

Components of an OpenSim Model

What is a musculoskeletal model?

1. Skeleton:

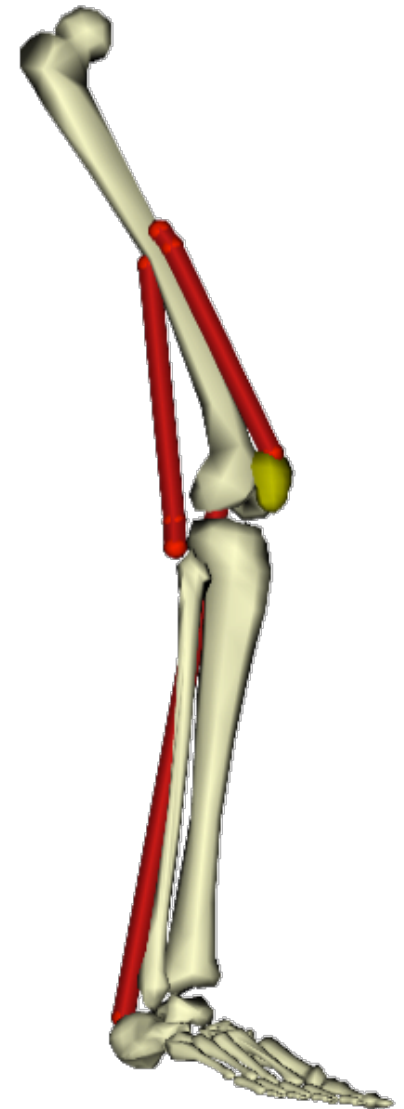
- Bones are rigid bodies
- Joints permit motion between bodies
- Constraints limit motion

2. Muscles :

- Specialized forces

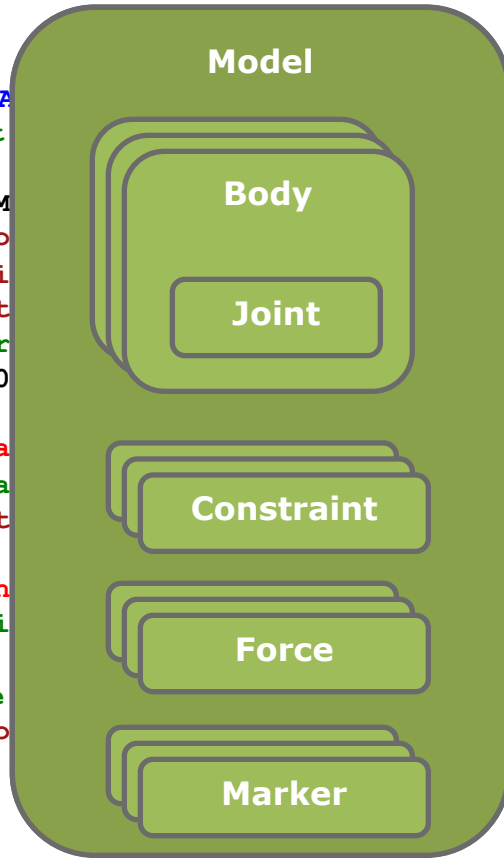
3. Other forces:

- PrescribedForce
- BushingForce
- CoordinateActuator
- Contact



OpenSim Model File

```
<Model name="A
  <!--Default
  <defaults>
  <credits> M
  <publicatio
  <length_uni
  <force_unit
  <!--Acceler
  <gravity> 0
  <!--Bodies
  <BodySet na
  <!--Constra
  <Constraint
  <!--All the
  <ForceSet n
  <!--Kinemati
  <MarkerSet
  <!--Surface
  <ContactGeo
</Model>
```

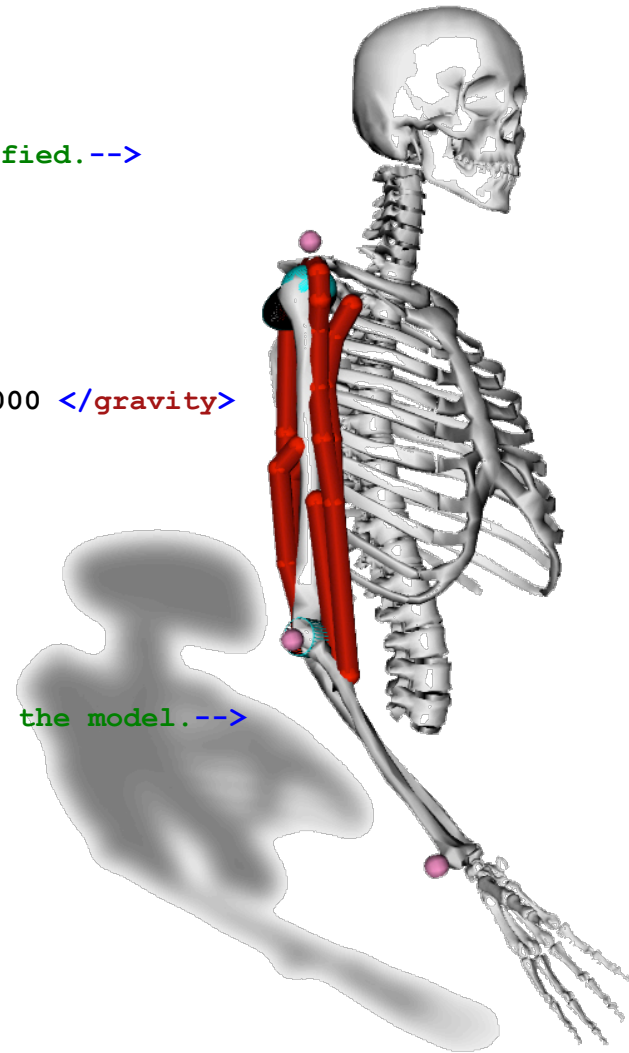


are not specified.-->

0.00000000 </gravity>

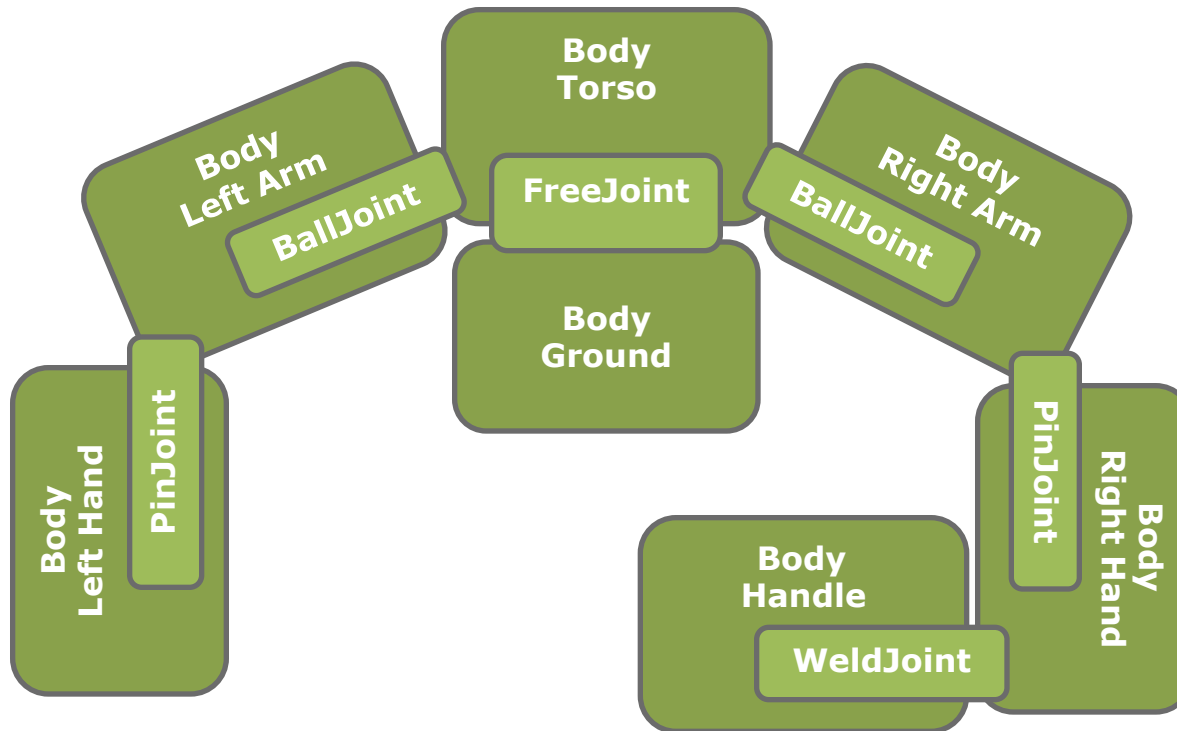
-->

elements in the model.-->



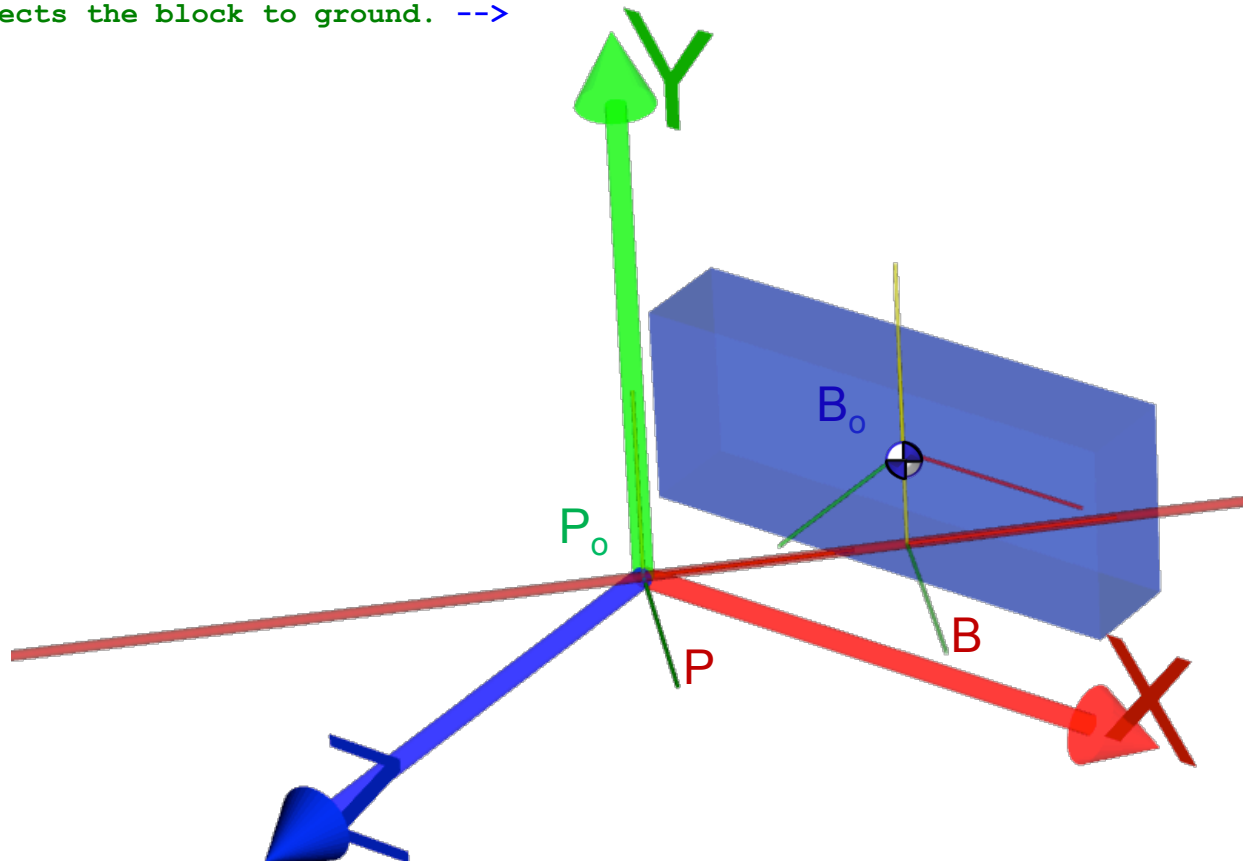
Tree Topology of Multibody Models

Each body is connected by ONE joint to create a chain or open tree structure.

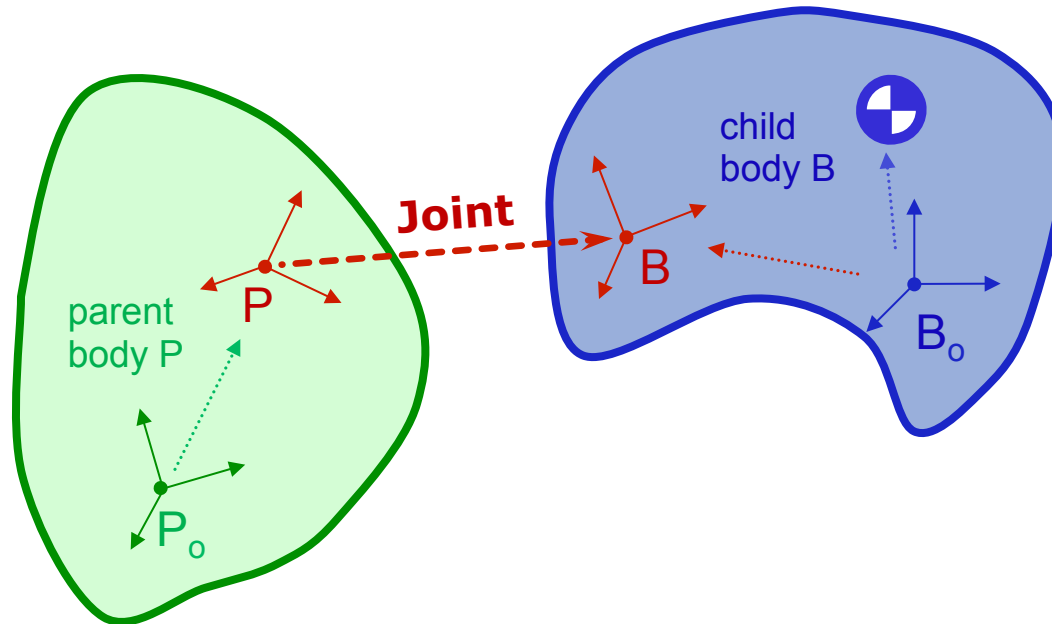


Defining a Body and its Joint

```
<Body name="block">  
  <mass> 5.00 </mass>  
  <mass_center> 0.0 0.0 0.0 </mass_center>  
  <inertia_xx> 0.1 </inertia_xx>  
  ...  
  <inertia_yz> 0.0 </inertia_yz>  
  <!--Joint connects the block to ground. -->  
<Joint>
```



Body and Joint Reference Frames



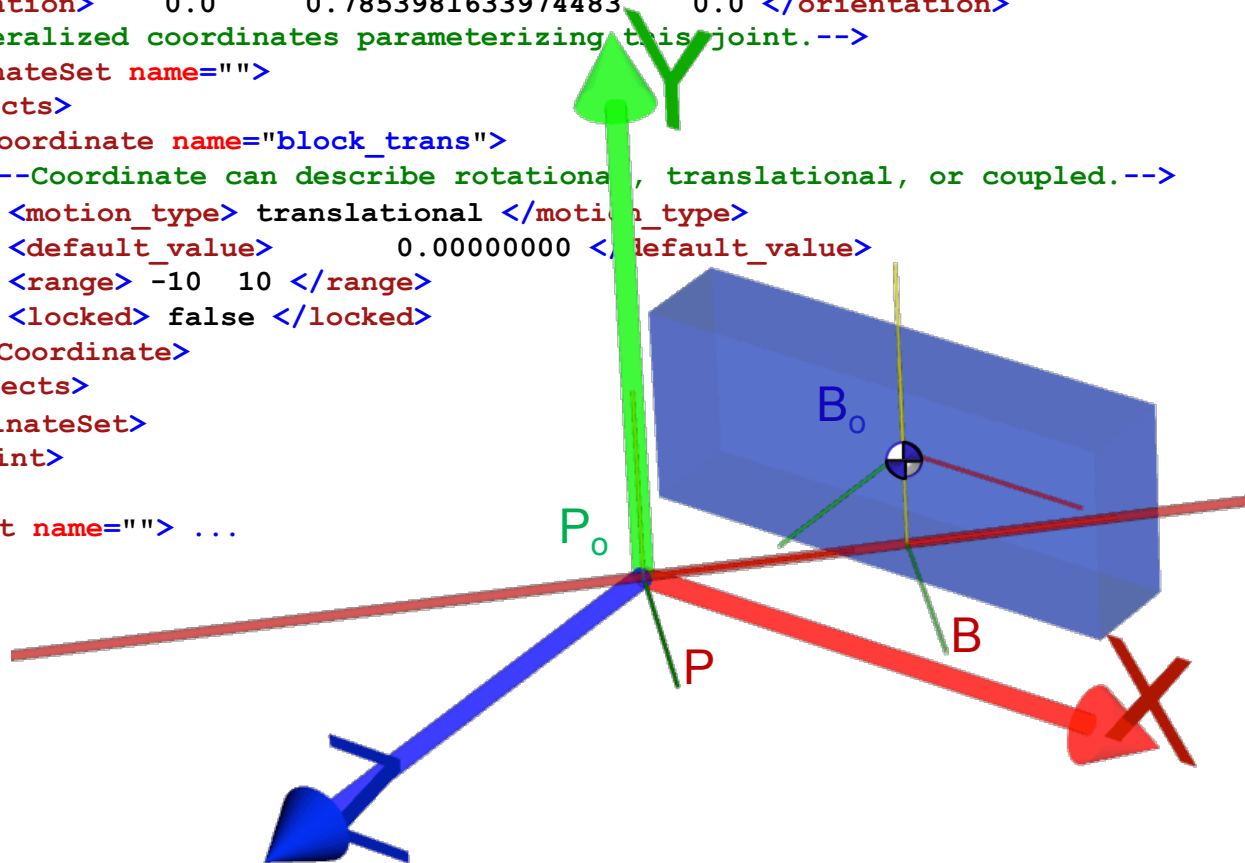
B specified by joint `location` and `orientation`

P specified by joint `locationInParent` and `orientationInParent`

Joint coordinates specify the kinematics of B relative to P

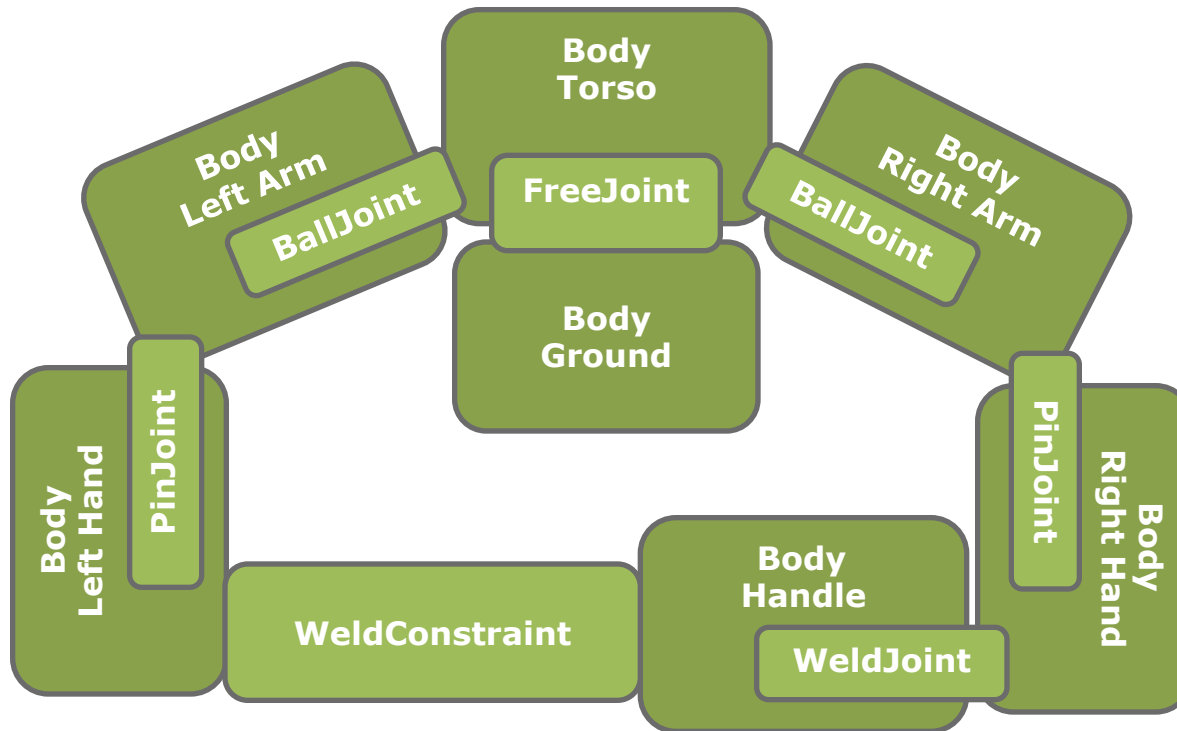
Defining a Body and its Joint

```
<Joint>
  <SliderJoint name="">
    <parent_body> ground </parent_body>
    <location_in_parent> 0.0 0.0 0.0 </location_in_parent>
    <!-- 45 degrees in the horizontal plane -->
    <orientation_in_parent> 0.0 0.7853981633974483 0.0 </orientation_in_parent>
    <location> 0.0 -0.1 0.0 </location>
    <orientation> 0.0 0.7853981633974483 0.0 </orientation>
    <!-- Generalized coordinates parameterizing this joint.-->
    <CoordinateSet name="">
      <objects>
        <Coordinate name="block_trans">
          <!-- Coordinate can describe rotational, translational, or coupled.-->
          <motion_type> translational </motion_type>
          <default_value> 0.00000000 </default_value>
          <range> -10 10 </range>
          <locked> false </locked>
        </Coordinate>
      </objects>
    </CoordinateSet>
  </SliderJoint>
</Joint>
<VisibleObject name=""> ...
</Body>
```



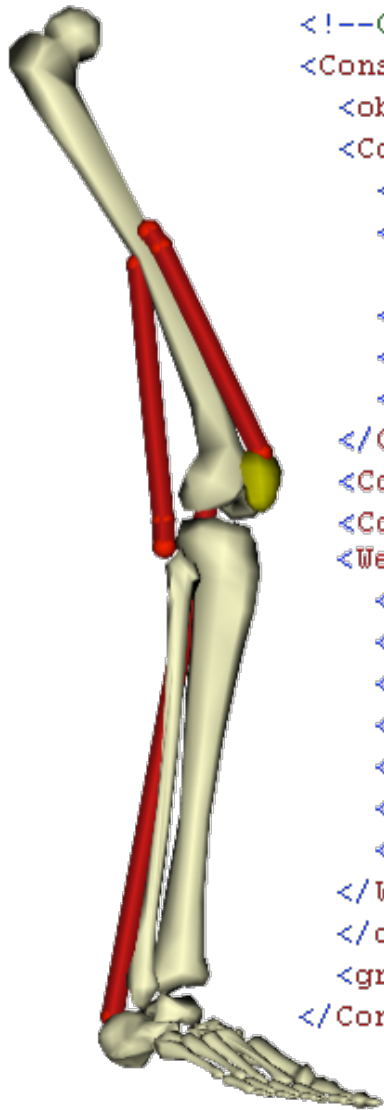
Tree Topology of Multibody Models

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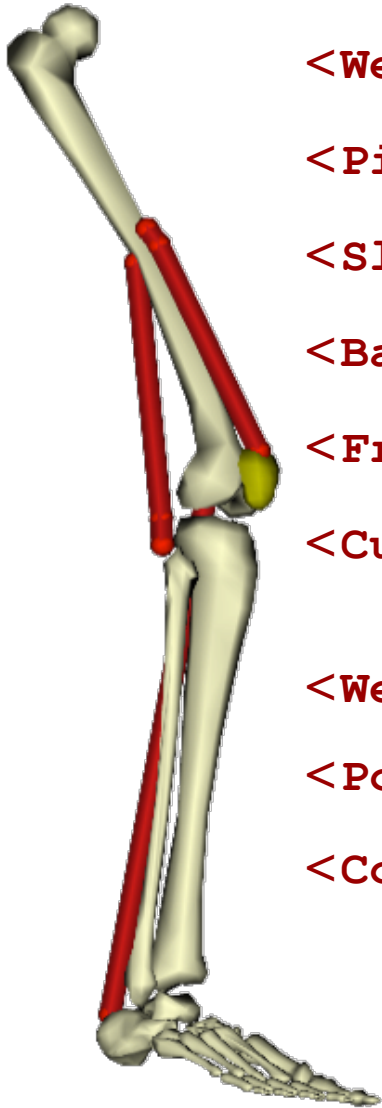
Constraint is required to form a closed loop

Kinematic Constraints



```
<!--Constraints in the model.-->
<ConstraintSet name="">
  <objects>
    <CoordinateCouplerConstraint name="pat_tx_r">
      <isDisabled> false </isDisabled>
      <coupled_coordinates_function>
        <natCubicSpline name="">...</natCubicSpline>
      </coupled_coordinates_function>
      <independent_coordinate_names> knee_angle_r </independent_coordinate_names>
      <dependent_coordinate_name> pat_tx_r </dependent_coordinate_name>
    </CoordinateCouplerConstraint>
    <CoordinateCouplerConstraint name="pat_ty_r">...</CoordinateCouplerConstraint>
    <CoordinateCouplerConstraint name="pat_angle_r">...</CoordinateCouplerConstraint>
    <WeldConstraint name="">
      <isDisabled> false </isDisabled>
      <body_1> ground </body_1>
      <body_2> calcn_r </body_2>
      <location_body_1>          0.0000000000      0.0000000000      0.0840000000
      <orientation_body_1>      0.0000000000      0.0000000000      0.0000000000
      <location_body_2>          0.0000000000      0.0000000000      0.0000000000
      <orientation_body_2>      0.0000000000      0.0000000000      0.0000000000
    </WeldConstraint>
  </objects>
</groups/>
</ConstraintSet>
```

Available Joints and Constraints



<WeldJoint>: No q 's, adds body frame to parent

<PinJoint>: One q , rotation about common Z

<SliderJoint>: One q , translation along common X

<BallJoint>: Three q 's, rotation about body-fixed X, Y, Z

<FreeJoint>: Six q 's, rotations like Ball and 3 translations

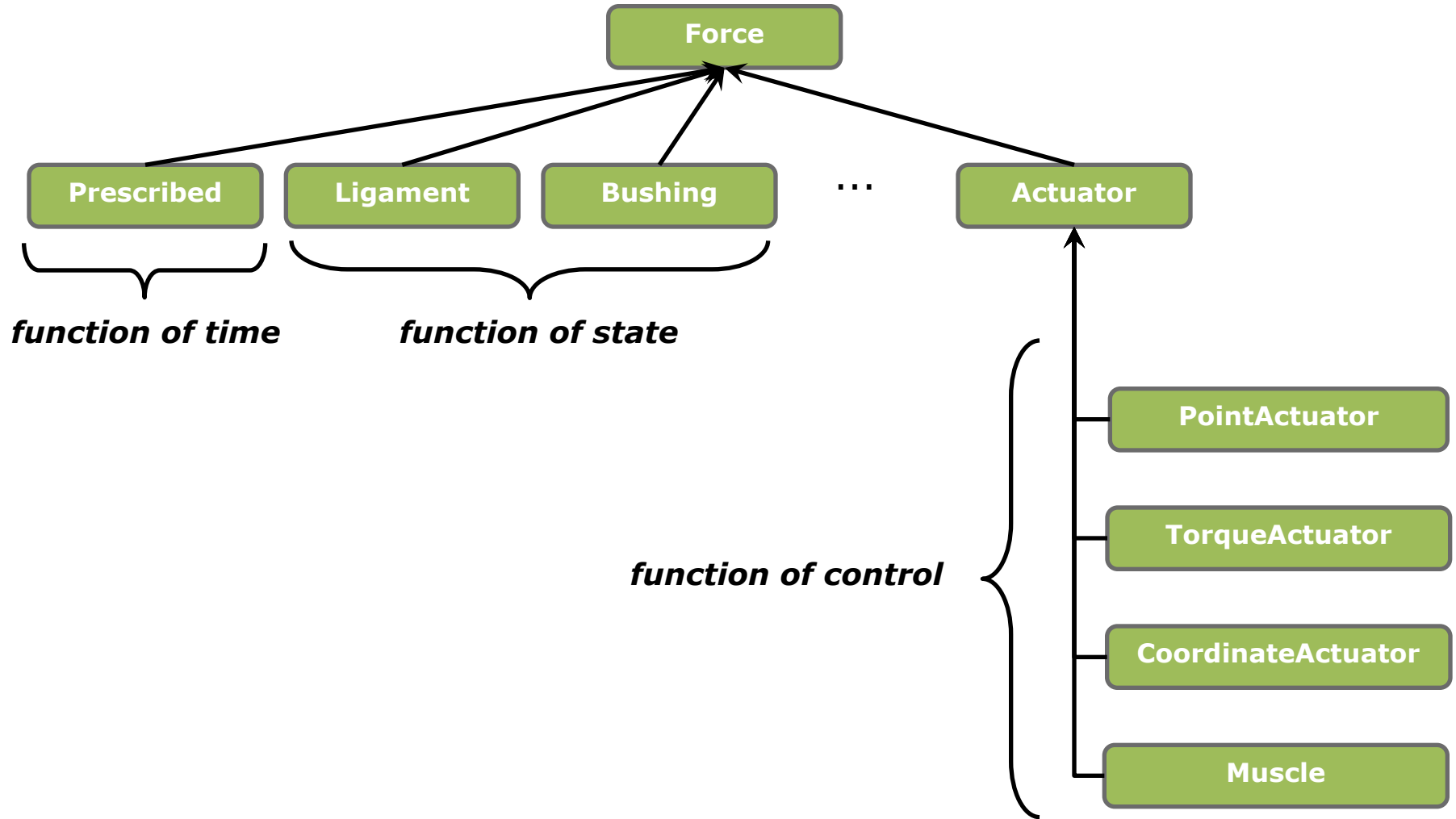
<CustomJoint>: User-defined SpatialTransform, 1 to 6 q 's

<WeldConstraint>: frames on two bodies are fixed

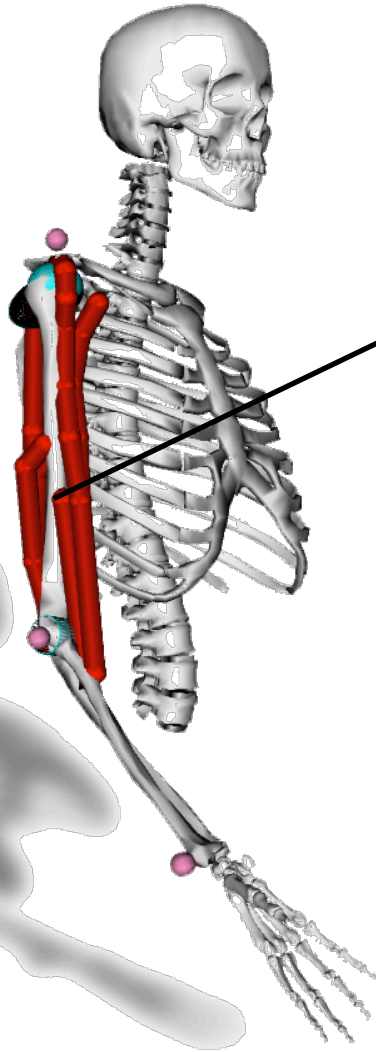
<PointConstraint>: points on two bodies are fixed

<CoordinateCouplerConstraint>: $q_{dep} = F(q_{ind})$

Types of Forces in OpenSim



Muscle Actuator Example



```
<Thelen2003Muscle name="brachialis_r">
  <GeometryPath name="">
    <!-- points on bodies that define the path of the muscle -->
    <PathPointSet name="">
      <objects>
        <PathPoint name="brachialis_r-P1">
          <location> -0.00240000 -0.15330000 0.00710000 </location>
          <body> humerus_r </body>
        </PathPoint>
        <PathPoint name="brachialis_r-P2">
          <location> 0.00000000 0.03100000 -0.00530000 </location>
          <body> r_ulna_radius_hand </body>
        </PathPoint>
      </objects>
    </groups/>
  </PathPointSet>
  <PathWrapSet name=""> ...
</GeometryPath>
  <!--maximum isometric force of the muscle fibers-->
  <max_isometric_force> 972.00000000 </max_isometric_force>
  <!--optimal length of the muscle fibers-->
  <optimal_fiber_length> 0.08580000 </optimal_fiber_length>
  <!--resting length of the tendon-->
  <tendon_slack_length> 0.05300000 </tendon_slack_length>
  <!--angle between tendon and fibers at optimal fiber length-->
  <pennation_angle> 0.00000 </pennation_angle>
  <!--time constant for ramping up of muscle activation-->
  <activation_time_constant> 0.01000000 </activation_time_constant>
  <!--time constant for ramping down of muscle activation-->
  <deactivation_time_constant> 0.04000000 </deactivation_time_constant>
  <!--maximum contraction velocity at full activation (fiber length/s)-->
  <Vmax> 10.00000000 </Vmax>
  . . .
</Thelen2003Muscle>
```

Hands On Example: Add a Body and Actuator to the Model

- Adding a joint to the model **increases/decreases** the number of degrees of freedom.
- Adding a constraint **increases/decreases** the number of system equations.
- How are actuators different from other types of OpenSim forces?