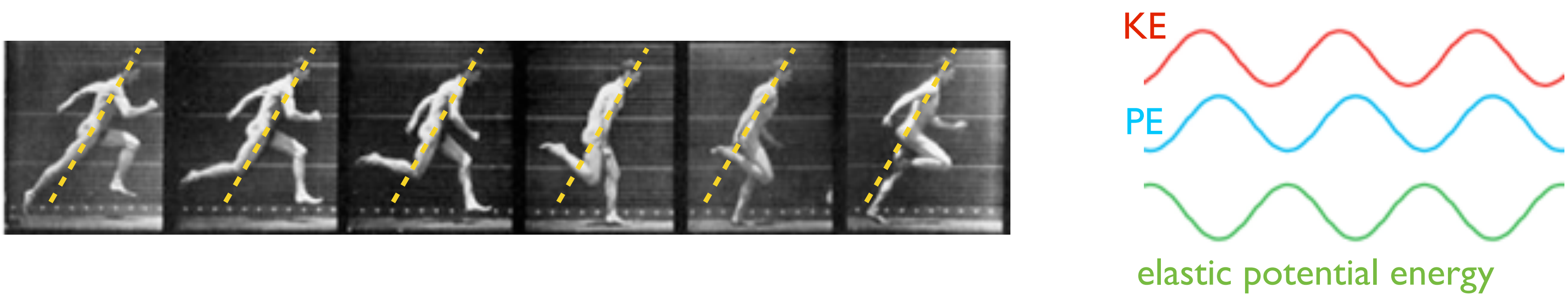
Review of walking



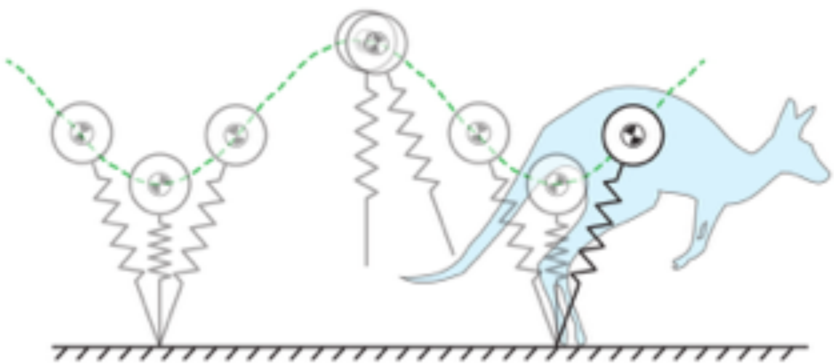
Matthis & Fajen, 2013

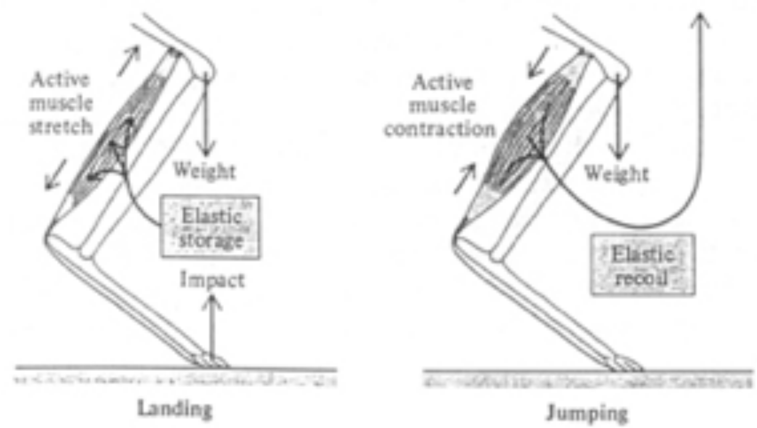
How much energy input is needed for walking?

Energy tradeoffs in walking and running

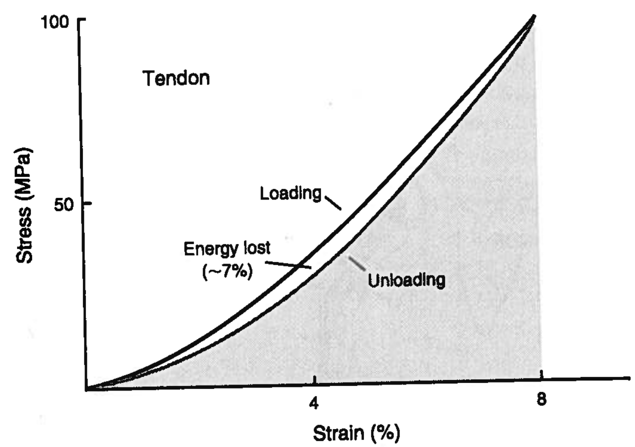


A model for running:
the spring-loaded inverted pendulum (SLIP)



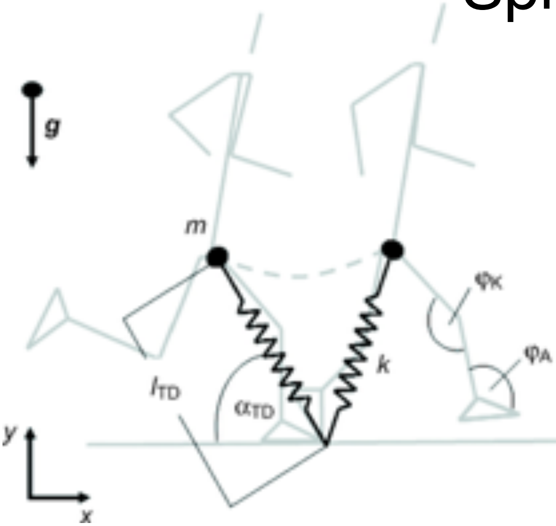


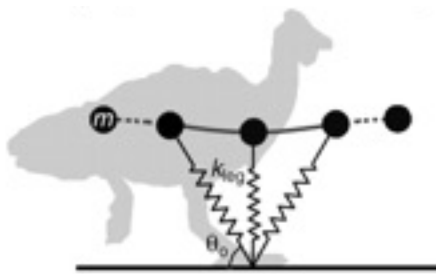
tendons are springy!

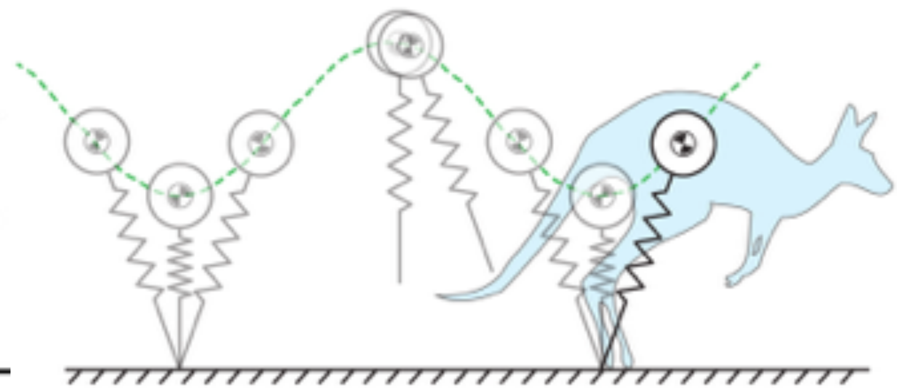


The jumper: for speeds greater than Fr = 1, gait must change with an airborne phase

Spring Loaded Inverted Pendulum

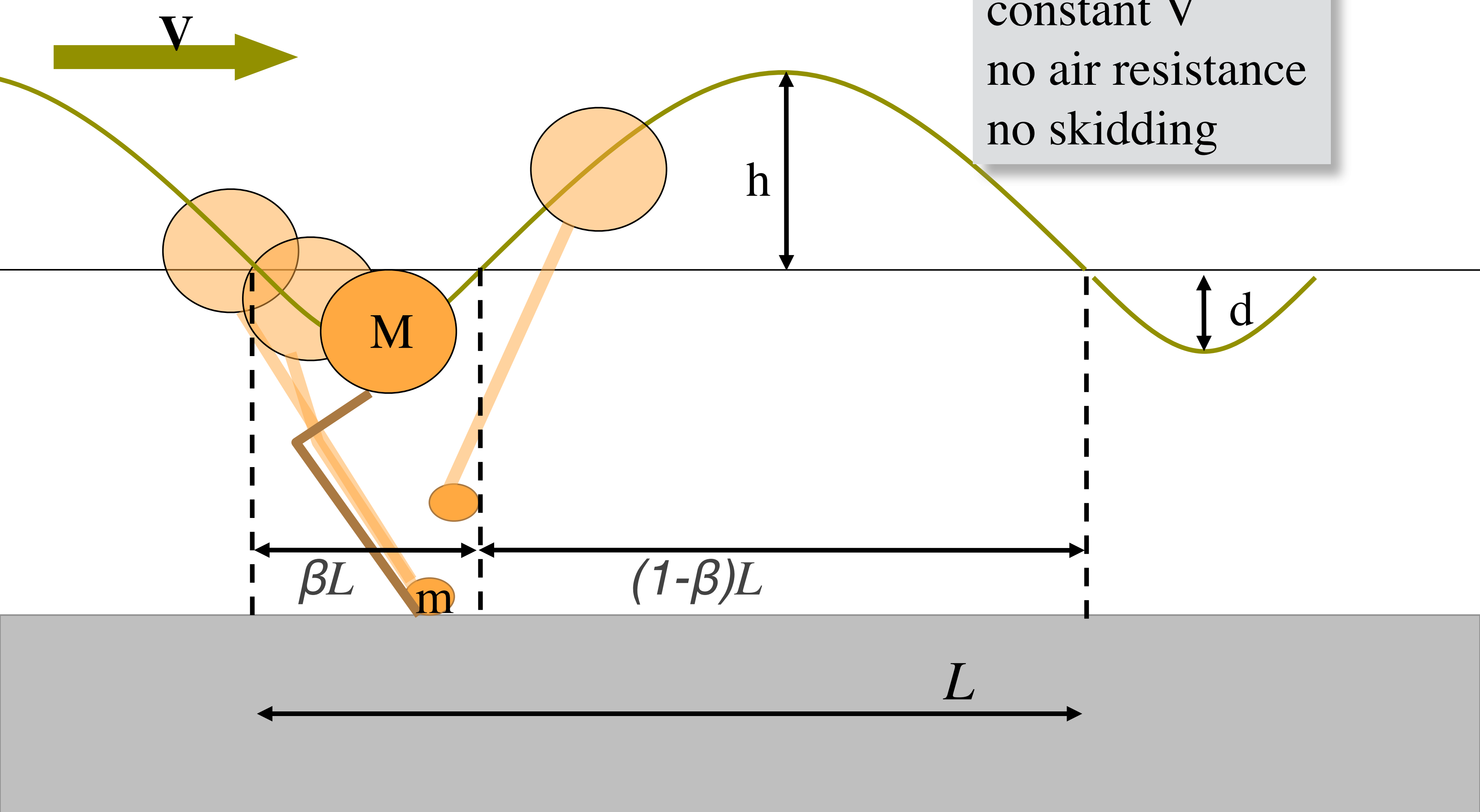






Goal: compute the power (rate of energy expenditure) as a function of size (M,m) and gait (jumpiness) $j = (1-\beta)/\beta$

Assume
- constant V
- no air resistance
- no skidding



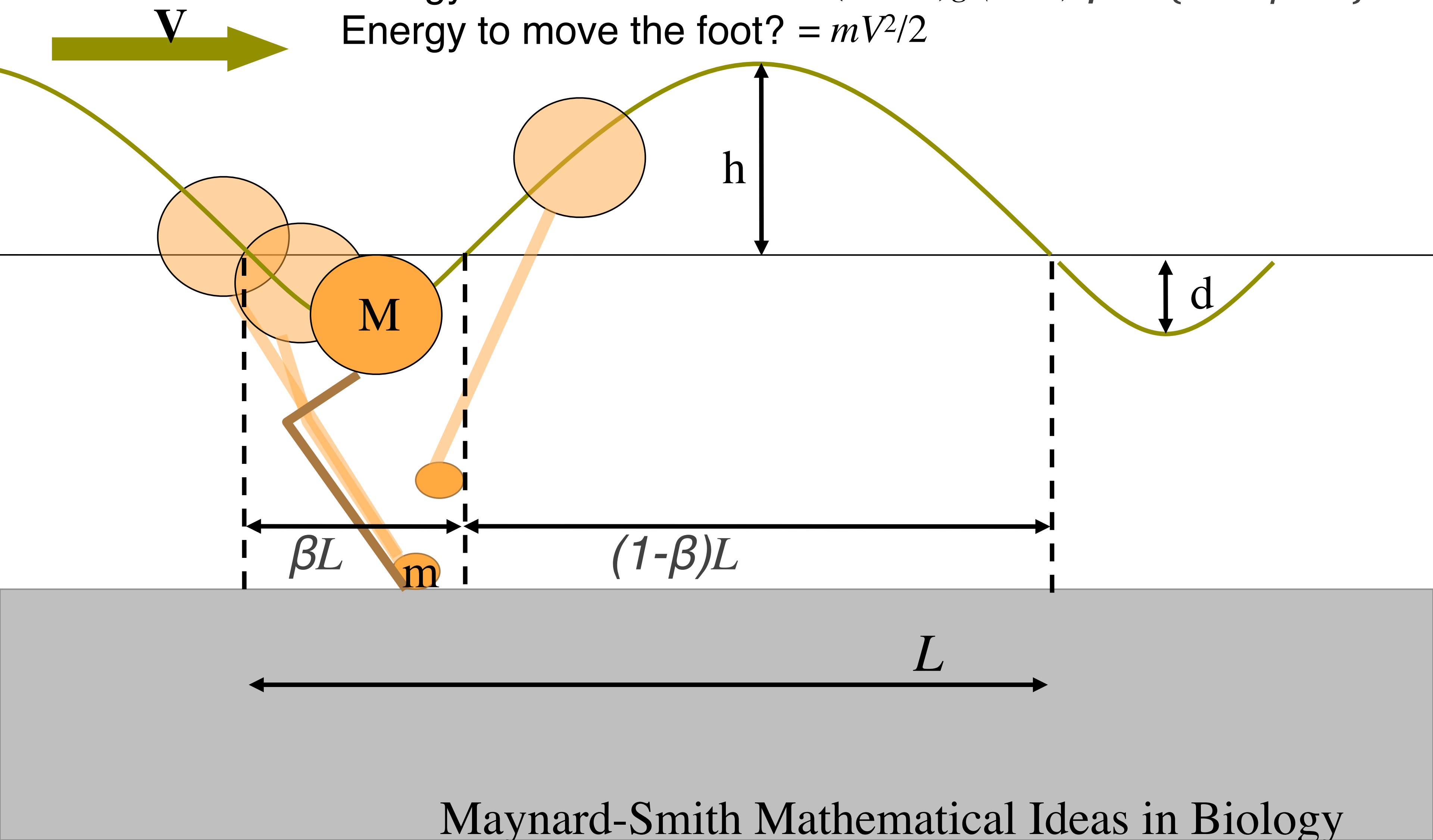
Maynard-Smith Mathematical Ideas in Biology

Goal: compute the power (rate of energy expenditure) as a function of size (M,m) and gait (jumpiness) $j = (1-\beta)/\beta$

Energy to launch? $= (M+m)g\,(h+d)$

Energy to break the fall? $= (M+m)g\,(h+d)\,\gamma$ $\{-1 < \gamma < 1\}$

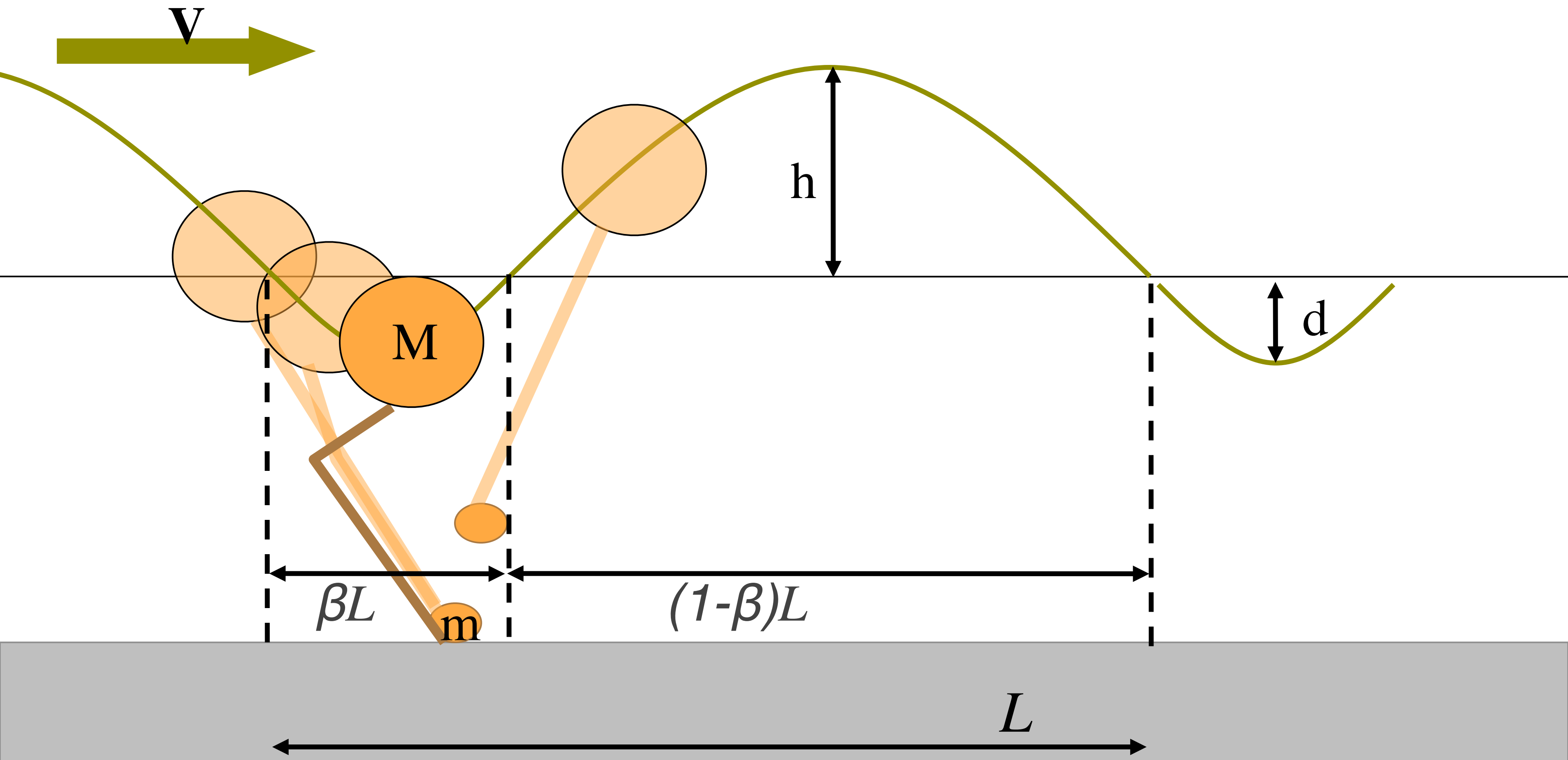
Energy to move the foot? $= mV^2/2$



Maynard-Smith Mathematical Ideas in Biology

Goal: compute the power (rate of energy expenditure) as a function of size (M,m) and gait (jumpiness) $j = (1-\beta)/\beta$

Total Energy $= (1+\gamma)(M+m)\dfrac{g^2 L^2(1-\beta)}{8V^2} + mV^2/2$

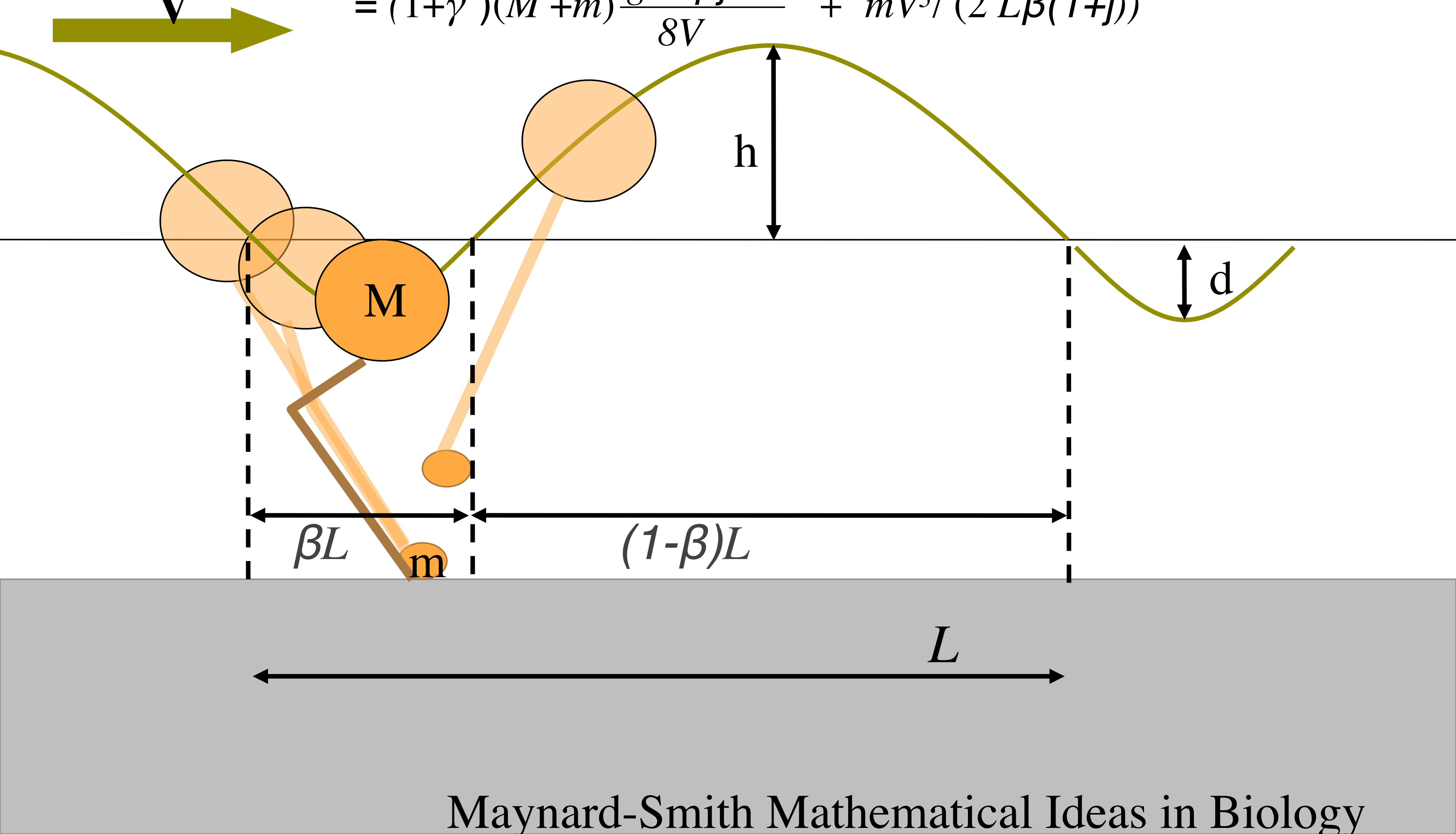


Maynard-Smith Mathematical Ideas in Biology

Goal: compute the power (rate of energy expenditure) as a function of size (M,m) and gait (jumpiness) $j = (1-\beta)/\beta$

Total Power $= (1+\gamma)(M+m)\dfrac{g^2 L(1-\beta)}{8V} + mV^3/(2L)$

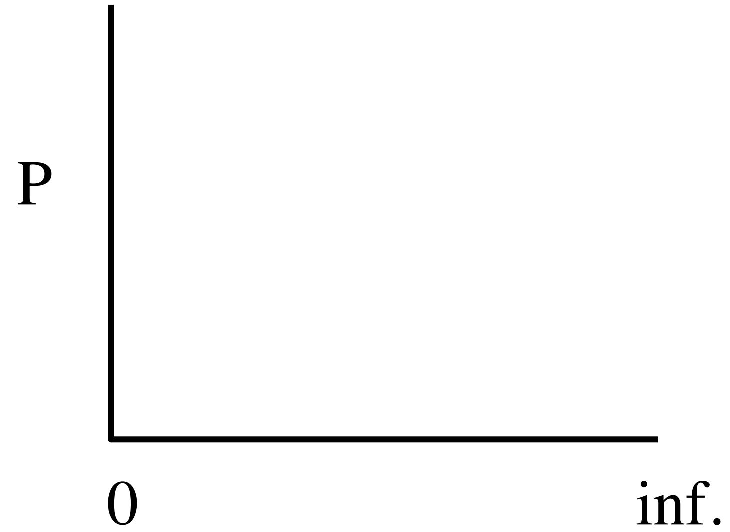
$= (1+\gamma)(M+m)\dfrac{g^2 L\beta j}{8V} + mV^3/(2L\beta(1+j))$



Maynard-Smith Mathematical Ideas in Biology

Total Power $= (1+\gamma)(M+m)\dfrac{g^2 L\beta j}{8V} + mV^3/(2L\beta(1+j))$

How does Power vary with
foot mass (m)?
body mass (M)?
body velocity (V)?
jumpiness (j)?



dP/dj = 0 —> Max, Min, inflection….