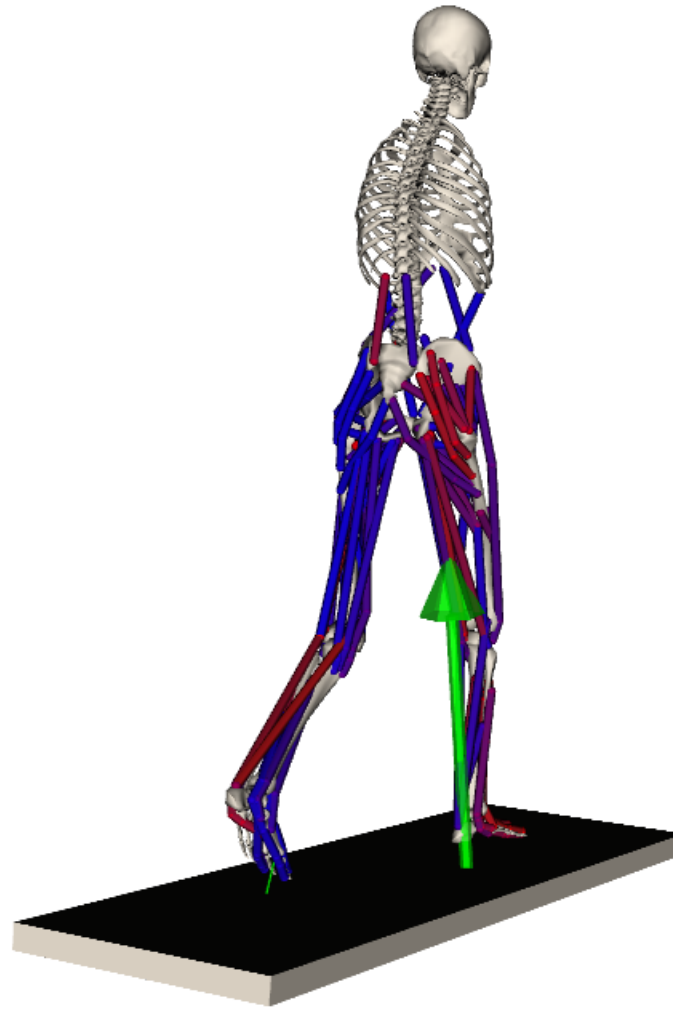


Agenda

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– <i>Jen Hicks</i> |
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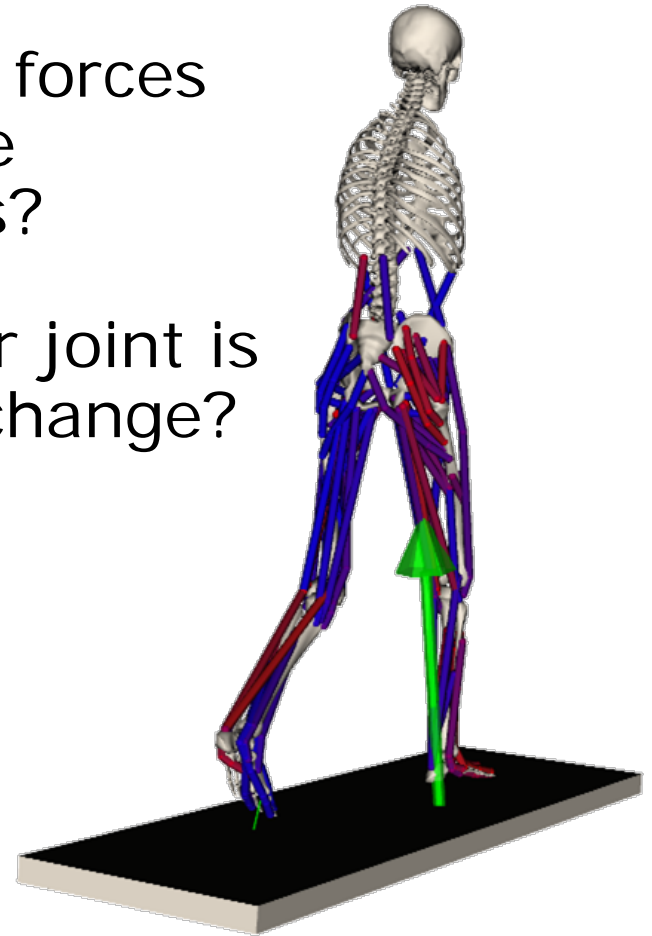


Forward Dynamics

OpenSim Workshop

Why Use Forward Dynamics Simulations?

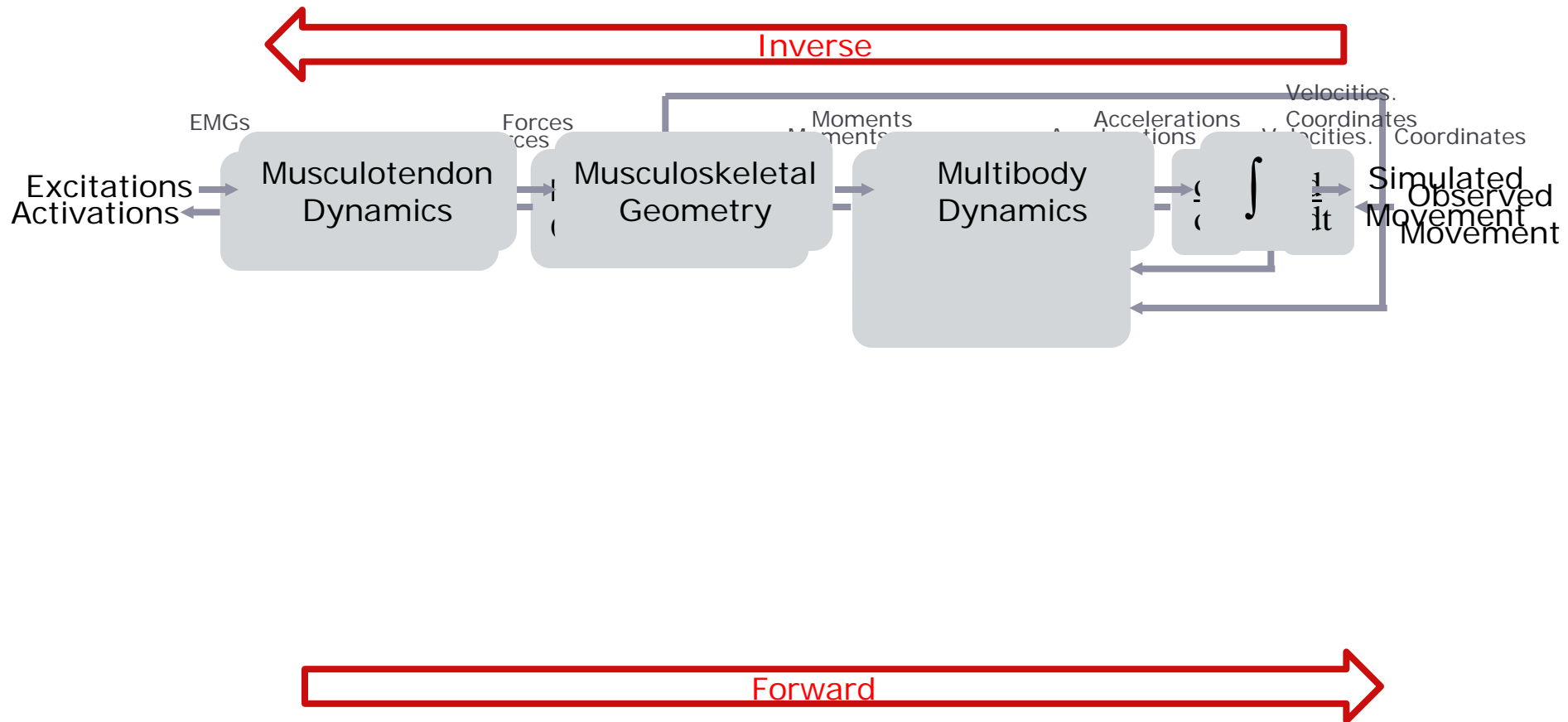
1. Validation: do forces estimated from inverse dynamics reproduce the observed motion?
2. Understanding: how do muscle forces generate motion – what are the “cause and effect” relationships?
3. Prediction: “what if” a muscle or joint is altered, how will performance change?



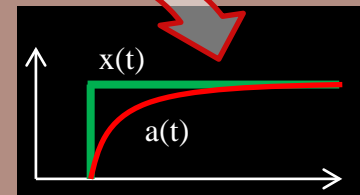
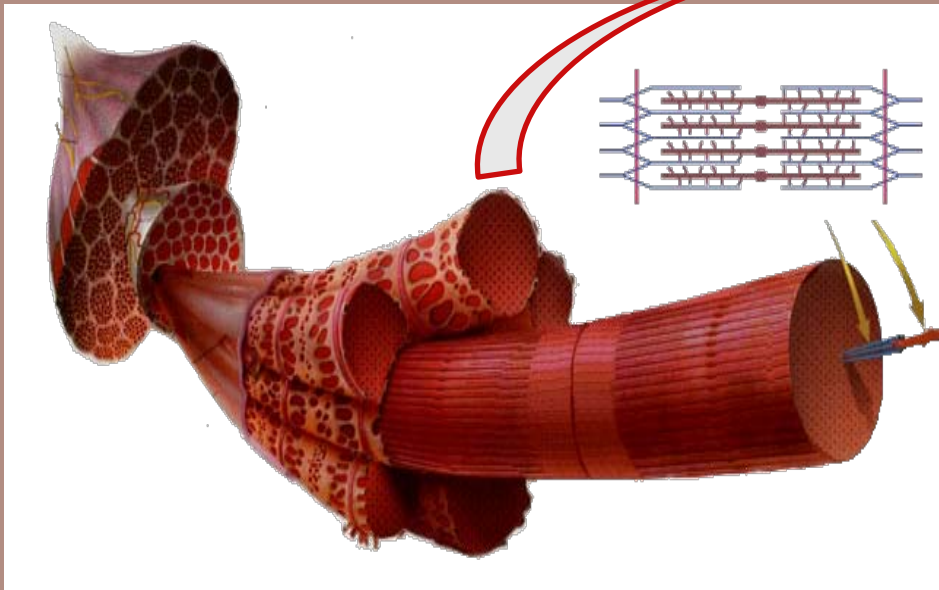
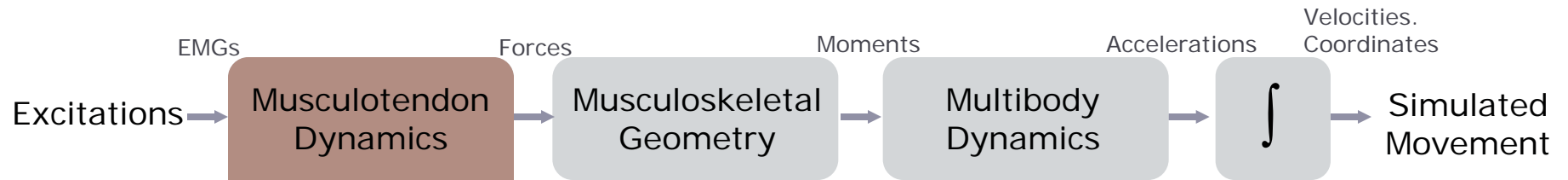
Key Concepts

- Musculoskeletal model dynamics
- States of a musculoskeletal model
- Controls of a musculoskeletal simulation
- Numerical integration of dynamical equations

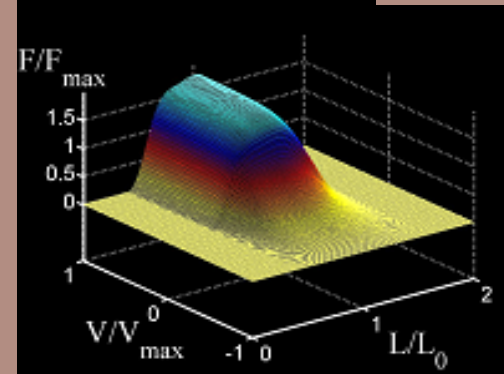
Overview of Forward Dynamics



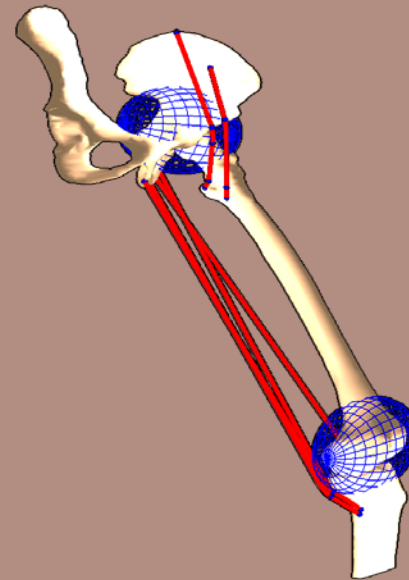
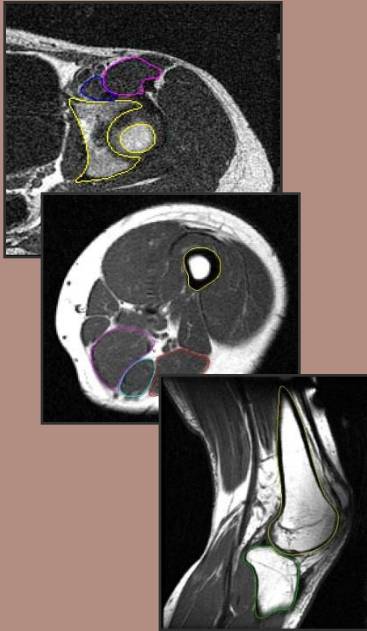
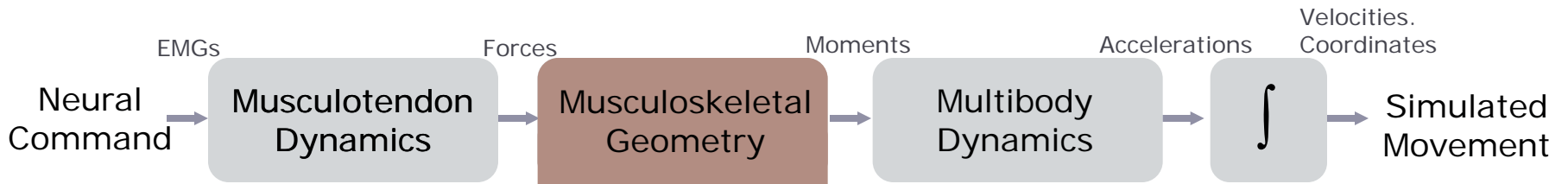
Musculoskeletal Model Dynamics



muscle activation, a
fiber length, l

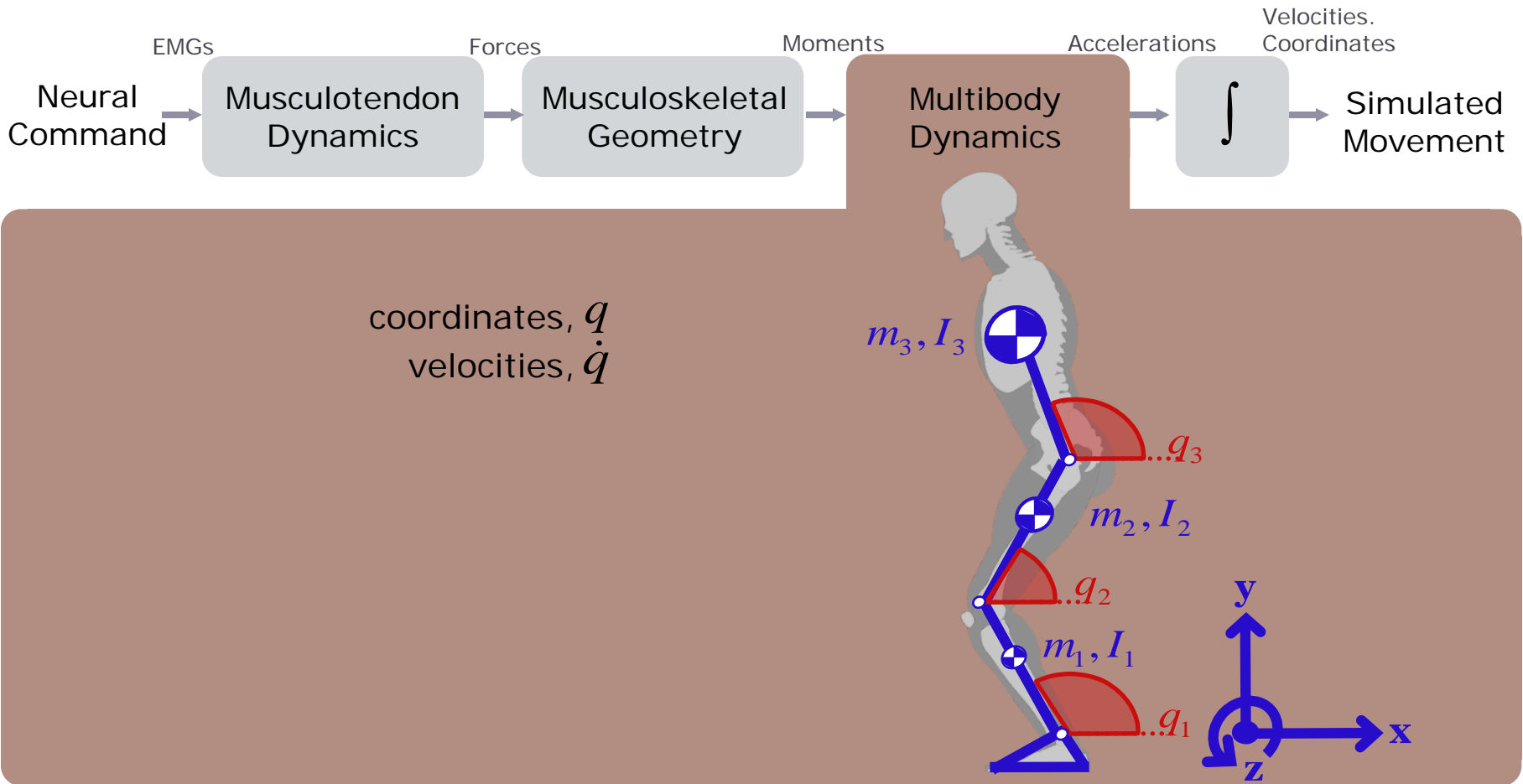


Musculoskeletal Model Dynamics

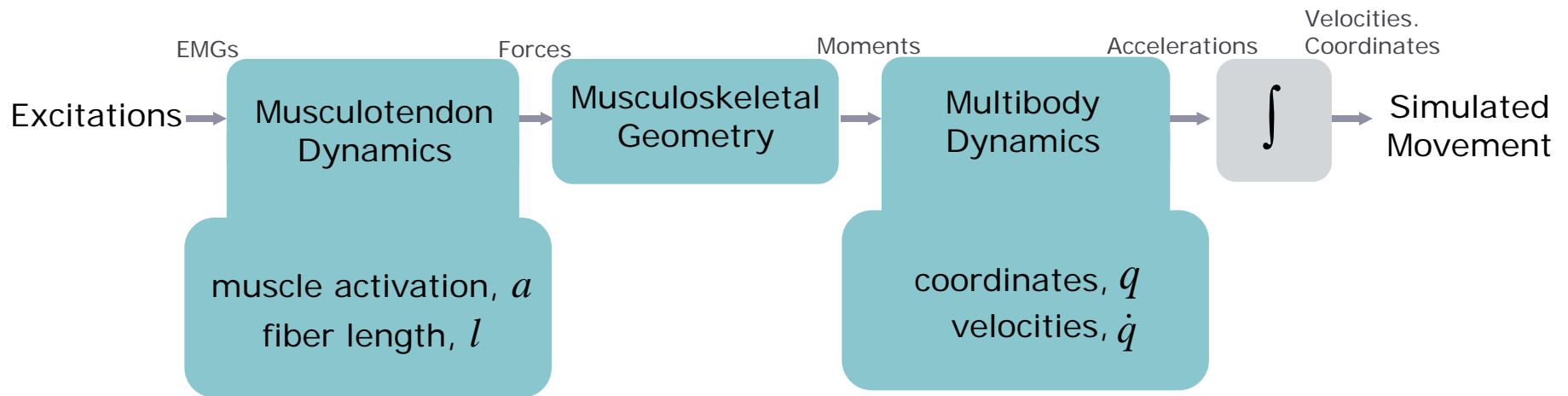


muscle lines of action
moment arms

Musculoskeletal Model Dynamics

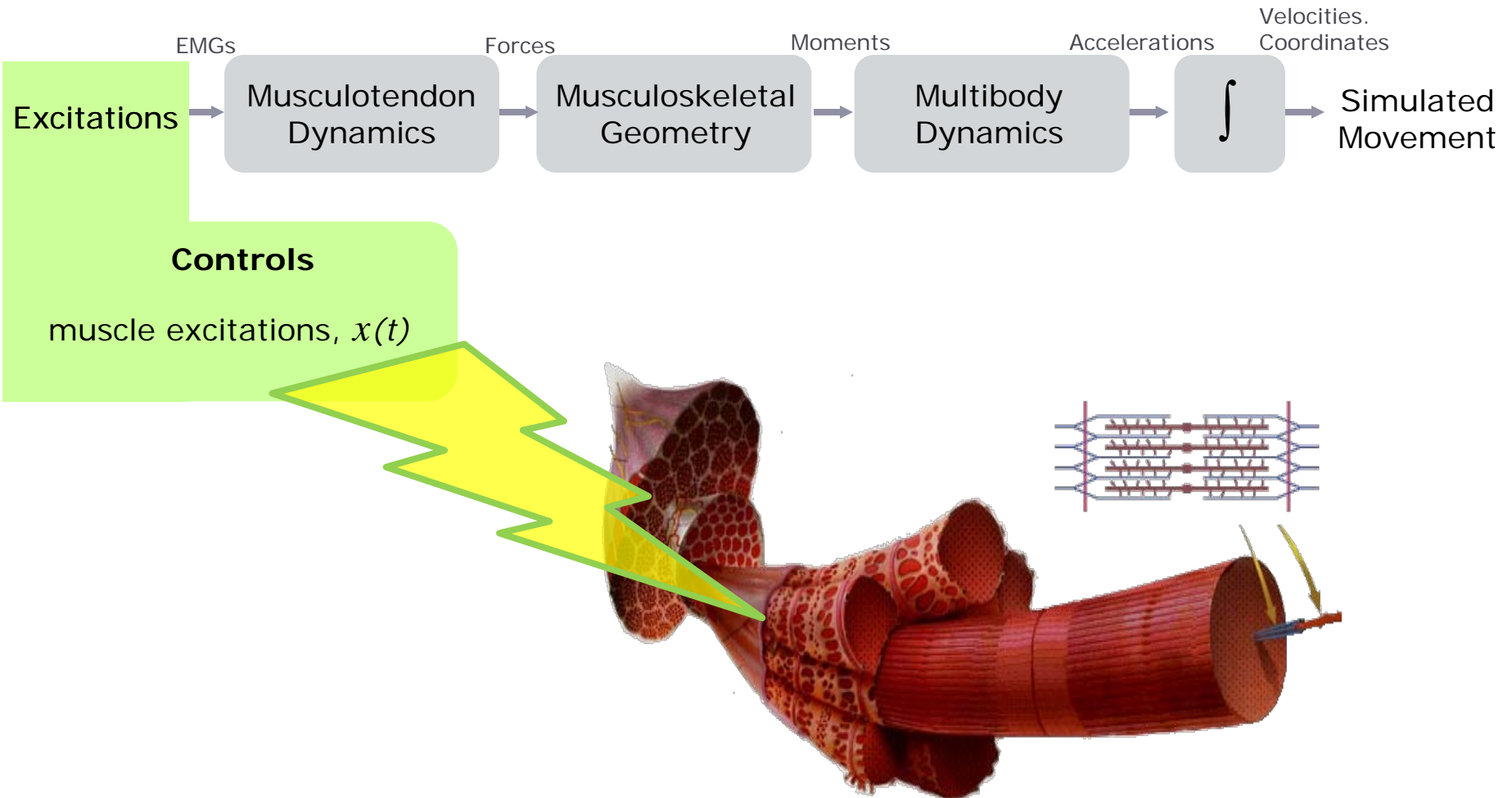


States of a Musculoskeletal Model

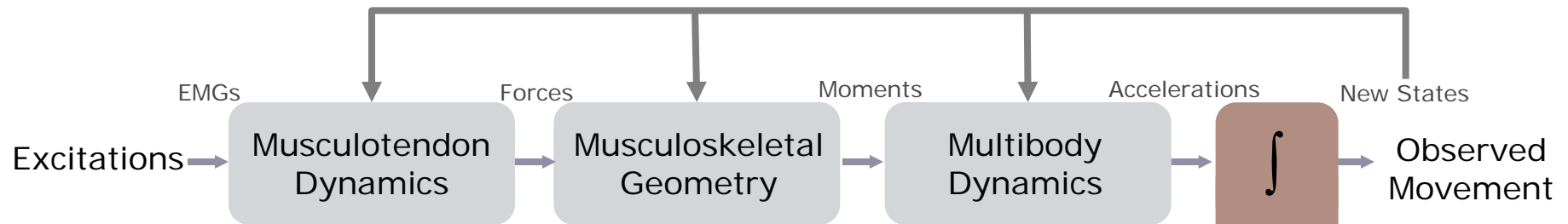


- States are model variables that are governed by the dynamics
- All measures of interest can be calculated from the states

Controls of a Musculoskeletal Model



Numerical Integration of Dynamical Equations



Controls

muscle excitations, $x(t)$

Initial States

joint coordinates, q
joint velocities, \dot{q}
muscle activation, a
fiber length, l

Model dynamical equations:

$$\ddot{q} = [\mathbf{M}(q)]^{-1} \{ \boldsymbol{\tau}_m(a, l, \dot{l}) - \mathbf{C}(q, \dot{q}) + \mathbf{G}(q) + F \}$$

$$\dot{a} = A(a, x)$$

$$\dot{l} = \Lambda(a, l, q)$$

Numerical Integrate from Initial States

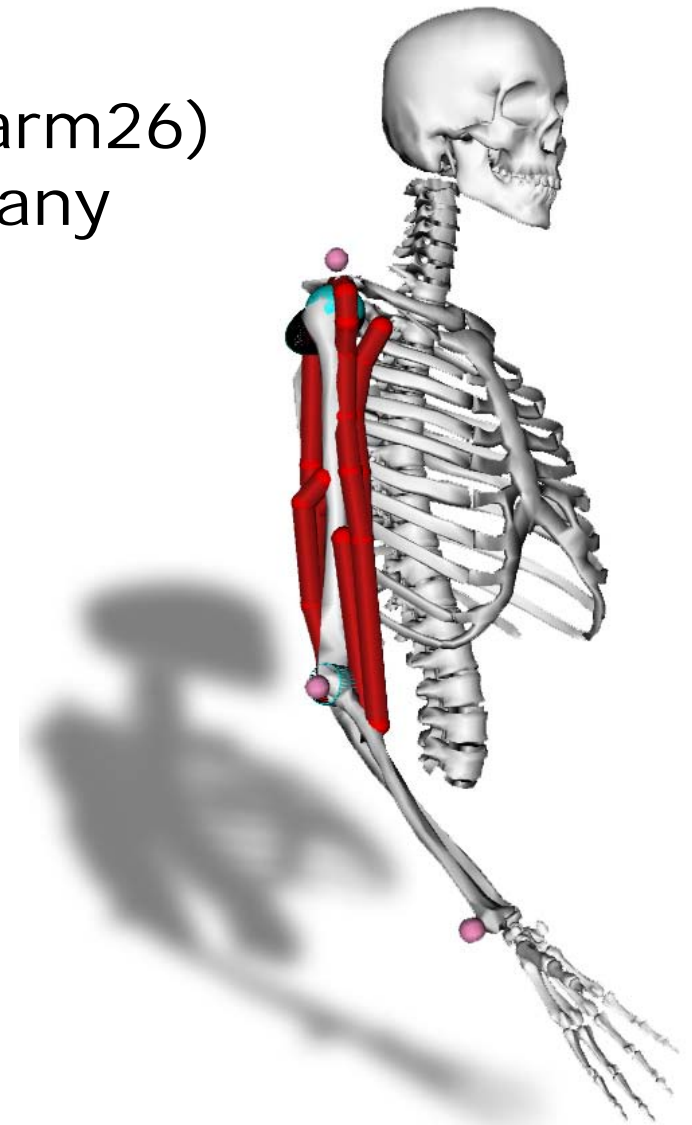
Exercise

1. A forward dynamics simulation is
 - A. a musculoskeletal model
 - B. muscle-driven
 - C. a simulation that uses feedback
 - D. the integration of dynamical equations

Exercise

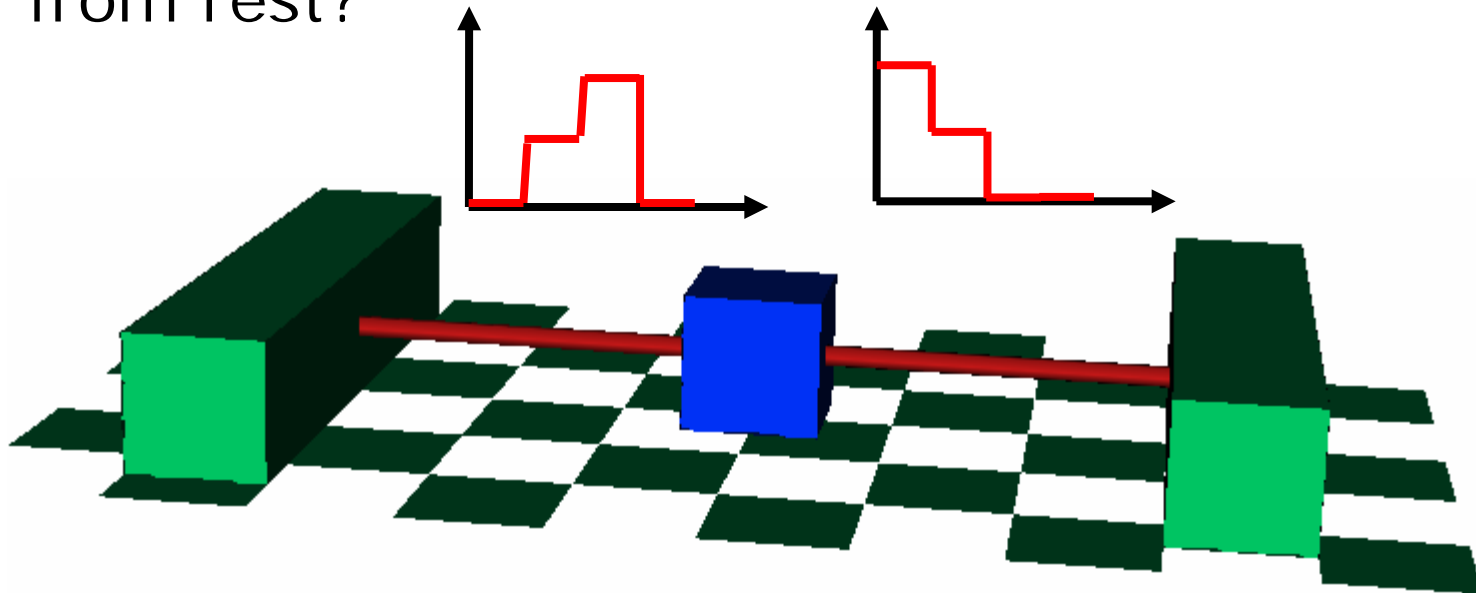
2. The musculoskeletal model (arm26) for this workshop has how many states?

- A. 3
- B. 9
- C. 12
- D. 16



Exercise

3. Given the model below with two identical muscles and their levels of excitation plotted versus time, which way will the block initially move if starting from rest?



A. To the left

B. Does not move

B. To the right

D. Upward

Exercise

4. Given initial q and \dot{q} and muscle a and l , how are these states determined at a small instant ahead in time?

- A. Specify controls and compute \dot{a} , \dot{l} and \ddot{q} from model dynamics
- B. Numerically integrate forces and controls from model differential equations
- C. Numerically integrate \dot{a} , \dot{l} and \ddot{q}
- D. Numerically differentiate forces and controls from the dynamical equations
- E. A & C

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